Final Report
on
The Preparatory Survey on Introduction of Smart Grid Project in Curitiba Metropolitan Area
In
Federative Republic of Brazil

July 2013

Japan International Cooperation Agency

Tokyo Electric Power Services Co.，Ltd.

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Abbreviations and Acronyms

Organization

ABNT	Associação Brasileira de Normas Técnicas
ABRADEE	Associação Brasileira de Distribuidores de Energia Elétrica
AES	Applied Energy Services in USA
ANA	Agência Nacional de Águas
ANATEL	English: National Telecommunications Agency Portuguese: Agencia Nacional de Telecomunicacoes
ANEEL	Agencia Nacional de Energia Eletrica
Ampla	AMPLA: Distribution Company in Rio de Janeiro
BNDES	Banco Nacional de Desenvolvimento Economico e Social
CCEE	Eng: Chamber for the Commercialization of Electric Power Por: Câmara de Comercialização de Energia Elétrica
CEB	Eng: Electric Power Company in Brazilia Por: Cia Energética de Brasilia
CEEE	Eng: Electric Power Company in Rio Grande do Sul Por: Companhia Estadual de Energia Eletrica
CESP	Eng: Electric Power Company in Sao Paulo Por: Companhia Energética de Sao Paulo
CMSE	Eng: Power Sector Monitoring Committee Por: Comitê de Monitoramento do Setor Elétrico
CNPE	Eng: National Energy Policy Council Por: Conselho Nacional de Política Energética
CONAMA	Conselho Nacional do Meio Ambiente
COPEL	Companhia Paranaense de Energia
CPFL	Eng: Electric Power Company in Sao Paulo Por: Companhia Paulista de Força e Luz
CPSE	Coordination Office of Implantation of Socio-Environment Program of Undertakings
CRC	Coast Resort City
CTEEP	Companhia de Transmissão de Energia Elétrica Paulista
Celesc	Eng: Electric Power Company in South Catarina Por: Centrais Eletricas de Santa Catarina
Celg	Eng: Electric Power Company in Goiás Por: Centrais Elétrica de Goiás
Cemig	Eng: Electric Power Company in Minas Gerais Por: Companhia Energética de Minas Gerais
DACD	Distribution Acquisition and Hiring Department
DADM	Materials Storage and Distrib. Department
DART	Geography and Works Standardization Department
DATC	Central Customer Service Department
DCEE	Maintenance and Services Operations Department
DDI	Chief Distribution Office
DEME	Electromechanical and Automation Maintenance Department
DETS	Procurement Eng. And Technology Department
DGCD	Distribution Commercial Management Department
DGCL	Key Clients Department

DGCS	Procurement Control Management Department
DGEE	Distribution Engineering Management Department
DMC	Chief Environment and Corporate Citizenship Office
DMEA	Electromechanical and Automation Maintenance Department
DMEP	Metering and Loss Department
DOMS	Maintenance and Services Operations Department
DPCO	Commercial Procedures Department
DPEX	Distribution Expansion Planning Department
DPSU	Procurement Planning Department
DSMCBN	Curitiba Norte maintenance center
DSMCTA	Centro de Distribuição de Curitiba Maintenance center
DSMLIT	Litoral Maintenance center
DSMSJP	São José dos Pinhais maintenance center
DUTE	Electric Power Utilization Department
EPE	Eng: Energy Research Company Por: Empresa de Pesquisa Energética
Endesa	Eng: Spanish Company subsided by ENEL in Italy Por: Empresa Nacional de Electricidad
FINEP	Federal Funding Agency for Researches and Projects
IAP	Eng: Environmental Institute of Paraná Por: Instituto Ambiental do Paraná
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis
IBGE	Brazilian Institute of Geography and Statistics
IEEE	Institute of Electrical and Electronics Engineers
INMETRO	Eng: Instituto Nacional de Metrologia (Private Electric Power Company) Por: Normalização e Qualidade Industrial
IPARDES	Eng: Paraná Institute of Economic and Social Development Por: Instituto Paranaense de Desenvolvimento Econ6mico e Social
Light	Group Light (Private Electric Power Company)
MCTI	Eng: Ministry of Science, Technology and Innovation Por: Ministerio Da Ciencia, Technologia e Inovacao
MDIC	Eng: Ministry of Development, Industry and Commerce Por: Ministerio do Desenvolvimento, Indústria e Comércio Exterior
MMA	Ministério do Meio Ambiente
MME	Eng: The Ministry of Mines and Energy Por: Ministerio de Minas e Energia
MOF	Eng: Ministry of Finance Por: Ministerio da Fazenda
RMC	Região Metropolitana de Curitiba
SCD	Distribution Commercial Superintendency
SDC	Regional Central-South Distribution Superintendency
SDL	Eng: Regional East Distribution Superintendency Por: Superintendencia de Distribuicao Leste
SDN	Regional Northwest Distribution Superintendency
SDO	Regional West Distribution Superintendency
SDT	Regional North Distribution Superintendency
SEA	Superintendence of Environmental Engineering

SED	Distribution Engineering Superintendency
SEMA	Eng: Water Resources of State of Paraná Por: Secretaria de Estado do Meio Ambiente e Recursos Hídricos
SMR	Market and Regulation Superintendency
SNUC	National System of Natural Conservation Units
SSD	Distribution Procurement Superintendency
TECPAR	Instituto de Tecnologia do Parana
TEPCO	Tokyo Electric Power Company
TEPSCO	Tokyo Electric Power Services Co.,Ltd.
UTP	Eng: Territorial Unit of Planning Por: Unidade Territorial de Planejamento
VEAL	High Voltage Studies Division
VEMT	Medium Voltage Studies Division
VEOP	Electrical Operational Studies Division
VGEO	Geography and Networks Management Division
VMCQ	Distribution Quality Maintenance and Control Division
VMEA	Electronics and Automation Maintenance Division
VMSE	Substations Electromechanical Maintenance Division
VNOT	Standardization and New Technology Division
VOEP	Operation and Protection Studies Division
VOTR	Real Time Operation Division
VPES	Subtransmission Electrical System Protection Division
VPRE	Preoperation and operation analysis division
VPRO	Projects and Works Division
VSER	Distribution Services Division
VSSC	Supervision and Control System Infrastructure Support Division

Others

AC	Alternativ Current
AIS	Air Insulated Switchgear
ALBS	Automatic Load Break Switch
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
APA	Eng: Environmental Protection Areas Por: Área de Proteção Ambiental
BCU	Bay Control Unit
BEMS	Building Electricity Monitoring system
CB	Circuit Breaker
CCC	Fuel Consumption Bill
CDE	Energetic Development Account
CFURH	Financial Compensation for the Use of Water Resources
CGO	Distribution Management Superintendency
CIP	Contribution for Financing the Public Lighting Service
CO2	Carbon dioxide

COFINS	Eng: Contribution to the Social Security Financing Por: Contribuicao para o Financiamento da Seguridade Social
COS	System Operation Center
CPU	Central Prossessing Unit
CRCL	Customer Relations Coordination
CSP	Joint Support Plans
CT	Current Transformer
CVT	Current Transformer and Voltage Transforemr
DAS	Distribution Automation System
DB	Data Base
DBID	Department of Biodiversity
DC	Direct Current
DEC	Duration of outages per consumer per year
DG	Distributed Generation
DIC	Duration of interruption per individual consumer unit (=SAIDI)
DIS	Distribution
DLF	Distribution Load Forecasting
DMIC	Maximum continuous interruption per consumer unit or connection point
DMS	Distribution Management System
DR	Demand Response
DSR	Directional Short circuit Relay
DWDM	Dense Wavelength Division Multiplex
EIA	Environment Impact Assessment
EMS	Energy Management System
ESS	System Service Charges
EV	Electrical Vehicle
EV	Electric Vehicle
FCB	Feeder Circuit Breaker
FDIR	Fault Detection, Isolation and Restoration
FEC	Frequency of outages per consumer per year
FIC	Frequency of interruption per individual consumer unit (=SAIFI)
FIRR	Financial Internal Rate of Return
FLM	Feeder Load Management
FMSR	Fault Management and System Restoration
FRG	Fazenda Rio Grande
FTTB	Fiber To The Building
FUNAI	Eng: National Foundation for Indians Por: Fundação Nacional do Índio
FY	Fiscal Year
G-PON	Gigabit Passive Optical Network
GE-PON	Gigabit Ethernet Passive Optical Network
GET	Generation and Transmission
GIS	Geographical Information System
GPRS	General Packet Radio Service
GPT	Grand Potential Transformer
GW	Gate Way

HEMS	Home Electricity Management System
HMI	Human Machine Interface
ICMS	Tax on Circulation of Merchandise and Services
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEE	Initial Environmental Examination
IP	Internet Protocol
IPCA	Eng: Extended National Consumer Price Index Por: Índice Nacional de Preços ao Consumidor Amplo
IPP	Independent Power Producer
ITU	International Telecommunication Union
LAN	Local Area Network
LBFR	Load Balancing via Feeder Reconfiguration
LBS	Load Break Switch
LFA	Load Flow Application
LI	License of Installation
LO	License of Operation
LP	License of Prevision
M-RTU	Master Remote Terminal Unit
MAE	Wholesale Market for Electric Power
MCH	Micro/Mini Central Hidroelétrica (under 1 MW)
MDMS	Metering Data Management Server
MPLS	Multiprotocol Label Switcting
MV	Medium Voltage
NAN	Neighborhood Area Network
NCA	Network Connectivity Analysis
NTC	Norma Tecnica Copel
NUC	Central Urban Nuclear
OC	Overcurrent
OFR	Over Frequency Relay
OH	Over Head
OLT	Optical Line Terminal
OMS	Outage Management System
ONS	Eng: National Power System Operator Por: Operador Nacional do Sistema Elétrico
ONS	National System Operator fee
ONU	Optical Network Unit
OPGW	Optical Ground Wire
OSI	Open System Interconnection reference model
OVGR	Over Voltage Ground Relay
OVR	Over Voltage Relay
PC	Primary Concentrator
PCBs	polychlorinated biphenyl
PCH	Pequena Central Hidroelétrica (1 MW～ 30 MW)

PDD	Eng: Distribution Development Plan Por: Plano de Desenvolvimento da Distribuição
PDE	Plan for Expansion of Energy
PIB	Eng: Gross Domestic Production (GDP) Por: Produto Interno Bruto
PIS	Eng: Social Integration Programs Por: Programas de Integracao Social e de Formacao do Patrimonio do Servidor Publico
PNE	Plan of National Energy
PON	Passive Optical Network
PRODIST	Procedimentos de Distribuicao de Energia Eletrica no Sistema Eletrico Nacional
PROEX	Programa de Expansão do Sistema de Distribuição de Tensão
PROINFA	Alternative Energy Sources Incentive Program
PTW	Permit To Work
PV	Photovoltaic
R&D	Research and Development
RAS	Eng: Simplified Environmental Report Por: Relatório Ambiental Simplificado
RGR	Global Reversal Reserve
RMU	Ring Main Unit
RPR	Reverse Power Relay
RPS	Renewable Portfolio Standard
RTU	Remote Terminal Unit
SADSEA	Support Sector for Management of SEA
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation system
SCADA	Supervisory Control and Data Acquesition
SDH	Synchronous Digital Hierarchy
SE	State Estimation
SHP	Small Hydropower
SIN	National Interconnected System
SISNAMA	Sistema Nacional do Meio Ambiente
SM	Smart Meter
SNMP	Simple Network Management Protocol
SOD	Sistema de Operacao da Distribuicao
SS	Substation
SV	Supersvison
SVR	Step Voltage Regulator
SW	Switch
TDMA	Time Division Multiple Access
TEL	Telecommunication
TFSEE	Electric Energy Service Inspection Fee (ANEEL's inspection fee)
TOU	Time of Use
UFR	Under Frequency Relay
UVR	Under Voltage Relay
VAR	Voltage levels and Reactive power

VTs	Voltage Transformer
VVC	Volt-VAR Control
WAN	Wide Area Network
WHM	Watt Hour Meters
XLPE	Cross Linked Polyethlene

Currency Equivalents

Currency Unit = Brazil Real (R$)

1 R$ = 100 centavos

Exchange Rate: 1R$ = 48.8 Yen (4 / 2013) provided by JICA

1US$ = 2 R$ (4 / 2013)

Fiscal Year: January 1 to December 31 of next year

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Chapter1 Outline of the Project

1.1 Background of Study

Curitiba City, the capital of Parana State, located in the south east of Brazil, has developed environment-friendly urban areas since the 1960s and been known worldwide as a futuristic city taking environment into consideration with various policies such as rapid bus transport system introduced for the first time in the world based on the functional land use plan and unique environmental education promotion collecting thoroughly separated wastes. While the electrification of the Curitiba Metropolitan Area centering around Curitiba City has reached almost 100%, the distribution loss is as high as approximately 8% and the average annual outage time per customer is approximately 660 minutes, longer than the national average, approximately 600 minutes per annum (approximately 9 minutes per annum in Japan). Thus, the improvement of electrical power supply efficiency and stabilization along with the urbanization is an urgent issue while recently the population moves from the surrounding areas causing industrialization to progress rapidly.

Parana State has reinforced actions in the field of global warming countermeasures and biodiversity, with regards to the development of a sustainable environmental city making the Curitiba Metropolitan Area a model. In addition, the State has a plan to use clean energy and promote the efficiency of energy use taking environment into consideration with the introduction of smart grid with two cities, including Curitiba City, having started the actions already. Parana State Power Corporation (COPEL), which supplies electrical power in the whole state, has decided to promote introduction of renewable energy, reduce outage and improve power supply reliability and plans to invest approximately US$ 330 million in the field of smart grid by 2014. This work can reduce the distribution loss and outage time and improve the reliability of power supply through the introduction of smart grid technologies such as distribution automation, effective in reducing the outage time so that it has a high priority in COPEL's investment plan. Furthermore, the Brazilian Government has organized a working group to promote the stabilization of power supply, spread of dispersed electric power sources and efficient energy use and examined the concrete institutional design. This work introducing a smart grid into the Curitiba Metropolitan Area will further enhance its reputation as a famous environmental city in Brazil and be marked as advanced action by the federal government.

1.2 Objective

This study aims to formulate a new yen loan project reducing the distribution loss with advanced distribution network and improving electrical power supply reliability. Specifically, the studies such as purposes, summary, project costs, implementation systems, operation and maintenance systems and environmental and social considerations necessary to examine the work as Japan's cooperation loan project are carried out.

1.3 Summary of study

1.3.1 Overview of COPEL

1) Organization

COPEL's organization structure is shown as follows.

The organizations related to this project are COPEL Distribution S.A. and COPEL Telecommunication S.A. These are subsidiary companies of COPEL Holdings (parent company), which has other companies such as COPEL Generation and Transmission. These companies' financial accounts are consolidated.

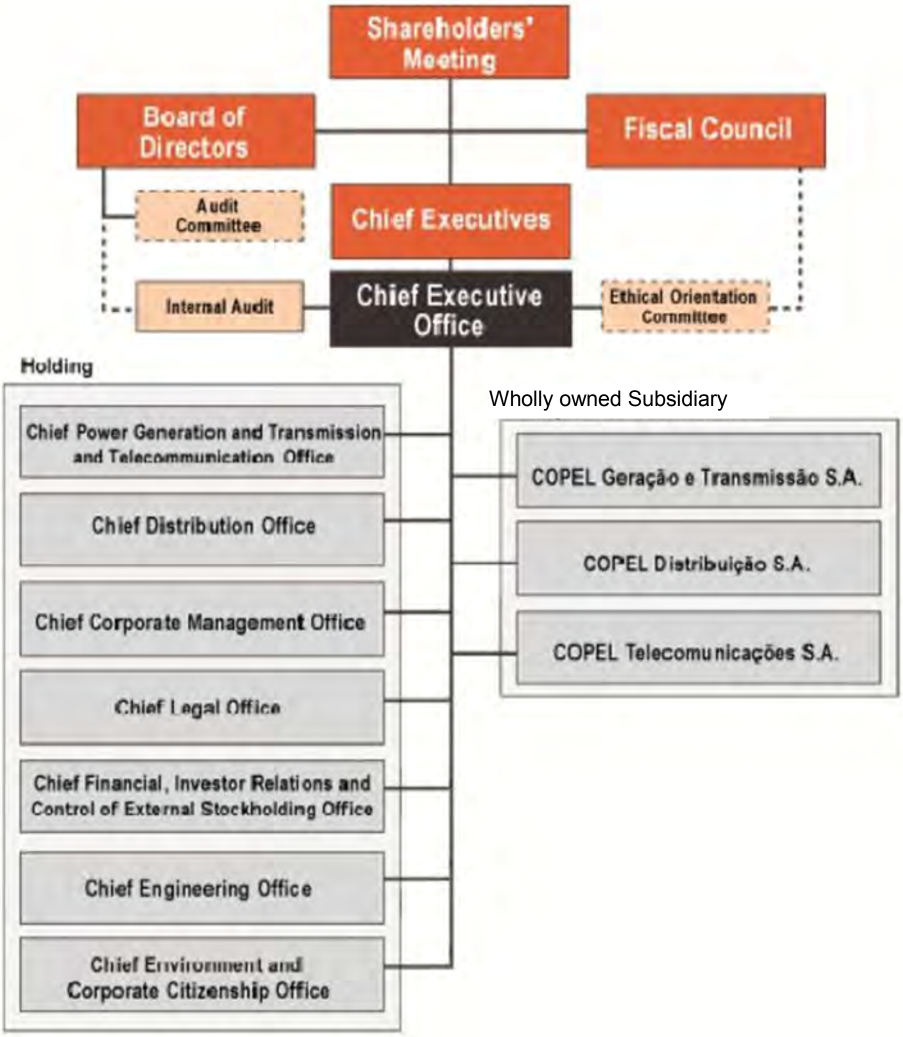


Figure 1.3-1 Organization Chart of COPEL Distribution and TELECOM

(Source: COPEL's annual report and financial statements 2010)

2) Power generation and consumption

Regarding the situation of the balance of demand and supply in Brazil, the supply is currently sufficient to meet its demand based on “Plan for Expansion of Energy 2030” (PDE 2020). The supply in Parana state is also sufficient to meet its demand because the transmission line is connected throughout the whole of Brazil.

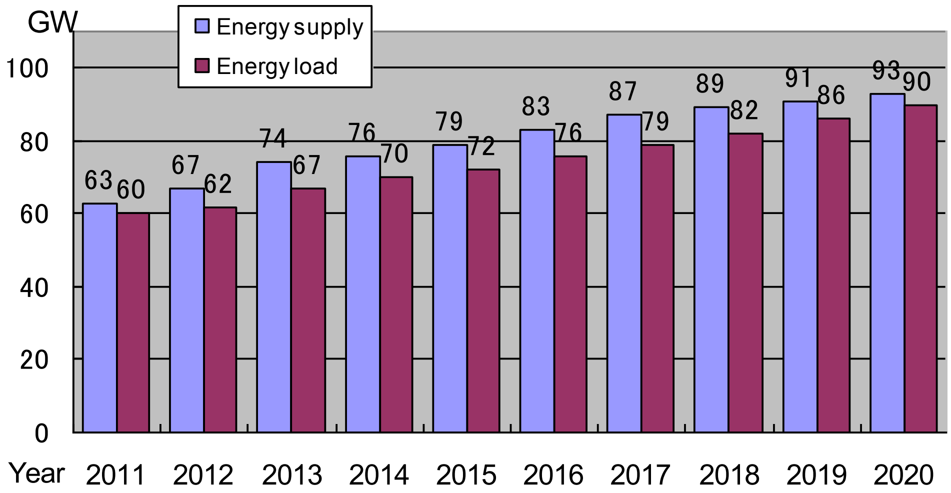


Figure 1.3-2 Trends of Power Generation and Consumption

(Source: RDE 2020)

Power consumption of Parana State is shown in Figure 1.3-3.

The growth rate of the power demand in the Curitiba Metropolitan Area is expected to increase at 4% to 6% in the future.

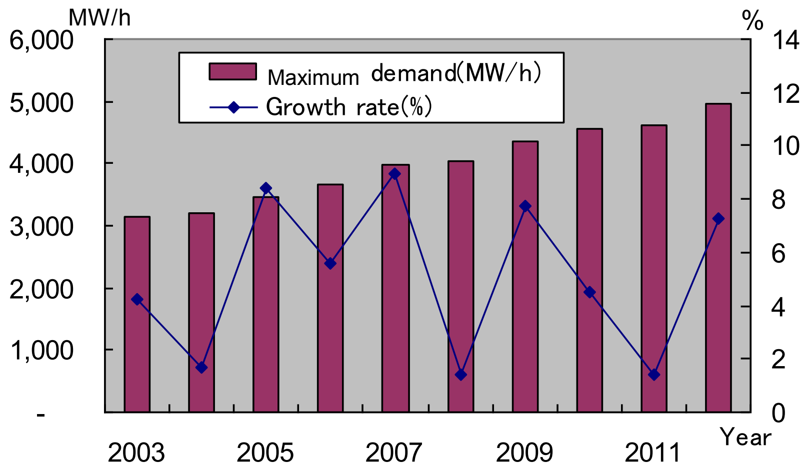


Figure 1.3-3 Trends of Maximum Demand and Growth Rate

(Source: JICA Survey Team)

3) Distribution

(1) Outage situation in COPEL

SAIDI and SAIFI of COPEL in recent 5 years are shown in Table1.3-1.

Table 1.3-1 SAIFI and SAIFI in COPEL

Year	SAIDI (hours)	SAIFI (No. of outages)
2008	12.19	10.69
2009	12.91	11.03
2010	11.46	9.46
2011	10.64	8.26
2012	10.25	7.84

(Source: COPEL Answer material)

(2) Distribution loss

According to the interview with COPEL, COPEL does not measure non-technical losses by itself. However, COPEL has a duty to report technical and non-technical losses to the ANEEL yearly based on the ANEEL formula.

The following Table 1.3-2 shows the ANEEL regulation thresholds and COPEL's situation in 2012 based on the ANEEL formula.

Table 1.3-2 ANEEL Thresholds for Technical and Non-technical loss

	ANEEL Regulation (%)	COPEL Situation in 2012 based on ANEEL Formula (%)
Technical Loss	6.40	6.40
Non-technical Loss	1.40	2.05
Total	7.80	8.45

(Source: COPEL Answer material)

(3) Voltage drop

The average voltage drops in the urban area (Curitiba City) and the suburban areas (other areas than Curitiba City: 23 Municipalities) in FY 2012 were 2.19% and 4.50%, respectively.

The following Table 1.3-3 shows the results from the analysis of transition in voltage drop for the next 10 years based on an assumption that the electricity demand grows at 6% per year. The details is introduced in 6.3.5 in Chapter 6.

Table 1.3-3 Trend of Voltage Drop in COPEL

	Voltage Drop (V)	
	City (Curitiba City)	Local Area (23 Municipalities)
Increasing Rate	6%	4%
2012	302	621
2013	328	688
2014	356	759
2015	386	832
2016	417	908
2017	451	987
2018*	486	916
2019	524	995
2020	563	1,078
2021	605	1,164
2022	650	1,253

*2018 is the year of starting to operate the Project and the improvement(0.91→0.98) by Capacitor is included.

(Source: JICA Survey Team)

(4) Power factor

The average power factor in the urban area (Curitiba City) is 0.94 which is within the standard value (more than 0.92). On the other hand, that of the suburban areas (other areas than Curitiba City: 23 Municipalities) is 0.91 which does not satisfy the standard.

The power factor in the Curitiba Metropolitan Area is distributed as shown in the Table 1.3-4 and the details is introduced in 2.8 3) in Chapter 2 and 9.2.2 in chapter 9.

Table 1.3-4 Power Factor on Distribution Feeders

Power factor	< 0.85	0.86 – 0.9	0.91 – 0.95	0.96 <
No of feeder	37	71	130	116
Average	0.91			

(Source: COPEL Material)

1.3.2 Project site

Project target area is finally defined as 23 municipalities and Curitiba City based on COPEL's request.

The features of 24 cities are explained as shown in Table 1.3-5

Table 1.3-5 Socio-Economic Indication of Municipalities

	Socio-Economic Indicators									Electricity Indicators (Quantity ・Quality・Financial Cost)								
Municipalities 1)	Total Population	Urban Population	Rural Population	Area (Km²)	Population Density (habitants/Km²)	Distance to Capital (km)	GDP/capita (R$)	No. of Establishments 2)	Investment Amount 3) (Million R$)	No.of sales office	No.of Sub station	No. of Consumers	Electricity Consumption (MWH)	SAIFI (FIC) (No./Year per consumer)	SAIDI(DIC) (Hour/Year per consumer)	No. of Penalties (SAIFI,SAIDI)	Penalty (R$) (SAIFI, SAIDI)	Penalty (R$) (Voltege Drop)
1 Adrianópolis	6,376	2,060	4,316	1,341.33	4.68	134.90	9,860	71	340.00	0	1	2,254	4,842	43.03	26.29	2,893	22,299	–
2 Agudos do Sul	8,270	2,822	5,448	191.82	44.07	73.50	6,039	132	-	0	1	3,165	8,039	38.17	57.47	5,858	17,531	–
3 Almirante Tamandaré	103,204	98,892	4,312	191.11	551.81	15.15	5,926	1,088	-	1	1	32,516	135,275	16.52	29.30	10,490	78,551	24,798
4 Araucária	119,123	110,205	8,918	471.38	260.70	28.60	101,411	2,327	-	1	2	44,152	401,101	11.04	17.11	49,100	158,497	5
5 Balsa Nova	11,300	6,870	4,430	344.19	33.52	49.73	23,717	254	-	0	1	4,837	43,461	16.45	25.91	1,315	4,260	–
6 Bocaiúva do Sul	10,987	5,128	5,859	825.76	13.66	41.60	8,433	180	-	0	1	4,570	17,484	25.85	31.77	9,357	33,519	–
7 Campina Grande do Sul	38,769	31,961	6,808	540.63	72.89	32.24	12,876	688	15.00	0	1	15,566	80,824	18.88	49.68	16,485	72,367	–
10 Campo Magro	24,843	19,547	5,296	278.22	91.70	19.00	7,483	335	-	0	0	8,189	26,457	19.86	27.99	19,099	40,630	–
11 Cerro Azul	16,938	4,808	12,130	1,341.32	12.69	84.56	9,772	192	-	0	1	5,870	10,892	34.31	72.71	7,712	12,469	–
12 Colombo	212,967	203,203	9,764	197.81	1,099.28	17.30	7,547	3,474	-	1	2	73,728	345,686	12.17	15.45	79,683	155,793	1,269
13 Contenda	15,891	9,231	6,660	300.57	54.20	49.00	9,384	224	-	0	1	5,751	19,465	12.28	17.87	3,457	6,476	–
14 Curitiba	1,751,907	1,751,907	-	435.50	4,079.87	-	24,720	58,833	1.62	7	22	744,070	4,158,448	5.91	7.81	427,533	1,264,211	2,735
15 Doutor Ulysses	5,727	929	4,798	787.32	7.22	131.45	13,662	48	-	0	0	2,059	2,648	-	-	-	-	–
17 Itaperuçu	23,887	19,956	3,931	320.16	76.75	30.76	7,418	357	-	0	0	7,803	28,419	15.89	20.63	1,097	3,318	–
18 Lapa	44,932	27,222	17,710	2,097.75	21.61	72.10	13,840	987	210.00	0	2	16,379	100,585	19.26	30.62	11,868	35,293	–
19 Mandirituba	22,220	7,414	14,806	381.39	60.11	45.70	10,044	597	-	0	2	8,633	47,298	23.91	31.22	15,280	51,526	–
21 Pinhais	117,008	117,008	-	61.14	1,952.65	8.90	20,129	3,181	-	1	1	43,461	303,192	8.74	11.46	52,692	116,006	418
22 Piraquara	93,207	45,738	47,469	225.22	426.35	22.52	5,489	754	-	1	1	26,224	85,363	16.31	25.97	27,495	69,967	2,287
23 Quatro Barras	19,851	17,941	1,910	181.27	112.59	25.10	27,510	412	4.30	1	1	7,394	88,723	11.53	18.02	14,652	68,672	425
24 Quitandinha	17,089	4,887	12,202	446.40	38.90	71.10	6,973	212	-	0	1	6,380	17,769	21.88	39.72	8,389	22,663	–
25 Rio Branco do Sul	30,650	22,045	8,605	816.71	37.77	28.36	16,613	423	625.00	1	1	10,797	469,569	32.44	91.81	24,219	82,024	688
27 São José dos Pinhais	264,210	236,895	27,315	944.28	289.38	18.60	41,217	5,965	1.54	1	4	99,551	973,207	10.37	17.09	100,014	270,844	481
28 Tijucas do Sul	14,537	2,285	12,252	671.93	22.15	67.10	10,944	292	-	0	1	6,125	18,100	14.98	22.98	3,284	12,637	–
29 Tunas do Paraná	6,256	2,792	3,464	671.71	9.91	79.21	10,162	115	-	0	2	2,196	14,414	30.71	76.55	9,554	50,263	–
Total Area	**2,980,149**	**2,751,746**	**228,403**	**14,064.91**	**211.89**	**–**	**–**	**81,141**	**1,197.46**	**15**	**50**	**1,181,670**	**7,401,261**	**20.02**	**33.28**	**972,115**	**2,854,918**	**33,116**

(Source: IBGE, IPARDE,COPEL)

TEPSCO TEPCO

1.3.3 Proposed project

Proposed projects based on COPEL's needs are of DAS/DMS, Protection relay for earth fault and AMI.

The target area and installation schedule is shown in the following table.

Smart meter for AMI is recommended to apply to 30% of residential customers in Curitiba City. (Refer to Chapter 5)

Table 1.3-6 Proposed Projects

	Proposed project and Installation plan	
	1st Installation (2014-2017)	2nd Installation (Expansion) (2018- 2019)
1. DAS /DMS	1 Control center Distribution equipment for Curitiba Metropolitan Area (23 cities)	Distribution equipment for Curitiba City
2. Protection relay for earth fault	50 substations (Curitiba Metropolitan Area and Curitiba City)	
3. AMI	120,000 residential customers in Curitiba City	100,000 residential customers in Curitiba City
4. EMS / renewable power / Battery	Study	Continue to study
5. DR	Study	Continue to study
6. EV	Study	Continue to study
7. BEMS	Study	Continue to study
8. HEMS	Study	Continue to study

(Source: JICA Survey Team)

The proposed system configuration is shown in the following figure.

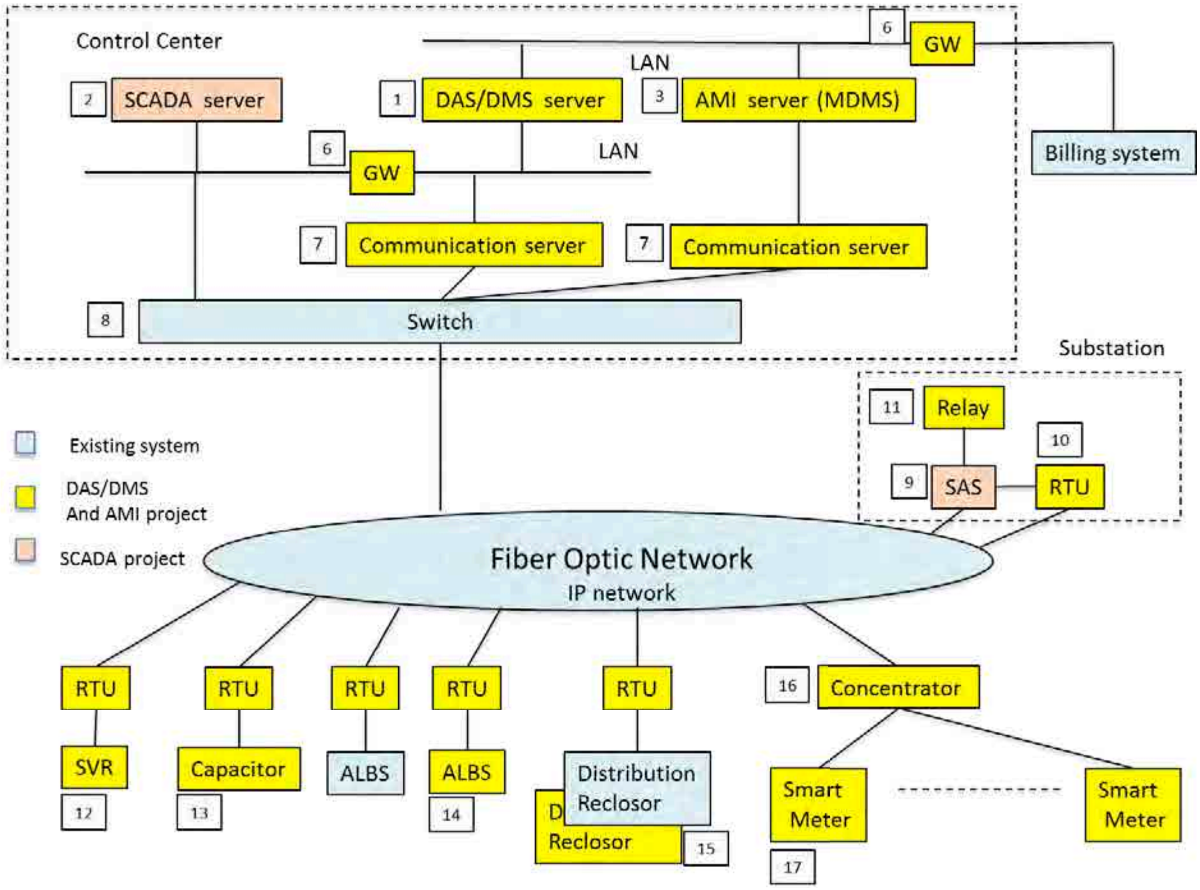


Figure 1.3-4 System Configuration of DAS/AMI

(Source: JICA Survey Team)

Remarks: Existing SCADA to monitor and control substations is rather dated and the capacity is not sufficient, so that the replacement will be planned as a different project of COPEL.

1.3.4 Scope and project cost

The scope of this project for Curitiba City and the metropolitan area is shown in Table 1.3-7.

Table 1.3-7 Scope of Project

System / facilities	Quantity
DAS / DMS	1 system (Dual system)
AMI	1 system (Dual system)
M-RTU	50 sets
Protection relay and the adaptation work	50 sets
RTU	1,753 units
SVR	120 units
Capacitor	120 units
LBS	1,753 units
RTU for existing Recloser	528 units
Concentrator	2,200 units
Smart Meter	220,000 units
OH Distribution line (for loop)	360 km
Optical fiber	4,122 km

(Source: JICA Survey Team)

1.3.5 Benefits of this project

The following effects can be expected by applying the project.

1) Reduction of outage duration
2) Reduction of technical loss
3) Reduction of non-technical loss
4) Saving construction of power generation and the transmission
5) Reduction of operation / maintenance cost
6) Reduction of CO_2 emission
7) Saving construction of substation
8) Expansion for future project / business of COPEL

The summarized effects are shown in the following table.

Table 1.3-8 Benefit and Effect of the Project

Benefit	Effect	Effected Result
1.Reduction of outage duration	80%	10.25H → 2.05H
2.Reduction of technical loss	1.35%	6.40% → 5.05%
3.Reduction of non-technical loss	70%	2.05% → 0.62%
4.Saving construction of power generation and the transmission	Peak load can be reduced by cutting residential load, so that the construction of power generation for the peak can be saved.	220MW → 0MW As effect of reduction
5.Reduction of operation / maintenance cost	Faulty section is automatically isolated, so that maintenance crews can be saved. DAS/DMS can reduce office work	COPEL <For reference> No of customer: 4 million (28 million) Sales: 27GWh (293 GWh) Employee: 7,169 (5,521) ( ): TEPCO data
6.Reduction of CO2 emission	Effect by reduction of outage duration. Effect by reduction of technical loss	60,423 tonCO2 / year→0 tonCO2 / year As effect of reduction
7.Saving construction of substation	Maximum operation can be increased up to 13% (70% ⇒ 83%)	33Substations → 28Substations 5 substations can be saved in 20 years
8.Expansion to future project / business of COPEL	New business by using optical fiber and smart meters.	Easy to expand to DR and EMS

(Source: JICA Survey Team)

1.3.6 Economical evaluation

1) Project cost

The total investment cost of project is R$463 million as shown in Table 1.3-9.

Table 1.3-9 Total investment cost of project (Unit: R$ thousand)

Item		Total	2015	2016	2017	2018	2019	2020
I	Procurement / Construction	292,314	0	107,623	144,445	25,480	14,765	0
	Distribution Field Equipment	85,982	0	31,086	25,136	18,175	11,589	0
	13kV OH Line	41,400	0	18,182	23,218		0	0
	Optical Cable	33,718	0	14,225	19,493		0	0
	138/13.8kV Substation	19,344	0	7,918	8,967		2,459,016	0
	DAS	16,026	0	14	15,258	741	14	0
	AMI (Smart Meter & MDMS)	81,919	0	31,073	45,495	5,351		0
	Base cost	278,394	0	102,498	137,567	24,267	14,062	0
	Physical contingency	13,920	0	5,125	6,878	1,213	703	0
II	Consulting services	20,997	4,045	5,268	4,968	4,542	1,784	390
	Base cost	19,998	3,853	5,017	4,731	4,326	1,700	371
	Physical contingency	1,000	193	251	237	216	85	19
A. Total (I+II)		313,311	4,045	112,891	149,413	30,022	16,550	390
a	Land Acquisition	0	0	0	0	0	0	0
b	Administration cost	15,666	202	5,645	7,471	1,501	827	20
c	Tax	133,931	366	49,517	66,955	16,205	865	23
B. Total (a+b+c)		149,597	568	55,162	74,426	17,707	1,692	42
TOTAL (A + B)		462,908	4,613	168,053	223,839	47,729	18,242	432

(Source: JICA Survey Team)

2) Financial evaluation (FIRR)

Based on the project investment costs described in 9.1 and project effects explained in 9.2, the project can be evaluated with financial internal rate of return (FIRR) calculation.

FIRR of total project is 8.5% as shown in Table 1.3-10.

Table 1.3-10 FIRR of total project

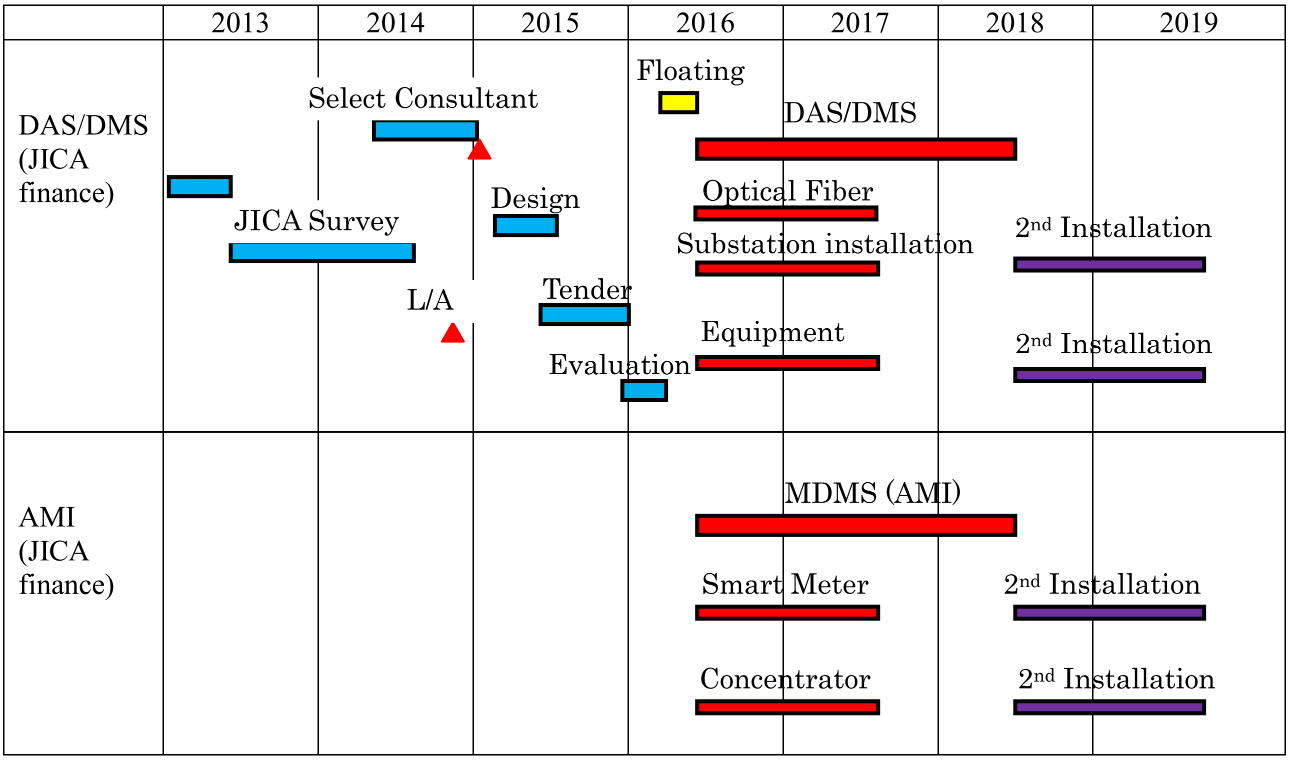
Year	Investment	Revenues or Cost Reduction	Maintenance Cost Increase	Cash flow
2015	4,614	0	0	-4,614
2016	168,053	0	0	-168,053
2017	223,839	5,618	2,201	-220,422
2018	47,729	22,220	4,410	-29,920
2019	18,241	23,315	4,484	591
2020	432	56,451	4,487	51,531
2021		39,460	4,487	34,973
2022		41,590	4,487	37,103
2023		43,848	4,487	39,360
2024		65,241	4,487	60,754
2025		48,778	4,487	44,290
2026		51,467	4,487	46,980
2027		54,317	4,487	49,830
2028		76,339	4,487	71,851
2029		60,542	4,487	56,054
2030		63,936	4,487	59,449
2031		67,535	4,487	63,048
2032		90,350	4,487	85,862
2033		75,393	4,487	70,905
2034		79,679	4,487	75,191
2035		84,222	4,487	79,735
2036		108,038	4,487	103,550
2037	-24,238	94,142	4,487	113,893
			FIRR=	8.46%

(Source: JICA Survey Team)

1.3.7 Implementation schedule

This project will be implemented from 2014 to 2019 and the outline of schedule including COPEL's project (SCADA) and the preparation of this project is shown in the following table.

Table1.3-11 Project Schedule



(Source: JICA Survey Team)

1.3.8 Social and Environmental analysis

The project components necessary to be considered in terms of environmental and social impacts are identified as:

- Construction works: installation of equipment in substations and distribution lines
- Disposal of old equipment

The construction works at substations and distribution lines do not require the land acquisition and resettlement of residents since there is neither new substation construction nor expansion of substations due to the project. In this sense, serious environmental and social impacts due to this project are not predicted.

As the result of scoping and further survey based on information from COPEL and other stakeholders, document review, and site survey, some items during the construction of distribution line extension and waste disposal are identified as the only minor negative impacts. Those can be alleviated by the normal practices of safety orientation by COPEL. No significant impact is predicted in any issues.

An alternative to this type of project producing the same level of improvement in reliability of power supply is difficult to identify. Without this project, expansion of power generation facilities and substations might be required in the future which may cause more environmental cost compared to the project.

1.4 Study member

This study member consists of 8 experts as shown in Table 1.4-1.

Table 1.4-1 Study Member

Expert	Name	Company
1. Leader and Smart Grid	FUJISAWA Atsushi	Tokyo Electric Power Service Company (TEPSCO)
2. Substation	KATO Kiyotaka	TEPSCO
3. Distribution system	FUJITANI Keiichi	Tokyo Electric Power Company (TEPCO)
4. Distribution facilities	FUJISAWA Yshitetsu	Shikoku Electric Power Company
5. Communication	YANASE Takashi	TEPCO
6. Installation and Procurement	NAKAMURA Minoru	TEPSCO
7. Economic analysis	AOYAMA Toru	International Develop. Associates., Ltd.
8. Environmental and Social Considerations	MISHIMA Mitsue	OPMAC Corporation

(Source: JICA Survey Team)

1.5 Schedule of study

The following 3 site surveys were implemented.

1) 1st survey

- Date: from 2013/2/13 to 2013/3/4

- Visiting sites: MME, ANEEL, MCTI, MDIC, ANATEL, COPEL, and TECPAR

2) 2nd survey

- Date: from 2013/4/2 to 2013/4/29

- Visiting sites: Government of Parana State, COPEL, etc.

3) 3rd survey

- Date: from 2013/6/3 to 2013/6/23

- Visiting sites: MME, ANEEL, COPEL Holding, COPEL Distribution

Chapter2 Overview of Electricity Sector

2.1 Electricity Industry System in Brazil

2.1.1 Historical Overview of Electricity Industry in Brazil

Historical overview of the electricity industry in Brazil is summarized in Table 2.1-1.

Table 2.1-1 History of Electricity Industry in Brazil

Year	Situation
1970s	The government managed the electricity sector.
1980s	Construction of 15 large hydro power plants was delayed due to lack of funds. (latter half)
1990s	Law 8.631 was enacted to invalidate the tariff equalization and make generators and distributors have supply contracts between them. (1993) Law 9.074 was enacted to establish the concept of IPP and free consumers. (1995) The MME implemented and coordinated electricity sector restructuring projects. (1996) Consequently, unbundling of generation, transmission and distribution became necessary. The ANEEL was established to regulate the electricity sector. (1998) The ONS (National Power System Operator) to operate the national electric system and Wholesale Market for Electric Power (MAE) to trade electric power were established.
2000s	The new president set forth a model to regulate the power sector completely and the privatization of Eletrobras' three subsidiaries was stopped because of a serious electricity crisis. (2001) The new administration enacted laws 10.487 and 10.848 and Resolution 5.163 aiming at long-term private investment and selected a model with severe competition. (2004) The Energy Research Company (EPE), Power Sector Monitoring Committee (CMSE) which assesses electric power supply safety continuously and Electricity Commercialization Chamber (CCEE) which supports continuation of the MAE's activities accompanied with the electric power commercialization within the interconnected system were established.

(Source: Survey Team)

Until the early 1990s, the government had managed the electricity sector in Brazil. In the 1970s, the government implemented big power projects. However, in the latter half of the 1980s, this government-owned corporation model was in peril because of tariffs depending on a lot of subsidies and lack of revenues. Therefore, construction of fifteen large-scale hydro plants was delayed due to shortage of the investment funds. This situation required a reform and so the first restructuring was implemented to allow private capital entry and improve the economic situation.

The law 8.631 was enacted in 1993. This invalidated the tariff equalization and made generators and distributors have supply contracts between them. In addition, the law 9.074 enacted in 1995 established the concept of Independent Power Producer (IPP) and free consumers in order to enhance this effect.

The Ministry of Mines and Energy (MME) has implemented and coordinated electricity sector restructuring projects since 1996. Consequently, it was concluded that unbundling of the electric power companies, that is, division of generation, transmission and distribution, was necessary. It was decided that the generation be commercialized (auction) to promote competition and the transmission and distribution be administered by the government with regulation because they were considered natural monopolies (the transmission was administered by the government, but the distribution was privatized and bids of new transmission lines were tendered so that the private participated).

An organization to regulate became necessary and the ANEEL (Electric Power National Agency) was created. Furthermore, the ONS (National Power System Operator) to operate the national electric system and Wholesale Market for Electric Power (MAE) to trade electric power were established.

In 2001, the electric power system was on the verge of a very serious crisis in supply and the situation required implementing an electric power rationing plan. This electricity crisis brought about doubts about the course the electric sector was directed to. Thus, the new president set forth a model to regulate the power sector completely and the privatization of Eletrobras' three subsidiaries was stopped. But, the new administration enacted laws 10.487 and 10.848 in March 2004 and Resolution 5.163 in July of the same year aiming at long-term private investment and selected a model with severe competition. The existing institutions were maintained and some were reinforced so that the Energy Research Company (EPE), Power Sector Monitoring Committee (CMSE) which assesses electric power supply safety continuously and Electricity Commercialization Chamber (CCEE) which supports continuation of the MAE's activities accompanied with the electric power commercialization within the interconnected system were established.

2.1.2 Present Situation of Electric Sector in Brazil

1) Outline of Administration Organizations in Electricity Sector

The MME has the overall responsibility for policy setting in the electricity sector while ANEEL, which is linked to the MME, is responsible for Brazilian electricity regulation and standard of specification.

The National Energy Policy Council (CNPE) consisting of related ministers (the chairman is the Minister of Energy and Mines) is an inter-ministerial advisory board to the Brazilian President in charge of formulating power-related policies and guidelines, and to assure the supply of raw materials used in power generation in remote areas of Brazil while the Comitê de Monitoramento do Setor Elétrico (CMSE) monitors and evaluates power supply continuity and safety throughout Brazil.

The ONS, which is an independent non-profit private system operator, was created to operate, supervise and control power generation within the National Interconnected System (SIN), and to manage Brazilian power transmission grid. The ONS is under ANEEL's control and regulation.

The CCEE has obligations to determine the settlement price for differences or spot price, execute the energy accounting process, settle the amounts calculated in the energy accounting process financially and prepare and execute electricity auctions within the regulated contracting environment by delegation of the ANEEL.

Finally, EPE was created in 2004 with the specific mission of carrying out studies and research in order to provide background information to Brazilian energy sector monitoring and long term planning activities.

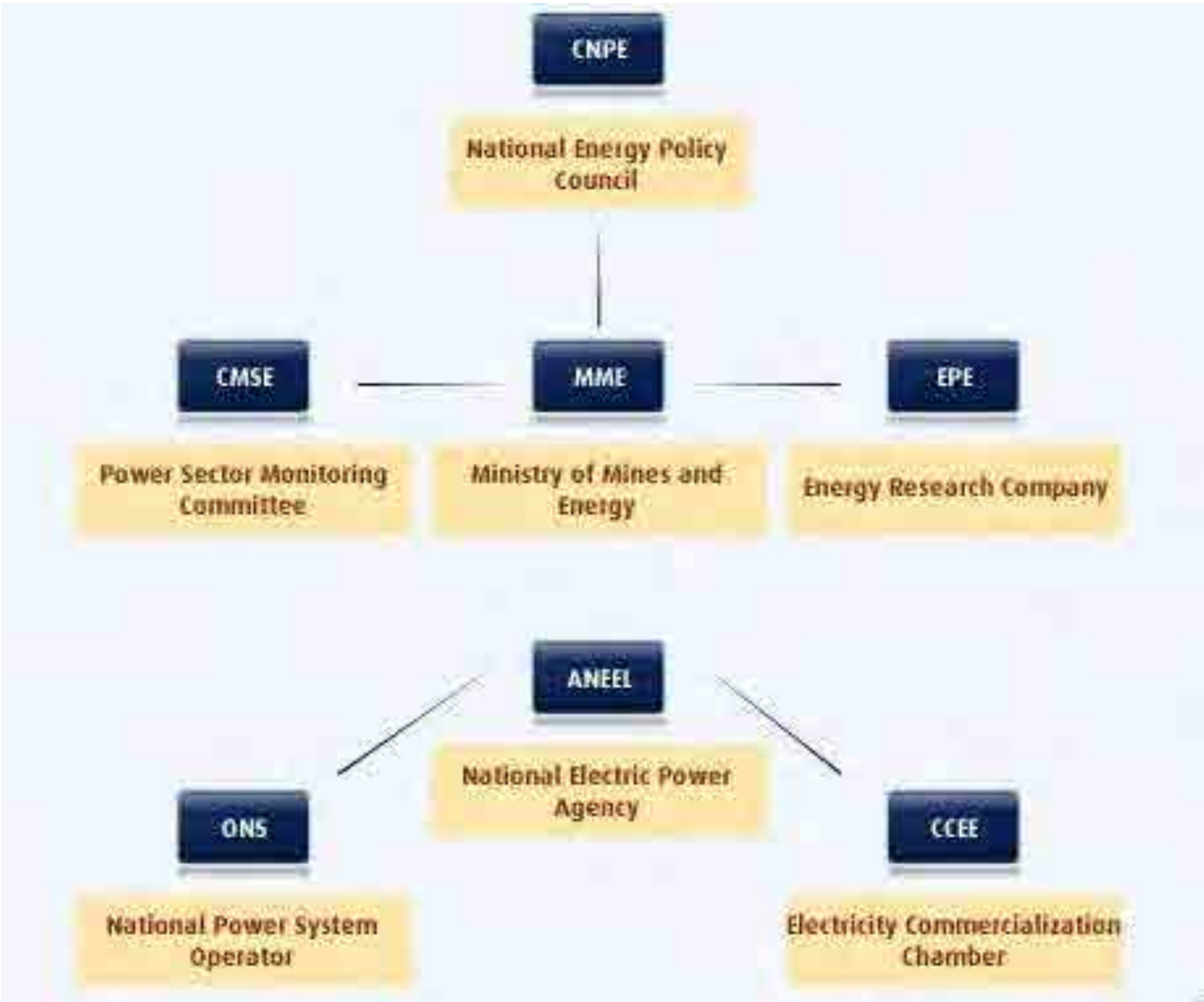


Figure 2.1-1 Structure of Electricity Sector in Brazil

(Source: "Study on collection of basic information concerning smart grid/ smart community introduction in Brazil)

2) Outline of Generation Companies in Brazil

The MME shows that the total installed generation in Brazil is 115 GW. 71% of that, namely 81,430MW, is hydro in 2011. Eletrobras, national power corporation (the federal government owns 67.38% including BNDES's 22% of the stocks so that more than half of the shares are public and the remaining shares are private including free floating), controlled approximately 35.6% (41.621GW) of the total generation capacity (116,795,837kW) in 2011, Brazil, and is the biggest supplier according to the Eletrobras annual report. It has 28 hydro (including Itaipu), 119 thermal, two nuclear and four wind/ solar power plants. Among those, large and important plants are as follows:

- Tucuruí (8,370 MW),
- Brazilian part of Itaipu (7,000 MW),
- Paulo Afonso and Moxotó Complex (4,280MW),
- Xingó (3,162 MW),
- Angra 1& 2 (2,007 MW),
- Serra da Mesa (1,275 MW),
- Furnas (1,226 MW)
- Sobradinho (1,050 MW)

In spite of the privatization promotion, the reason why these power plants remained in the hands of the national power corporation is said that the private did not apply for the bids of these big power plants because the government attached the employee's pension obligation to the power plants.

In addition, Petrobras whose ordinary (common)[1] stocks are shared by the federal government at 50.2% has generating power with 5,806MW capacities.

There are state-owned power generation companies and the large companies among them can be mentioned as follows.

- CESP (Companhia Energética de Sao Paulo) in Sao Paulo State: 57 generating units (6 hydro plants) with 7.455GW capacities
- Cemig (Companhia Energética de Minas Gerais) in Minas Gerais State: 65 generation plants (59 hydro and three thermal and three wind) with 6.964GW capacities (including Light's)
- COPEL (Companhia Paranaense de Energia) in Parana State: 19 (17 hydro one thermal and one wind) generation plants with 4.55GW capacities

[1] The shares of the Corporation shall be common shares, entitled to vote whereas preferred shares, the latter, always without vote entitlement. (Article 5, Petrobras Bylaw)

- CELESC (Centrais Eletricas de Santa Catarina) in Santa Catarina State: 12 hydro plants with 81.9MW capacities

The sum of Eletrobras', Petrobras' and four state generation companies' capacities accounts for 57% of the total generation capacities in Brazil, that is, more than a half.

On the other hand, there are main private generation companies mentioned as follows.

- Tractebel Energia: 22 power plants (9 hydro, and 6 thermal and 7 complementary) with 6.69GW capacities
- AES (Applied Energy Services): two power plants (10 hydro, 7 small hydropower and one thermal) with 3.29GW capacities
- CPFL (Companhia Piratininga de Forca e Luz): 22 power plants with 2.233GW capacities
- Duke Energy Brazil: 8 plants with 2.307GW
- Endesa (Empresa Nacional de Electricidad): 13 power plants with 1.0046GW capacities
- Light: three power plants with 853MW capacities

Table 2.1-2 Main Power Generation Companies in Brazil

Company	Generation Capacity	Share	Public/ Private	Main Plants
Eletrobras	41.621 GW	35.6%	Public	Itaipu, Tucurui
Petrobras	5.806 GW	5.0%	Public	Juiz de Fora TEP
CESP	7.455 GW	6.4%	Public	Ilha Solteira
Cemig	6.964 GW	6.0%	Public	Belo Monte
Tractebel Energia	6.69 GW	5.7%	Private	Ita
Copel	4.55 GW	3.9%	Public	Foz do Areia
AES	3.29 GW	2.8%	Private	Tietê
Duke Energy Brasil	2.307 GW	2.0%	Private	Capivara
CPFL	2.233 GW	1.9%	Private	Serra da Mesa
Endesa	1.0046 GW	0.86%	Private	Cachoeira
Light	853 MW	0.73%	Private	Itaocara

(Source: JICA Survey Team)

The number of generation companies registered in ONS is 100. In addition, ONS shows new generation data like Table 2.1-3.

Table 2.1-3 Average Monthly Generation Data by State (March 2013) (Unit: MW)

State	Hydro	Thermal	Wind	Total
Acre	0.00	0.00	0.00	0.00
Alagoas	3.90	0.00	0.00	3.90
Bahia	1,664.31	853.50	45.56	2,563.37
Ceara	0.00	800.69	138.53	939.22
Federal District	0.00	0.00	0.00	0.00
Espirito Santo	162.40	363.08	0.00	525.48
Goias	2,012.39	198.32	0.00	2,210.71
Maranhao	908.24	621.80	0.00	1,530.04
Mato Grosso	766.58	398.74	0.00	1,165.32
Mato Grosso do Sul	0.00	336.49	0.00	336.49
Minas Gerais	5,096.67	331.23	0.00	5,427.90
Para	6,991.27	0.00	0.00	6,991.27
Paraiba	0.00	198.21	0.00	198.21
Parana	9,748.70	481.83	0.00	10,230.53
Pernambuco	572.17	587.39	0.00	1,159.56
Piaui	105.36	22.08	0.00	127.44
Rio de Janeiro	814.13	4,570.90	0.00	5,385.03
Rio Grande do Norte	0.00	217.13	102.08	319.21
Rio Grande do Sul	1,388.68	795.84	22.05	2,206.57
Rondonia	512.48	116.50	0.00	628.98
Santa Catarina	2,188.78	463.20	0.00	2,651.98
Sao Paulo	6,996.40	632.50	0.00	7,628.90
Sergipe	1,501.24	0.00	0.00	1,501.24
Tocantins	1,140.98	0.00	0.00	1,140.98
Total	42,574.68	11,989.43	308.22	54,872.33

(Source: ONS)

3) Outline of Transmission Companies in Brazil

According to the Reference Foam of Eletrobras 2012, its total length of high voltage transmission lines in Brazil is 54,104.9km, which accounts for 56% in 2011. Therefore, the total length of transmission line in Brazil is approximately 96,600km.

Main state-owned transmission companies are as follows.

- CEMIG: 10,060km
- CEEE (Companhia Estadual de Energia Eletrica): 6,056km (Rio Grande do Sul State)
- COPEL: 2,029km
- CELESC: 252.5km (Santa Catarina State)

While the sum of these public transmission lines accounts for approximately 75% share, major private transmission companies are mentioned as follows.

- CTEEP (Companhia de Transmissão de Energia Elétrica Paulista, a Colombian enterprise): 12,993km (Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, Minas Gerais, Rondônia, Mato Grosso, Mato Grosso do Sul, Goiás, Tocantins, Maranhão and Piauí States)

- Alusa (Alupar): 5,464.5km
- Terna (Italian company): 2,447km

The number of transmission companies registered in ONS is 75 in 2012.

The transmission network in Brazil is shown in Figure 2.1-2.

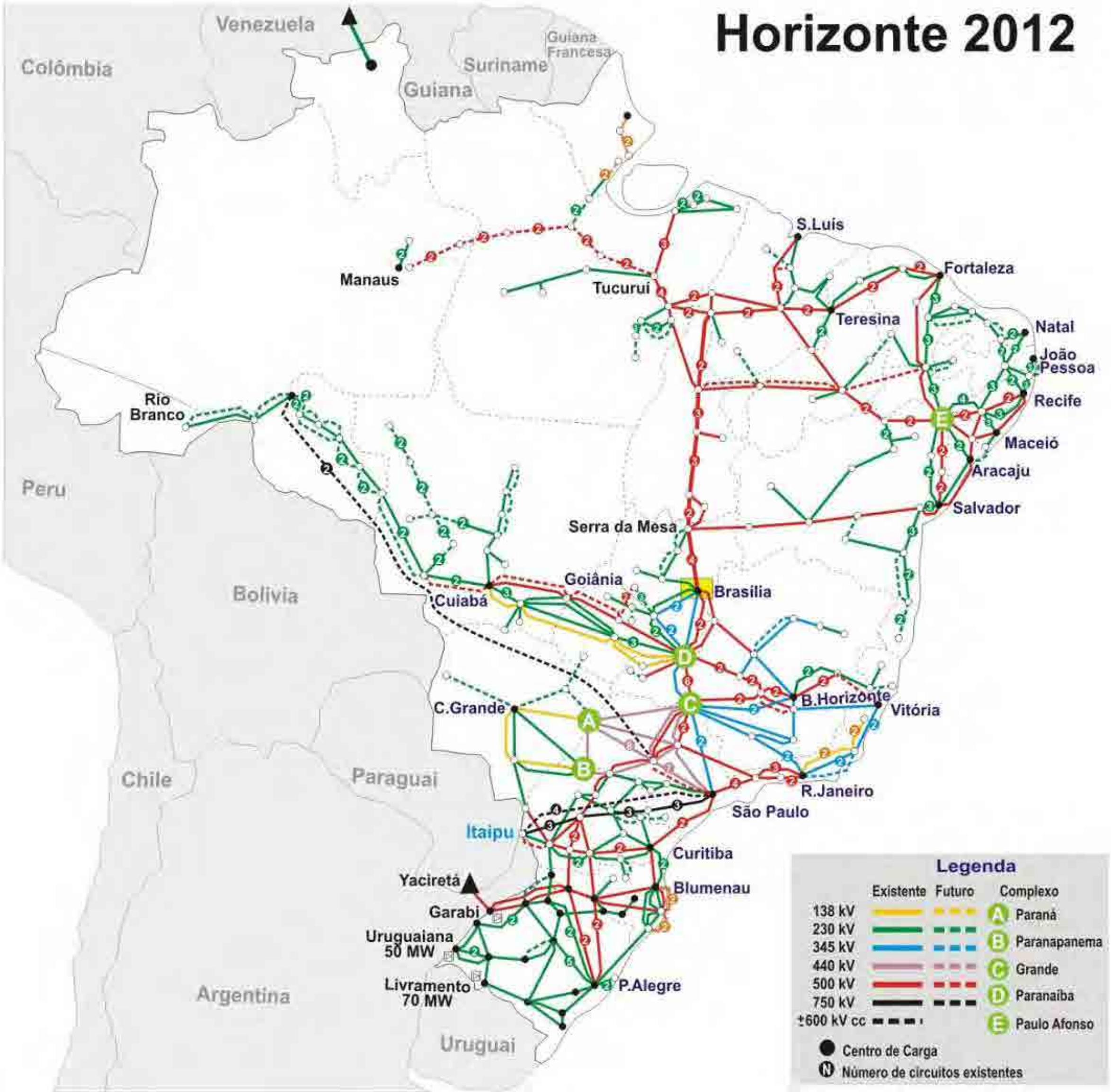


Figure 2.1-2 Transmission Network in Brazil

(Source: Ivan Camargo, "Innovative Regulation for the Development of Smart Grid in Latin America" 2011)

4) Outline of Distribution Companies in Brazil

While privatization of the distribution companies in Brazil has progressed as shown in the Table 2.1-4 below, COPEL, which is the object of this study, is a public electric corporation described below. The overview of distribution companies in Brazil is shown in Table 2.1-5.

Table 2.1-4 Top 20 Distribution Companies in Brazil in 2012

Rank	Name	Supply Area	Capital (Private/ public/ foreign entry)	Supply Power (GWh)	Market Share (%)
1	Eletropaulo	Sao Paulo State	AES (US)'s affiliated company	37,622	11.8
2	Cemig	Minas Gerais State	Public	24,714	7.8
3	Copel	Parana State	Public	22,737	7.1
4	CPFL Paulista	Sao Paulo State	Private	21,467	6.7
5	Light	Rio de Janeiro State	Private	20,054	6.3
6	Celesc	Santa Catarina State	Public	15,018	4.7
7	Coelba	Bahia State	Iberdrola (Spain) has an 8.5% share. (In addition, it has a 39% share of Neoenergia, the biggest shareholder of Coelba.)	14,305	4.5
8	Elektro	Sao Paulo State	Iberdrola (Spain) has a 34.45% share.	12,083	3.8
9	Celg	Goias State	Public	10,480	3.3
10	Celpe	Pernambuco State	Iberdrola (Spain) has a 39% share.	9,922	3.1
11	Bandeirante	Sao Paulo State	Portuguese Electric Power Corporation (EDP) has a share. (China seems to have an approximately 25% share.)	9,399	3.0
12	CPFL Piratininga	Sao Paulo State	Private	9,041	2.8
13	Ampla	Rio de Janeiro State	ENDESA (Spain) had a 70% share, but it seems to obtain the remaining 30%.	8,993	2.8
14	Coelce	Ceara State	ENDESA (Spain) has a 2.27% share.	8,693	2.7
15	CEEE	Rio Grande do Sul State	Public	7,596	2.4
16	AES Sul	Rio Grande do Sul State	AES (US)'s affiliated company	7,469	2.3
17	RGE	Rio Grande do Sul State	Private	6,444	2.0
18	Celpa	Para State	Private	6,412	2.0
19	Escelsa	Espirito Santo State	An affiliated company of EDP (Portuguese public electric power corporation)	5,665	1.8
20	CEB	Federal District	Public	5,634	1.8
Others				54,417	17.1
National Total				318,167	100.0

Note: Top 8 companies supply more than a half of the total national demand

(Source: ANEEL Data)

Table 2.1-5 Overview of Distribution Companies in Brazil in 2011

Utility	Area (km2)	Number of Consumers	Urban Medium Voltage Grid Lenght (km)	Rural Medium Voltage Grid Lenght (km)
AES-Sul	98,569.37	1,214,292	5,445.96	36,618.05
AmE	1,589,854.13	693,981	3,605.07	6,773.48
AMPLA	32,612.47	2,631,185	14,014.84	19,159.85
BANDEIRANTE	8,490.56	1,355,402	6,322.59	5,549.10
BOA VISTA	5,686.99	82,552	620.35	782.07
CAIUÁ-D	9,149.00	217,816	1,085.44	5,335.89
CEA	142,814.90	155,664	3,012.06	1,516.18
CEAL	29,099.44	923,153	3,065.05	15,794.56
CEB-DIS	5,789.46	879,019	4,526.39	4,889.67
CEEE-D	85,600.89	1,435,927	8,494.97	30,367.37
CELESC-DIS	85,707.82	2,433,293	11,653.07	65,431.82
CELG-D	336,930.15	2,394,769	32,869.62	136,473.73
CELPA	499,486.16	685,954	2,135.85	23,634.57
CELPE	99,513.14	2,978,413	6,981.24	64,945.11
CELTINS	278,069.90	477,958	2,247.09	67,471.08
CEMAR	332,246.24	1,899,733	5,242.69	78,358.19
CEMIG-D	605,227.36	7,343,934	33,902.96	365,968.48
CEPISA	263,546.99	1,022,773	4,233.00	34,018.89
CERON	238,378.00	518,309	3,040.57	42,587.83
CERR	218,611.92	33,672	207.80	5,003.70
CFLO	1,200.00	51,652	330.58	923.66
CHESP	3,393.62	31,624	145.84	2,447.71
CJE	252.15	33,848	232.35	313.44
CLFM	1,843.88	41,830	290.95	1,858.98
CLFSC	11,869.74	187,918	1,246.48	5,984.97
CNEE	3,395.00	103,633	493.89	2,398.76
COCEL	1,207.50	42,359	653.58	889.46
COELBA	564,368.89	4,958,254	11,447.95	145,117.96
COELCE	135,298.80	2,799,896	5,892.52	68,109.54
COOPERALIANÇA	569.00	33,144	376.12	103.16
COPEL-DIS	196,635.93	4,006,939	24,073.50	155,045.62
COSERN	52,790.62	1,158,067	2,432.02	25,675.62
CPEE	2,588.67	52,267	518.80	2,412.93
CPFL- Piratininga	4,328.77	1,209,726	5,324.62	3,288.69
CPFL-Paulista	89,732.79	3,746,509	19,869.22	60,132.72
CSPE	3,801.90	75,575	581.33	2,906.51
DEMEI	45.00	28,387	116.84	18.49
DMEPC	603.10	66,917	376.10	406.10
EBO	1,983.96	173,902	521.87	1,592.96
EDEVP	11,791.00	165,068	783.54	5,967.05
EEB	3,488.00	133,889	584.15	4,513.65
EFLJC	262.50	2,684	17.13	2.20
EFLUL	237.40	6,028	56.21	121.64
ELEKTRO	121,232.31	2,269,500	11,481.80	71,838.70
ELETROCAR	2,560.00	32,832	178.18	1,346.69
ELETROACRE	160,688.44	199,805	942.84	11,948.73
ELETROPAULO	4,503.96	6,519,347	17,084.37	2,791.96
ELFSM	4,988.19	92,892	385.49	6,245.51
EMG	15,867.06	396,702	2,083.41	20,223.54
ENERSUL	328,219.72	843,807	4,787.47	75,135.06
ENF	935.05	94,897	414.40	704.82
EPB	54,446.53	1,161,818	3,078.01	33,669.41
ESCELSA	41,372.16	1,297,527	5,961.47	41,936.29
ESE	17,629.03	633,265	1,802.09	15,264.14
FORCEL	280.00	6,484	67.27	193.41
HIDROPAN	151.00	15,308	153.39	104.22
IENERGIA	1,252.00	30,659	198.44	1,243.38
LIGHT	11,017.86	3,917,720	17,669.78	5,178.63
MUX-Energia	17.26	9,492	59.92	18.10
RGE	85,930.21	1,300,031	6,726.17	42,815.85
SULGIPE	5,762.21	125,631	269.84	4,595.71
UHENPAL	1,858.60	14,529	72.75	1,013.80

(Source: ANEEL Data)

2.2 Overview of COPEL's Business and Organization

COPEL's shareholding structure is shown in Figure 2.2-1.

Figure 2.2-1 Shareholding Structure of COPEL

(Source: COPEL's ANNUAL REPORT AND FINANCIAL STATEMENTS 2010)

The following chart (Figure 2.2-2) features COPEL's organizational structure, with three wholly-owned subsidiaries, committees and councils.

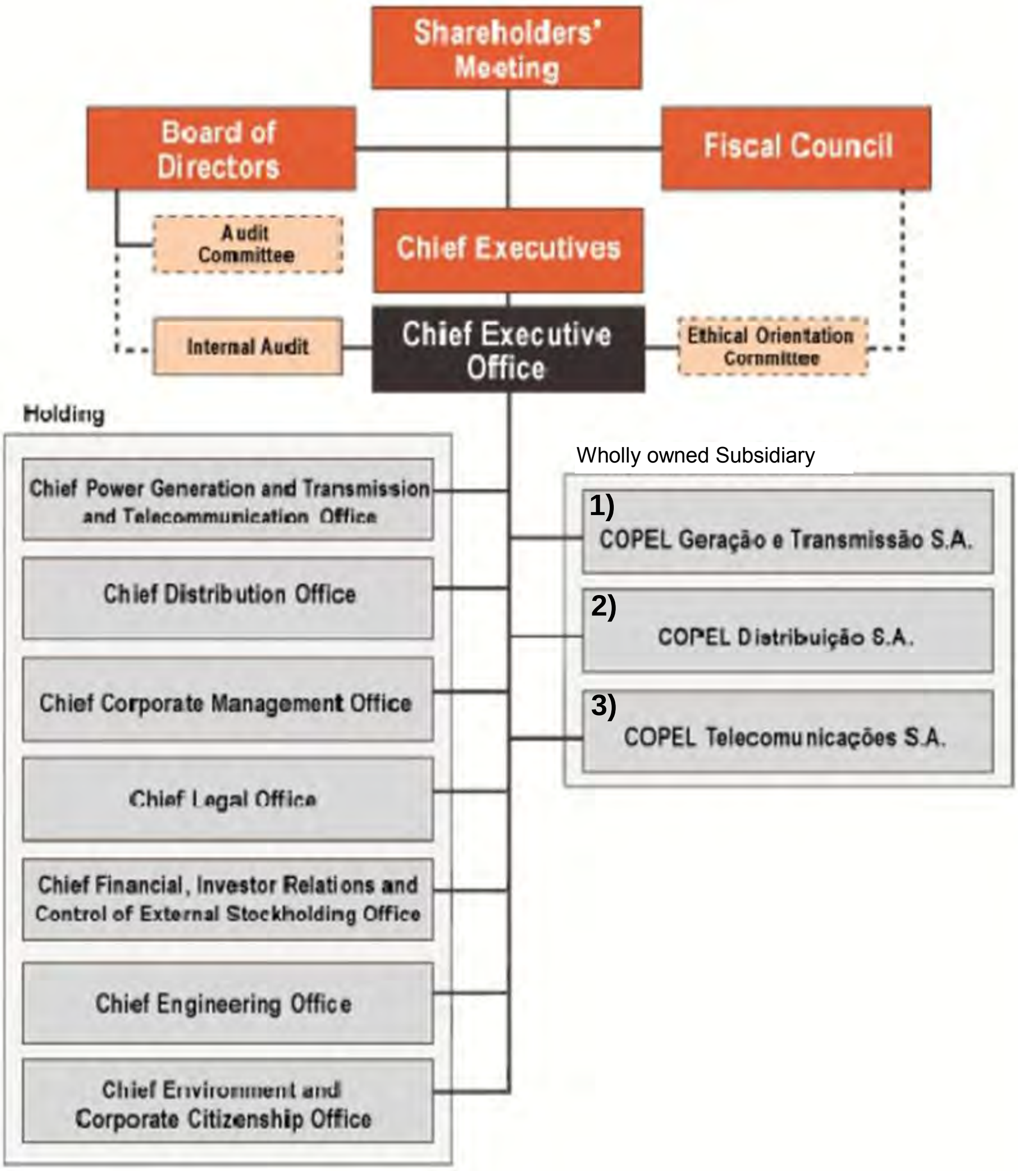


Figure 2.2-2 COPEL's Organizational Structure

(Source: COPEL's ANNUAL REPORT AND FINANCIAL STATEMENTS 2010)

COPEL is a mixed capital company, controlled by the Parana State Government. COPEL and its subsidiaries are engaged in researching, studying, planning, building, and exploiting the production, transformation, transportation, distribution, and sale of energy, in any form, but particularly electric energy. These activities are regulated by the ANEEL, which reports to the MME. Additionally, COPEL takes part in consortiums, private enterprises, or mixed capital companies in order to operate mostly in the areas of energy, telecommunications, natural gas, and water supply and sanitation. The subsidiary companies are as follows.

1) COPEL Geração e Transmissão S.A.

Wholly owned subsidiary that operates the Company's power generation business, which is based on the operation of 17 hydroelectric power plants and one thermoelectric power plant, amounting to total installed capacity of 4,549.59 MW, and power transmission services, based on 31 substations at voltages equal to or greater than 230 kV and 2,028.7 km of transmission lines in the state of Paraná, most of which are part of the Brazilian Basic Transmission Network. The concession for 1,744.3 km of these lines expires in July 2015, the concession for 137.1 km (Bateias – Jaguariaíva 230 kV line) expires in August 2031, the concession for 31.6 km (Bateias – Pilarzinho 230 kV line) expires in March 2038, and the concession for 115.7 km (Cascavel-Oeste – Foz do Iguaçu) expires in November 2039, all subject to extension at the discretion of the granting authority.

2) COPEL Distribuição S.A.

Wholly owned subsidiary that runs the Company's Power distribution and regulated sales to 1,117 locations in 396 municipalities. Currently, 392 municipalities are wholly serviced by Copel Distribuição S.A in the State of Paraná, and also the municipality of Porto União, in the State of Santa Catarina. Its current concession, which expires on July 7, 2015, may be extended for another 20 years, at the discretion of the granting authority.

3) COPEL Telecomunicações S.A.

Wholly owned subsidiary that is engaged in providing communications and telecommunications services and in conducting studies, projects, and planning in the field of telecommunications, as well as any related activities, as authorized by law, for an indeterminate period of time, on a non-exclusive basis, both nationally and internationally, with a service area comprising the State of Paraná and Region II of the General Grants Plan of the National Telecommunications Agency - ANATEL, which reports to the Ministry of Communications.

4) Companhia Paranaense de Gás – Compagas

Mixed capital company in which Copel holds a 51% interest. Compagas owns a concession contract which grants and regulates its concession for the operation of the public service of piped gas distribution in the State of Paraná. This contract lasts 30 years starting from July 06, 1994, and can be renewed for an equal period upon request from the licensee. The concession grants the operation of piped gas distribution services and other related activities, for use by all consumer segments. The company currently has a distribution network of 574 km set up throughout municipalities in the State of Paraná.

5) Elejor – Centrais Elétricas do Rio Jordão S.A.

Special purpose company in which Copel holds a 70% voting interest and which was constituted to implement and run the Fundão – Santa Clara Power Complex, on the Jordão River, within the Iguaçu River sub-basin, in the State of Paraná, comprising the Santa Clara and Fundão Power Plants. These facilities feature 240.34 MW of installed capacity, in addition to small hydropower units embedded in the Santa Clara and Fundão dams, with 3.6 MW and 2.4 MW of installed capacity, respectively. Its concession to operate as an independent power producer was issued by the ANEEL on October 25, 2001, for a 35-year term, renewable upon request by the holder for up to 20 years and at the granting authority's discretion.

6) UEG Araucária Ltda.

Limited liability Company held by Copel (with a 20% interest) and Copel Geração e Transmissão (with a 60% interest). It was set up to generate and sell electric power, using natural gas as fuel. The Araucária Power Plant has an installed capacity of 484.15 MW. Its authorization to operate as an independent power producer was issued by the ANEEL on December 22, 1999 for a 30-year term, renewable upon request by the holder and at the granting authority's discretion.

UEG Araucária signed a lease agreement with Petróleo Brasileiro S.A. – Petrobras for the lease of its power generation plant.

Concerning the financial organization in COPEL, its structure is shown in Figure 2.2-3.

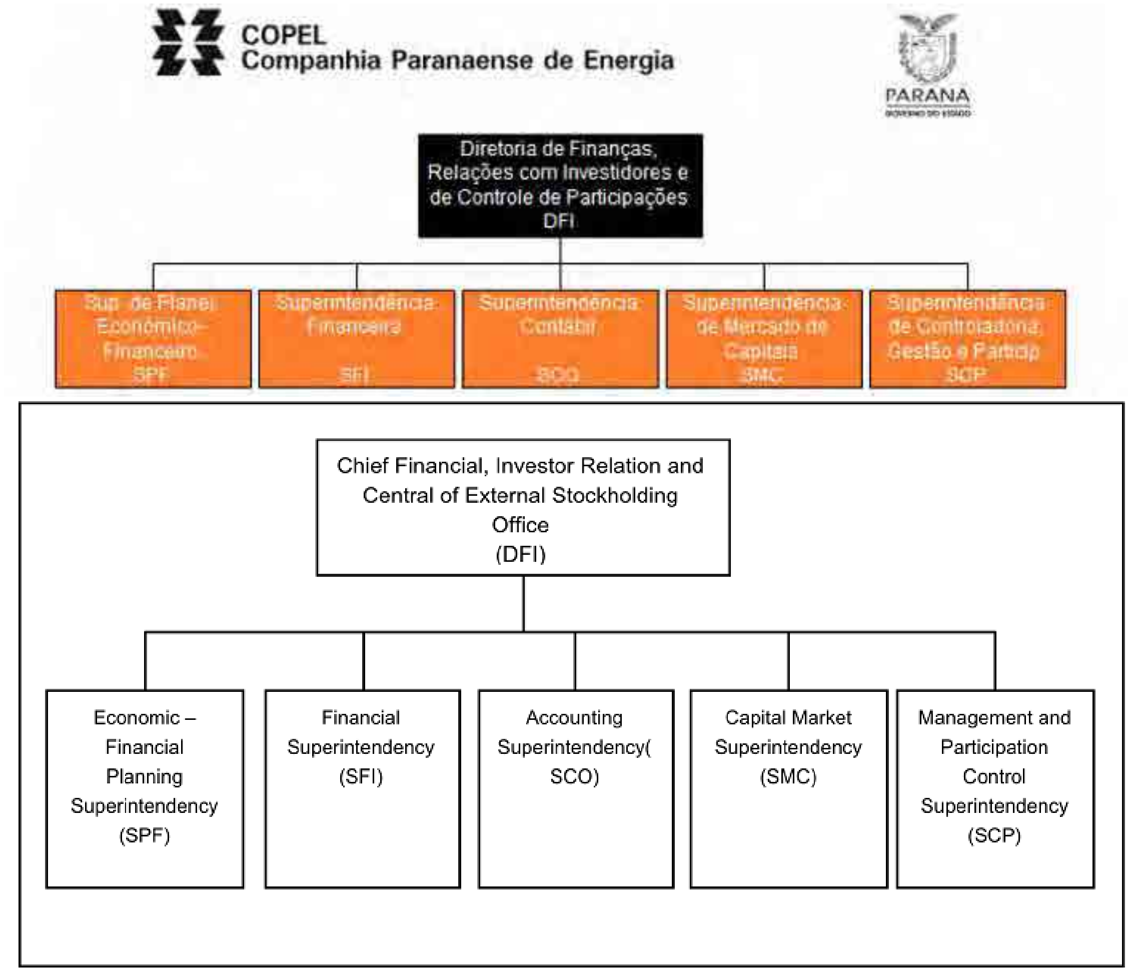


Figure 2.2-3 COPEL's Financial Organization Structure

(Source: COPEL's Material)

According to the interview with accounting staff of COPEL Distribution, although COPEL's 233 financial area employees (as of June, 2013) belong to the subsidiary companies legally based on the labor law, there is no financial area employee in COPEL parent company. The financial groups belonging to subsidiary companies are operating including the financial function of COPEL parent company. Concerning project financing, the Economic Financial Planning Superintendence and Financial Superintendence in addition to Chief Financial, Investor Relation and External Stockholding executive make the project financing decisions.

Incidentally, COPEL's recent big projects are hydro generation plant (R$ 169 million) and transmission (R$ 50 million) projects. The financing resources are BNDES and bond issues. The interest rate of bond is approximately 8.21%.

If this Smart Grid project is financed by JICA, the final loan borrowers would be COPEL Distribution and COPEL Telecom. However, if there is an indirect borrower, e.g., COPEL parent company, as the first borrower and the loan is transferred to the two subsidiary companies (Distribution and Telecommunications), IOF (financial transmission tax) is imposed. Its rate is 0.75% plus 0.0045%/day. Therefore, the indirect borrower does not seem advantageous from the viewpoint of tax reduction according to the interviewed staff of Accounting Superintendency (DCGG), COPEL Distribution.

2.3 Overview of Electricity Sector (Distribution) in Curitiba Metropolitan Area

There are 29 municipalities in the Curitiba Metropolitan Area, but one of them, Campo Largo, is not covered by COPEL. The distribution networks in the Curitiba Metropolitan Area are divided into four districts: Curitiba City, north, east and south. In addition, there are 16 sales offices in the Area shown in Table 2.3-1 and Figure 2.3-1. Curitiba City has seven sales offices, but other municipalities have one for several municipalities.

Table 2.3-1 Sales Office Numbers in Curitiba Metropolitan Area

Municipalities	Sales office No.
Adrianopolis	0
Agudos do Sul	0
Almirante Tamandare	1
Araucaria	1
Balsa Nova	0
Bocaiuva do Sul	0
Campina Grande do Sul	0
Campo do Tenente	0
Campo Largo	0
Campo Magro	0
Cerro Azul	0
Colombo	1
Contenda	0
Curitiba	7
Doutor Ulysses	0
Fazenda Rio Grande	1
Itaperuçu	0
Lapa	0
Mandirituba	0
Pien	0
Pinhais	1
Piraquara	1
Quatro Barras	1
Quitandinha	0
Rio Branco do Sul	1
Rio Negro	0
Sao Jose dos Pinhais	1
Tijucas do Sul	0
Tunas do Parana	0
TOTAL	**16**

(Source: COPEL material)

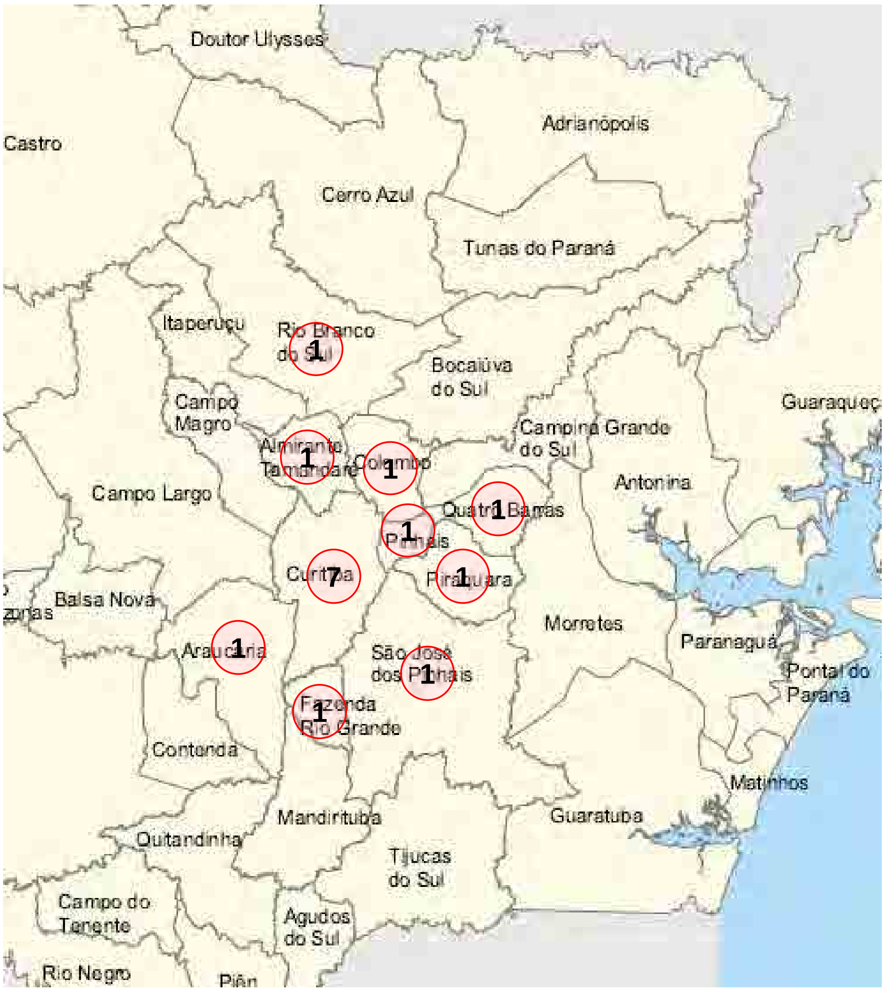


Figure 2.3-1 Location of Sales Office Numbers in Curitiba Metropolitan Area

(Source: COPEL material)

2.4 Present Situation and Forecast of Demand and Supply

2.4.1 Present Situation and Forecast of Demand and Supply in Brazil

In the "Plan of National Energy 2030" (hereinafter referred to as PNE 2030) announced in 2007, the MME expects the growth of the energy demand from 2005 to 2030 will be 2.5 to 4.3% per year and the growth rate of the power demand in 2005 to 2030 will be 3.5 to 5.1% for whole Brazil. In the latest "Plan for Expansion of Energy 2020" (hereinafter referred to as PDE 2020) which is a realistic implementation plan of PNE 2030, the Energy Research Company (hereinafter referred to as EPE) expects the growth rate of energy demand will be 5.1% and growth rate of the power demand will be 4.8%.

Regarding the situation of the balance of demand and supply, despite the electricity crisis in 2001 when water reserves were abnormally low, the supply is currently sufficient to meet its demand. The peak demand in Brazil is expected to rise continuously at an annual rate of 4 or 5 % for the next 20 years. The static balance of the Brazilian Interconnected System is expected to have positive balance of physical energy and physical security between 4 % and 11 % of the power load throughout the period from 2011 to 2020 in PDE 2020. At the regional level, on average, the Southeast/Midwest and Southern regions are importers, while the Northern and Northeast regions are exporters.

In PDE 2020, the maximum available power was calculated to compare with expected peak demand for the next 10 years. The results show that the available power supply remains at least 7,900 MW greater than the coincident peak demand of the Brazilian Interconnected System during the study. The worst situation occurs in October 2019, but still with a power reserve representing 7.5 % of the peak demand. The supply logistics of fuel oil and natural gas takes a key role at the end of the period with the thermal power plants generating at the maximum availability as a backup of the run-off-river plants.

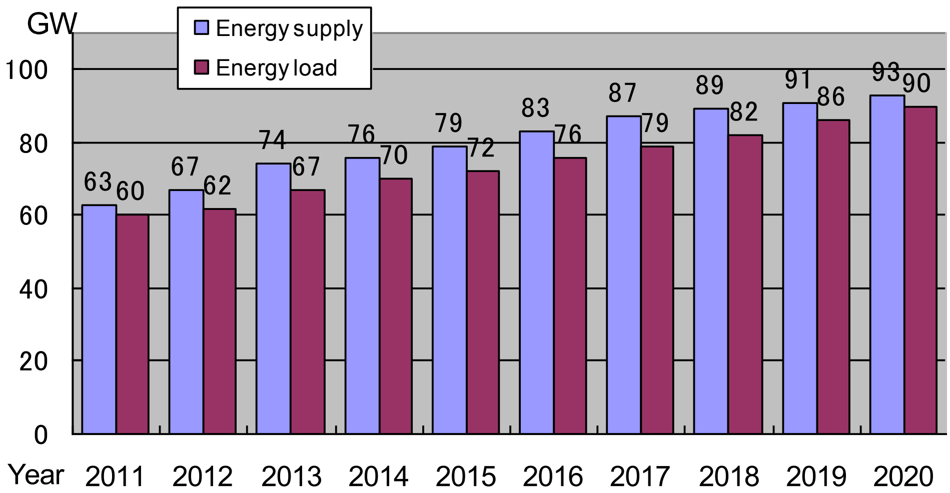


Figure 2.4-1 Static Electricity Balance (GW average)

(Source: PDE 2020)

The electricity consumption forecast by each sector in PDE2020 is shown in the following table. The growth rate of the commercial sector is higher than the other sector. The growth rate of the industry sector is relatively lower than the other sector.

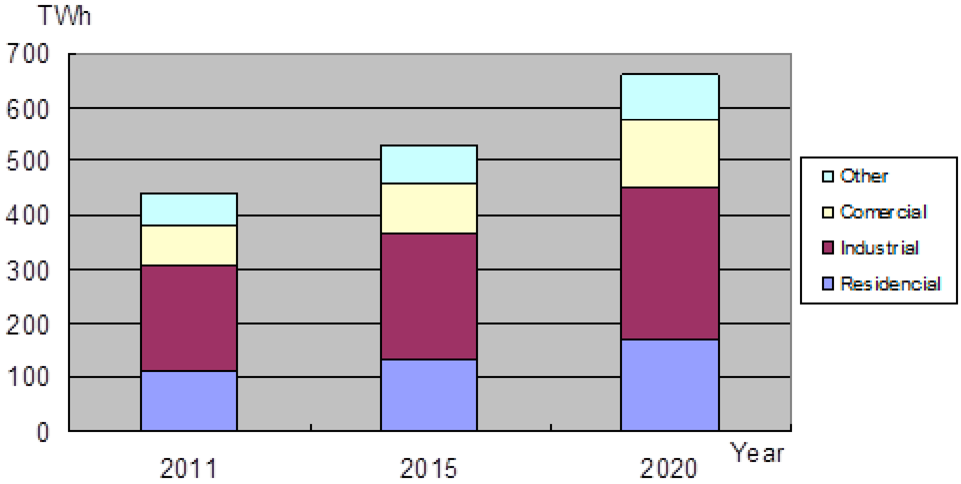


Figure 2.4-2 Electricity consumption by each sector (TWh)

(Source: PDE 2020)

2.4.2 Present Situation and Forecast of Demand and Supply in Curitiba Metropolitan Area

In COPEL, the medium and long-term power supply and demand forecast is analyzed by the research institute, and the short-term power supply and demand forecast and the adjustment of the supply and demand is conducted at the central dispatching center. However, the result of the supply and demand forecast is nondisclosure at COPEL. Therefore the future power demand forecast is considered based on the economic growth rate forecast of the Paraná state and the past trend data of the COPEL service area for the above mentioned reason.

The economic growth rate forecast of the Paraná state and the whole country of Brazil is shown in the following table. The economic growth rate of the Paraná state will be about 4 % per year, which is higher value as compared with the economic growth rate of the whole country of Brazil. For this reason, it is expected that the economic growth in the Paraná state is higher than the economic growth in the whole country of Brazil in future.

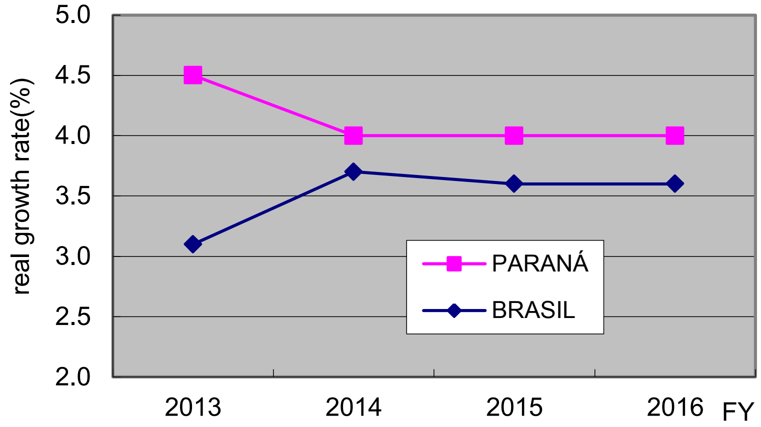


Figure 2.4-3 Annual Real Growth Rate of the Paraná State and Brazil

*(Source: *[2])*

The past trend of the maximum power demand excluding peak hour demand (average of 2003-2012) in the COPEL service area is shown in Figure 2.4-4 and power consumption by each sector is shown in Figure 2.4-5. The power demands in November and December are high, and the power demand in May, June and July are low. The cause is considered to be influence by air conditioner load along with the average temperature of the Curitiba city. Moreover, the growth rate of the average power demand excluding peak hour demand from 2003 to 2012 is shown in Figure 2.4-6. Although there is a fluctuation each year, it is increasing steadily at 4% to 6% per year.

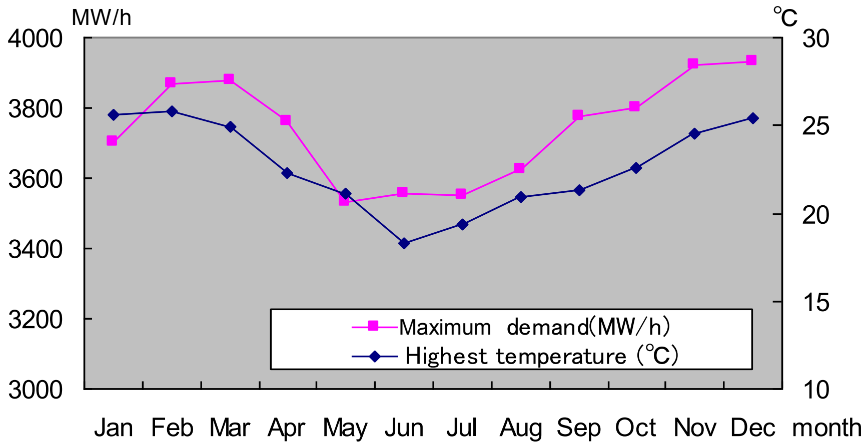


Figure 2.4-4 Average Maximum Demand in COPEL Area

(Source: JICA Survey Team)

[2] Mediana das expectativas de mercado, levantadas pelo Banco Central em 01/03/2013, para o PIB do Brasil e projeção do IPARDES para o PIB do Paraná. No caso do valor do PIB, além da taxa real de crescimento, foi aplicado o IPCA projetado pelo Banco Central.

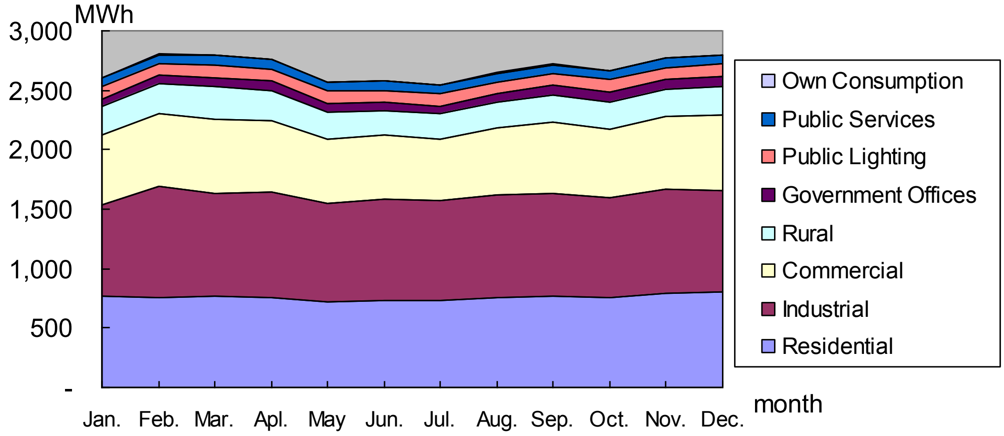


Figure 2.4-5 Power Consumption by Each Sector

(Source: JICA Survey Team)

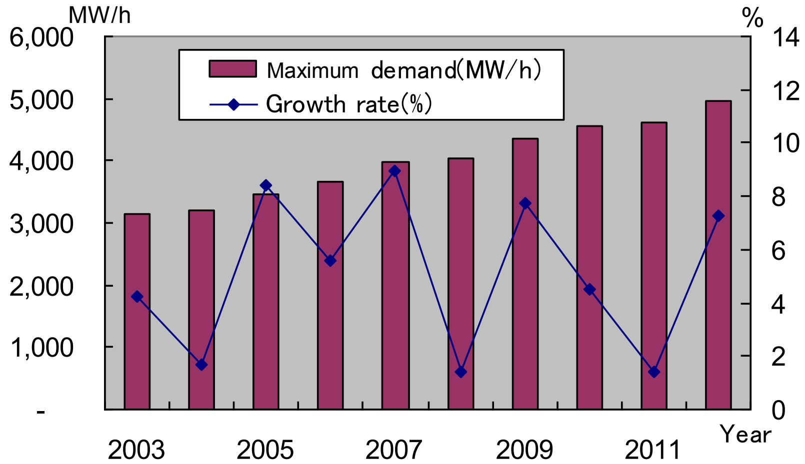


Figure 2.4-6 Maximum Demand and Growth Rate in COPEL Area

(Source: JICA Survey Team)

Both the economic growth rate forecast of the Paraná state and the power demand forecast of the COPEL service area based on past demand, brought a result with an increase of 4 to 6% per year. Although the result of the supply and demand forecast is nondisclosure at COPEL, there is transformer capacity upgrading data for 69kV and 138kV in PROEX described in chapter 2.5.1.The rate of transformer capacity increase for 69kV and 138kV per year is about 6 %. Therefore, the growth rate of the power demand in the Curitiba Metropolitan Area is expected to increase at 4% to 6% in the future.

2.4.3 Present Situation of Power demand in Proposed Candidate Project Area

The power consumption and number of customers in the Curitiba Metropolitan Area are shown in the following table. Curitiba City has more than half of the power consumption and number of customers. The cells in the following table except the gray cell are proposed candidate areas for implementation of the smart grid project. There are 24 proposed candidate project areas. The power consumption of São José dos Pinhais area which is 12.4% and Branco do Sul area which is 6.0% is comparatively high in the proposed candidate project areas. The power consumption density in the proposed candidate project areas, in particular, Curitiba City, Pinhais, Colombo and São José dos Pinhais, are also high.

Table 2.4-1 Present Situation of Power Consumption in Proposed Candidate Project Area

Municipality	No.of sales office	No.of Sub station	No. of Consumers	Electricity Consumption (MWh)	Electricity Consumption Share(%)	Density Electricity Consumption (MWh/km2)
Adrianópolis	0	1	2,254	4,842	0.1%	3.6
Agudos do Sul	0	1	3,165	8,039	0.1%	41.9
Almirante Tamandaré	1	1	32,516	135,275	1.7%	707.8
Araucária	1	2	44,152	401,101	5.1%	850.9
Balsa Nova	0	1	4,837	43,461	0.6%	126.3
Bocaiúva do Sul	0	1	4,570	17,484	0.2%	21.2
Campina Grande do Sul	0	1	15,566	80,824	1.0%	149.5
Campo do Tenente	0	1	2,395	12,200	0.2%	40.1
Campo Largo	0	2	43,647	280,969	3.6%	219.1
Campo Magro	0	0	8,189	26,457	0.3%	95.1
Cerro Azul	0	1	5,870	10,892	0.1%	8.1
Colombo	1	2	73,728	345,686	4.4%	1747.6
Contenda	0	1	5,751	19,465	0.2%	64.8
Curitiba	7	22	744,070	4,158,448	52.9%	9548.8
Doutor Ulysses	0	0	2,059	2,648	0.0%	3.4
Fazenda Rio Grande	1	2	32,127	133,809	1.7%	1159.8
Itaperuçu	0	0	7,803	28,419	0.4%	88.8
Lapa	0	2	16,379	100,585	1.3%	47.9
Mandirituba	0	2	8,633	47,298	0.6%	124.0
Piên	0	1	3,896	31,393	0.4%	122.2
Pinhais	1	1	43,461	303,192	3.9%	4959.2
Piraquara	1	1	26,224	85,363	1.1%	379.0
Quatro Barras	1	1	7,394	88,723	1.1%	489.5
Quitandinha	0	1	6,380	17,769	0.2%	39.8
Rio Branco do Sul	1	1	10,797	469,569	6.0%	575.0
Rio Negro	0	0	1,785	6,205	0.1%	10.3
São José dos Pinhais	1	4	99,551	973,207	12.4%	1030.6
Tijucas do Sul	0	1	6,125	18,100	0.2%	26.9
Tunas do Paraná	0	2	2,196	14,414	0.2%	21.5

(Source: COPEL material (2012))

The following table except the gray cells shows the power consumption in the 24 proposed candidate project areas according to the categories such as residential, industrial, commercial, agricultural and public uses. In PDE 2020 according to the power demand by the categories for the past ten years in Brazil, the growth rates of commercial, residential and agricultural sectors are comparatively high. Therefore, high growth of the power demand is expected in the area where the shares of the power consumption by the commercial, residential and agricultural sectors are high among the 24 proposed candidate project areas.

Table 2.4-2 Power Consumption in the Proposed Candidate Project Areas According to the Categories

	Municipality	Residential		Industrial		Commercial		Agriculture, Livestock		Public		other		total
		(MWh)	(%)	(MWh)	(%)	(MWh)	(%)	(MWh)	(%)	(MWh)	(%)	(MWh)	(%)	
1	Adrianópolis	2,252	47%	459	9%	672	14%	822	17%	634	13%	4	0%	4,842
2	Agudos do Sul	2,251	28%	441	5%	972	12%	3,518	44%	851	11%	6	0%	8,039
3	Almirante Tamandaré	56,097	41%	50,147	37%	13,918	10%	3,573	3%	11,519	9%	21	0%	135,275
4	Araucária	77,912	19%	233,659	58%	58,507	15%	9,178	2%	21,706	5%	138	0%	401,101
5	Balsa Nova	5,406	12%	26,189	60%	5,779	13%	4,030	9%	2,046	5%	12	0%	43,461
6	Bocaiúva do Sul	4,507	26%	7,384	42%	1,580	9%	2,598	15%	1,414	8%	0	0%	17,484
7	Campina Grande do Sul	25,141	31%	31,976	40%	15,007	19%	3,573	4%	5,125	6%	2	0%	80,824
8	Campo do Tenente	2,556	21%	4,897	40%	1,335	11%	2,444	20%	965	8%	3	0%	12,200
9	Campo Largo	71,298	25%	141,912	51%	38,395	14%	6,544	2%	22,704	8%	116	0%	280,969
10	Campo Magro	12,905	49%	4,513	17%	2,896	11%	3,402	13%	2,742	10%	0	0%	26,457
11	Cerro Azul	4,056	37%	1,645	15%	1,173	11%	2,598	24%	1,407	13%	12	0%	10,892
12	Colombo	131,864	38%	126,697	37%	55,115	16%	6,970	2%	24,967	7%	74	0%	345,686
13	Contenda	5,839	30%	3,421	18%	3,191	16%	4,769	24%	2,238	11%	7	0%	19,465
14	Curitiba	1,580,444	38%	789,561	19%	1,404,102	34%	1,383	0%	371,686	9%	11,272	0%	4,158,448
15	Doutor Ulysses	983	37%	29	1%	192	7%	910	34%	534	20%	1	0%	2,648
16	Fazenda Rio Grande	52,598	39%	52,892	40%	16,615	12%	1,907	1%	9,764	7%	33	0%	133,809
17	Itaperuçu	9,881	35%	11,612	41%	3,394	12%	1,064	4%	2,467	9%	1	0%	28,419
18	Lapa	17,599	17%	47,647	47%	10,570	11%	16,956	17%	7,786	8%	27	0%	100,585
19	Mandirituba	7,714	16%	20,630	44%	5,538	12%	10,671	23%	2,737	6%	8	0%	47,298
20	Piên	3,186	10%	19,051	61%	1,706	5%	5,550	18%	1,896	6%	3	0%	31,393
21	Pinhais	88,301	29%	110,759	37%	52,511	17%	102	0%	51,393	17%	126	0%	303,192
22	Piraquara	44,693	52%	13,447	16%	10,562	12%	3,085	4%	13,568	16%	8	0%	85,363
23	Quatro Barras	13,798	16%	62,541	70%	5,685	6%	1,158	1%	5,528	6%	14	0%	88,723
24	Quitandinha	3,947	22%	1,378	8%	2,529	14%	8,656	49%	1,255	7%	4	0%	17,769
25	Rio Branco do Sul	12,631	3%	444,244	95%	5,046	1%	2,222	0%	5,415	1%	10	0%	469,569
26	Rio Negro	818	13%	529	9%	266	4%	4,284	69%	306	5%	3	0%	6,205
27	São José dos Pinhais	178,130	18%	597,004	61%	134,696	14%	18,650	2%	44,570	5%	157	0%	973,207
28	Tijucas do Sul	4,555	25%	1,561	9%	3,028	17%	7,236	40%	1,717	9%	4	0%	18,100
29	Tunas do Paraná	2,758	19%	7,315	51%	3,306	23%	253	2%	766	5%	16	0%	14,414
	Total	**6,558,563**		**7,390,911**		**5,048,376**		**2,024,829**		**2,185,665**		**25,445**		

(Source: COPEL material (2012))

2.5 Review of Distribution System Planning Analysis in Curitiba Metropolitan Area

2.5.1 Review of Distribution System Planning in the Curitiba Metropolitan Area

In COPEL, the Distribution Expansion Planning Department makes the distribution system expansion plan for ten years based on the analysis of the medium and long-term power supply and demand forecast, and submits to the ANEEL every five years. The system expansion plan for 69kV and above level voltage is reported to ANEEL as "PROGRAMA DE EXPANSÃO DO SISTEMA DE DISTRIBUIÇÃO DE ALTA TENSÃO" (hereinafter referred to as PROEX). The latest version of PROEX is "PROEX 2011-2020". The system expansion plan for 34.5 kV and below voltage level, which is five years distribution system expansion plan, is summarized into the data format of the PDD and reported to the ANEEL through the system. The PDD is a database and is not summarized in report form. The new transformers installation and the capacity upgrading plan for 69kV and 138kV is shown in Table 2.5-1. A photos of the construction site of 13.8kV and 69kV are shown in Figure 2.5-1.

Table 2.5-1 Plan for the new transformers installation and the capacity upgrading of 69kV and 138kV

	Voltage Level (kV)	Year (MVA)											Total
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
New Installing	138	479.1	622.5	712.5	541.6	557.5	375.0	250.0	187.5	333.4	125.0	166.7	4,350.6
	69	135.8	41.7	125.0	458.4	125.0	166.7	0.0	0.0	0.0	0.0	0.0	1,052.6
	Total	615.0	664.1	837.5	1,000.0	682.5	541.7	250.0	187.5	333.4	125.0	166.7	5,403.2
Upgraiding	138	9.4	41.7	20.8	62.5	0.0	20.8	30.0	0.0	0.0	0.0	0.0	185.2
	69	0.0	0.0	10.0	0.0	31.3	33.3	0.0	0.0	0.0	0.0	0.0	74.5
	Total	9.4	41.7	30.8	62.5	31.3	54.1	30.0	0.0	0.0	0.0	0.0	259.7
Total		605.6	622.5	806.7	937.5	651.2	487.6	220.0	187.5	333.4	125.0	166.7	5,143.5

(Source: PROEX 2011-2020)

(13.8kV)

(69kV)

Figure 2.5-1 Construction site of 13.8kV and 69kV

(Source: Photo by Survey Team)

A plan of 5,143.48MVA capacity increase for 69kV and 138kV transformer in ten years, which is about 500 MVA capacity increase per year with an annual average, and the total 69kV and 138kV transformer capacity is 8,547.8 in 2012, so the rate of capacity increase per year is about 6 %. When the growth rate of the power demand in the Paraná state is assumed in 4 to 6% per year, this new transformer installation and the capacity upgrading plan is shown to be appropriate.

2.5.2 Review of Distribution System Analysis in Curitiba Metropolitan Area

The COPEL uses the system analysis software named GISPlan for the 13.8kV and 34.5 kV systems, which uses geography data. The information technology section which belongs to the head office of COPEL developed the system analysis software in 2008. The GISPlan has taken in data once a month from GISMap which is a facilities management database. The information, including the feeder current at a substation, etc., is also updated automatically once a month through the GISMap. The GISMap has the facilities information of all COPEL service area including daily load data, and can display the opening and closing information while off-line.

Moreover, in the distribution control center, the operator uses the distribution system operation and maintenance management software named SOD for daily operation work. The SOD can display the opening and closing information while off-line and the information for SOD is also updated automatically everyday through the GISMap. The relationship between GISPlan, SOD and GISPlan is shown in the following figure.

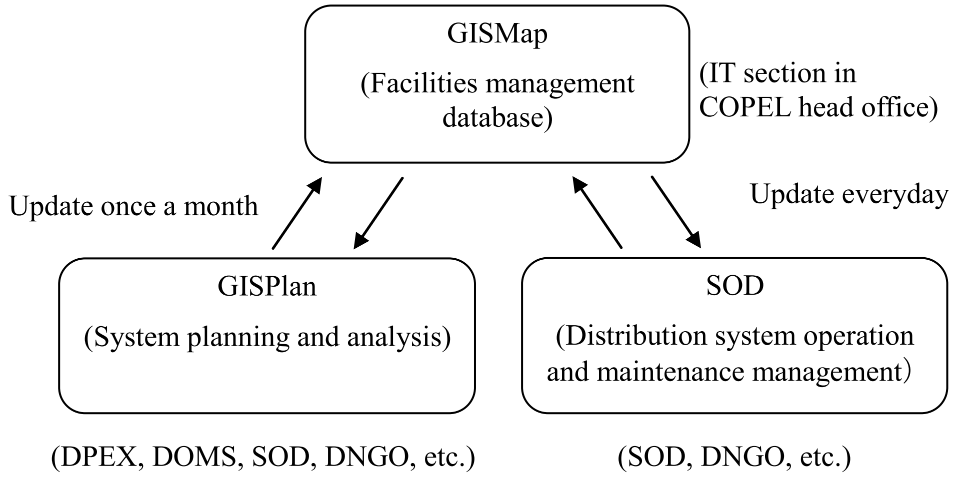


Figure 2.5-2 Image of Facilities Management Software

(Source: JICA Survey Team)

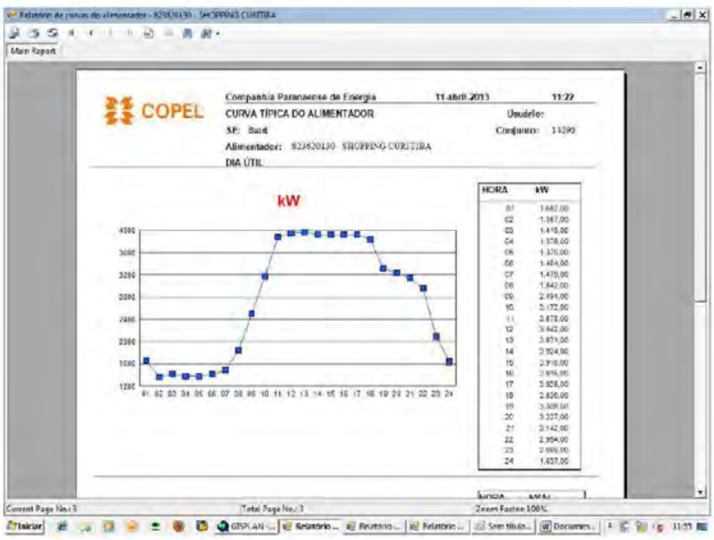


Figure 2.5-3 Daily Load Data

(Source: COPEL material)

The functions of GISPlan are load flow analysis, voltage analysis, loss analysis, short-circuit and grand-fault analysis, load increase simulation, reliability study, outage management and distribution system planning. Regarding load flow analysis, voltage analysis and loss analysis, it has optimal design function and graphic interface function (classification by color, current level or by a voltage level, etc.), respectively. In addition, the section of system protection carries out short-circuit and grand-fault analysis.

The department in charge of analyzing and planning of the 13.8kV and 34.5 kV systems using the GISPlan is DPEX. DPEX carries out the plan and design work for 13.8 kV and 34.5 kV of the distribution system in Paraná state. The DPEX main role is to design a voltage drop and a current value in a standard. There are 23 engineers in DPEX under a chief engineer. Moreover, DPEX carries out the medium and long term distribution system plan using GISPlan. It can check that deviation of a standard value does not arise using GISPlan functions because GISPlan can display the planned outage area and simulates the load flow, voltage drop and power factor at planned outage area. An analysis result and a distribution system planning screen are shown in the following figure.

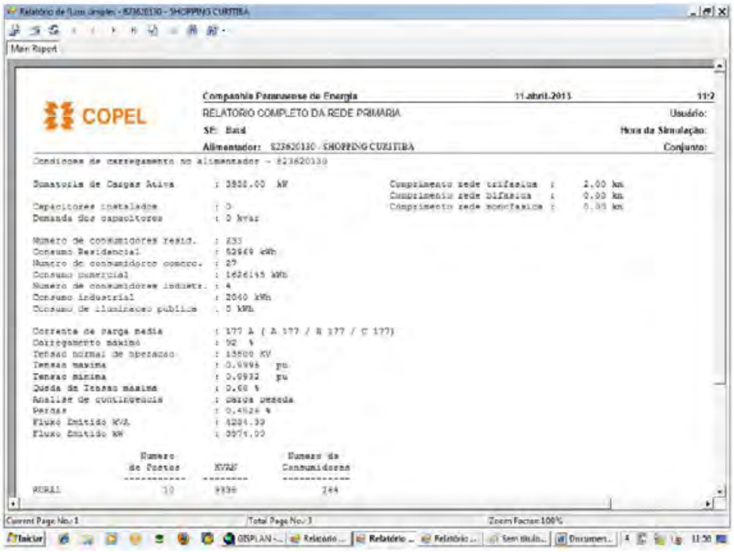


Figure 2.5-4 Screen of Distribution System Analysis result

(Source: COPEL material)

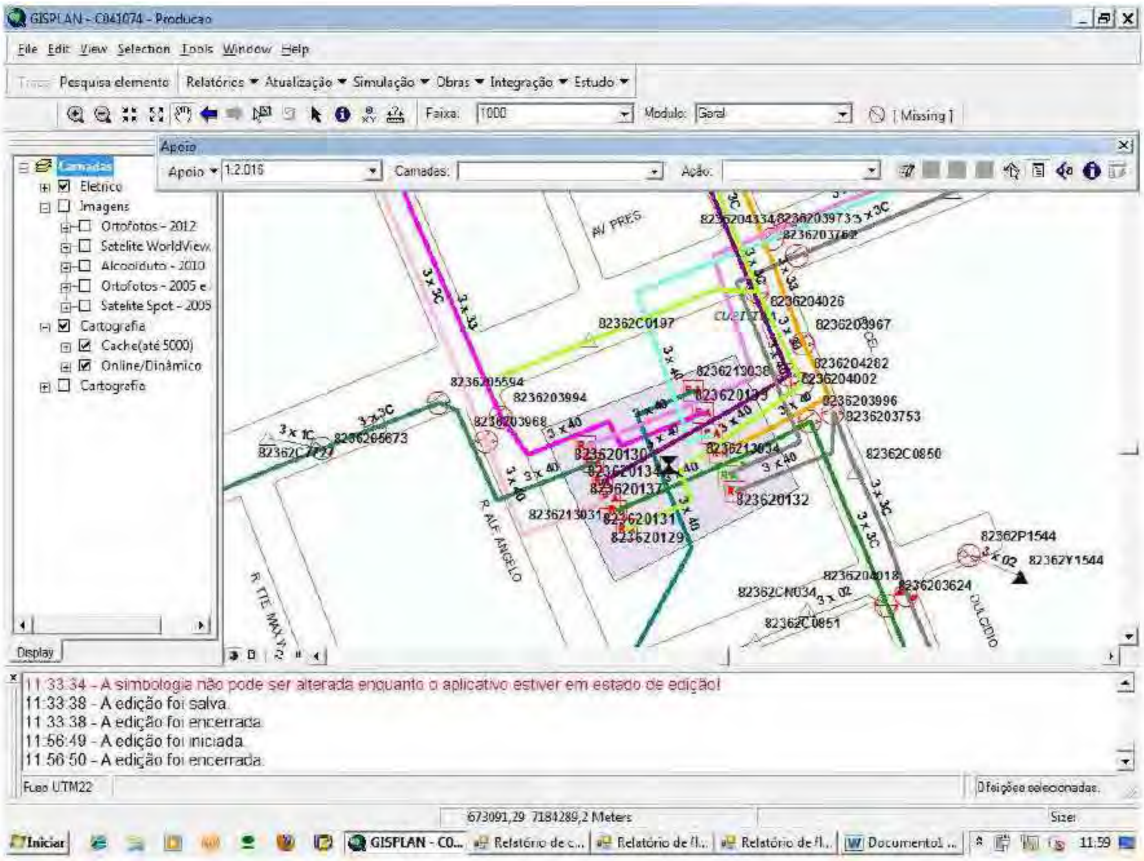


Figure 2.5-5 Screen of Distribution System Planning

(Source: COPEL material)

The procedure of distribution system planning map updating is shown in Figure 2.5-6. First, the DPEX changes the map according to the plan and sends the map to each Distribution Superintendence. Secondly, each Distribution Superintendence constructs the facilities according to the map and sends the map to the DNGO who finally fixes the map. IT section in COPEL head office is in charge of managing this system and plan to introduce the system into the new DAS/DMS system, as shown in Figure 6.2-2.

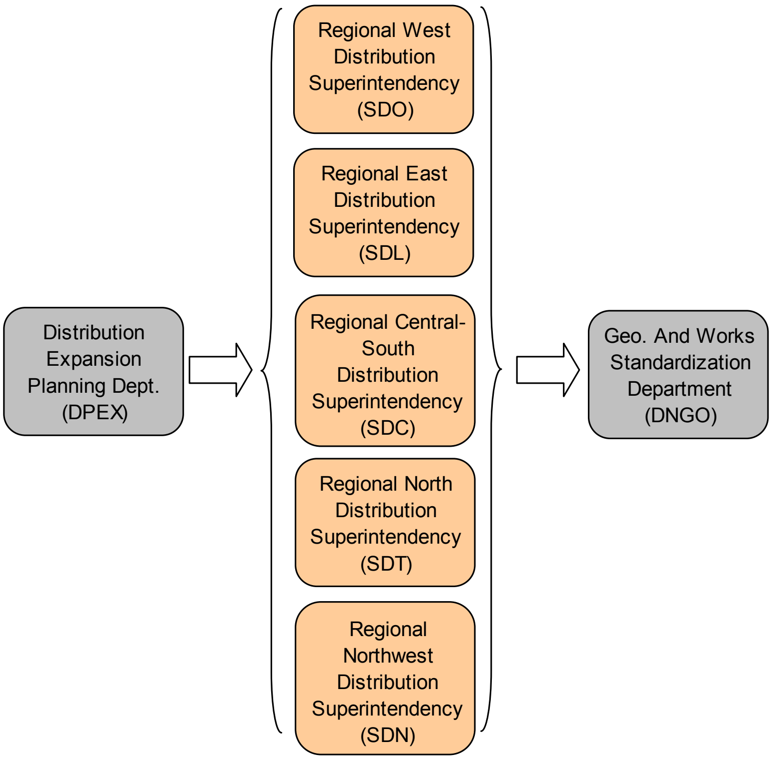


Figure 2.5-6 Procedure of distribution system planning map updating

(Source: COPEL material)

2.6 Outage Situation in Curitiba Metropolitan Area

1) COPEL Service Area

SAIDI and SAIFI for recent 5 years in COPEL service area are shown in Table 2.6-1. SAIDI and SAIFI are improved year after year, because the ANEEL made a regulation for SAIDI/SAIFI/DMIC (ANEEL Procedimentos de Distribuicao de Energia Eletrica no Sistema Eletrico Nacional – PRODIST Modulo 8 – Qualidade da Energia Eletrica.) making distribution companies pay a penalty in case that SAIDI/SAIFI/DMIC are exceeding the standard values described in 2.8. 4) (1). However, there is still room for improvement compared with the Japanese situation.

Table 2.6-1 SAIDI and SAIFI in COPEL Service Area

Year	SAIDI (hours)	SAIFI (No. of outages)
2008	12.19	10.69
2009	12.91	11.03
2010	11.46	9.46
2011	10.64	8.26
2012	10.25	7.84

(Source: COPEL Answer material)

COPEL have analyzed the cause of SAIFI on transmission lines and distribution lines. The COPEL analysis for SAIFI in distribution line is shown in Table 2.6-2. From this table, planning factors occupy only 10% approximately and the other 90% is due to unpredictable factors such as faulty components, lightning and fallen trees, etc. touching the network, because they make up over 10%. Main possible reason for faulty components is aged deterioration. Therefore, in order to improve SAIFI, periodical replacement of distribution facilities and protection reinforcement against lightning and wind, etc. are important factors for COPEL.

Table 2.6-2 Reasons for SAIFI in Distribution Line in COPLE Service Area

Reason for SAIFI		**Ratio**
Planning Factors	Improvements and / or Expansions	5.0%
	Corrective Maintenance	4.9%
Unpredictable Factors	Faulty Component	13.4%
	lightning	13.6%
	Wind	7.2%
	Tree, etc. touching the network	12.8%
	Collisions (Vehicles, Trucks)	4.0%
	Not Identified	39.1%
Total		100.0%

(Source: COPEL material)

2) Curitiba Metropolitan Area

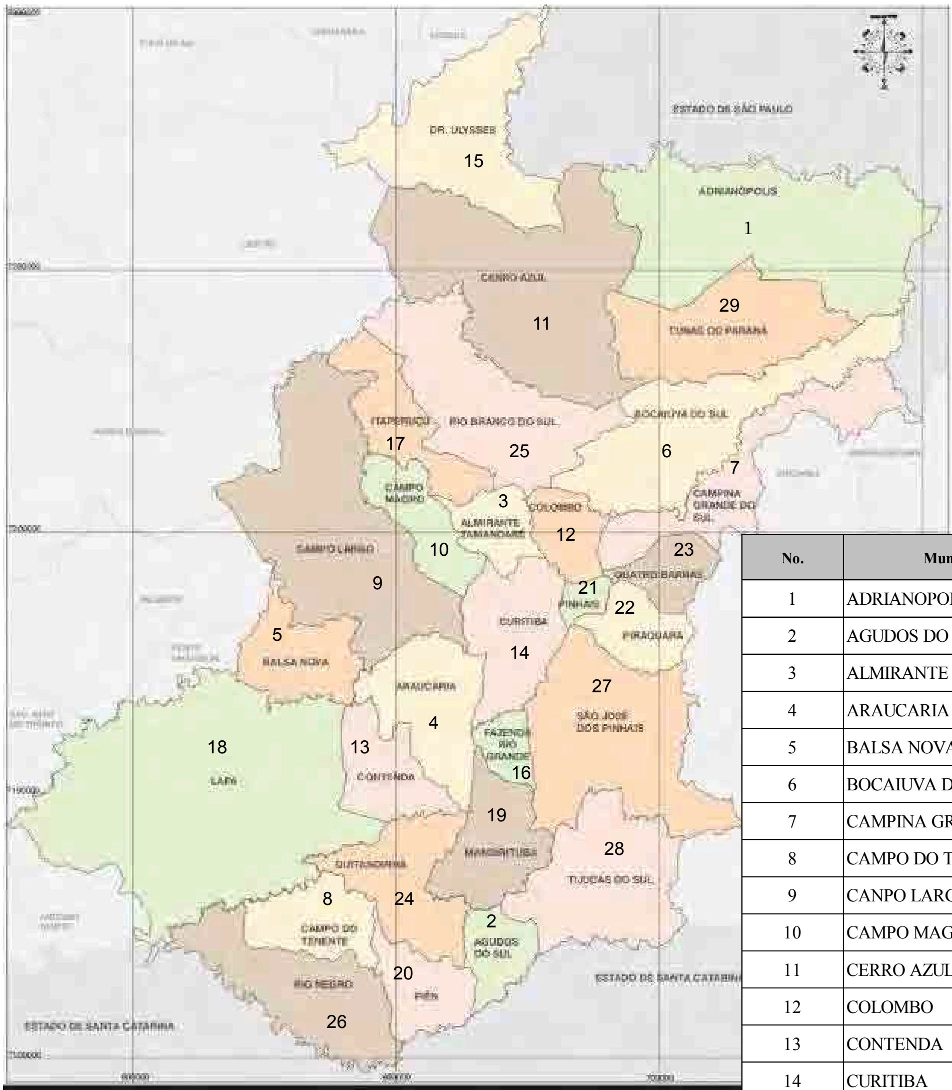
SAIDI and SAIFI in 2012 in the Curitiba metropolitan area are shown in Table 2.6-3. From the result of comparing Table 2.6-1 with this table, SAIDI/SAIFI in the Curitiba metropolitan area is larger than in COPEL service area. The main possible reason is a concentration of customers in Curitiba metropolitan area, because the concentration of customers leads to a concentration of distribution facilities, thus increasing possibility of outage.

In the SAIDI/SAIFI shown in Table 2.6-3, the SAIDI/SAIFI in Curitiba city has better values comparing other municipalities. Its main reasons are as follows;

The SAIFI in Curitiba city: There is a big difference in average lengths of feeders between Curitiba city (17km) and other 23 municipalities (103km).

The SAIDI in Curitiba city: The insulated distribution lines have been installed instead of bare lines.

Table 2.6-3 SAIDI and SAIFI in 2012 in Curitiba Metropolitan Area



No.	Municipalities	SAIDI (hours)	SAIFI (No. of outages)
1	ADRIANOPOLIS	26.29	43.03
2	AGUDOS DO SUL	57.47	38.17
3	ALMIRANTE TAMANDARÉ	29.30	16.52
4	ARAUCARIA	17.11	11.04
5	BALSA NOVA	25.91	16.45
6	BOCAIUVA DO SUL	31.77	25.85
7	CAMPINA GRANDE DO SUL	49.68	18.88
8	CAMPO DO TENENTE	31.44	20.91
9	CANPO LARGO	21.89	8.47
10	CAMPO MAGRO	27.99	19.86
11	CERRO AZUL	72.71	34.31
12	COLOMBO	15.45	12.17
13	CONTENDA	17.87	12.28
14	CURITIBA	7.81	5.91
15	Doutor Ulysses	–	–
16	FAZENDA RIO GRANDE	14.76	12.07
17	ITAPERUÇU	20.63	15.89
18	LAPA	30.62	19.26
19	MANDIRITUBA	31.22	23.91
20	PIEN	26.02	18.73
21	PINHAIS	11.46	8.74
22	PIRAQUARA	25.97	16.31
23	QUATRO BARRAS	18.02	11.53
24	QUITANDINHA	39.72	21.88
25	RIO BRANCO DO SUL	91.81	32.44
26	Rio Negro	–	–
27	SÃO JOSE DOS PINHAIS	17.09	10.37
28	TIJUCAS DO SUL	22.98	14.98
29	Tunas do Parana	76.55	30.71
	Municipalities Average	31.84	19.28

(Source: COPEL material)

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2.7 Loss Situation in Transmission and Distribution Lines in Curitiba Metropolitan Area

According to the interview with COPEL, COPEL does not measure non-technical losses by itself. However, COPEL has a duty to report technical and non-technical losses to the ANEEL yearly, based on the ANEEL formula regulated by ANEEL PRODIST Modulo 7 – Calculo de Perdas na Distribuicao (refer to the Appendix 2-1). Table 2.7-1 shows the ANEEL regulation thresholds and COPEL's situation in 2012 based on the ANEEL formula related to the loss situation in transmission and distribution lines in COPEL service area. Based on the ANEEL's regulation, COPEL cannot recover the costs related to the losses in transmission and distribution lines exceeding the ANEEL's regulation thresholds. Therefore, COPEL might require an effort to improve the non-technical loss as well as SAIDI/SAIFI/DMIC and voltage-drop.

Table 2.7-1 Loss Situation in Transmission and Distribution Lines in COPEL Service Area

	ANEEL Regulation (%)	COPEL Situation in 2012 based on ANEEL Formula (%)
Technical Loss	6.40	6.40
Non-technical Loss	1.40	2.05
Total	7.80	8.45

(Source: COPEL material)

2.8 Power Quality/ Penalty in Curitiba Metropolitan Area

1) SAIDI/SAIFI/DMIC

The indicators of continuity in Brazil are regulated by ANEEL PRODIST Modulo 8 – Qualidade da Energia Eletrica. The indicators are as follows;

- DIC(=SAIDI) :duration of interruption per individual consumer unit
- FIC(=SAIFI) :frequency of interruption per individual consumer unit
- DMIC :maximum continuous interruption per consumer unit or connection point

(Reference)

- DEC :duration of outages per consumer per year (Substation)
- FEC :frequency of outages per consumer per year (Substation)

Relationship between these indicators and penalty is also described in ANEEL PRODIST Modulo 8 – Qualidade da Energia Eletrica (refer to the Appendix2-2). The relationships to relative voltages for this project in COPEL are shown in Table 2.8-1 to Table 2.8-4. COPEL should pay penalties to customers if SAIDI/SAIFI/DMIC fit the categories in these tables. The penalty amount is decided by each category. The actual record of COPEL's penalty in 2012 is showed in Table 2.8-5. Actual amount of the total penalties is approximately R$ 3 million. Therefore, JICA team advises COPEL to give a first priority to reduction of these penalties by reliability improvement of distribution lines in this project (For details in 5.1).

Table 2.8-1 SAIDI/SAIFI/DMIC in 1kV to 69kV in Urban Area

DEC or FEC	1kV to 69kV in Urban Area						
	SAIDI(DIC) (hours)			SAIFI(FIC) (No. of interruption)			DMIC (hours)
	Annual	Every 3 Months	Each Month	Annual	Every 3 Months	Each Month	Each Month
1	11.25	5.62	2.81	6.48	3.24	1.62	2.36
2	11.68	5.84	2.92	6.93	3.46	1.73	2.39
3	12.12	6.06	3.03	7.37	3.68	1.84	2.41
4	12.55	6.27	3.13	7.82	3.91	1.95	2.44
5	12.99	6.49	3.24	8.27	4.13	2.06	2.46
6	13.43	6.71	3.35	8.71	4.35	2.17	2.49
7	13.86	6.93	3.46	9.16	4.58	2.29	2.52
8	14.30	7.15	3.57	9.61	4.80	2.40	2.54
9	14.73	7.36	3.68	10.05	5.02	2.51	2.57
10	15.17	7.58	3.79	10.50	5.25	2.62	2.60
11	15.61	7.80	3.90	10.95	5.47	2.73	2.62
12	16.04	8.02	4.01	11.40	5.70	2.85	2.65
13	16.48	8.24	4.12	11.84	5.92	2.96	2.68
14	16.91	8.45	4.22	12.29	6.14	3.07	2.71
15	17.35	8.67	4.33	12.74	6.37	3.18	2.74
16	17.79	8.89	4.44	13.18	6.59	3.29	2.76
17	18.22	9.11	4.55	13.63	6.81	3.40	2.79
18	18.66	9.33	4.66	14.08	7.04	3.52	2.82
19	19.09	9.54	4.77	14.52	7.26	3.63	2.85
20	19.53	9.76	4.88	14.97	7.48	3.74	2.88
>20 e ≦ 22	19.97	9.98	4.99	15.42	7.71	3.85	2.91
>22 e ≦ 24	20.84	10.42	5.21	16.31	8.15	4.07	2.98
>24 e ≦ 26	21.71	10.85	5.42	17.20	8.60	4.30	3.04
>26 e ≦ 28	22.58	11.29	5.64	18.10	9.05	4.52	3.10
>28 e ≦ 30	23.45	11.72	5.86	18.99	9.49	4.74	3.17
>30 e ≦ 32	24.33	12.16	6.08	19.88	9.94	4.97	3.24
>32 e ≦ 34	25.20	12.60	6.30	20.78	10.39	5.19	3.31
>34 e ≦ 36	26.07	13.03	6.51	21.67	10.83	5.41	3.38
>36 e ≦ 38	26.94	13.47	6.73	22.57	11.28	5.64	3.45
>38 e ≦ 40	27.81	13.90	6.95	23.46	11.73	5.86	3.52
>40 e ≦ 45	29.34	14.67	7.33	25.02	12.51	6.25	3.55
>45 e ≦ 50	31.52	15.76	7.88	27.26	13.63	6.81	3.80
>50 e ≦ 55	33.70	16.85	8.42	29.49	14.74	7.37	4.06
>55 e ≦ 60	35.88	17.94	8.97	31.72	15.86	7.93	4.34
>60 e ≦ 65	38.06	19.03	9.51	33.96	16.98	8.49	4.64
>65 e ≦ 70	40.24	20.12	10.06	36.19	18.09	9.04	4.96
>70 e ≦ 80	43.51	21.75	10.87	39.54	19.77	9.88	5.47
>80 e ≦ 90	47.87	23.93	11.96	44.01	22.00	11.00	6.23
>90 e ≦ 100	52.23	26.11	13.05	48.48	24.24	12.12	7.10
>100 e ≦ 110	56.59	28.29	14.14	52.95	26.47	13.23	8.07
>110 e ≦ 120	60.95	30.47	15.23	57.42	28.71	14.35	9.17
>120	63.13	31.56	15.78	59.65	29.82	14.91	9.77

(Source: ANEEL Module8- Power Quality)

Table 2.8-2 SAIDI/SAIFI/DMIC in 1kV to 69kV in Rural Area

DEC or FEC	1kV to 69kV in Rural Area						
	SAIDI(DIC) (hours)			SAIFI(FIC) (No. of interruption)			DMIC (hours)
	Annual	Every 3 Months	Each Month	Annual	Every 3 Months	Each Month	Each Month
1	31.98	15.99	7.99	15.49	7.74	3.87	4.32
2	32.62	16.31	8.15	15.96	7.98	3.99	4.39
3	33.26	16.63	8.31	16.43	8.21	4.10	4.46
4	33.90	16.95	8.47	16.90	8.45	4.22	4.53
5	34.54	17.27	8.63	17.37	8.68	4.34	4.60
6	35.18	17.59	8.79	17.84	8.92	4.46	4.67
7	35.82	17.91	8.95	18.31	9.15	4.57	4.74
8	36.46	18.23	9.11	18.78	9.39	4.69	4.81
9	37.10	18.55	9.27	19.25	9.62	4.81	4.88
10	37.74	18.87	9.43	19.72	9.86	4.93	4.95
11	38.38	19.19	9.59	20.19	10.09	5.04	5.02
12	39.02	19.51	9.75	20.66	10.33	5.16	5.09
13	39.66	19.83	9.91	21.13	10.56	5.28	5.16
14	40.30	20.15	10.07	21.60	10.80	5.40	5.24
15	40.94	20.47	10.23	22.07	11.03	5.51	5.31
16	41.58	20.79	10.39	22.54	11.27	5.63	5.38
17	42.22	21.11	10.55	23.01	11.50	5.75	5.45
18	42.86	21.43	10.71	23.48	11.74	5.87	5.52
19	43.50	21.75	10.87	23.95	11.97	5.98	5.59
20	44.14	22.07	11.03	24.42	12.21	6.10	5.66
>20 e ≦ 22	44.78	22.39	11.19	24.90	12.45	6.22	5.73
>22 e ≦ 24	46.06	23.03	11.51	25.84	12.92	6.46	5.87
>24 e ≦ 26	47.34	23.67	11.83	26.78	13.39	6.69	6.01
>26 e ≦ 28	48.61	24.30	12.15	27.72	13.86	6.93	6.15
>28 e ≦ 30	49.89	24.94	12.47	28.66	14.33	7.16	6.29
>30 e ≦ 32	51.17	25.58	12.79	29.60	14.80	7.40	6.43
>32 e ≦ 34	52.45	26.22	13.11	30.54	15.27	7.63	6.57
>34 e ≦ 36	53.73	26.86	13.43	31.48	15.74	7.87	6.72
>36 e ≦ 38	55.01	27.50	13.75	32.42	16.21	8.10	6.86
>38 e ≦ 40	56.29	28.14	14.07	33.36	16.68	8.34	7.00
>40 e ≦ 45	58.53	29.26	14.63	35.01	17.50	8.75	7.24
>45 e ≦ 50	61.73	30.86	15.43	37.36	18.68	9.34	7.60
>50 e ≦ 55	64.92	32.46	16.23	39.71	19.85	9.92	7.95
>55 e ≦ 60	68.12	34.06	17.03	42.06	21.03	10.51	8.30
>60 e ≦ 65	71.32	35.66	17.83	44.42	22.21	11.10	8.65
>65 e ≦ 70	74.52	37.26	18.63	46.77	23.38	11.69	9.01
>70 e ≦ 80	79.32	39.66	19.83	50.30	25.15	12.57	9.54
>80 e ≦ 90	85.71	42.85	21.42	55.00	27.50	13.75	10.24
>90 e ≦ 100	92.11	46.05	23.02	59.70	29.85	14.92	10.95
>100 e ≦ 110	98.50	49.25	24.62	64.41	32.20	16.10	11.65
>110 e ≦ 120	104.90	52.45	26.22	69.11	34.55	17.27	12.36
>120	108.10	54.05	27.02	71.46	35.73	17.86	12.71

(Source: ANEEL Module8- Power Quality)

Table 2.8-3 SAIDI/SAIFI/DMIC in Less Than 1kV in Urban Area

DEC or FEC	Less than 1kV in Urban Area						
	SAIDI(DIC) (hours)			SAIFI(FIC) (No. of interruption)			DMIC (hours)
	Annual	Every 3 Months	Each Month	Annual	Every 3 Months	Each Month	Each Month
1	16.00	8.00	4.00	11.20	5.60	2.80	2.09
2	16.47	8.23	4.11	11.45	5.72	2.86	2.18
3	16.95	8.47	4.23	11.70	5.85	2.92	2.26
4	17.43	8.71	4.35	11.95	5.97	2.98	2.35
5	17.91	8.95	4.47	12.20	6.10	3.05	2.43
6	18.38	9.19	4.59	12.45	6.22	3.11	2.52
7	18.86	9.43	4.71	12.70	6.35	3.17	2.60
8	19.34	9.67	4.83	12.95	6.47	3.23	2.69
9	19.82	9.91	4.95	13.20	6.60	3.30	2.77
10	20.30	10.15	5.07	13.45	6.72	3.36	2.86
11	20.77	10.38	5.19	13.70	6.85	3.42	2.94
12	21.25	10.62	5.31	13.95	6.97	3.48	3.03
13	21.73	10.86	5.43	14.20	7.10	3.55	3.11
14	22.21	11.10	5.55	14.45	7.22	3.61	3.20
15	22.69	11.34	5.67	14.70	7.35	3.67	3.29
16	23.16	11.58	5.79	14.95	7.47	3.73	3.37
17	23.64	11.82	5.91	15.20	7.60	3.80	3.46
18	24.12	12.06	6.03	15.45	7.72	3.86	3.54
19	24.60	12.30	6.15	15.70	7.85	3.92	3.63
20	25.08	12.54	6.27	15.96	7.98	3.99	3.71
>20 e ≦ 22	25.89	12.94	6.47	16.47	8.23	4.11	3.80
>22 e ≦ 24	27.48	13.74	6.87	17.42	8.71	4.35	3.97
>24 e ≦ 26	29.06	14.53	7.26	18.37	9.18	4.59	4.14
>26 e ≦ 28	30.65	15.32	7.66	19.32	9.66	4.83	4.31
>28 e ≦ 30	32.23	16.11	8.05	20.28	10.14	5.07	4.48
>30 e ≦ 32	33.82	16.91	8.45	21.23	10.61	5.30	4.65
>32 e ≦ 34	35.40	17.70	8.85	22.18	11.09	5.54	4.82
>34 e ≦ 36	36.99	18.49	9.24	23.13	11.56	5.78	4.99
>36 e ≦ 38	38.57	19.28	9.64	24.08	12.04	6.02	5.16
>38 e ≦ 40	40.16	20.08	10.04	25.04	12.52	6.26	5.33
>40 e ≦ 45	42.93	21.46	10.73	26.70	13.35	6.67	5.63
>45 e ≦ 50	46.89	23.44	11.72	29.08	14.54	7.27	6.05
>50 e ≦ 55	50.86	25.43	12.71	31.46	15.73	7.86	6.48
>55 e ≦ 60	54.82	27.41	13.70	33.84	16.92	8.46	6.90
>60 e ≦ 65	58.78	29.39	14.69	36.22	18.11	9.05	7.33
>65 e ≦ 70	62.74	31.37	15.68	38.60	19.30	9.65	7.75
>70 e ≦ 80	68.68	34.34	17.17	42.17	21.08	10.54	8.39
>80 e ≦ 90	76.61	38.30	19.15	46.93	23.46	11.73	9.24
>90 e ≦ 100	84.53	42.26	21.13	51.69	25.84	12.92	10.09
>100 e ≦ 110	92.46	46.23	23.11	56.45	28.22	14.11	10.94
>110 e ≦ 120	100.38	50.19	25.09	61.21	30.60	15.30	11.80
>120	104.34	52.17	26.08	63.59	31.79	15.89	12.22

(Source: ANEEL Module8- Power Quality)

Table 2.8-4 SAIDI/SAIFI/DMIC in Less Than 1kV in Rural Area

DEC or FEC	Less than 1kV in Rural Area						
	SAIDI(DIC) (hours)			SAIFI(FIC) (No. of interruption)			DMIC (hours)
	Annual	Every 3 Months	Each Month	Annual	Every 3 Months	Each Month	Each Month
1	36.00	18.00	9.00	28.00	14.00	7.00	4.57
2	36.57	18.28	9.14	28.29	14.14	7.07	4.67
3	37.15	18.57	9.28	28.59	14.29	7.14	4.77
4	37.73	18.86	9.43	28.89	14.44	7.22	4.87
5	38.30	19.15	9.57	29.19	14.59	7.29	4.97
6	38.88	19.44	9.72	29.49	14.74	7.37	5.07
7	39.46	19.73	9.86	29.79	14.89	7.44	5.17
8	40.03	20.01	10.00	30.09	15.04	7.52	5.28
9	40.61	20.30	10.15	30.39	15.19	7.59	5.38
10	41.19	20.59	10.29	30.69	15.34	7.67	5.48
11	41.76	20.88	10.44	30.98	15.49	7.74	5.58
12	42.34	21.17	10.58	31.28	15.64	7.82	5.68
13	42.92	21.46	10.73	31.58	15.79	7.89	5.78
14	43.49	21.74	10.87	31.88	15.94	7.97	5.88
15	44.07	22.03	11.01	32.18	16.09	8.04	5.98
16	44.65	22.32	11.16	32.48	16.24	8.12	6.08
17	45.22	22.61	11.30	32.78	16.39	8.19	6.19
18	45.80	22.90	11.45	33.08	16.54	8.27	6.29
19	46.38	23.19	11.59	33.38	16.69	8.34	6.39
20	46.96	23.48	11.74	33.68	16.84	8.42	6.49
>20 e ≦ 22	47.79	23.89	11.94	34.16	17.08	8.54	6.59
>22 e ≦ 24	49.42	24.71	12.35	35.10	17.55	8.77	6.79
>24 e ≦ 26	51.05	25.52	12.76	36.04	18.02	9.01	6.99
>26 e ≦ 28	52.68	26.34	13.17	36.98	18.49	9.24	7.20
>28 e ≦ 30	54.31	27.15	13.57	37.92	18.96	9.48	7.40
>30 e ≦ 32	55.94	27.97	13.98	38.86	19.43	9.71	7.60
>32 e ≦ 34	57.57	28.78	14.39	39.80	19.90	9.95	7.80
>34 e ≦ 36	59.20	29.60	14.80	40.74	20.37	10.18	8.01
>36 e ≦ 38	60.83	30.41	15.20	41.69	20.84	10.42	8.21
>38 e ≦ 40	62.45	31.22	15.61	42.63	21.31	10.65	8.41
>40 e ≦ 45	65.30	32.65	16.32	44.27	22.13	11.06	8.76
>45 e ≦ 50	69.38	34.69	17.34	46.62	23.31	11.65	9.27
>50 e ≦ 55	73.45	36.72	18.36	48.98	24.49	12.24	9.77
>55 e ≦ 60	77.52	38.76	19.38	51.33	25.66	12.83	10.28
>60 e ≦ 65	81.59	40.79	20.39	53.68	26.84	13.42	10.79
>65 e ≦ 70	85.66	42.83	21.41	56.03	28.01	14.00	11.29
>70 e ≦ 80	91.77	45.88	22.94	59.56	29.78	14.89	12.05
>80 e ≦ 90	99.92	49.96	24.98	64.26	32.13	16.06	13.06
>90 e ≦ 100	108.06	54.03	27.01	68.97	34.48	17.24	14.07
>100 e ≦ 110	116.20	58.10	29.05	73.67	36.83	18.41	15.08
>110 e ≦ 120	124.35	62.17	31.08	78.38	39.19	19.59	16.09
>120	128.42	64.21	32.10	80.73	40.36	20.18	16.60

(Source: ANEEL Module8- Power Quality)

Table 2.8-5 Actual Record of COPEL Penalty in 2012 for SAIDI/SAIFI/DMIC

Municipal		Total DIC	Total FIC	Total DMIC	TOTAL (DIC+FIC+DMIC)	Total QTY DIC	Total QTY FIC	Total QTY DMIC	Total QTY TOTAL
1	ADRIANOPOLIS	R$ 12.13	R$ 22,073.18	R$ 213.61	R$ 22,299	45	2,768	80	2,893
2	AGUDOS DO SUL	R$ 5,756.65	R$ 475.26	R$ 5,412.08	R$ 17,531	1,189	270	1,471	2,929
3	ALMIRANTE TAMANDARÉ	R$ 67,397.34	R$ 5,925.73	R$ 5,227.47	R$ 78,551	5,241	3,794	1,455	10,490
4	ARAUCARIA	R$ 58,608.21	R$ 62,635.18	R$ 37,253.91	R$ 158,497	16,807	22,905	9,388	49,100
5	BALSA NOVA	R$ 1,854.47	R$ 518.62	R$ 1,887.13	R$ 4,260	724	358	233	1,315
6	BOCAIUVA DO SUL	R$ 3,663.35	R$ 26,708.39	R$ 3,147.69	R$ 33,519	1,001	7,643	713	9,357
7	CAMPINA GRANDE DO SUL	R$ 40,524.40	R$ 6,782.10	R$ 25,060.70	R$ 72,367	8,320	5,078	3,087	16,485
8	CAMPO DO TENENTE	R$ 2,564.35	R$ 2,456.78	R$ 3,203.55	R$ 8,225	1,148	527	1,351	3,026
9	CAMPO LARGO	R$ 9,086.43	R$ 700.06	R$ 4,744.75	R$ 14,531	856	323	1,085	2,264
10	CAMPO MAGRO	R$ 15,029.44	R$ 16,988.80	R$ 8,611.44	R$ 40,630	8,173	5,914	5,012	19,099
11	CERRO AZUL	R$ 8,282.92	R$ 940.46	R$ 3,245.21	R$ 12,469	5,105	719	1,888	7,712
12	COLOMBO	R$ 40,001.54	R$ 66,392.92	R$ 49,398.05	R$ 155,793	22,688	37,489	19,506	79,683
13	CONTENDA	R$ 1,848.42	R$ 2,736.94	R$ 1,890.61	R$ 6,476	959	1,710	788	3,457
14	CURITIBA	R$ 448,105.09	R$ 372,179.96	R$ 443,926.43	R$ 1,264,211	152,911	122,157	152,465	427,533
15	Doutor Ulysses	—	—	—	—	—	—	—	—
16	FAZENDA RIO GRANDE	R$ 19,903.85	R$ 37,250.77	R$ 21,715.88	R$ 78,871	10,142	27,248	6,888	44,278
17	ITAPERUÇU	R$ 31.88	R$ 1,673.04	R$ 1,613.43	R$ 3,318	57	293	747	1,097
18	LAPA	R$ 21,127.61	R$ 6,077.98	R$ 8,087.53	R$ 35,293	7,019	1,911	2,938	11,868
19	MANDIRITUBA	R$ 13,099.12	R$ 11,369.16	R$ 27,058.11	R$ 51,526	4,531	5,906	4,843	15,280
20	PIEN	R$ 33,372.10	R$ 60,672.90	R$ 9,428.13	R$ 103,473	7,437	11,558	2,026	21,021
21	PINHAIS	R$ 34,848.55	R$ 24,241.34	R$ 56,916.15	R$ 116,006	16,491	15,935	20,266	52,692
22	PIRAQUARA	R$ 27,135.99	R$ 26,692.99	R$ 16,138.15	R$ 69,967	8,132	13,246	6,117	27,495
23	QUATRO BARRAS	R$ 35,574.86	R$ 16,880.11	R$ 16,217.33	R$ 68,672	5,851	6,400	2,401	14,652
24	QUITANDINHA	R$ 9,821.68	R$ 926.45	R$ 11,915.18	R$ 22,663	4,905	915	2,569	8,389
25	RIO BRANCO DO SUL	R$ 47,938.09	R$ 23,782.55	R$ 10,303.85	R$ 82,024	11,040	9,611	3,568	24,219
26	Rio Negro	—	—	—	—	—	—	—	—
27	SÃO JOSE DOS PINHAIS	R$ 107,530.47	R$ 87,681.23	R$ 75,632.66	R$ 270,844	37,792	35,864	26,358	100,014
28	TIJUCAS DO SUL	R$ 5,950.02	R$ 5,097.75	R$ 1,589.72	R$ 12,637	1,221	1,356	707	3,284
29	TUNAS	R$ 35,535.14	R$ 1,700.52	R$ 13,027.09	R$ 50,263	5,643	502	3,409	9,554
Total (29Municipalities)		R$ 1,094,604	R$ 891,561	R$ 862,866	R$ 2,854,918	345,428	342,400	281,359	969,186

(Source: COPEL material)

TEPSCO TEPCO

2) Voltage

Voltage quality is regulated by ANEEL Resolution No.676/2003. Regulations on relative voltages for this project in COPEL are shown in Table 2.8-6 and Table 2.8-7. TL stands for standard voltage and TC stands for contract voltage. Voltage classification is categorized by 3 categories (Good, Poor and Critical). Poor and Critical have repair periods such as within 90 days or within 15 days, respectively. The voltage quality is not constantly measured and it is measured at the meter based on customer's complaint. If COPEL cannot repair voltage in the poor condition within 90 days, COPEL should pay a penalty to the customer. And regarding the critical condition, COPEL needs to repair voltage within 15 days. If COPEL cannot repair it within 15 days, COPEL should pay a penalty to the customer as well.

Table 2.8-8 shows the actual record of voltage penalty, which COPEL paid in 2012. The total amount is approximately R$33,000. Although this amount is smaller than penalty for SAIDI/SAIFI/DMIC, JICA team advises COPEL to give priority to improvement of voltage in this project as well (For details in 5.1).

Table 2.8-6 Voltage Management Range at Service Point for Over 1kV and Less Than 69kV

Voltage Classification		Relationship between Standard Voltage (TL) and Contract Voltage (TC)
Good	Normal Condition	0.93TC ≦ TL ≦ 1.05TC
Poor	Repair Period within 90days	0.9TC ≦ TL ≦ 0.93TC
Critical	Repair Period within 15days	TL < 0.90TC or TL > 1.05TC

(Source: ANEEL Resolution No.676/2003)

Table 2.8-7 Voltage Management Range at Service Point for Less Than 1kV

Voltage Classification		Voltage Management Range for Standard Voltage (TL)
Good	Normal Condition	201≦TL≦231 / 116≦TL≦133
Poor	Repair Period within 90days	189≦TL<201 or 231<TL≦233 / 109≦TL<116 or 133<TL≦140
Critical	Repair Period within 15days	TL<189 or TL>233 / TL<109 or TL>140

(Source: ANEEL Resolution No.676/2003)

Table 2.8-8 COPEL's Voltage Penalty in Curitiba Metropolitan Area in 2012

Municipalities		Voltage Penalty (R$)
1	Adrianopolis	—
2	Agudos do Sul	—
3	Almirante Tamandare	24,798
4	Araucaria	5
5	Balsa Nova	—
6	Bocaiuva do Sul	—
7	Campina Grande do Sul	—
8	Campo do Tenente	—
9	Campo Largo	—
10	Campo Magro	—
11	Cerro Azul	—
12	Colombo	1,269
13	Contenda	—
14	Curitiba	2,735
15	Doutor Ulysses	—
16	Fazenda Rio Grande	10
17	Itaperuqu	—
18	Lapa	—
19	Mandirituba	—
20	Pien	—
21	Pinhals	418
22	Piraquara	2,287
23	Quatro Barras	425
24	Quitandinha	—
25	Rio Branco do Sul	688
26	Rio Negro	—
27	Sao Jose dos Pinhals	481
28	Tijucas do Sul	—
29	Tunas do Parana	—
TOTAL		33,116

(Source: COPEL material)

3) Power Factor

Power factor is regulated by the ANEEL PRODIST Modulo 8 – Qualidade da Energia Eletrica as well. As a prior condition whereby customers connect to COPEL's grid by over 0.92, COPEL has responsibility for improvement of power factor more than 0.92. Regarding power factor less than 0.92, responsibility of this category belongs to the customers. Therefore, in case of power factor less than 0.92, COPEL can request that customers improve their power factor. In addition, COPEL measures amount of negative power at meter in large customer and charge penalty (the measured amount of negative power x 0.8) to the customers, which is added to electricity bill.

Table 2.8-9 Power Factor in COPEL

Average in COPEL	0.95
COPEL Responsibility	more than 0.92
Customer Responsibity	not less than 0.92

(Source: COPEL material)

2.9 Socio-economic Situation of Curitiba Metropolitan Area

2.9.1 Location, Area, and Demography

The State of Paraná is located in the south of Brazil, the center of Brazilian economy, neighboring to the States of São Paulo, Santa Catarina, Mato Grosso do Sul, and it is also in contact with the borders of Argentina and Paraguay. GDP per capita of Paraná state in 2010 is the seventh place among 26 states and 1 federal district in Brazil (Table 2.9-1)

Table 2.9-1 GDP per Capita of States and Federal District in Brazil

State	GDP per capita (R$)		State / Federal District	GDP per capita (R$)	
	2005	2010		2005	2010
North			Sergipe	6,821	11,572
Rondônia	8,408	15,098	Bahia	6,583	11,007
Acre	6,692	11,567	**Southeast**		
Amazonas	10,320	17,173	Minas Gerais	10,012	17,932
Roraima	8,123	14,052	Espírito Santo	13,846	23,379
Pará	5,617	10,259	Rio de Janeiro	16,052	25,455
Amapá	7,344	12,361	São Paulo	17,977	30,243
Tocantins	6,957	12,462	**South**		
Northeast			Paraná	12,339	20,814
Maranhão	4,150	6,889	Santa Catarina	14,539	24,398
Piauí	3,700	7,073	Rio Grande do Sul	13,310	23,606
Ceará	5,054	9,216	**Center-west**		
Rio Grande do Norte	5,948	10,208	Mato Grosso do Sul	9,557	17,766
Paraíba	4,690	8,481	Mato Grosso	13,365	19,644
Pernambuco	5,931	10,822	Goiás	8,992	16,252
Alagoas	4,687	7,874	Distrito Federal	34,510	58,489

(Source: Brazilian Institute for Geography and Statistics (IBGE) "Contas Regionais do Brasil")

The Curitiba Metropolitan Area (in Portuguese, "RMC": Região Metropolitana de Curitiba) in the eastern area of Paraná State consists of 29 municipalities defined by the State Law (Lei Estadual) No. 139/2011 (Figure 2.9-1). The total population is approximately 3.2 million, which is about 31% of the total population of the State of Paraná (Figure 2.9-1). Population of Curitiba City is 1.75 million, accounting for more than half of the total population in Critiba Metropolitan Area. Total area is 16,629 km^2, nearly 8% of the whole area of the State of Paraná with -199, 307 km^2. Population is more concentrated in this area of Parana State, that is, 197.62 habitants / km^2 while the density in Paraná State is 52.4 habitants/ km^2.

In the State of Paraná, there are three other metropolitan areas: the Londorina, Maringá, and Umuarama

Metropolitan Areas, which are also the economic centers. In comparison, the population of Curitiba Metropolitan Area is the largest in the State of Parana and it is in the eighth place among the 36 metropolitan areas in Brazil (refer to Table 2.9-2 and Figure 2.9-2).

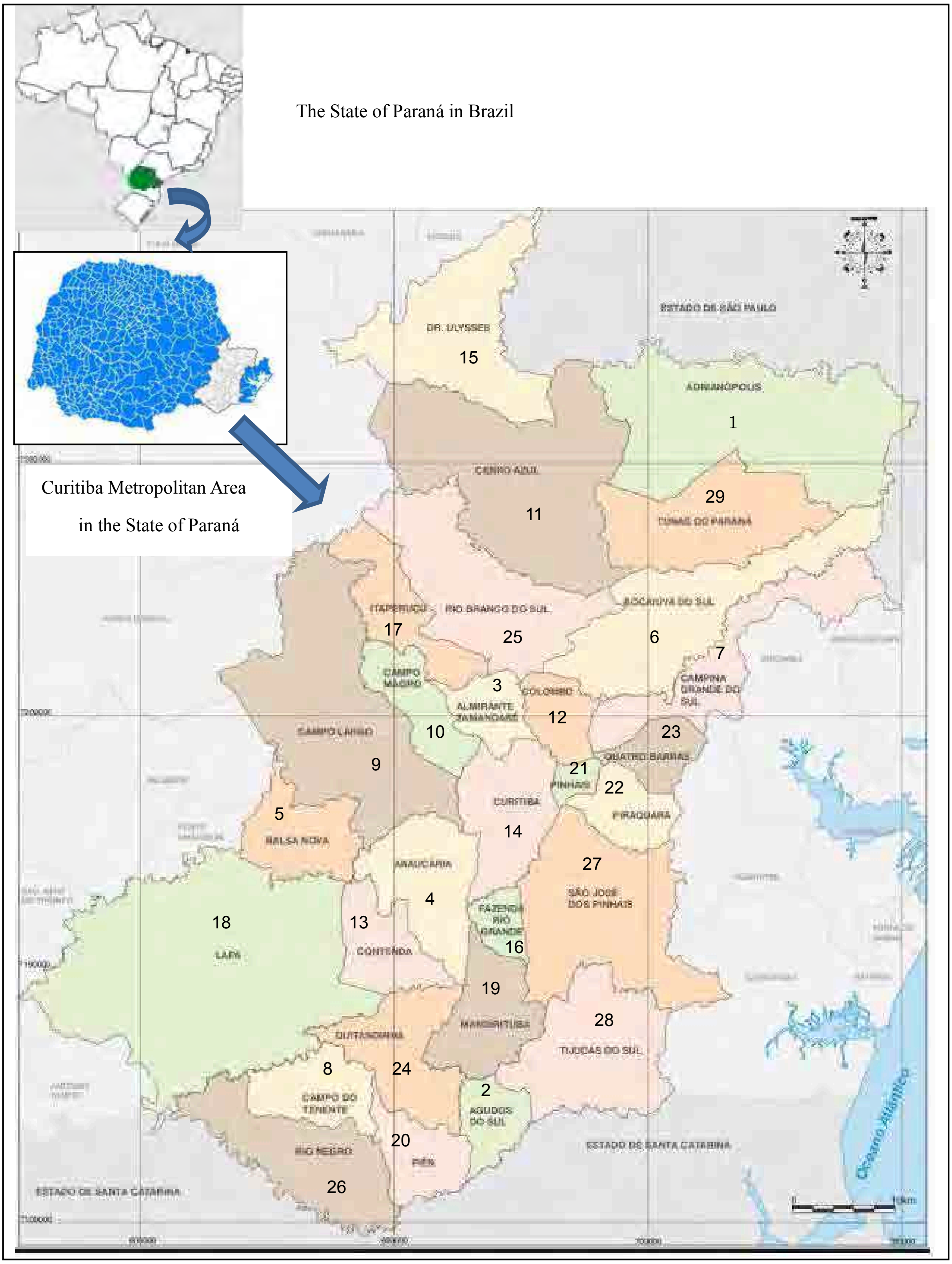


Figure 2.9-1 Curitiba Metropolitan Area

Note: Numbering of municipalities in this figure is the same as shown in Tables in this report.

(Source: Elaborated by the maps of IPARDE and COMEC)

Table 2.9-2 Population of Metropolitan Areas in Brazil

	State	GDP per Capita	Total Population		Metropolitan Area	State	Total Population
1	São Paulo	São Paulo	19,683,975	19	Norte/Nordeste Catarinense	Santa Catarina	1,094,412
2	Rio de Janeiro	Rio de Janeiro	11,835,708	20	Florianópolis	Santa Catarina	1,012,233
3	Belo Horizonte	Minas Gerais	5,414,701	21	Aracaju	Sergipe	835,816
4	Porto Alegre	Rio Grande do Sul	3,958,985	22	Vale do Rio Cuiabá	Mato Gross	833,766
5	Recife	Pernambuco	3,690,547	23	Londrina	Paraná	764,348
6	Fortaleza	Ceará	3,615,767	24	Vale do Itajaí	Santa Catarina	689,731
7	Salvador	Bahia	3,573,973	25	Campina Grande	Pernambuco	687,039
8	Curitiba	Paraná	3,174,201	26	Vale do Aço	Minas Gerais	615,297
9	Campinas	São Paulo	2,797,137	27	Maringá	Paraná	612,545
10	Goiânia	Goiás	2,173,141	28	Agreste	Alagoas	601,049
11	Manaus	Amazonas	2,106,322	29	Cariri	Ceará	564,478
12	Belém	Pará	2,101,883	30	Carbonífera	Santa Catarina	550,206
13	Grande Vitória	Espirito Santo	1,687,704	31	Foz do Rio Itajaí	Santa Catarina	532,771
14	Baixada Santista	São Paulo	1,664,136	32	Macapá	Amapá	499,466
15	Natal	Rio Grande no No	1,351,004	33	Chapecó	Santa Catarina	403,494
16	Grande São Luís	Maranhão	1,331,181	34	Tubarão	Santa Catarina	356,721
17	João Pessoa	Pernambuco	1,198,576	35	Lages	Santa Catarina	350,532
18	Maceió	Alagoas	1,156,364	36	Sudoeste Maranhense	Maranhão	345,873

(Source: Brazilian Institute for Geography and Statistics (IBGE) "Census 2010")

Figure 2.9-2 Main Metropolitan Areas in Brazil (2009)

(Source: IBGE)

Examining the demographic indicators in each municipality in Table 2.9-3, a large disparity is observed among them. Municipalities located far from Curitiba City, such as Adrianóplís, Dourtor Ulisess in the North and Tucunas do Paraná in the south have less than only 10 inhabitants /km^2 while Curitiba has more than 4,000 habitants/km ^{2} and Colombo and Pinhais have more than 1,000 inhabitants /km^2.

Population distribution also differs among the municipalities. The urbanization rates of some municipalities are very high with more than 90% (Almirante Tamandaré, Araucária, Colombo, Fazenda Rio Grande and Quatro Barras,), while others are less than 40% (Adrianópolis, Agudos do Sul, Cerro Azul, Doutor Ulysses, Mandirituba, Quitandinha and Tijucas do Sul) as more population is located in rural area.

Table 2.9-3 Demographic Indicators of Curitiba Metropolitan Area (2010)

Municipalities	Total Population	Urban Population	Rural Population	Urbanization rate (%)	Area (km^2)	Density (habitants/km^2)
1 Adrianópolis	6,376	2,060	4,316	32.31	1341.33	4.68
2 Agudos do Sul	8,270	2,822	5,448	34.12	191.82	44.07
3 Almirante Tamandaré	103,204	98,892	4,312	95.82	191.11	551.81
4 Araucária	119,123	110,205	8,918	92.51	471.38	260.70
5 Balsa Nova	11,300	6,870	4,430	60.80	344.19	33.52
6 Bocaiúva do Sul	10,987	5,128	5,859	46.67	825.76	13.66
7 Campina Grande do Sul	38,769	31,961	6,808	82.44	540.63	72.89
8 Campo do Tenente	7,125	4,194	2,931	58.86	304.29	23.81
9 Campo Largo	112,377	94,171	18,206	83.80	1282.56	89.93
10 Campo Magro	24,843	19,547	5,296	78.68	278.22	91.70
11 Cerro Azul	16,938	4,808	12,130	28.39	1341.32	12.69
12 Colombo	212,967	203,203	9,764	95.42	197.81	1,099.28
13 Contenda	15,891	9,231	6,660	58.09	300.57	54.20
14 Curitiba	1,751,907	1,751,907	-	100.00	435.50	4,079.87
15 Doutor Ulysses	5,727	929	4,798	16.22	787.32	7.22
16 Fazenda Rio Grande	81,675	75,928	5,747	92.96	115.38	732.50
17 Itaperuçu	23,887	19,956	3,931	83.54	320.16	76.75
18 Lapa	44,932	27,222	17,710	60.58	2097.75	21.61
19 Mandirituba	22,220	7,414	14,806	33.37	381.39	60.11
20 Piên	11,236	4,523	6,713	40.25	256.93	44.58
21 Pinhais	117,008	117,008	-	100.00	61.14	1,952.65
22 Piraquara	93,207	45,738	47,469	49.07	225.22	426.35
23 Quatro Barras	19,851	17,941	1,910	90.38	181.27	112.59
24 Quitandinha	17,089	4,887	12,202	28.60	446.40	38.90
25 Rio Branco do Sul	30,650	22,045	8,605	71.92	816.71	37.77
26 Rio Negro	31,274	25,710	5,564	82.21	603.71	52.45
27 São José dos Pinhais	264,210	236,895	27,315	89.66	944.28	289.38
28 Tijucas do Sul	14,537	2,285	12,252	15.72	671.93	22.15
29 Tunas do Paraná	6,256	2,792	3,464	44.63	671.71	9.91
TOTAL	**3,223,836**	**2,956,272**	**267,564**	**91.70**	**16,627.79**	**197.62**

(Source: Paraná Institute of Economic and Social Development (IPARDE))

2.9.2 Economic and Social development

GDP in the Curitiba Metropolitan Area is approximately R$95 million, the fifth largest economy in the metropolitan areas in Brazil[3]. The share of service sector accounts for 69.4% in total production value. The rest is industrial sector, 29%, and agricultural sector, 1.6%.

Economic Activities in the Curitiba Metropolitan Area vary depending on the municipality. Outside of Curitiba, municipalities with more than R$10 million in GDP are Araucária and José dos Pinhais where

3 For reference, total GDP in Brazil in 2010 was R$3,770.1 billion, of which GDP of the State of Parana occupied about 8%.

industrial investment has been concentrated. Industrial and service sectors have developed also in Campo Largo, Colombo and Pinhais which have more than R$1 million in GDP. On the other hand, Adrianópolis, Campo Tenente, Cerro Azul and Doutor Ulysses have the largest shares of agricultural products and the GDP in these areas are around R$100 to 200 thousand.

Table 2.9-4 Economic and Social Indicators of Curitiba Metropolitan Area (2010)

	Economic Indicators					Social Indicators			
						Education	Health	Poverty Rate	
		Share in total production value 1)							
Municipalities	GDP (1,000 R$)	Agriculture (%)	Industry(%)	Service (%)	Investment Amount (Million R$) 2)	Literacy Rate (%)3)	Infant Mortality Rate (No./1,000 live births)	Year 2000 (%)	Year2010 (%)
1 Adrianópolis	85.48	54.67	6.57	38.76	340.00	83.18	-	43.44	24.30
2 Agudos do Sul	73.93	44.51	7.28	48.22	-	91.16	-	38.91	18.90
3 Almirante Tamandaré	723.92	1.27	32.53	66.20	-	93.94	7.58	22.17	8.10
4 Araucária	12,371.03	0.59	42.67	56.74	-	96.45	10.53	17.71	4.90
5 Balsa Nova	290.36	8.61	54.98	36.42	-	95.45	17.14	21.57	18.30
6 Bocaiúva do Sul	107.81	30.48	14.20	55.31	-	90.95	27.59	29.02	12.40
7 Campina Grande do Sul	584.85	2.54	22.63	74.83	15.00	93.97	24.10	21.35	8.20
8 Campo do Tenente	106.38	50.82	6.94	42.24	-	90.94	20.41	38.07	17.00
9 Campo Largo	1,640.61	3.90	31.35	64.75	805.20	95.50	17.09	15.91	6.70
10 Campo Magro	208.68	11.93	23.09	64.98	-	93.83	15.08	21.46	8.70
11 Cerro Azul	216.29	59.68	5.55	34.77	-	82.27	25.51	48.66	30.70
12 Colombo	2,128.44	1.35	27.70	70.95	-	95.35	12.77	17.34	6.70
13 Contenda	159.10	25.71	16.86	57.43	-	94.94	20.00	28.29	11.20
14 Curitiba	53,106.50	0.05	19.55	80.40	1.62	97.87	9.11	8.61	4.90
15 Doutor Ulysses	103.02	68.29	3.48	28.23	-	82.66	16.13	57.29	40.00
16 Fazenda Rio Grande	618.79	1.11	30.12	68.77	1.41	95.53	14.06	20.11	11.40
17 Itaperuçu	204.99	6.18	29.06	64.77	-	89.21	26.55	35.64	11.00
18 Lapa	778.81	24.21	22.48	53.30	210.00	94.33	15.53	31.54	14.00
19 Mandirituba	276.21	15.12	32.93	51.95	-	93.37	11.36	26.56	13.90
20 Piên	280.43	19.62	49.59	30.79	-	95.79	20.00	27.95	13.00
21 Pinhais	4,493.03	0.04	19.38	80.58	-	96.65	12.97	14.18	9.20
22 Piraquara	547.47	1.49	24.09	74.42	-	94.97	14.63	23.17	10.60
23 Quatro Barras	609.31	0.91	60.58	38.51	4.30	95.27	9.40	17.46	7.90
24 Quitandinha	151.33	39.30	9.53	51.17	-	92.89	6.41	41.5	21.20
25 Rio Branco do Sul	583.35	9.80	52.79	37.41	625.00	89.53	11.72	31.87	14.30
26 Rio Negro	590.21	11.14	42.31	46.54	-	96.46	33.08	19.22	9.50
27 São José dos Pinhais	13,690.89	0.55	53.76	45.69	1.54	96.60	11.87	14.03	5.00
28 Tijucas do Sul	214.05	17.74	6.72	75.54	-	91.41	35.93	32.21	13.90
29 Tunas do Paraná	49.32	17.31	18.79	63.89	-	81.75	20.98	35.35	22.90
TOTAL	**94,994.58**	**1.51**	**29.03**	**69.47**	**2,004.07**	–	–	–	–

Note: 1) Percentage of each sector (Agriculture, Industry, and Service) is calculated based on the total products added to basic price respectively.

2) Commitment investment amount in two years under the Paraná State government investment incentive program (Parana Competitivo), as of 12/2012.

3) Literacy rate in a group of people who are 15 years old and more.

(Source: IPARDE)

As the background of industrial and service sector development, location of the Curitiba Metropolitan Area has an advantage of access to the large production and consumption markets in Brazil and also to other countries in Mercosur such as Argentina and Paraguay. Surrounding area of Curitiba City has an industrial park with 43 million m^2 area where large industries have developed in the field of automobile (Renault, Nissan, Volvo, Audi, etc.), steel, food, and others.

In some municipalities outside of Curitiba and its surrounding area, there are factories of large Brazilian companies. For example, a refinery plant (REPAR) of PETROBRAS (Brazilian Oil Company) is located in Aráucaria and a cement factory of Votorantin is operated in Rio Branco do Sul. As of year 2012, there are 11 Japanese companies in the Curitiba Metropolitan Area (Table 2.9-5).

Table 2.9-5 Japanese Companies in Curitiba Metropolitan Area

Location (Municipality)	Company Name	Products
Curitiba	Denso do Brasil Ltda.	Automobile Parts
	Furukawa Industrial S.A.	Telecommunication cable
	Pecval Indústria Ltda （Shimizu Industry）	Automobile Parts
	Toshiba Sistemas de Transmissão e Distribuição do Brasil Ltda	Transmission and Transformer Equipment
São José dos Pinhais	Nissan do Brasil Automóveis Ltda	Automobile
	JTEKT Automotiva Brasil Ltda.	Automobile parts
	Sysmex do Brasil Indústria e Comércio Ltda.	Medical Products
Fazenda Rio Grande	KYB MANDO do Brasil Fabricante de Autopeças S/A.	Automobile parts
	SNR-NTN	Automobile parts
	Hamaya do Brasil	Home electric appliances and recycled parts
	Sumitomo Rubber do Brasil ,Ltda	Automobile tire

(Source: the Japanese Consulate General of Curitiba "Overview of the State of Paraná (Parana Syu Gaiyo)" November, 2012.)

With respect to social development in Table 2.9-4, the literacy rate in most municipalities in Curitiba Metropolitan Area exceeds that of Brazil taken as a whole (90.4%); however, the rate in 6 municipalities (Adrianópolis, Cerro Azul, Doutor Ulysses, Itaperuçu, Rio Branco do Sul, Tunas do Paraná) are somewhat below the rate at national level. The infant mortality rates in municipalities distant from Curitiba are relatively high in comparison to other municipalities. This implies health facilities are less developed in these areas. Reviewing poverty rates in 2010, Doutor Ulysses and Colombo show relatively high rates, more than 30%. Comparing the poverty rates in 2000 and 2010, all the municipalities show improvement. This is attributable to economic development in the region during this period, and also to the Federal Government program to support the poor family.

2.9.3 Electrification Rate

Electrification rates in the area are high, nearly 100% in the total area (Table 2.9-6), owing to the federal Governmental efforts on rural electrification program, "Luz para todos (Light for All)" during the last ten years. All the municipalities show more than 95% electrification rates. Mostly, electricity access is from power distribution companies. Curitiba and Piraquara have more than 2,000 connections from other sources such as independent power generators.

Table 2.9-6 Access to Electricity in Curitiba Metropolitan Area (2010)

Municipalities	Access to Electricity (No. of Connection)				Electrification Rate
	From Distibution Company	From Other Source	No access	Total	
1 Adrianópolis	1,853	25	95	1,973	95.2%
2 Agudos do Sul	2,543	8	22	2,573	99.1%
3 Almirante Tamandaré	30,028	289	87	30,404	99.7%
4 Araucária	35,040	434	34	35,508	99.9%
5 Balsa Nova	3,522	-	3	3,525	99.9%
6 Bocaiúva do Sul	3,215	-	32	3,247	99.0%
7 Campina Grande do Sul	11,543	28	24	11,595	99.8%
8 Campo do Tenente	2,026	-	19	2,045	99.1%
9 Campo Largo	34,033	52	78	34,163	99.8%
10 Campo Magro	7,364	8	34	7,406	99.5%
11 Cerro Azul	4,986	-	190	5,176	96.3%
12 Colombo	63,185	359	86	63,630	99.9%
13 Contenda	4,637	11	38	4,686	99.2%
14 Curitiba	574,013	2,044	134	576,191	100.0%
15 Doutor Ulysses	1,621	-	66	1,687	96.1%
16 Fazenda Rio Grande	23,532	154	10	23,696	100.0%
17 Itaperuçu	6,836	8	29	6,873	99.6%
18 Lapa	13,917	35	141	14,093	99.0%
19 Mandirituba	6,675	16	26	6,717	99.6%
20 Piên	3,341	7	23	3,371	99.3%
21 Pinhais	35,477	50	5	35,532	100.0%
22 Piraquara	23,079	2,992	57	26,128	99.8%
23 Quatro Barras	6,056	11	10	6,077	99.8%
24 Quitandinha	5,197	9	29	5,235	99.4%
25 Rio Branco do Sul	8,977	42	114	9,133	98.8%
26 Rio Negro	9,555	-	19	9,574	99.8%
27 São José dos Pinhais	80,146	491	90	80,727	99.9%
28 Tijucas do Sul	4,453	17	15	4,485	99.7%
29 Tunas do Paraná	1,725	39	29	1,793	98.4%
TOTAL AREA	**1,008,575**	**7,129**	**1,539**	**1,017,243**	**99.8%**

(Source: Brazilian Institute of Geography and Statistics (IBGE))

Chapter3 Present Situation and Plan of Smart Grid in Brazil

3.1 Present Situation of Smart Grid in Brazil

The MME planned all the listed smart grid projects in Brazil, setting smart grid as an important policy. The list of smart grid projects is not released at present.

Outside of the government, ABRADEE, the association of 41 power distribution companies accounting for 99% of the electric power supplies in Brazil, is working for seven smart grid projects with the approval of the ANEEL.

The smart grid project names, main project partners, other partners and sponsors are shown in the following table. The structure and relationship of each smart grid project is shown in Figures 3.1-1 and -2. The progress and result are published in the ABRADEE's website (http://www.abradee.com.br/: Note that the project progress and result can be accessed by registered member only).

Table 3.1-1 Smart Grid Projects

Project No.	Project Title	Main Project Partner	Project Partners and Sponsors
RB1	Coordination & Integration	iABRADEE	CEMIG,ANEEL Aptel
RB2	AMI/AMR Smart Metering	LACTEC	Aes Eletropaulo
RB3	Advanced Distribution Automation	Univertity of São Paulo ENERq	ELEKTRO
RB4	DG, EV, Storage	KEMA	LIGHT
RB5	IT & Telecom	CPqD	CPFL Energia
RB6	Public Policies	Fundação Getúlio Vargas	Eletrobrás
RB7	Customer View	iABRADEE Instituto Innovare e Cia da Estratégia	CEMIG

(Source: ABRADEE Presentation)

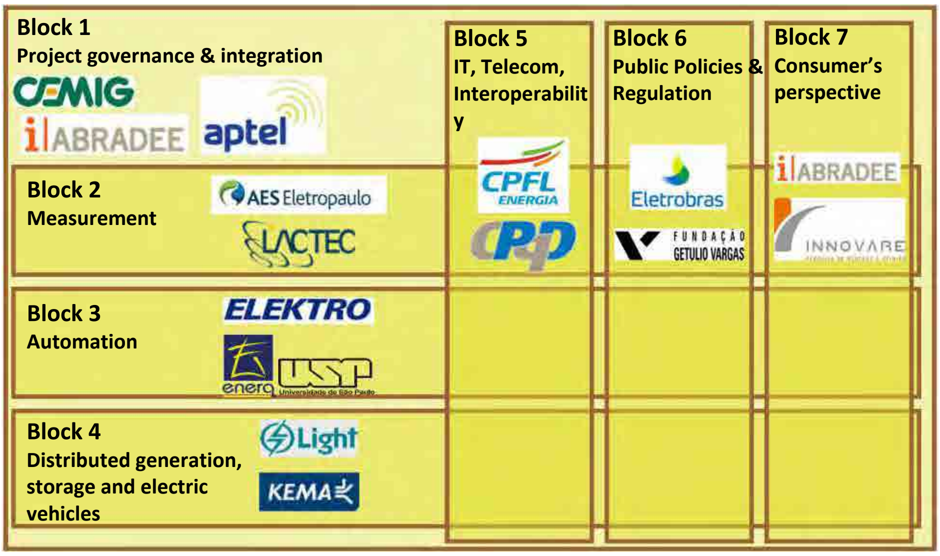


Figure 3.1-1 Structure of Smart Grid Project

(Source: ABRADEE Presentation)

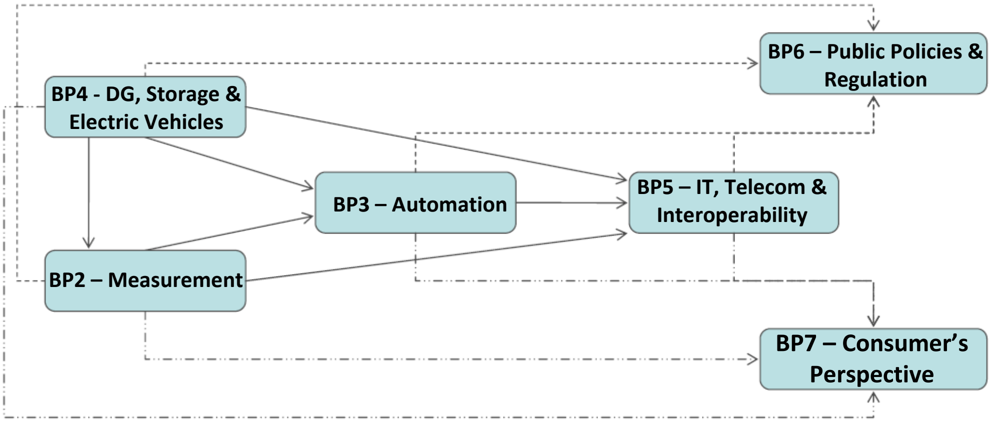


Figure 3.1-2 Relationship of Smart Grid Projects

(Source: ABRADEE Presentation)

Moreover, almost all the Brazilian distribution companies began studying smart grid in order to prepare for themselves and strategically direct their investments in new infrastructure and Research and Development projects towards the modernization of the Brazilian electric system.

A lot of distribution companies have carried out model projects of smart grid by using funds stored in the ANEEL. The overview of major distribution companies' projects and plans is as follows. The latest information is shown in the Appendix3-1.

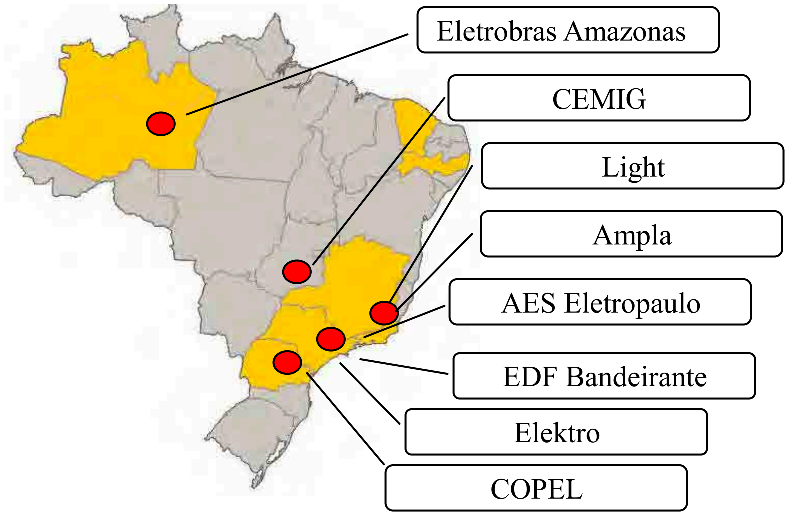


Figure 3.1-3 Location of Distribution Companies

(Source: ABRADEE Presentation)

1) Eletrobras

- Parintins City (island) in the Amazon River has plans to implement a smart grid (micro grid) model project. The project consists of automated meter reading (AMR) with smart meters, distributed generation (Photovoltaic: PV, etc.) and existing diesel generators.
- The project name is "Reference model for Utility Distribution Companies"
- The project budget is 21,792,669 R$.

2) AES Eletropaulo

- Has been operating the AMR in Slum Morada do Sol area as a pilot project.
- The project name is "Structuring project for Intelligent Grids in Metropolitan Regions"
- The project budget is 32,270,359 R$.

3) Light

- Has been exchanging watt hour meters (WHM) for smart meters since 2009, in order to prevent theft of power.
- Has been operating the DAS in order to monitor faults in underground network and reclosers in overhead (OH) network.
- The project budget is 31,241,316 R$.

4) AMPLA

- AMPLA has plans to conduct a smart grid pilot project in the city of Armação dos Búzios, employing it as a smart city. The project is due to be implemented from July 2011 to June 2014 and the scope/specification is to be decided from now onwards. (Smart meter, Electrical Vehicle: EV, etc.)

- The project name is “Study of the effects of the deployment of smart electrical grid technologies”
- The project budget is 32,270,359 R$.

5) CEMIG (Compania Energetica de Minas Gerais)

- A pilot project to develop a functional smart grid model has been implemented to support the decision for large-scale deployment in the distribution grid.
- The project name is “Functional Smart Grid model”
- The project budget is 37,227,232 R$.

6) EDP Bandeirante

- Has installed a lot of remote power measurement systems as a pilot project.
- The project name is “Pioneer lot of the Electronic Measurement Module”
- The project budget is 8,687,278 R$.

7) Elektro

- Has been developing a smart grid reference model applied to the deployment of smart cities
- The project name is “Reference model for deployment of Smart Electrical Grids”
- The project budget is 15,191,348 R$.

8) COPEL (Compania Paranaense de Energia)

- The details are shown in Chapter 3.3.

Moreover, there were 26 registered smart grid projects from 2009.4 to 2013.3 in ANEEL. If the project implementation company registers the project, ANEEL makes a database, such as in Table 3.1-2. The project implementation company, project title, project cost and registration date is shown in Table 3.1-2.

Table 3.1-2 Smart Grid Projects registered in ANEEL

Company	Project Title	Project Cost	Registration Date
EMG	Methodology for Technological Roadmap of Smart grids concept.	R$ 1,984,076	2009/7/7
BANDEIRANTE	Products line for optimization and control of residential energy use in the Smart Grid concept.	R$ 213,579	2010/4/15
CEAL	Development of innovative software technology for the Smart Grid.	R$ 915,600	2010/8/3
LIGHT	L1-Development of interoperable smart grid platform, integrating metering and automation systems of distribution and using digital certificates to support Smart Grid program.	R$ 13,113,984	2010/9/27
LIGHT	L2-Development of real time management system of underground distribution network, through monitoring, diagnosis and reconfiguration, within the platform and Smart Grid program concepts.	R$ 4,955,696	2010/9/29
LIGHT	L3: Overhead Network Management System, Considering Faults Management and Restoration, insertion of GDs and isolated operation mode integration with the platform and Smart Grid program.	R$ 4,979,689	2010/9/30
LIGHT	L4-Development of system for energy management on demand associated with other services, with a focus on efficient consumption by interactive multimedia channels integrated with the Smart Grid Program.	R$ 5,059,545	2010/10/5
LIGHT	L5: Development of a smart system of renewable sources management, distributed storage and rechargeable electric vehicles integrated with the Smart Grid concept and platform.	R$ 3,132,402	2010/10/6
AMPLA	Public lighting consumption metering via mesh network in smart grid environment.	R$ 1,916,280	2011/4/19
CEEE-D	Research and development of a modular 660kVA biogas plant with remote management in response to smart grid concepts.	R$ 3,591,060	2012/11/13
CEEE-D	Efficient use of intelligent energy networks innovative potential (Smart Grid) on improving quality management of electric energy distribution systems.	R$ 576,554	2010/12/8
ELEKTRO	Smart Relay for Public Lighting with Interface Network for ELEKTRO Smart Grid.	R$ 877,960	2010/12/23
CEEE-GT	Efficient management of distributed electric power generation from local solid waste using the innovative potential of intelligent energy networks (Smart Grid).	R$ 415,445	2010/12/1
EMG	Development of standardization methodology of substations adherent to Smart Grid concepts, considering the use of IEC61850 communication protocol.	R$ 4,224,550	2011/2/25
CEEE-D	Efficient use of intelligent energy networks' (Smart Grid), innovative potential on improving quality management of electric energy distribution systems.	R$ 576,554	2010/12/2
ELEKTRO	Medium Range Radio Communicator System using Mesh Technology for Asset Management and Electric Power System with Network Interface for ELEKTRO Smart Grid.	R$ 877,960	2011/8/2
CEMIG-D	Development of PLC Modem for Telecommunication Applications and Smart Grids in Low voltage Networks.	R$ 4,121,602	2011/3/2
CEEE-D	Operational validation of Submersible dry transformer integrated with the Smart Grid.	R$ 1,296,617	2011/10/26
CELESC-DIS	SMARTFIX - Automatic Recovery Methodology of Distribution Networks Using Mixed Sources of Information for Detection and Location of Faults in Smart Grid Environments.	R$ 1,516,231	2011/11/28
CELESC-DIS	Quantification of low voltage losses to the new reality of Smart Grids.	R$ 589,090	2012/2/29
CEMIG-D	D423 - DE - Development of Smart Grid Functional Model through systemic integration of smart solutions to automation of distribution network, advanced metering and consumer participation infrastructure.	R$ 25,318,843	2010/11/18
CELESC-DIS	Development of a current leakage metering of Insulation Systems to be used in Smart Grids.	R$ 893,920	2012/5/16
CELESC-DIS	Development of a Smart Grid network prototype for micro-renewable energies.	R$ 2,429,620	2012/5/18
COSERN	Mobile Emulator Projection and Manoeuvre in medium votage, with features applicable to substations in the smart grid.	R$ 891,800	2012/6/5
CEB-DIS	SISGRID - Intelligent system based on smart grid concept for metering and estimated technique and commercial losses in lattice circuits spot type distribution network with economic viability.	R$ 1,738,048	2012/8/20

(Source: JICA Survey Team)

In addition, the Inova Energia Joint Action Plan was announced, which is an initiative aimed at coordinating actions that foster innovation and improve the integration of support tools provided by the BNDES, ANEEL and Financier of Studies and Projects (FINEP). The purposes are as follows;

- To support the development and dissemination of electronic devices, microelectronics, systems, integrated solutions and standards for the implementation of smart grids in Brazil

- To support Brazilian companies in the field of technology development and production chains of the following alternative renewable energies: solar photovoltaic, thermo and wind power for generating electricity
- To support initiatives that promote the development of integrators and the consolidation chain components in the production of hybrid/electric vehicles, preferably ethanol powered, and improving energy efficiency of motor vehicles in the country
- To increase the coordination of actions to promote and improve the integration of the available financial support instruments

The selection and fostering of business plans within the Inova Energia will aim at production chains linked to the three thematic areas below;

- Smart grids
- Energy Generation through Alternative Sources
- Hibrids and Energy Efficient Vehicles

The selection process will be conducted by the Inova Energia Assessment Committee composed of members and deputy members appointed by the ANEEL, FINEP and BNDES, to coordinate and promote the Joint Public Selection Process by the ANEEL, FINEP and BNDES, with powers to perform the selection companies, analyze and select business plans submitted by the companies, and structure Joint Support Plans (CSP) as per the following steps:

- Step 1: Expression of Interest
- Step 2: Selection of Leading Companies
- Step 3: Presentation of the Business Plans
- Step 4: Selection of the Business Plans
- Step 5: Structuring of the Joint Support Plans

After these steps, the ANEEL, BNDES and FINEP shall examine the claims in light of the specific procedures of their respective support tools.

Figure 3.1-4 Selection process

(Source: ANEEL)

The BNDES, ANEEL and FINEP shall make funds available in a total of R$ 3 billion for the years 2013 to 2016. The resources shall be committed only to the extent that there is approval and subsequent adoption of projects, regardless of the indicated financial instrument(s). The amount of available resources could increase if the total value of projects exceeds the initially available approved amount.

Table 3.1-3 Availability of Resources by Institution/Program

Availability of Resources by Institution/Program		
Institution	Program	Sum (R$)
FINEP	Inova Brasil	1.2 billion
	Economic Subsidy	
	ICT/Company Cooperation	
	Variable Income	
BNDES	Credit	1.2 billion
	BNDES Funtec	
	Variable Income Instruments	
ANEEL	Mandatory R&D Resources	0.6 billion
TOTAL		3.0 billion

(Source: ANEEL)

3.2 Present Situation and Plan of Smart Grid in Parana State Government

The Parana State Government is planning Smart Community Project in Fazenda Rio Grande and Morretes. The main contents of the wide area project are safety of water, sewage and gas to schools and hospitals. That plan includes introduction of photovoltaic power generation to the Soccer World Cup stadium. Additionally, electric vehicles are being studied, however, there is no specific plan at present and remain as concepts only with aims of further study in the future.

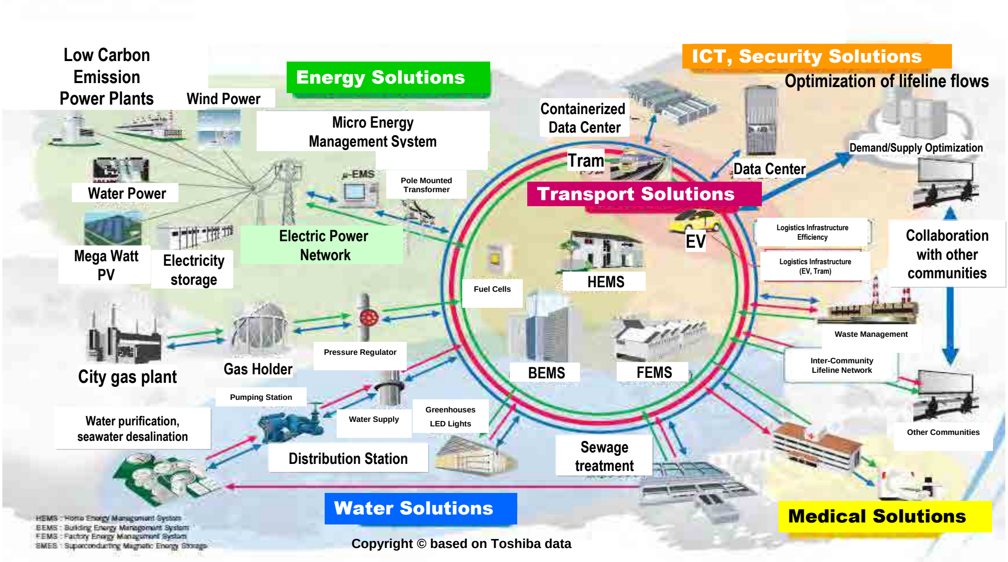


Figure 3.2-1 Conception Overview of Smart Community

(Source: TOSHIBA)

Moreover, the Parana State Government planned “Smart Energy Program” in addition to the smart grid project which COPEL has installed in the Curitiba Metropolitan Area. TECPAR serves as the main program implementer of the Parana State Government in the plan, and COPEL has also participated. The program consists of the following three projects.

- Green Energy Coast Project

The plan, similar to that in the Curitiba Metropolitan Area, along the seashore is carried out. It focuses on renewable energy, especially wind power generation plant.

- Green Silicon Project

It cooperates with the commercial and industrial association of Parana State and the installation of a photovoltaic generation plant including Itaipu area is planned.

- TECPAR Technology Platforms

It is related to bioenergy and a biofuel plant is planned. The pilot plant of biofuel is in the site of TECPAR.

The Green Energy Coast Project is related to smart grid project, and so the detail of the project is described below.

The Coast of Green Energies is a development project for the coastal area in State of Parana under the umbrella of Parana State program called Smart Energy Parana. It is multi-institutional with the involvement of the government, private sector, academia, research institutions and society, and proposing interventions in distributed generation (DG) from renewable sources integrated into smart grids as a pilot project, composed of the following points.

- Technical analysis that include electro-energy
- Regulatory issues
- Use of incentives of various technological alternatives
- Environmental and economic impacts
- Technical and high qualified training
- Attraction of industries
- Creation of new business and jobs
- Education and the awareness concerning the proper use of these technologies

The Coast of Green Energies will be a master plan through a study that aims to accomplish economic and technical elements that enable proper decision making for its deployment. Accordingly, the scope of this study should include the following activities.

- Definition of initial master plan guidelines
- Identification of the Coastal Area Counties
- Technical details of the approved options
- Planning the startup of the pilot project – master plan
- Proposing a model for deployment, operation and sustainability of the pilot project

3.3 Present Situation and Plan of Smart Grid in Curitiba Metropolitan Area

In the Curitiba Metropolitan Area, smart grid projects are carried out in two cities (Curitiba City and Fazenda Rio Grande). Each situation is as follows.

3.3.1 Curitiba

The main objective of the smart grid project in Curitiba is to improve reliability of distribution line before the FIFA World Cup held in Brazil in June 2014. The Federal Government made funding available to improve electricity infrastructure for the host cities. Therefore, COPEL utilizes it to develop distribution facilities including installation and automation of LBS and/or reclosers in its distribution lines.

The first goal of Curitiba smart grid project is to install LBS and/or reclosers in distribution lines and to control all these facilities remotely. The second step is to improve reliability by installing distribution facilities such as DAS and so on. Additionally, the present plan of COPEL is to cover more than 90% of the area in Curitiba City by the FIFA World Cup through replacement of the existing LBS and reclosers with new LBS and/or reclosers.

(Reference)

- ILJIN Electric Co.,Ltd. Production
- Maximum operation voltage : 15kV
- Operation current : 630A

Figure 3.3-1 LBS in Curitiba Area

(Source: Photo by Survey Team)

In Curitiba smart grid project, the following are being conducted.

- Remote monitoring and control of LBS (approximately 200 units) (Control is taken after the grid situation is confirmed in GIS.)
- In the coastal area, remote monitoring and control of reclosers
- For important customers such as large demand customers, remote control of LBS for exchanging normal/buck-up feeders

3.3.2 Fazenda Rio Grande

One of the reasons why COPEL selected Fazenda Rio Grande as a site for COPEL's smart grid projects is that the distribution network in Fazenda Rio Grande has similarity to COPEL's other distribution network. Therefore, there is a possibility to make it a good showcase for other areas in COPEL.

The main purpose of the Fazenda Rio Grande smart grid project is research and development of the smart grid technology, and acquisition of experience. Fazenda Rio Grande smart grid is ongoing. However, this project is not as fast as Curitiba smart grid project in which COPEL makes more efforts to install equipment by the FIFA World Cup in June 2014.

In Fazenda Rio Grande smart grid project, there are some installed facilities to evaluate smart grid technologies which include small PV generation, GPRS communication, automated capacitor bank and automated voltage regulator. Therefore, Fazenda Rio Grande smart grid project has many concepts such as testing of new facilities and so on. New facilities mean facilities from some manufacturers (S&C, Cooper, Lupa, etc.) and prototype facilities developed in Research and Development projects with universities and research institutes. For example, the energy meter is one of the R&D prototype facilities, which was installed at some substations where the optical fiber communication is used. The distribution transformer monitoring is one of the R&D prototype facilities, which uses the blue tooth radio to download local data and is installed on the low voltage side to monitor power quality. The fault location sensors utilize the detection of surge current to indicate a possible fault downstream, which uses the GPRS communication.

(Reference)
- ILJIN Electric Co.,Ltd. Production
- Maximum operation voltage : 15kV
- Operation current : 630A

Figure 3.3-2 LBS in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

1) Telecommunications

This project utilizes many telecommunication media provided by COPEL Telecom and already used for normal facilities operation, etc.

- Optical Fiber

It is utilized to connect two substations (Fazenda Iguaçu and Fazenda Rio Grande).

- WiFi Mesh

It uses 2.4GHz and 5GHz (5.1 to 5.7GHz) radio waves in the downtown area. There are approximately 11 radio waves of each frequency which proves a WiFi cloud of approximately 22 redundant access points. The specification of the WiFi Mesh is regulated by the ANATEL Resolution 506.

- Mobile (GPRS)

It is utilized for capacitor bank and voltage regulator. The GPRS system has a gateway connecting to COPEL Distribution SCADA. During the testing period, this is utilized for fault locator on the feeders (13.8kV and 34.5kV).

- Bluetooth

It is utilized as a short range communication system for the local data downloading. It is also utilized for the power transformer monitoring facility.

2) Automation and Monitoring

- Photovoltaic Panel and PV system

Photovoltaic panels are installed in Fazenda Iguaçu Substation to study the performance of the panels, inverters and batteries as an R&D project. The generated power is utilized to provide energy for substation service power. Two different types of inverters are being tested for interference with each other and for type-approval procedure of inverter used by customers asking to connect PV system with COPEL's grid.

(Reference)
- 3 arrays: Kyocera (Poly) 135kWx30panels
- Kyocera (Poly) 135kWx20panels
- Solarterra (Mono) 70kWx20panels

Figure 3.3-3 PV Panels in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

(Reference)

- Lead-acid battery
- MOURA(Brazil)
- 200Ahx12Unitis

Figure 3.3-4 Battery in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

(Reference)

- XANTREX(Canada)　　Cp electronica(Brazil)

Figure 3.3-5 Inverters in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

- Capacitor Bank Controller

It is one of R&D prototype facilities which were developed to study the performance of the controller. It uses the GPRS communication.

(Reference)
- Cooper Production
- 1200kVAR
- Self-operation

Figure 3.3-6 Capacitor Bank Controller in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

- Single Phase Recloser

There are some rural feeders which use only one phase without grounding. To protect these single phase lines, the single phase recloser is installed and being tested.

(Reference)
- Cooper Production
- Self-operation

Figure 3.3-7 Old Mechanical Recloser in Fazenda Rio Grande Area

(Source: Photo by Survey Team)

- Setup Voltage Regulator

There are long feeders which have high voltage drop. To improve the voltage level, the setup voltage regulator is installed and being tested.


(Reference)

➢ Cooper Production	Toshiba Production
➢ Self-operation	Self-operation
➢	New pole construction

Figure 3.3-8 Setup Voltage Regulator in Fazenda Rio Grande Area

(Source: JICA Survey Team)

3.4 Brazilian Government Policies, Laws and Regulations

3.4.1 Brazilian Government Policies and Related Ministries and Agencies

In recent years, there was a big change in the electric power sector. Especially, the calculation method change of the electricity tariff in 2012 was a big event historically. The smart grid is needed increasingly with this policy introduction.

However, at present the federal government has not yet finalized the policies regarding smart grid. The MME has studied and created a working group for smart grid within the ministry, however, the MME is planning to create a new working group, expand the number of members of the following related ministries and agencies and to decide smart grid policies.

- MCTI (Ministerio Da Ciencia, Technologia e Inovacao: Ministry of Science, Technology and Innovation)
- MDIC (Ministerio do Desenvolvimento, Indústria e Comércio Exterior: Ministry of Development, Industry and Commerce)
- MOF (Ministerio da Fazenda: Ministry of Finance)
- ANATEL (Agencia Nacional de Telecomunicacoes: National Agency of Telecommunications)

The ANEEL has started decisions of rules for operation and setting up the standard for smart grid technology and supporting the human resource development for future smart grid related projects. The post for the smart grid is planned in the MCTI. Smart grid related product specifications are examined by SGT 13 group of the Associação Brasileira de Normas Técnicas (ABNT).

3.4.2 Brazilian Government Laws and Regulations

1) The Alternative Energy Sources Incentive Program (PROINFA)

The Alternative Energy Sources Incentive Program -PROINFA, established on April 26th, 2002 by enactment of the Federal Law 10,438. The major purposes are as follows.

- Brazilian energy matrix diversification
- Reducing greenhouse gases emissions

The program was divided into two stages: the first for project implementation in short term and the second for implementation in medium terms. It started from April 2004. The program's main goal is to fund energy generation projects from wind (wind power) to small hydropower (SHP) and biomass in financially attractive conditions supported by the Brazilian Development Bank (BNDES: Banco Nacional de Desenvolvimento Economico e Social). The purchase of energy generated is guaranteed by Eletrobras for 20 years.

This program provides institutional option support to the development of renewable energy through a hybrid system of policy support for renewable power generation that includes the Feed-in remuneration system since it sets a price for electricity produced from renewable sources and the Quota System which initially establishes quotas of initial power to be contracted.

The Feed-in system consists of more advantageous tariffs for generating plants that use renewable sources of energy as Renewable Portfolio Standard (RPS) if compared to tariffs for conventional sources of energy. The aim is to enable the implementation of such plants which have higher costs of production. These tariffs are guaranteed for a determined period of time, from 10 to 20 years: ANEEL, Technical Note 0043/2010.

2) Resolution No. 247/2006, December 21, 2006

Resolution No. 247/2006 regulates the right of Renewable Power Plants trade energy with Especial Consumer (retail energy trade) and gives benefits as wheeling fees discounts.

<Targets of Renewable Power Plant>

- Very small hydro power plant called Micro/Mini Central Hidroelétrica (MCH) (under 1 MW);
- Small hydro power plant called Pequena Central Hidroelétrica (PCH) – (over 1 MW and under 30 MW*);
- Biomass power plant under 30 MW*;
- Wind power plant under 30 MW*;
- Solar power plant under 30 MW*. (* Power injected in grid)

<Definition of Especial Consumer>

- One consumer unit or group of consumer units that have over 500 kW of demand

<Wheeling fees discount>

- Especial consumers will get 50 percent or more in case of trade with Renewable Power Plant.

3) Time of Use Tariff

The ANEEL is now considering a new regulation that provides different rates by time of consumption, offering cheaper rates during periods when the system is less used by consumers. The subject was under Public Hearing No.120/2010.

The rate structure is how different types of consumers pay for the use of electric power, divided by subgroups according to hours of use, voltage and location. The new system will be applied to each distributor in its rate revision between 2012 and 2014.

For low voltage customers, whether in residential, commercial, industrial and rural areas, the main change is the creation of a white rate mode, which is an alternative to the conventional one and will offer three different levels for the energy rate according to the time of consumption. Monday to Friday, a cheaper rate will be applied in most hours of the day; more expensive one in others, when the energy reaches the maximum, in the early evening; and intermediate will be between those two times. On weekends and holidays, the cheapest rate will be used for all hours of the day.

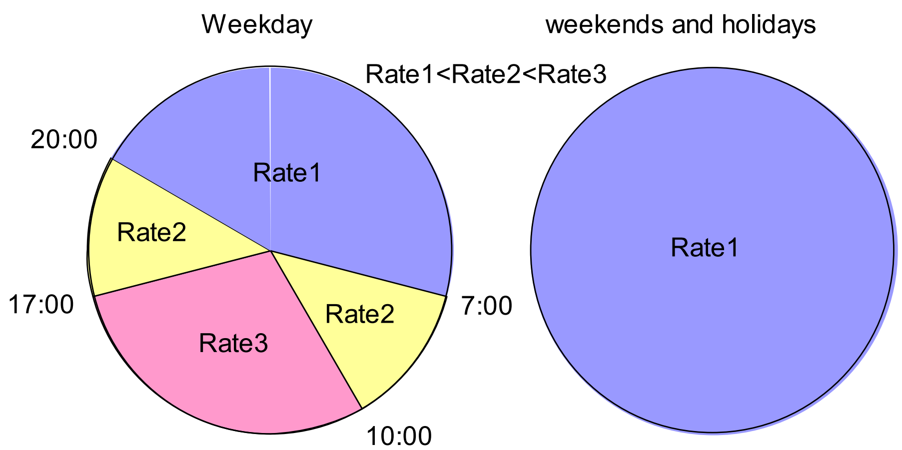


Figure 3.4-1 Image of Time of Use Tariff

(Source: JICA Survey Team)

4) Net-metering (Resolution No. 482/2012)

In 2012 the Resolution No. 482/2012, which establishes the Clearing System of Electricity in Brazil using net metering, was published. One of the main objectives is to reduce obstacles of distributed generation (up to 1 MW) connection to low voltage lines. The feature of net-metering is as follows,

- Net metering allows a two-way flow of electricity between a distribution company and customer with distributed generator.
- Should the generation be lower than the load, the customer only pays the price difference between the energy used and the energy generated.
- Bidirectional meters flow backwards when electricity flows into a grid.

With this system, a consumer can install small electricity generators in its consumer unit (photovoltaic solar panels and small wind turbines) and the energy generated is used to bring down the power consumption of the unit. When the generation is greater than consumption, the surplus energy can be used to shoot down the consumption tariff in another post or in the following month invoice. The energy credits generated are valid for 36 months. There is also the possibility for the consumer to use those credits to another drive, since the two consumer units are in the same concession area and are of the same owner. It is also important to note that in order to participate in the Clearing System, the generators installed in the consumer unit must qualify as micro or mini generation distributed as defined in Module 1 of PRODIST. The other form of measurement and connection requirements, operation and protection can be found in Section 3.7 of Module 3 of PRODIST.

5) Measurement at Low Voltage (Resolution No. 502/2012)

In 2012 the Resolution No. 502/2012, which regulates measurement systems of power consumer units from Group B, was published. The Resolution establishes two types of equipment: the first, to be installed at no cost, allows consumers to join the white rate which varies with consumption slots. The other model of meter, most complete, will offer access to specific information about individual service, and installation may be charged by the distributor. The deadline for the distributors to fit and offer the new meters ends on February, 2014.

Chapter4 Power Situation in Candidate Areas

4.1 Transmission and Substation System

4.1.1 Generation System in Brazil

The balance of electric power supply and demand in Brazil was tenporarily tight because of a shortage of hydro generation due to a drought in the past, however, power plants were constructed so that the balance of supply and demand in Brazil could be maintained. The demand is estimated approximately to double in the next decade because of strong economic growth, the Soccer World Cup and the Olympic Games which are to be held in 2014 and 2016, respectively. New development of hydro power plant, however, is in a very difficult situation from the viewpoint of environmental preservation.

In Brazil, 80% of the total generating power is hydro power and remaining 20% includes other generation sources such as natural gas, coal, diesel and nuclear power generation. Recently the government established renewable energy promotion program (PROINFA) in 2002 publishing renewable energy purchase prices of power companies at the very early stage and renewable energy has been developed in Brazil, however, the amount of renewable energy such as wind and photovoltaic is not so remarkable.

In COPEL, the generation and distribution is divided into two different companies; COPEL Generation and COPEL distribution. The power stations owned by COPEL generation are shown in Table 4.1-1. The power generation and transmission, however, is controlled by ONS as stated below with distribution being completely independent from generation.

Table 4.1-1 Power Stations owned by COPEL

Own Generation YTD From January to December, 2011				
Plants	Installed Capacity (MW)	Assured Energy (MWmed)	Verified Generation	
			GWh	MWmed
Hydropower plants	4,529.61	1,948.33	25,717.14	2,935.75
Gov. Bento Munhoz da Rocha Netto	1,676	576	8,195.18	935.52
Gov. Ney Aminthas de B. Braga	1,260	603	7,661.72	874.63
Gov. José Richa	1,240	605	7,762.94	886.18
Gov. Pedro V. Parigot de Souza	260	109	1,586.35	181.09
Guaricana	36	16.08	178.46	20.37
Chaminé	18	11.6	87.64	10.00
Apucaraninha	10	6.71	63.05	7.20
Mourão	8.2	5.3	58.12	6.63
Derivação do Rio Jordão	6.5	5.85	50.02	5.71
Marumbi	4.8	2.96	23.43	2.68
São Jorge	2.3	1.62	12.25	1.40
Chopim I	1.98	1.48	13.78	1.57
Rio dos Patos	1.72	1.02	9.01	1.03
Cavernoso	1.3	0.96	5.45	0.62
Melissa	1	0.64	6.09	0.69
Salto do Vau	0.94	0.6	3.33	0.38
Pitangui	0.87	0.51	0.33	0.04
Thermal power plant	20.00	10.30	71.75	8.19
Figueira	20.00	10.30	71.75	8.19
TOTAL	4,549.61	1,958.63	25,788.89	2,943.94

(Source: COPEL annual Report)

As shown in Figure 4.1-1, the electric power system in Brazil is divided into four areas: the North, North-East, South-East and South. These four areas are operated as Systema Interligado Nacional (SIN) by Operador Nacional do Sistema Elecrico (ONS). Curitiba City is located in the South area and one of the large consumption cities in the South area. In the South area, major power generation is hydro power generation and the generation plants are located in the west of Parana State. The generated power is transmitted to Curitiba and other consuming cities by 500kV transmission lines. The largest hydro power station is ITAIPU located on the borders with Paraguay. The generated power is transmitted to Sao Paulo by 650kV DC and 750kV AC transmission lines.

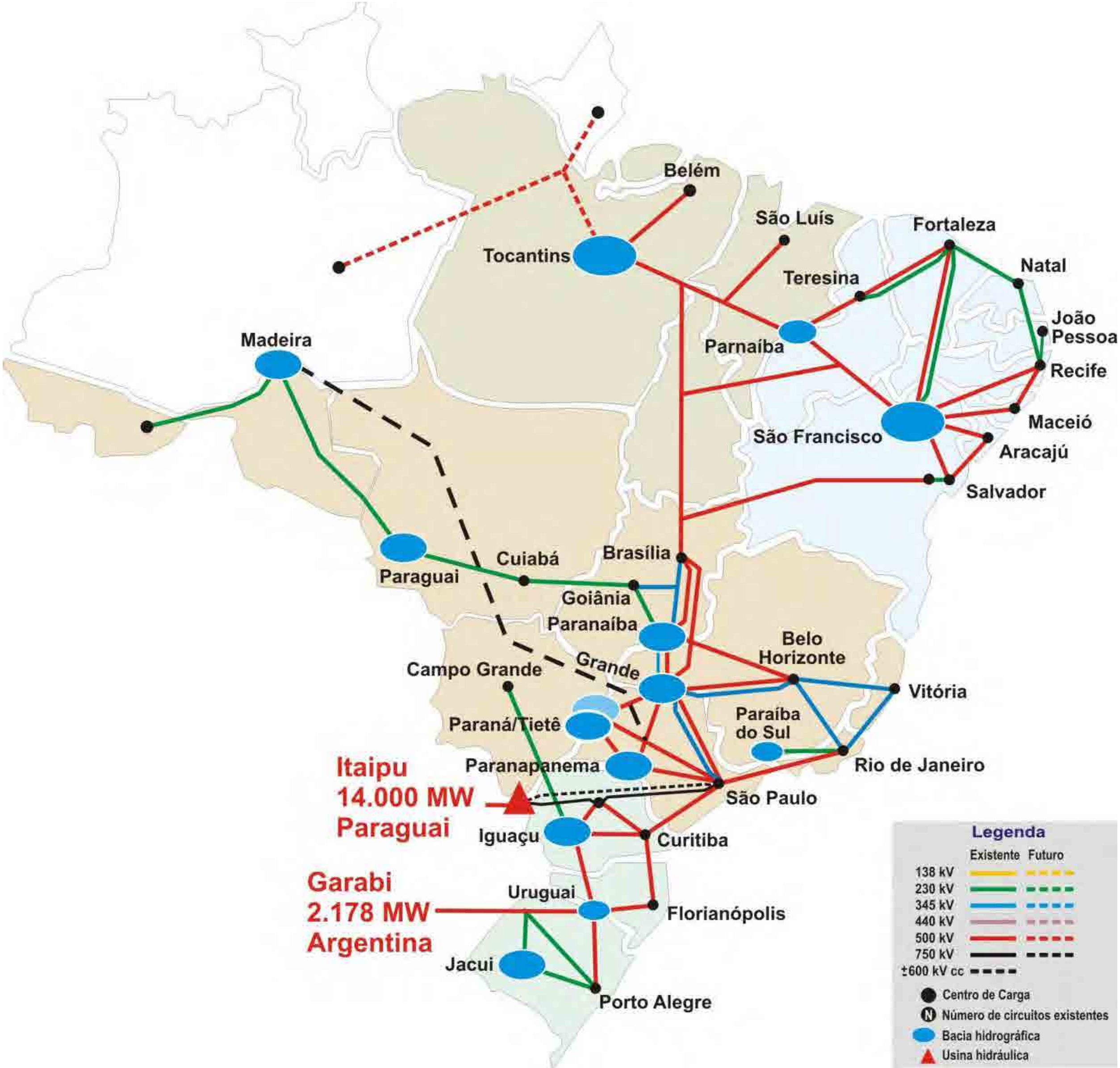


Figure 4.1-1 Power Transmission System in Brazil

(Source: ONS)

4.1.2 Transmission and Substation System

Focusing on the power transmission system in Parana State, as shown in Figure 4.1-2, power generation plants are located in the South-west area and power is transmitted to Curitiba, Londrina and Maringa by 500kV transmission lines. According to COPEL, in case of emergency such as power shortage in overall Brazil, the power system in Parana State will be separated from the other areas in Brazil in order to maintain stable power supply in Parana State.

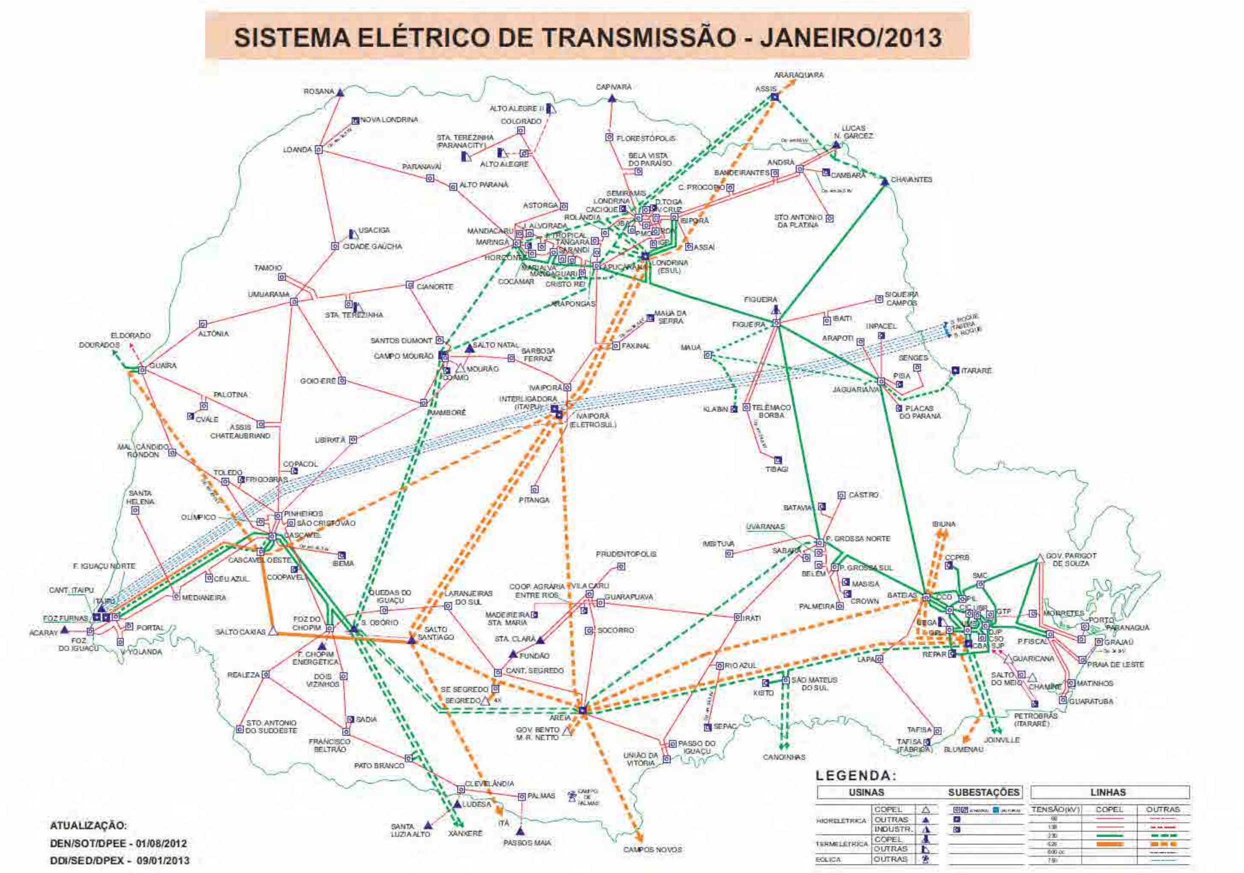


Figure 4.1-2 Transmission System in Parana State in 2013

(Source: COPEL)

The candidate areas where smart grid systems will be provided are located around Curitiba City shown in Figure 4.1-3. In Curitiba City, the 500/230kV transmission lines are established to supply electric power which can be supplied to the candidate areas by 138kV distribution lines. There is no 138kV distribution line in some of the candidate areas in 2013. However, according to the planned diagram shown in Figure 4.1-4, COPEL is planning to provide 138kV distribution lines to almost all the candidate areas by 2021.

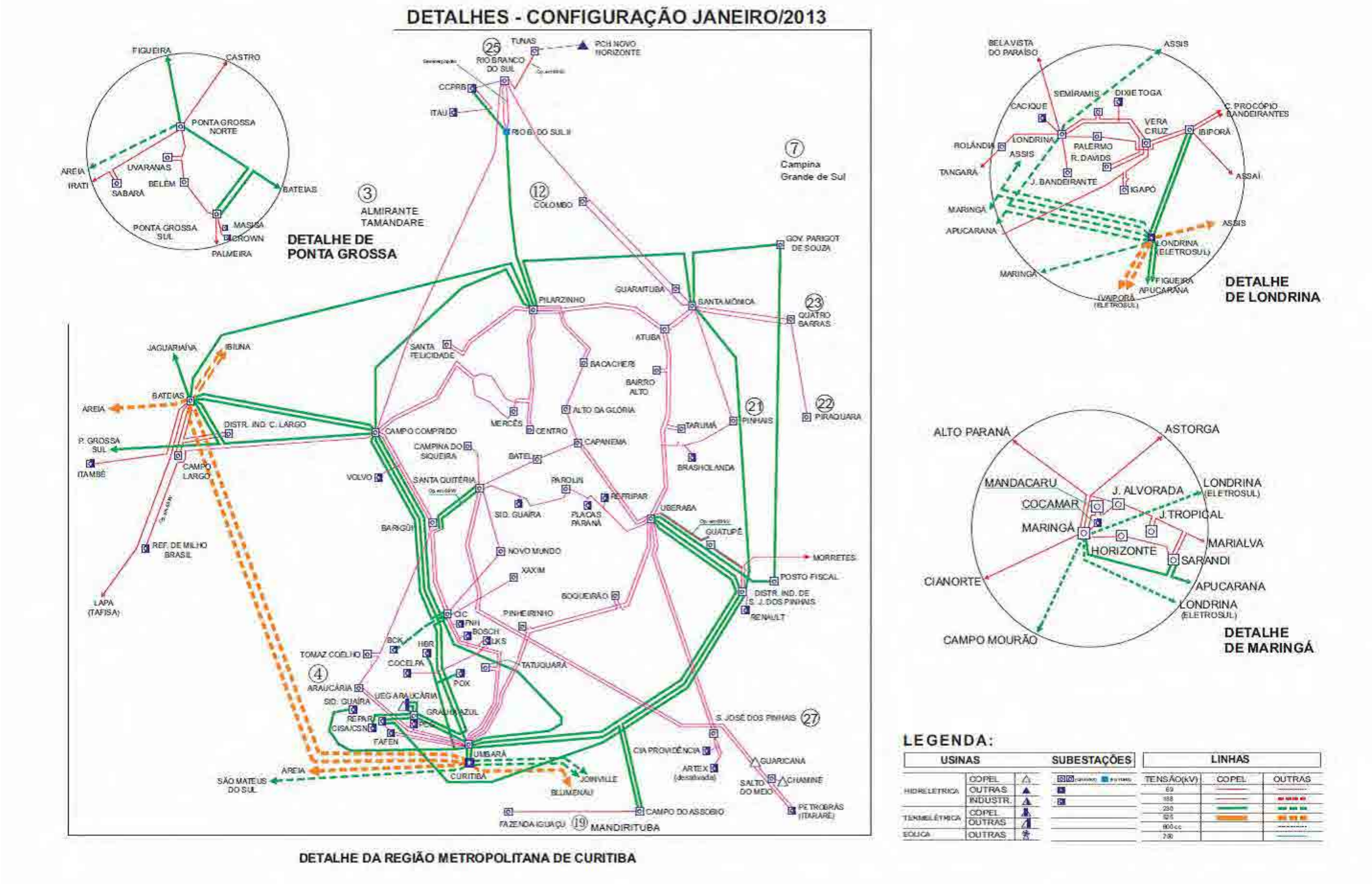


Figure 4.1-3 Transmission System in Curitiba in 2013

(Source: COPEL)

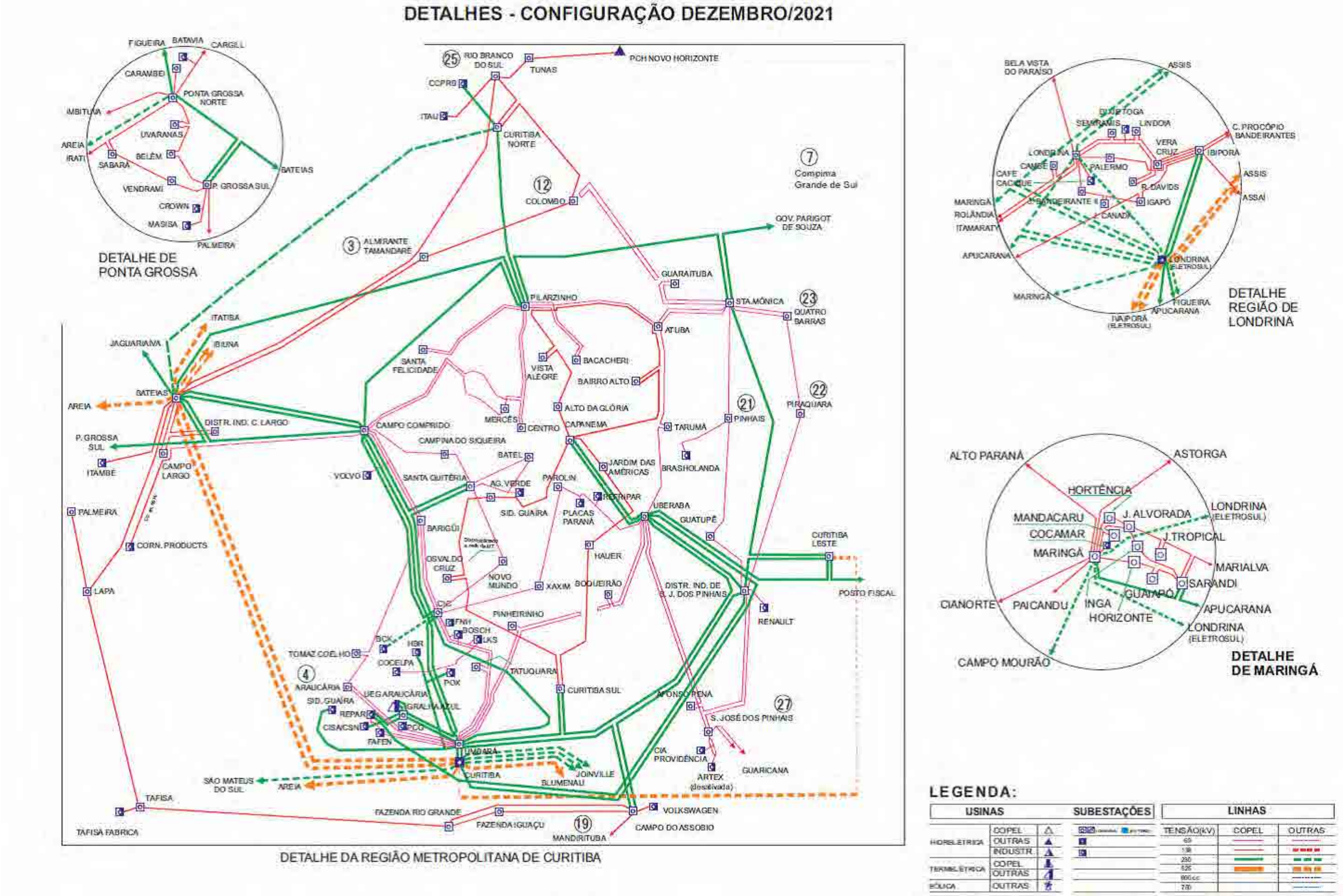


Figure 4.1-4 Transmission System in Curitiba in 2021

(Source: COPEL)

4.1.3 Power System Control

COPEL has a Control Center to manage the transmission and distribution systems in Curitiba. There, it is possible to control 500kV, 230kV, 138kV and 69kV transmission and distribution lines in Parana State. Figure 4.1-5 shows the Control Center in Curitiba. In front of the control desks, there is a large display to show all the transmission and distribution systems in Parana. Two rows of control desks are provided in the Control Center. The front side is for 138kV and 69kV distribution control and next row is for control of 500kV and 230kV transmission lines. In addition, COPEL has provided the additional control facilities with limited functions in other places to operate the system in case of emergency at the Control Center. The lower voltage distribution lines can be controlled by Distribution Control Center by COPEL.

Figure 4.1-5 Central Control Center for Transmission System

(Source: Photo by Survey Team)

4.2 Distribution Substation

4.2.1 Distribution Control System

As shown in Figure 4.2-1, COPEL has a Distribution Control Center in Curitiba in order to control all the distribution system in Curitiba City. From the Distribution Control Center, it is possible to control all the distribution system from 13.8kV to 138kV. The circuit breakers on 13.8kV feeders can be controlled, but load break switches (LBSs) and reclosers cannot be controlled by the Distribution Control Center at this moment. In addition, COPEL has the distribution control system which can control LBSs and reclosers only in Curitiba City. However, the function of distribution control facility is very limited, for example, any mapping system is not connected to the distribution control facility satisfactorily. It is possible to control the load break switches and reclosers by equipment number and then an operator should confirm the location of equipment on the map. This system is quite different from the Distribution Automation System (DAS) in Japan. COPEL has acknowledged this system is not sufficient for reliable operation and management of distribution system. They have started to develop a new DAS in Curitiba and Fazenda Rio Grande by the coming Soccer World Cup.

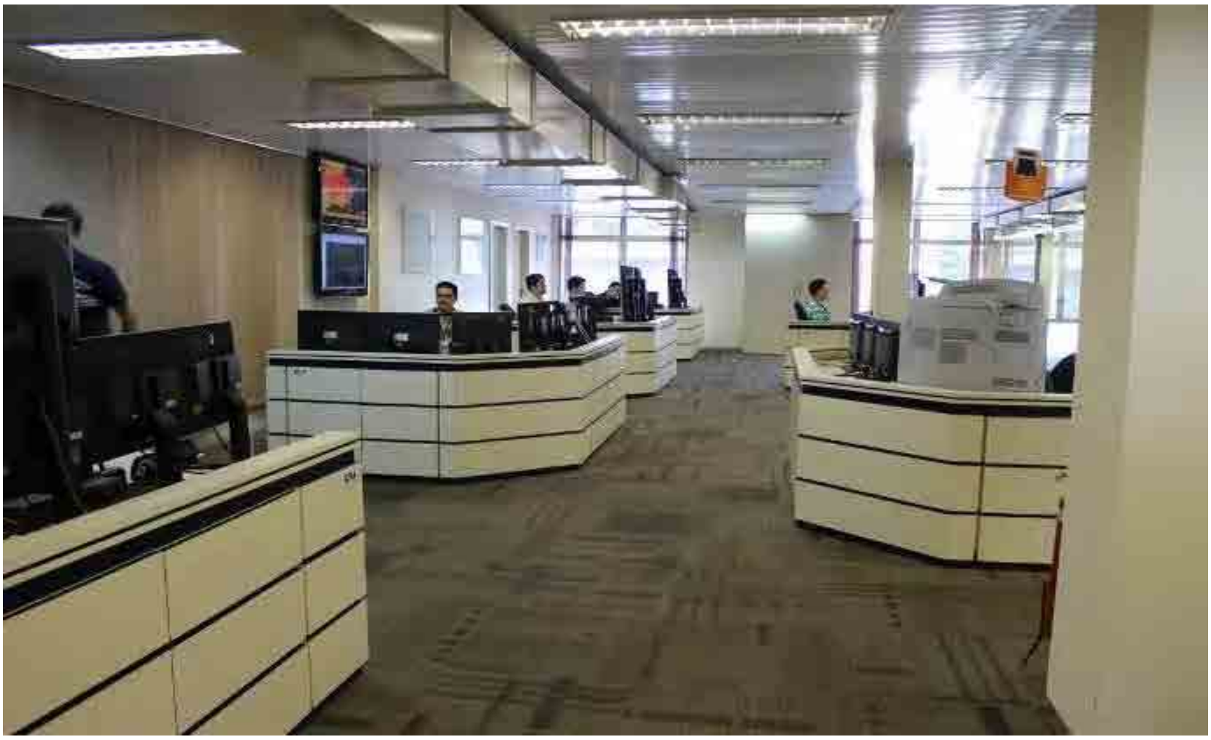


Figure 4.2-1 Central Control Center for Distribution System

(Source: Photo by Survey Team)

4.2.2 Substation Configuration

Survey Team investigated Fazenda Rio Grande and Rio Branco do Sul which is one of the candidate areas in this survey and could collect the information about the typical substation of COPEL.

4.2.2.1 Fazenda Rio Grande Substation

This substation is an air insulated switchgear (AIS) type and composed of vertical gas circuit breakers and horizontal disconnection switches and CT/VTs. A 138kV busbar has double busbar configuration with two incoming lines and several outgoing 13.8kV distribution feeders. The earthing system is direct earthing for 138kV, 69kV and 34.5kV systems. A transformer has delta connection to 13.8kV and providing earthing reactors to feed earth fault current.

Figure 4.2-2 Fazenda Rio Grande Substation
(Source: Photo by Survey Team)

The substation is constructed on a precast concrete pole as shown in Figure 4.2-2 because of economical reasons. COPEL explained the concrete pole is manufactured to provide complete safety earthing according to their specification. The size of substation control building is about 15meters by 15meters and control panels, protection panels, SAS, communication facility and power supply facility are provided in the building. COPEL explained that the substation for lower than 138kV is unmanned. Necessary interfacing between substation and remote control center is provided with the SAS. On the other hand, this SAS is aged about ten years and main components such as computer have already been model-changed. Accordingly, they had started to develop a new SAS in COPEL.

4.2.2.2 Rio Branco do Sul Substation

The type of Rio Branco do Sul Substation is AIS. COPEL explained that they applied AIS system to most distribution substations. A few distribution substations are GIS type. Primary voltage of the substation is 69kV and transformed to secondary 34.5kV and tertiary 13.8kV by two auto-transformers with 20 and 40MVA. Secondary winding is star-connection and tertiary winding is delta connection with earthing reactors. COPEL explained that they have normal winding (not auto–transformer) transformers in other substations.

The control system composed of mechanical control panels and SAS has almost the same configuration as that of Fazenda Rio Grande as shown in Figure 4.2-3. As shown in Figure 4.2-4, the protection relays are not unique with several types of different manufacture and principle. This is the result of open tender in which contractors are decided by the lowest offer price. Earthing system of 13.8kV which is reactor earthing is the same as that in Fazenda Rio Grande. Primary (69kV) and secondary (34.5kV) are direct earthing system.

Figure 4.2-3 SAS at Rio Branco do Sul Substation
(Source: Photo by Survey Team)

Figure 4.2-4 Relay Panel at Rio Branco do Sul Substation
(Source: Photo by Survey Team)

4.2.3 Substation Control

Here, the result of site survey is summarized about the control system. In COPEL system, the principle of control system is almost the same as that of the other substations. The control system is composed of mechanical control panels as shown in Figure 4.2-7 and SAS system in Figure 4.2-5.

In order to replace the aged SAS, COPEL is planning to develop a new SAS in two years. The new SAS is planned to introduce IEC61850 standard. Detailed functions of new SAS will be studied next stage. However, COPEL does not seem to consider developing new relays based on IEC61850.

The features of the existing SAS are described below.

i) The operation log data are stored in SAS for 1 month.

ii) Operation log data of facilities in the substation only are stored only in the local SAS.

iii) Circuit breakers and disconnecting switches can be controlled remotely.

iv) Voltages, currents, watt and var. data can be stored in SAS.

v) Protection relay data can be input to the SAS by serial port (RS232/IP).

vi) The communication scheme to remote control center is IP (DNP2) using fiber optic cable.

Figure 4.2-5 Control Panel at Fazenda Rio Grandel Substation

(Source: Photo by Survey Team)

4.2.4 13.8kV Feeder Protection System

In COPEL's distribution system, overcurrent and earth fault relays have been applied to 34.5kV and 13.8kV feeders. Also a two-shot reclosing scheme has been applied to 13.8kV and 34.5kV feeders. The purpose of reclosing is just for recovering from a fault on a feeder, but not for so-called step by step energizing scheme applied to distribution lines in Japan. Distribution line wire of COPEL is bare aluminum and so there are many cases that a tree contacts power wire and causes high resistance earth fault. In such a case it is very difficult to detect such a fault by earth fault relay (51N) in some cases. COPEL cannot increase the sensitivity of earth fault relay (51N) because the error current is 2A on the primary side and so sets the relay from 10 to 20 A for earth fault relay. COPEL's distribution system is delta connection with reactor earthing which is almost the same as Japanese distribution system so that it seems appropriate to apply the same sensitive earth fault detection relay as applied in Japan. Japanese distribution protection scheme, especially for earth fault protection, is described in Clause 6.4.3 in Chapter 6.

4.3 Overhead Line Distribution Network / Distribution Facilities

4.3.1 Voltage Level

Voltage levels in COPEL service area are shown in Table 4.3-1, with the voltage levels for this project being less than 34.5kV. This means that the main target for this project is distribution facilities, the main components of which are lower than 34.5kV. Of course, in case that some construction works are necessary for 69/34.5 kV and 13.8kV distribution substations, they are also included as the target for this project.

Table 4.3-1 Voltage Levels in COPEL Service Area

138	kV
69	kV
34.5	kV
13.8	kV
220/127	V

(Source: COPEL material)

4.3.2 Overhead Line Distribution Network

Single line diagram of typical 69/ 34.5kV and 13.8kV distribution substations in COPEL is shown in Figure 4.3-1. As described in Table 4.3-1, the main target of this project is less than 34.5kV. 34.5kV distribution line is utilized mainly as a connection line between 69kV/13.8kV distribution substation and 34.5kV/13.8kV distribution substation. However, as Figure 4.3-2 shows, there are some cases which have customers in 34.5kV distribution line. Therefore, 34.5 kV distribution line is also thought as the target of this project. Additionally, 3-phase 3-line system in 34.5kV/13.8kV and 3-phase 4-line system in 220/127V are utilized in COPEL as distribution system.

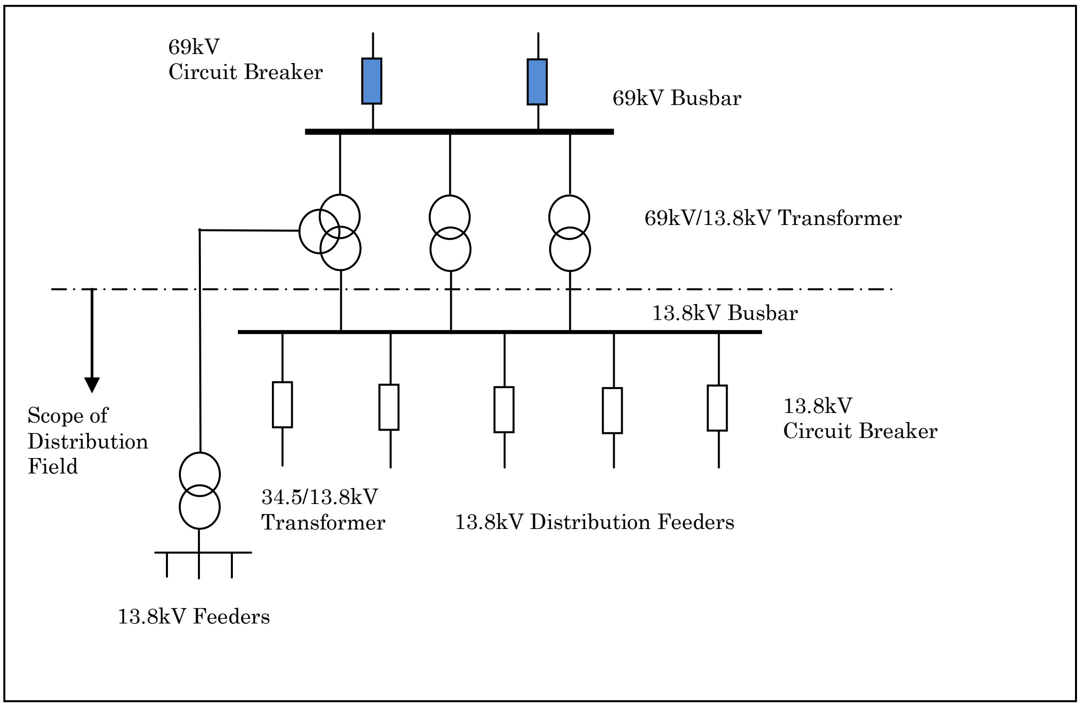


Figure 4.3-1 Single Line Diagram of Typical 69/ 34.5kV and 13.8kV Distribution Substation in COPEL

(Source: prepared by JICA Survey Team based on COPEL material)

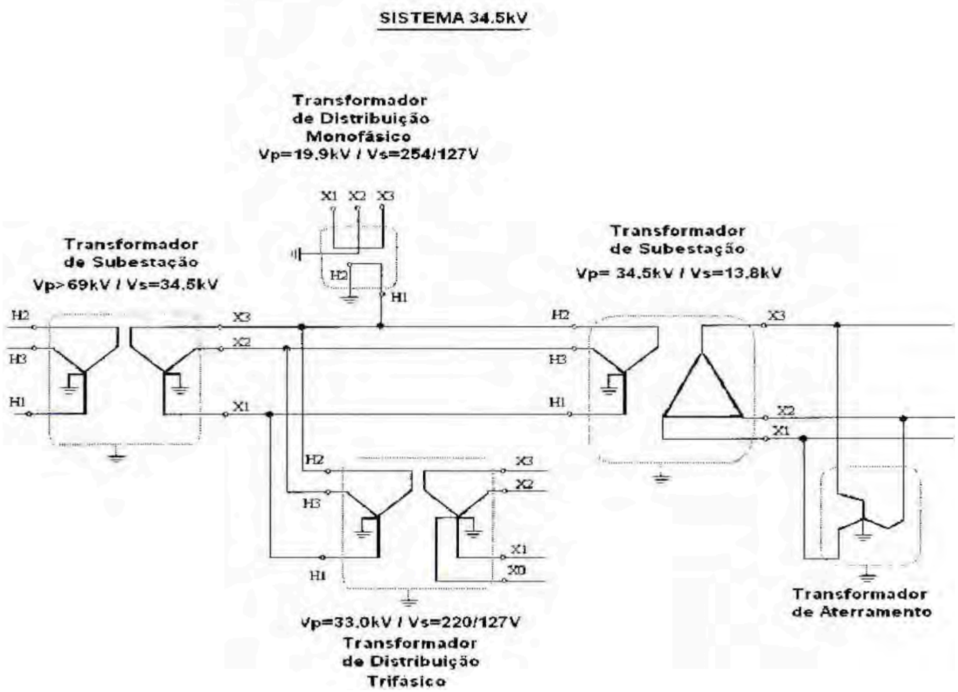


Figure 4.3-2 Single Line Diagram of 34.5kV Distribution Line

(Source: COPEL material)

Overview of the distribution facilities in the Curitiba Metropolitan Area is shown in Table 4.3-2. According to this table, many facilities in the Curitiba Metropolitan Area are concentrated in Curitiba City. Regarding the substations, most municipalities have at least 1 substation. Therefore, it might be said that electricity is supplied to each municipality by each substation located in each municipality. Voltage for the main feeder in distribution line is 13.8kV, because there are a few 34.5kV feeders. Underground distribution lines exist only in Curitiba. Additionally, Curitiba has over 600 looped points and based on this fact, it is understood that COPEL's smart grid project in Curitiba is going well, because in order to improve reliability of distribution line by the FIFA World Cup held in June 2014, COPEL has made a big effort to install and automate LBS and/or reclosers in the distribution lines.

Table 4.3-2 Overview of Distribution Facilities in Curitiba Metropolitan Area

Municipalities		No. of Substations	No. of 13.8kVfeeders	No. of 34.5kV feeders	Length of OH (km)	Length of UG (km)	No. of reclosers	No. of looped points (*)
1	Adrianopolis	1	1		2.8		6	0
2	Agudos do Sul	1	2		265		7	3
3	Almirante Tamandare	1	4		410		7	9
4	Araucaria	2	17	1	785		20	48
5	Balsa Nova	1	2		171		6	3
6	Bocaiuva do Sul	1	2		180		4	3
7	Campina Grande do Sul	1	3		356		9	6
8	Campo do Tenente	1	3		269		5	6
9	Campo Largo	2	5	1	260		23	12
10	Campo Magro	0	0		133		2	0
11	Cerro Azul	1	3		552		6	6
12	Colombo	2	9		501		16	24
13	Contenda	1	2		521		7	3
14	Curitiba	22	215		3655	10	297	642
15	Doutor Ulysses	0	0		0		1	0
16	Fazenda Rio Grande	2	10	2	459		6	27
17	Itaperuqu	0	0		83		1	0
18	Lapa	2	9	4	1431		14	24
19	Mandirituba	2	8		654		9	21
20	Pien	1	5	3	212		12	12
21	Pinhals	1	3		665		7	6
22	Piraquara	1	6		286		10	15
23	Quatro Barras	1	7	2	283		13	18
24	Quitandinha	1	3		490		7	6
25	Rio Branco do Sul	1	3	3	175		12	6
26	Rio Negro	0			0		3	0
27	Sao Jose dos Pinhals	4	32		1146		55	91
28	Tijucas do Sul	1	2		269		5	3
29	Tunas do Parana	2	2		260		7	3
TOTAL		56	358	16	14473.8	10	577	997

(*) The number of looped points is estimated as 3 switches for each 2 feeders.

(Source: COPEL materials)

4.3.3 Distribution Facilities

Overhead distribution lines are typical in the Curitiba Metropolitan Area, because there are a few underground lines, which are found only in Curitiba City. Main components of overhead line are as follows;

- LBS (oil or SF6)
- Recloser
- Transformer
- Distribution Line
- Electric Pole
- Voltage Regulator
- Capacitor Bank
- Surge Arrester, etc.

The following explanations give an overview of each facility and COPEL design standard, etc.

1) Facility and Design

・**LBS(Load Break Switch), Recloser**

LBS used in COPEL is generally an oil manual type, but LBS which is planned to be replaced by ALBS is changed to a SF6 gas type. Regarding recloser, COPEL uses a vacuum type and oil insulation type (KF type). Those types can be adopted to be controlled remotely by installing RTU, but they work by themselves without automation under the existing conditions. COPEL is considering replacement to new KFE type which can be controlled remotely in the future.

Regarding installation points in design for LBS and recloser, COPEL does not have any internal standards. However, it is recommended to install LBS or reclosers every 1.5~2.0 km with a load around 2000 kVA and at special points where special consumers exist in the actual design. On the other hand, regarding recloser, keeping harmony between recloser and substation is very difficult, so that maximum number of installed reclosers in one feeder is 2 under the existing conditions.

Specification of Typical LBS

Type	Latch Type	
Operating Method	Auto / Manual	
Voltage	15 kV	
Phase	3 Phase	
Frequency	60 Hz	
Continuous Rating Current	600 A	
Permmisible Current for Short Period	12 KA (1second)	
Measurement	Current	3 Phase (600:1)
	Voltage	Both Side (Total 6 Points) (13,800:1)
Accuracy	Current	±1.2% (600A)
	Voltage	±10% (13.8kV)

Figure 4.3-3 LBS

(Source: Photo by Survey Team)

Cooper
KF type

Figure 4.3-4 Old Mechanical Recloser

(Source: Photo by Survey Team)

On the other hand keeping coordination between recloser and substation is very difficult as per the reason below, so that maximum number of installed reclosers in 1 feeder is 3 under the existing conditions.

Reclosers have over current relays (OC relay) having different setting values and can separate only fault section by self-trip function of the OC relay when short circuit fault occurs. When the fault occurs at F3 as described in Figure A, the separation by R3 is realized without series trip of other reclosers except R3 by time coordination (different operating time in each recloser) of OC relays time dial setting inside reclosers.

Regarding OC relays setting in actual design, COPEL has standard trip-times of recloser (refer to Table 4.3-3) and decides actual setting value of OC relay based on minimum fault current at the end of feeder and operating characteristic curve of OC relay provided by manufacturer.

COPEL installs 3 units of recloser into 1 feeder at maximum for the following reasons.

- Trip-time of recloser shall be set in consideration of time-coordination of 0.3 to 0.4 seconds between reclosers in order to avoid series trip as described above, because recloser has operating errors (±10%) of OC relay and inside timer, etc.
- When fault occurs at the point of F1 near substation in Figure 4.3-5, faster trip of R1 is needed to minimize negative affect to distribution facilities due to larger fault current.

Based on the above items, the setting value of R1 is better to be set at as short a time as possible, however it cannot be overly shortened (1.2 second in COPEL) due to time coordination with other reclosers. Therefore, by considering negative impact at fault and shortened trip time of R1, etc., COPEL has a limitation of the maximum number (3) of installed recloser into 1 feeder.

In addition, JICA survey team confirmed with COPEL actual experiences of mal-operation and failure of operation of recloser caused by aged deterioration of OC relay etc., although they can set setting value of OC relay effectively.

Table 4.3-3 Standard Trip-times of Reclosers in COPEL

Recloser (in Figure A)	Trip-time (second)
R1	1.2
R2	0.8
R3	0.5

(Source: Interview with COPEL)

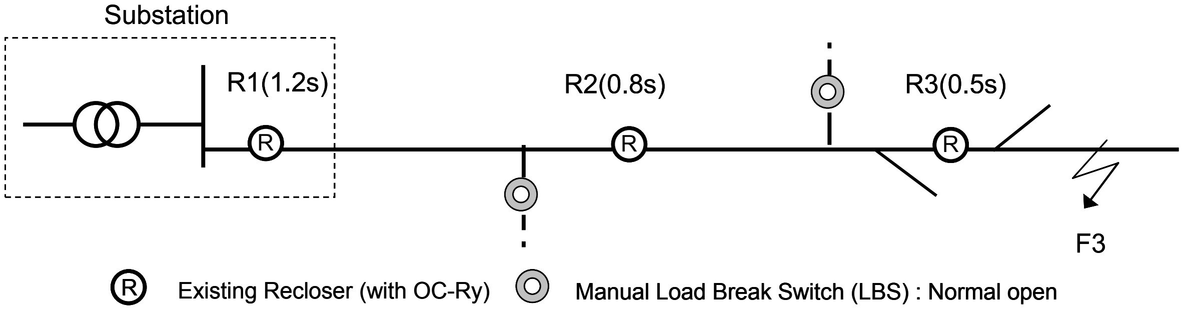


Figure 4.3-5 Example of Typical Distribution Line in COPEL

(Source: Created by JICA Survey Team)

In addition, this recloser has one more weak point of not detecting earth fault when earth fault with high impedance occurs. Because recloser has earth fault protection relay (51N) and this relay can detect and separate earth fault section when earth fault occurs. However, as described in 6.3.4 Protection Scheme for distribution lines, minimum setting current of this earth fault relay is 10A, therefore, earth fault current (less than 10A in general) in case of high impedance fault can not be detected by this relay.

・**Transformer**

A transformer used in COPEL is shown in Table 4.3-4 and its specification is regulated in NTC (Norma Tecnica Copel) which means COPEL internal regulation. Single-phase transformers and three-phase transformers are utilized in COPEL. The number of transformers in the target areas in this study is approximately 55 thousand units as shown in Table 4.3-5, which are purchased by manufacturers such as ABB, Toshiba, WEG, etc. The average of load factors are approximately 50% in urban areas and 20% in rural areas respectively shown in Table 4.3-6. The single-phase transformers are utilized in rural areas with low load and the three-phase transformers are utilized in residential areas with large load in general design. Additionally, regarding the three-phase transformers, 45kVA in residential areas and 112.5kVA in high density areas such as central urban areas, are selected in general design.

Table 4.3-4 Transformer Types in COPEL

Single Phase (kVA)	Three Phase (kVA)
3*	15
5*	30
10	45
15	75
25	112.5
–	150
–	225

*No new installation

(Source: Interview with COPEL)

Table 4.3-5 Numbers of Transformers in 13.8kV

	No. of Transformer (Units)
Urban Area (Curitiba City)	15,952
Suburban Areas (Other Areas than Curitiba City: 23 Municipalities)	39,450
Total	55,402

(Source: COPEL materials)

Table 4.3-6 Average Load Factor of Transformer in 13.8kV

Area		Average Load Factor
Urban Area (Curitiba City)	**Urban**	59%
North Suburban Areas	**Urban**	52%
	Rural	21%
South Suburban Areas	**Urban**	46%
	Rural	15%

(Source: COPEL materials)

TRAFO, 75kVA ROMAGNOLE, 225kVA

Figure 4.3-6 Transformers

(Source: Photo by Survey Team)

・**Distribution Line**

A distribution line used in COPEL is shown in Table 4.3-7. They have two types; protected and non-protected. The protected distribution line is utilized in urban areas and the non-protected distribution line is utilized mainly in rural areas. In the future, in order to improve reliability of distribution line, COPEL plans to install the protected distribution line, especially in urban areas as much as possible.

Table 4.3-7 Distribution Line Types in COPEL

Distribution Line	
Protected (Permissible Current)	Non-Protected (Permissible Current)
185mm^2 (525A)	336 MCM (510A)
70mm^2 (282A)	4/0 AWG (365A)
35mm^2 (187A)	2/0 AWG (275A)
—	02 AWG (185A)

Protected (35mm^2) Non-Protected (336 MCM)

(Source: COPEL materials and Typical Manufacturer)

Additionally, in design, selection of 13.8kV/34.5kV distribution line in new installation is conducted based on 50% of continuous permissible current of distribution line in normal operation and 90% of continuous permissible current for distribution line in short periods (e.g., during some maintenance).

・**Electric Pole**

An electric pole used in COPEL is shown in Table 4.3-8 and its specification is regulated in NTC (Norma Tecnica Copel). The average installation distance is 30m – 40m, but this distance depends on the characteristic of installation point. In design, the strength calculation is conducted and electric pole utilized is selected based on its result. In addition, main manufacturers are ROMAGNOLE, INCOPOSTES, OESTEPAR and the rate of these 3 main manufacturers is approximately 15% of total purchased amount of electric pole in COPEL.

Table 4.3-8 Electric Pole Type in COPEL

Electric Pole	
Height (m)	**Strength (kgf)**
10.5	150
	300
	600
	1,000
	2,000
12.0	200
	300
	600
	1,000
	2,000
	3,000
13.5	600
	1,000
	2,000
	3,000
15.0	600
18.0	600

(Source: COPEL materials)

Figure 4.3-7 Electric Pole

(Source: Photo by Survey Team)

・**Voltage Regulator**

Main purpose of installing voltage regulator is as a countermeasure for voltage drop with voltage regulator utilized in COPEL being a fixed type. The total number of existing voltage regulators in target areas in this study is 80 units as shown in Table 4.3-9. Regarding installation point, COPEL does not have any internal standards, and so the installation point is decided based on the characteristics of feeder. Additionally, although the voltage regulator can be automatized if it is installed with RTU in the Project, it is installed in remote areas where GPRS can not reach in general, so that it is installed to work by itself without automation under the existing conditions

2 units made by Cooper. Each Capacity is 100A

Figure 4.3-8 Voltage Regulators

(Source: Photo by Survey Team)

Table 4.3-9 Number of Voltage Regulators in each Municipality

Municipalities	No. of Voltage Regulator
ALMIRANTE TAMANDAR	3
ARAUCARIA	5
CAMPINA GRANDE DO SUL	4
CAMPO DO TENENTE	2
CAMPO LARGO	3
CERRO AZUL	4
COLOMBO	6
CONTENDA	3
Curitiba	5
FAZENDA RIO GRANDE	2
LAPA	10
MANDIRITUBA	5
PIEN	3
PINHAIS	1
PIRAQUARA	1
QUATRO BARRAS	2
QUITANDINHA	2
RIO BRANCO DO SUL	9
SAO JOSE DOS PINHAIS	8
TIJUCAS DO SUL	2
Total	80

(Source: COPEL materials)

・**Capacitor Bank**

Main purpose of installing a capacitor bank is that of a countermeasure for voltage drop and low power factor. Capacitor bank utilized in COPEL is fixed type mainly and a few self-time control types which can control on/off only according to time have already been installed. The total number of existing capacitor banks in target areas in this study is 209 units as shown in Table 4.3-10 and standard capacities are 300kVAR, 600kVAR and 1200kVAR. Regarding installation point, COPEL does not have any internal standards, and so the installation point is decided based on the characteristics of feeder as well as the voltage regulator. However, actual installation is conducted at approximately one third point of distribution line based on interview with COPEL. Additionally, the existing capacitor bank can be automatized if it is installed with RTU in the Project, but it is installed to work by itself without automation under the existing conditions as well as voltage regulator.

Cooper
Capacity1200kVAR

Figure 4.3-9 Capacitor Bank

(Source: Photo by Survey Team)

Table 4.3-10 Number of Capacitor Banks in each Municipality

Municipalities	Capacity (kVAR)	No. of Capacitor Bank
ALMIRANTE TAMANDAR	300	0
	600	3
	1200	0
ARAUCARIA	300	0
	600	4
	1200	2
CAMPINA GRANDE DO SUL	300	0
	600	1
	1200	0
COLOMBO	300	0
	600	5
	1200	1
CURITIBA	300	1
	600	90
	900	1
	1200	62
FAZENDA RIO GRANDE	300	0
	600	1
	1200	1
LAPA	300	0
	600	1
	1200	0
PINHAIS	300	0
	600	1
	1200	10
PIRAQUARA	300	0
	600	3
	1200	0
QUATRO BARRAS	300	1
	600	3
	1200	1
RIO BRANCO DO SUL	300	0
	600	1
	1200	1
SAO JOSE DOS PINHAIS	300	0
	600	9
	1200	5
TUNAS DO PARANA	300	0
	600	1
	1200	0
Total		209

(Source: COPEL materials)

・**Surge Arrestor**

COPEL utilizes the polymer and ZnO type surge arrestor purchased by domestic manufacturers such as DELMAR and BAUESTRO, and the value of earth resistance of surge arrestor is less than 20Ω regulated by MIT (Manual and Instrucao Tecnica Copel).

For installation point, COPEL has internal standards for surge arrestor and installation is conducted as follows;

- Urban area: each 500m (3 units (3-phase)),
- Rural area: each 700m (3 units (3-phase))
- Both Sides of Distribution Facilities (6 units (3-phase x 2 sides))

Figure 4.3-10 Polymer and ZnO Type surge arrestor

2) Operation

・**Voltage**

Operation voltage in distribution line is regulated in ANEEL Resolution No.676/2003 as described in 2.8.4 Power Quality and it can be understood that voltage drop in normal condition operation is up to 7% from Table 2.8-6. Additionally, in case voltage drop over 7% occurs, installation of voltage regulator or capacitor bank or thickening size of distribution line are conducted as countermeasures.

・**Current**

Similarly to the design, the current in normal operation is up to 50% of the continuous permissible current of distribution line and for short periods (e.g., during some maintenance) it can be as high as 90% of the continuous permissible current of distribution line. Additionally, short circuit current depends on the feeder characteristics and is calculated by the protection team case by case.

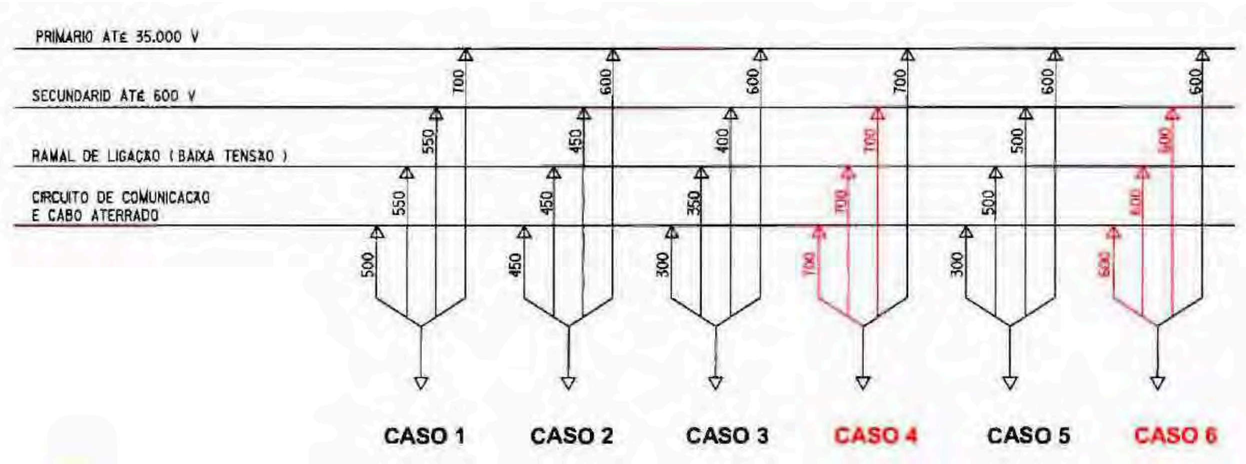
・**Power Factor**

As Table 2.8-12 shows, power factor is regulated by ANEEL PRODIST Modulo 8 – Qualidade da

Energia Eletrica. Based on this ANEEL regulation, COPEL has responsibility for improvement of power factor up to 0.92. Therefore, in case of power factor less than 0.92 in design, COPEL plans to install capacitor bank in distribution line as a countermeasure.

・**Safety Distance**

NBR15/688 regulates safety distance in distribution lines as a national standard. The contents are standards in case of across/side running over/along river or highway and values are 7m in urban areas and 8.3m in other areas. Based on this regulation, COPEL follows NTC856004 (Norma Tecnica COPEL) described in Figure 4.3-11. In design of distribution line, COPEL complies with this NTC which is stricter than NBR15/688. For example, in 13.8kV and Case 1, safety distance is 7m from the surface of public road.



Case1: Public Road
Case2: Building Entrance or Limited Place for Cars
Case3: Side Work or Alley
Case4: Highway
Case5: Farming Village (Place where only walker can reach)
Case6: Farming Village (Private road or road where cars or agricultural machinery can go)

Figure 4.3-11 Safety Distance in COPEL (NTC856004)

(Source: COPEL material)

・**Network Composition (Sectionalizing distribution network)**

COPEL does not have any standards for the network composition, which mentions where LBS should be installed in distribution network. However, Electromechanical and Automation Maintenance Department (DMEA) recommends to planning and operation engineers that LBS is installed in distribution network where it is most suitable to move load from one feeder to another feeder.

4.4 Underground Network

The area applied to the underground network is limited to very small area in Curitiba City in COPEL. The underground system has been applied to spot network and regular network system as shown in Figure 4.4-1.

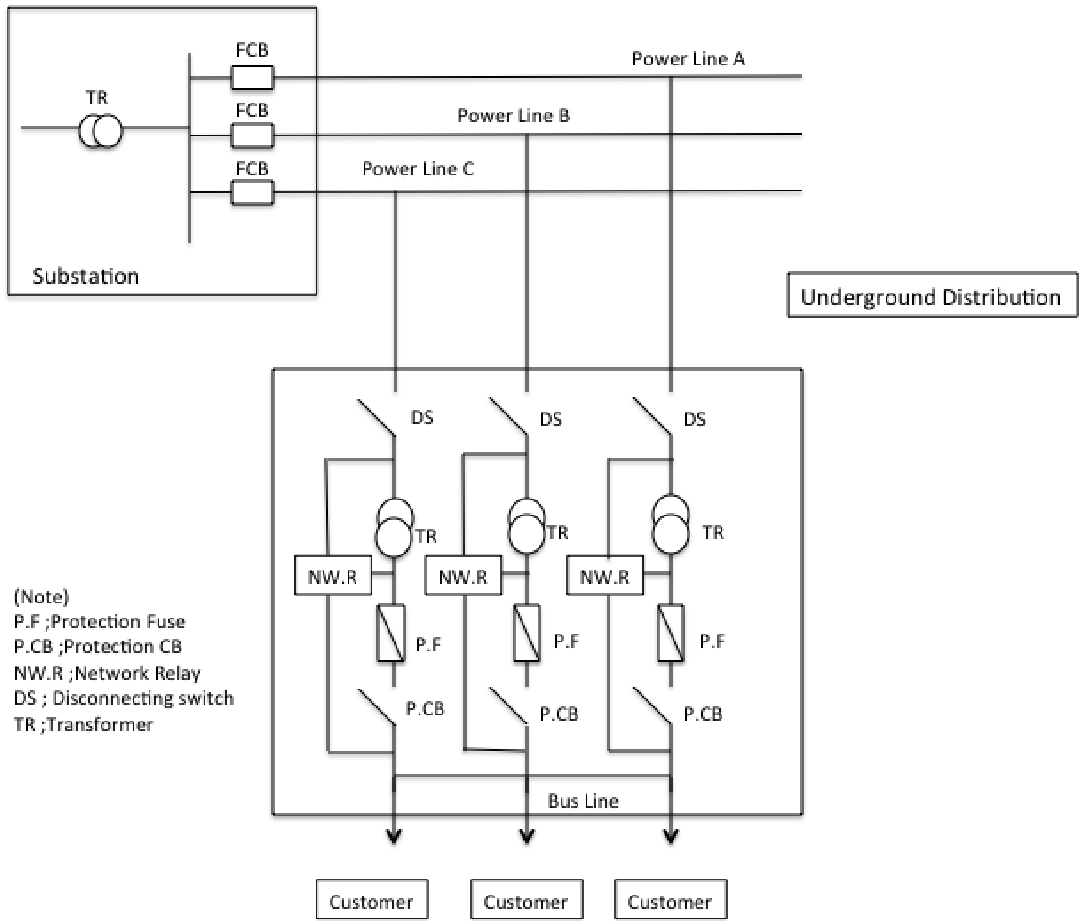


Figure 4.4-1 Spot Network diagram

(Source: JICA Survey Team)

COPEL will not expand the underground network due to large investment compared to Over Head network and large short circuit current on the low voltage side.

4.5 Telecommunication Facilities

The main system expected to be introduced in this project is the DAS (Distribution Automation System) and the AMI (Advanced Metering Infrastructure). The DAS is a system that monitors and controls the distribution grid, and two types of information transmission paths are needed. One path is between the Control Centers and substations. The other path is between the substations and automated switches on the feeders. At the same time, the DAS is required to cooperate with the existing SCADA (Supervisory Control and Data Acquisition) system using DNP3.0 as the SCADA protocol (Layer 5-7 of the OSI: Open System Interconnection reference model), and IP as the telecommunication protocol (Layer 3 and 4 of the OSI reference model). (See section 4.5.6)

On the other hand, the AMI system collects the customer side information to the center, and also controls the sophisticated digital meters on the customer side from the center. It requires telecommunication paths between the center and the customers' meters. There are various telecommunication system options in the AMI system. At present, the specific telecommunication media/ method/ system for AMI have not been defined in Brazil.

4.5.1 Backbone Optical Fiber Network

The figure 4.5-1 shows the status of the backbone optical fiber network of COPEL. This optical fiber network consists of mainly OPGW (Optical Ground Wire), and the total length is 7,945 km (as of 9/4/2012). In the intended project area, almost all the substations are able to access the backbone optical fiber network.

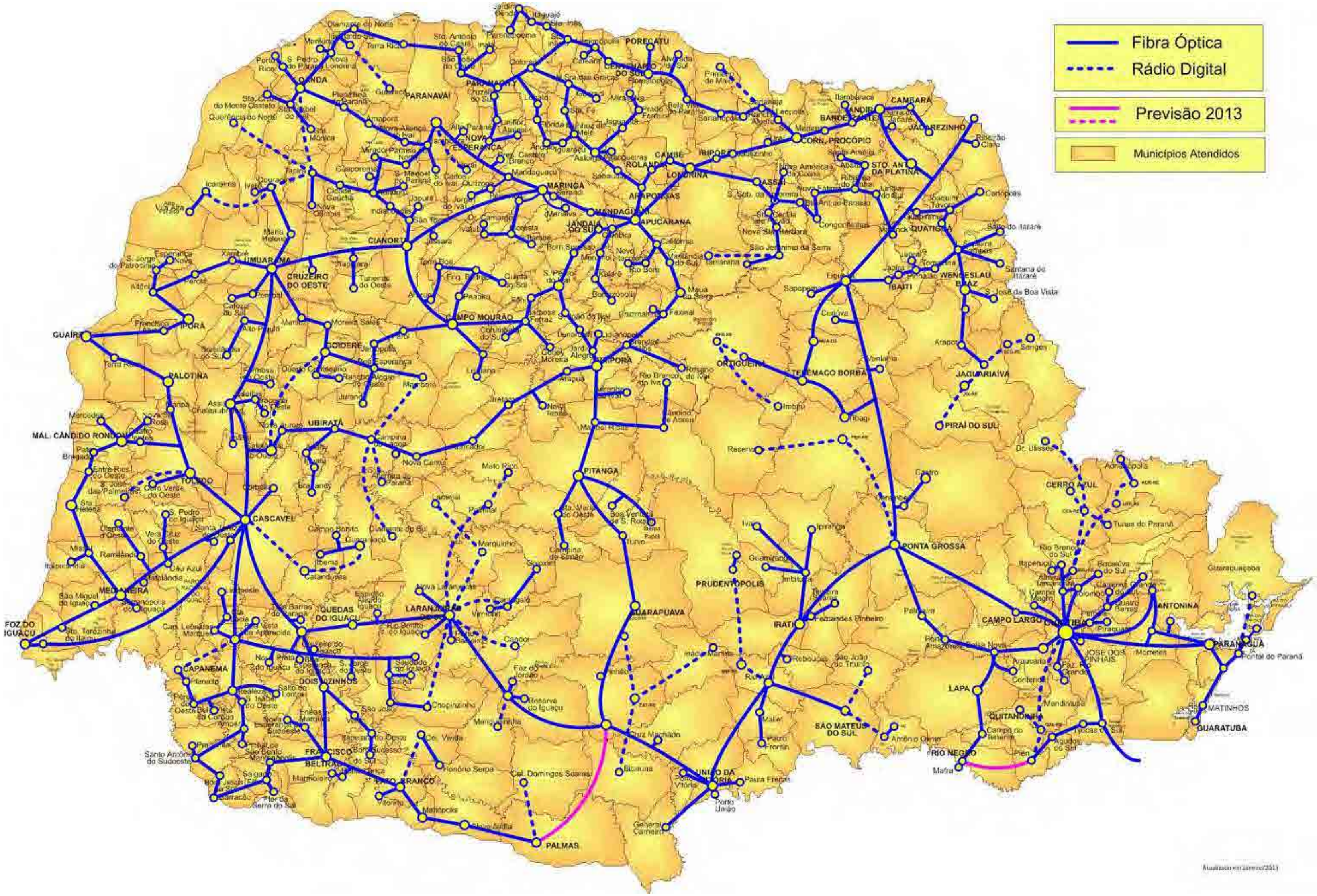


Figure 4.5-1 Backbone Optical Fiber Network of COPEL

(Source: COPEL)

4.5.2 Backbone Transmission System

The backbone transmission system on the backbone optical fiber network consists of DWDM (Dense Wavelength Division Multiplex) and SDH (Synchronous Digital Hierarchy) (10G / 2.5G / 622M / 155M bps), and the topology type is the ring network. The following diagram shows the backbone transmission network, and the equipment is HIT7300 (Nokia-Siemense).

The following diagram shows the logical network diagram of COPEL's backbone transmission system. The nodes (green hexagon, red square, blue square) are telecommunication equipment installed at substations, and the paths are optical fibers. A green hexagon represents ROADM (Reconfigurable Optical Add/Drop Multiplexer), which is a form of OADM (Optical Add/Drop Multiplexer) that adds the ability to remotely switch traffic form a WDM (Wavelength Division Multiplexer) system at the wavelength layer. This allows individual or multiple wavelengths carrying data channel to be added and/or dropped from transport fiber without the need to convert the signal on all of the WDM channels to electronic signal and back again to optical signals. A red square represents an optical amplifier, which is a device that amplifies an optical signal directly. A blue square represents a connection point of optical fibers.

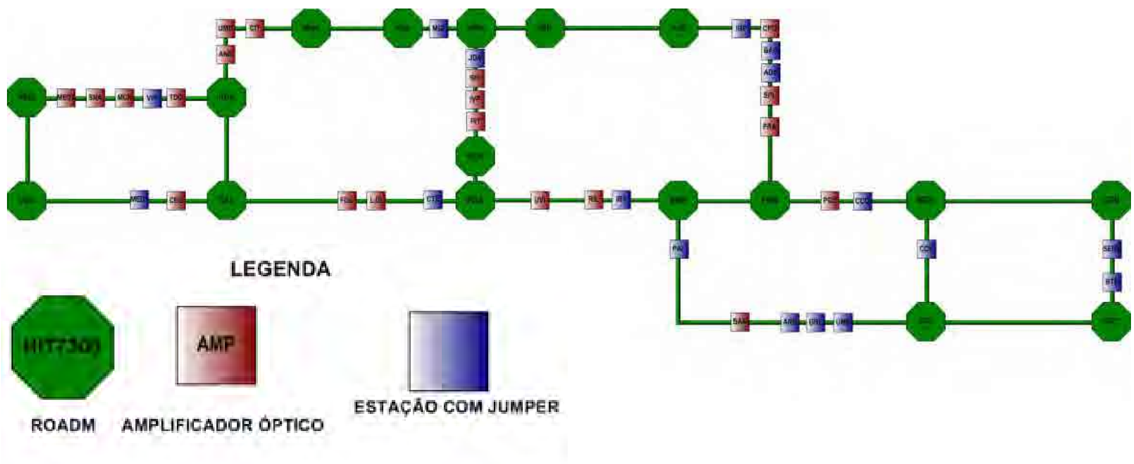


Figure 4.5-2 Backbone Transmission System of COPEL

(Source: COPEL)

4.5.3 IP Network

COPEL Telecommunications, a wholly-owned subsidiary, owns the IP network of COPEL. This IP network consists of a statewide router infrastructure that uses MPLS (Multiprotocol Label Switching) and municipal and metropolitan area networks with Gigabit switching equipment, in which Fast Ethernet ports are available for customer attendance.

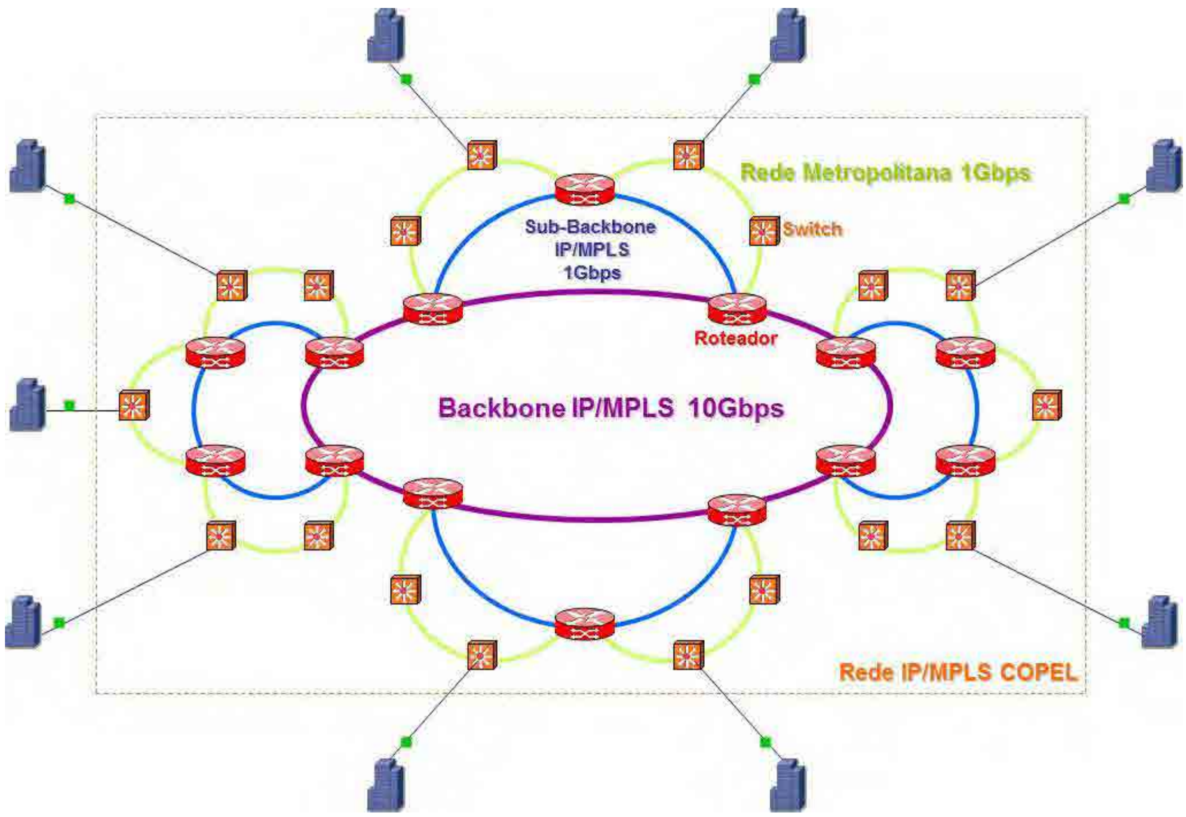
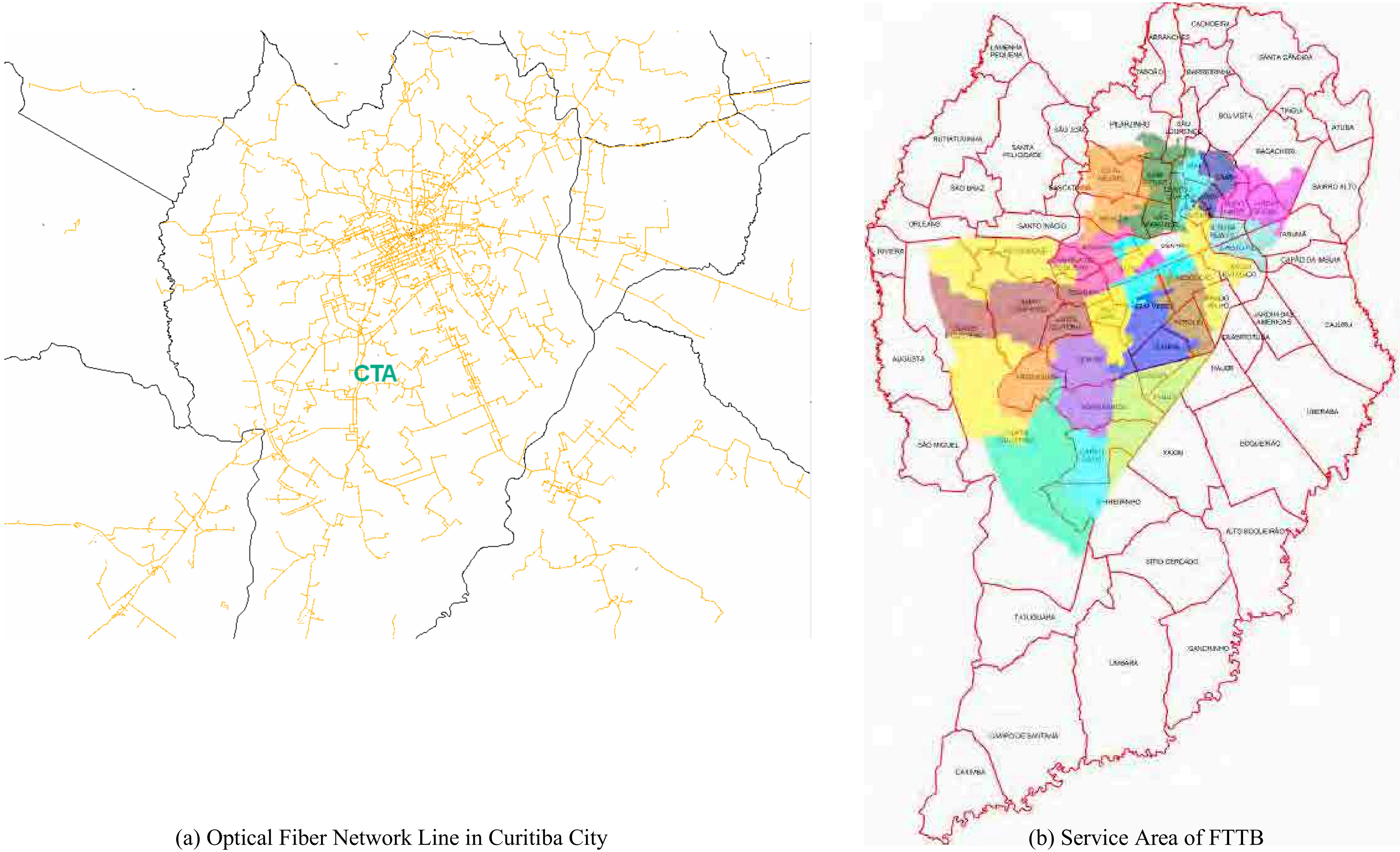


Figure 4.5-3 IP Network of COPEL Telecommunication

(Source: COPEL)

4.5.4 Access Optical Fiber Network

The access optical fiber network of COPEL is not yet available throughout Parana State, but its construction is relatively advanced in Curitiba City. At present, the total length of COPEL's access optical fibers is 16,053 km (as of 12/3/2012). The figure 4.5-4 shows the access optical fiber network which covers 165km^2 (38% of the City) in Curitiba City COPEL's optical fiber network is constructed, owned, and operated by COPEL Telecommunications.



(a) Optical Fiber Network Line in Curitiba City (b) Service Area of FTTB

Figure 4.5-4 Access Optical Fiber Network in Curitiba City

(Source: COPEL)

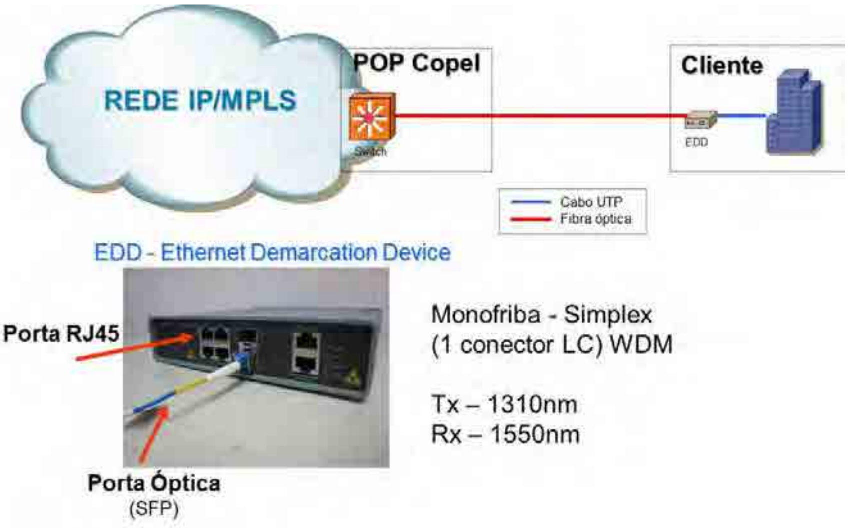


Figure 4.5-5 FTTB System Configuration Diagram

(Source: COPEL)

4.5.5 Surveillance and Maintenance for the Telecommunications Network

COPEL monitors and manages the telecommunications network from one center and the COPEL telecommunications center. The surveillance system uses the SNMP (Simple Network Management Protocol).

Figure 4.5-6 COPEL Telecommunication Center

(Source: JICA study team)

4.5.6 Existing SCADA System Protocol

The figure 4.5-7 shows the existing SCADA system diagram. There are three HMIs (Human Machine Interface) in the operator's room and two redundant SCADA servers, an event log server, and some gigabit switches to communicate with substations in the utilities room at Control Center. They communicate with IP (Internet Protocol). Also, DNP 3.0 over IP is used for the existing SCADA system and also the distribution automation system that is installed in Curitiba City.

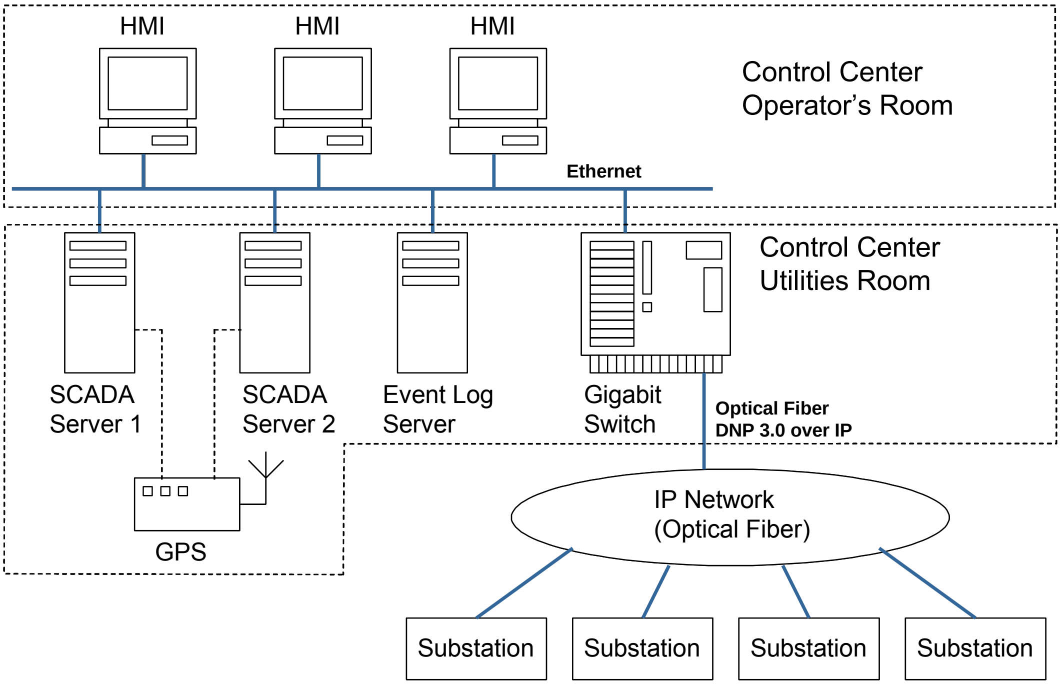


Figure 4.5-7 Existing SCADA system

(Source: JICA study team)

4.5.7 COPEL's Telecommunication Facilities for Smart Grid Trial

Currently, a smart grid trial is being conducted in Fazenda Rio Grande (FRG) in cooperation with the universities and research institutes. This section describes the communication facilities of the trial in FRG.

(a) Optical Fiber

Optical fiber is used as a telecommunications medium between the Control Center and the RTUs of Fazenda Iguaçu and Fazenda Rio Grande Substations. In addition, 6 automatic switches are connected to the optical fibers.

(b) WiFi Mesh

The WiFi Mesh using 2.4 GHz and 5 GHz bands radio waves is applied for AMI telecommunication media, and 22 access points were installed. However, automatic devices such as AMI meters have not been installed yet. The installation of those devices is planned in 2Q or 3Q of 2013.

(c) GPRS (General Packet Radio Service)

GPRS is used for a capacitor bank controller and a voltage regulator controller. The GPRS system has a gateway that connects GPRS to the COPEL SCADA.

(d) Bluetooth

It is a short range communication system used for local data downloading. It is used by power transformer supervision equipment.

4.5.8 Status of Radio Regulation for AMI in Brazil

In the case of AMI project, it is necessary to read many meters and to control connect/disconnect switches of meters or home appliances. One method is using radio. According to the hearing from ANATEL, there is no licensed frequency band defined only for AMI in Brazil at present (as of April 2013). However, the unlicensed frequency bands regulated by the Resolution 506 of ANATEL (refer to Appendix 4-1) are available for AMI. The Resolution 506 allows the communication equipment which is certified by ANATEL to use the frequency bands described in that regulation. Some manufactures apply the 900MHz band (902-907.5 MHz, 915-928 MHz) described in the section 9 of Regulation 506 for AMI.

4.6 Meter

COPEL utilizes single phase, dual phase and three-phase meters, all of which can consist of mechanical meters and electronic meters. The meters utilized in COPEL is procured by domestic bid. All of the meters going in for the bid in Brazil need to require pattern type approval of Instituto Nacional de Metrologia, Normatizacao e Qualidade Industrial (INMETRO) at first. When foreign company participates in the bid, it needs to get pattern type approval of INMETRO through pre-test in Brazil and the pre-test in Brazil needs cooperation of Brazilian laboratories such as TECPAR and COPEL authorized by INMETRO. The meter’s specifications are regulated in ABNT (Associacao Brasileira de Normas Tecnicas) with which the meters used in COPLE complied with. Main manufacturers in COPEL are Landis Gyr^{+}, Elster、Elo, etc.

Regarding installation, one meter is installed per customer, with meter reading conducted once a month by COPEL’s staff.

Table 4.6-1 shows the numbers of meters in the COPEL area.

Table 4.6-1 Numbers of Meters in COPEL Area

Municipalities		Single-phase		Dual-phase		Three-phase	
		Mechanical	Electrical	Mechanical	Electrical	Mechanical	Electrical
1	ADRIANOPOLIS	1,602	297	195	33	111	24
2	AGUDOS DO SUL	2,558	243	194	37	184	16
3	ALMIRANTE TAMANDARE	21,660	3,547	4,007	913	1,837	498
4	ARAUCARIA	29,077	4,006	5,664	2,045	2,606	773
5	BALSA NOVA	2,940	576	640	218	342	74
6	BOCAIUVA DO SUL	3,334	656	307	54	203	28
7	CAMPINA GRANDE DO SUL	10,527	1,362	1,640	810	878	329
8	CAMPO DO TENENTE	1,684	135	332	86	154	28
9	CAMPO LARGO	OUTSIDE COPEL CONCESSION					
10	CAMPO MAGRO	5,804	637	907	198	574	116
11	CERRO AZUL	4,943	483	207	42	178	34
12	COLOMBO	47,839	7,958	9,415	2,690	4,676	1,311
13	CONTENDA	4,111	546	535	111	385	78
14	CURITIBA	322,836	29,957	194,169	35,022	140,442	18,876
15	DOUTOR ULYSSES	1,692	127	38	9	41	9
16	FAZENDA RIO GRANDE	22,076	3,722	3,377	1,552	1,421	371
17	ITAPERUCU	6,265	908	193	87	236	145
18	LAPA	11,783	725	1,957	376	1,389	259
19	MANDIRITUBA	6,730	637	558	129	552	132
20	PIEN	2,747	225	577	110	226	23
21	PINHAIS	25,497	2,291	7,789	1,019	5,292	1,016
22	PIRAQUARA	17,734	2,965	3,113	871	1,551	359
23	QUATRO BARRAS	4,612	352	1,087	335	783	195
24	QUITANDINHA	5,169	514	392	78	261	45
25	RIO BRANCO DO SUL	8,555	1,139	473	145	336	131
26	RIO NEGRO	1,404	115	149	23	80	23
27	SAO JOSE DOS PINHAIS	56,050	6,170	19,244	5,831	9,260	3,097
28	TIJUCAS DO SUL	4,710	718	381	81	253	108
29	TUNAS DO PARANA	1,811	86	132	4	96	19
TOTAL		**635,750**	**71,097**	**257,672**	**52,909**	**174,347**	**28,117**

(Source: COPEL material)

Calibration and inspection are regulated by the ANEEL Regulation and INMETRO Regulation respectively. Inspection can be conducted both on site or in the laboratory, however COPEL inspects all meters in its own laboratory.

Table 4.6-2 Calibration and Inspection of Meter in COPEL

	Calibration (ANEEL Regulation)	Inspection (INMETRO Regulation)
Mechanical	25 years	8 years (4% Sampling)
Electronic	13 years	5 years (4% Sampling)

(Source : Interview with COPEL)

Additionally, meter price and installation cost are as follows;

- Meter Price

Mechanical Meter: Single phase 80R$/meter, Three-phase 300R$/meter

Electrical Meter : Single phase 40R$/meter, Three-phase 150R$/meter

- Installation cost

  Residential customer : 50R$/customer

  Large customer : 100 R$/customer

The photos and specifications of typical meters are as shown in Figure 4.6-1.

Single-phase, Electronic Landis Gyr+ E22A 1phase 2lines 120V, 15 (100) A 60Hz	Three-phase, Mechanical SIEMENS D58JC 3phase 3lines 120V, 15 (120) A 60Hz	Three-phase, Electronic Elster A1050 3phase 4lines 120V, 15 (120) A 60Hz

Figure 4.6-1 Typical Meters in COPEL

(Source: Photo by Survey Team)

4.7 Tariff System

4.7.1 Historical Overview of Electricity Tariffs in Brazil

Electricity tariffs in Brazil were universal nationally from the 1970s to the 1990s, but it was recognized that the universal tariffs impeded the distribution company’s efficiency and so Law 8.631/ 1993 was enacted to set the tariffs based on the specific characteristics for each distribution company. In addition, Law 8.987/ 1995, which introduced the economic-financial balance concept, was approved so that the tariffs were to be set for each concession (geographic territory). Thus, the electricity tariffs reflect peculiarities of each region, such as number of consumers, network length and market size comparing the costs and so on.

4.7.2 Tariff Components

Generally, tariffs of distribution companies reflect their costs and the electric bill consists of three costs, that is, 1) Generation, (2) Transmission and Distribution and (3) Charges and Taxes.

1) Generation

Law 10.848/ 2004 prescribes that electric power purchased from the generation companies and resold to the consumers by the distribution companies must be determined in public auctions. The objective of the auction is to guarantee competition and best prices in addition to the transparency of the purchase cost.

2) Transmission and Distribution

Transmission and distribution are natural monopolies and the ANEEL decides the tariffs based on the costs.

3) Charges and Taxes

Some of the charges and taxes are levied on only the distribution costs and the others are included in the costs of generation and transmission. The charges are CCC (Fuel Consumption Bill), RGR (Global Reversal Reserve: electricity sector expansion), TFSEE (Electric Energy Service Inspection Fee: ANEEL's inspection fee), CDE (Energetic Development Account: energy development account for alternative sources, universalization and low-income class subsidization), ESS (System Service Charges: National Interconnected System Service Charges), PROINFA (alternative source subsidization), P&D & Energy Efficiency (R&D and energy efficiency), ONS (National System Operator fee), CFURH (water resource compensation) and Itaipu Royalties (payment based on the Brazil/Paraguay Treaty). The taxes are always levied on the goods and services purchased. There are taxes of municipalities (CIP: Contribution for Financing the Public Lighting Service), states (ICMS: Tax on Circulation of Merchandise and Services) and the federal government (PIS: Social Integration Programs and COFINS: Contribution to the Social Security Financing). The distribution companies collect them within their tariffs and pass them to the authorities. The ANEEL publishes a resolution indicating the values of electric tariffs excluding taxes by consumer class (residential, commercial, industrial, etc.). The distribution companies include the taxes into the bills based on the values.

The shares of these components in 2006 are shown in Figure 4.7-1.

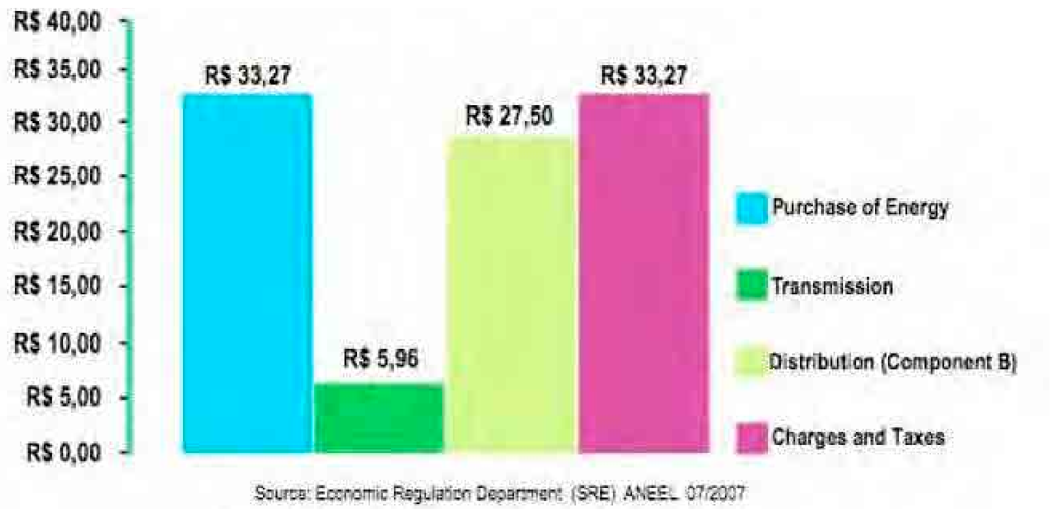


Figure 4.7-1 1 Shares of cost components in supposed electric bill R$100 (average in 2006)

(Source: ANEEL)

4.7.3 Tariff Settlement Procedures

The distribution companies make contracts on the occasion of winning the concession. The contracts include three tariff settlement mechanisms set as a rule. These three mechanisms are 1) Tariff Readjustment, 2) Tariff Review and 3) Extraordinary Tariff Review. On the other hand, the revenues required by the distribution companies are called "distribution service revenues" which can be divided into mainly two groups of costs. One is called Component A that includes uncontrollable costs independent from the management of the companies such as purchased power costs, transmission costs and charges. The other is called Component B that includes controllable costs, that is, managed by the companies. The examples of Component B are operation and maintenance costs, depreciation and investment remuneration. These components and the above three mechanisms are related as follows.

1) Tariff Readjustment

This is implemented annually on the contract anniversary except in tariff review below. Component A costs are calculated according to the formula. On the other hand, Component B costs are adjusted for the IGP-M (Market General Price Index calculated by Getúlio Vargas Foundation) – X (productivity). IGP-M seems similar to CPI (Consumer Price Index, that is, inflation rate) used in the British privatization method. Productivity, X, is set by the ANEEL due to the consumer number growth and the increase of existing market consumption.

2) Periodic Tariff Review

This allows for the repositioning of the tariff after the complete analysis of the efficient costs and remuneration of investment in an average interval of four years. Compared with the (1) annual readjustment, this review is wider and all of the costs are considered. The ANEEL uses not only the reviewed company's information but also the reference company methodology (company model).

3) Extraordinary Tariff Review

This is implemented on the occasion of unpredictable events affecting the companies, e.g. establishment of new charges.

Until 2003, there had been a cross-subsidy in the tariff calculation from the low voltage classes such as residential consumers to the high voltage classes such as industrial consumers and the low voltage class tariffs had been relatively higher. Therefore, the updating indexes of the low voltage class tariffs were set lower than those of the high voltage class tariffs from 2003 to 2007. Incidentally, the consumer classification is set as follows.

High voltage class

- A1: equal to or higher than 230kV
- A2: 88kV - 138kV
- A3: 69kV
- A3a: 30kV - 44kV
- A4: 2.3 - 25kV
- AS: lower than 2.3kV, but invoiced in Group A because served by the underground distribution system

Low voltage class

- B1: residential and low income
- B2: rural, rural electrification cooperative and irrigation public service
- B3: other classes
- B4: public lighting

The present A tariffs of COPEL are shown as an example in Table 4.7-1.

Table 4.7-1 A Tariffs of COPEL

TABLE C – BLUE RATE MODALITY												
	TUSD			TE								
SUB GROUP/ CLASS / SUB CLASS	TE			EDGE				Outside edge				
	EDGE	ITNERMEDIATE	OUTSIDE EDGE	TE	GREEN FLAG	YELLOW FLAG	RED FLAT	TE	GREEN FLAG	YELLOW FLAG	RED FLAT
	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh
A1 (230kV or more) -												
Gerdau Aços Longs	1.94	0.99	7.77	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A1 (230kV or more) -												
WHB Fundição S.A.	1.94	0.99	7.77	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A1 (230kV or more) -												
Cimento Rio Branco S.A.	2.02	1.01	7.77	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A1 (230kV or more) -												
Peroxidos do Brasil Ltda.	1.94	0.99	7.77	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A1 (230kV or more) -												
Petrobras	1.91	0.94	7.77	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A2 (88 to 138kV)	8.87	1.54	12.18	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A3 (69kV)	8.97	1.83	11.88	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A3a (30 to 44kV)	18.37	5.12	15.44	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
A4 (2,3 to 25kV)	18.37	5.12	15.44	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83
AS (undergound)	27.54	6.97	24.57	197.85	197.85	212.85	227.85	118.83	118.83	133.83	148.83

(Source: ANEEL)

The present B1 tariffs of distribution companies are shown in Table 4.7-1. These tariffs reflect the ANEEL's new tariff policies implemented in January 2013 in accordance with the President's announcement of electricity price reduction in 2012. In September 2012, the President stated that approximately one-fifth of Brazil's electricity-generation capacity, together with three-fourths of transmission and one-third of distribution networks, was tied to contracts that would expire between 2015 and 2017 and the government would immediately renew those expiring concessions on the condition that utilities would charge lower fees. She also said that the government would remove certain charges from consumers' power bills and together with the lower rates from the renewed operating licenses, which should lead to an average decline of 20% in electricity bills starting next year. The ANEEL took this tariff reduction into consideration and indicated the tariff review results in January 2013 shown in Table 4.7-1. B1 residential tariff of COPEL Distribution (subsidiary) Company is 0.24258 R$/kWh, which is lower than the average, 0.30199 R$/kWh, and rather close to the minimum, 0.19729 R$/kWh (CEA's).

COPEL's tariffs and their recent review procedure are described in detail below.

Table 4.7-2 B1 Tariffs of distribution companies (Jan. 24, 2013)

Distribution Company	B1 - Residential (R$/kWh)	Distribution Company	B1 - Residential (R$/kWh)
AES-SUL	0.25307	CPFL- Mococa	0.35474
AmE	0.27139	CPFL-Santa Cruz	0.26070
AMPLA	0.35015	CPFL- Sul Paulista	0.30200
BANDEIRANTE	0.28586	CPFL- Piratininga	0.25694
Boa Vista	0.26009	CPFL-Paulista	0.27621
CAIUÁ-D	0.26786	DEMED	0.29468
CEA	0.19729	DEMEI	0.33570
CEAL	0.30293	EBO	0.27455
CEB-DIS	0.24253	EDEVP	0.26172
CEEE-D	0.27588	EEB	0.31142
CELESC-DIS	0.25580	EFLJC	0.29925
CELG-D	0.29662	EFLUL	0.29916
CELPA	0.32076	ELEKTRO	0.28713
CELPE	0.29615	ELETROACRE	0.37060
CELTINS	0.34423	ELETROCAR	0.33184
CEMAR	0.36610	ELETROPAULO	0.23801
CEMAT	0.34187	ELFSM	0.32519
CEMIG-D	0.33090	EMG	0.36448
CEPISA	0.36292	ENERSUL	0.36048
CERON	0.33862	ENF	0.28524
CERR	0.31346	EPB	0.31782
CFLO	0.27350	ESCELSA	0.31509
CHESP	0.34387	ESE	0.29003
CNEE	0.27180	FORCEL	0.27633
COCEL	0.25927	HIDROPAN	0.33439
COELBA	0.32740	IENERGIA	0.29061
COELCE	0.29815	JARI	0.34191
COOPERALIANÇA	0.31187	LIGHT	0.31416
COPEL-DIS	0.24258	MUX-Energia	0.29727
COSERN	0.29825	RGE	0.32956
CPEE	0.30043	SULGIPE	0.33702
CPFL- Jaguari	0.20877	UHENPAL	0.34125

(Source: ANEEL)

4.7.4 COPEL's Recent Tariff Review

The ANEEL ratified the resolution No. 1.431, prescribing COPEL's tariffs, on January 24 2013. COPEL's tariff review and readjustment are implemented as shown in Figure 4.7-2.

Figure 4.7-2 COPEL's Tariff Review and Readjustment Periods

(Source: COPEL Distribution's material)

COPEL's tariff review was conducted in 2012. However, the extraordinary review was implemented in 2013 according to the President's announcement.

In the 2012 tariff review (Table 4.7-3), Component A increased 8.97% and Component B decreased 10.56% so that the total decreased 0.11% including 1.48% increase of allocation of allowances in tariff (cross-subsidization from urban tariffs to agricultural tariffs) according to the ANEEL's calculation. The cause of Component A cost increase is the generation and transmission cost increase and the cause of Component B decrease is that the ANEEL calculation decreased COPEL-DIS's profit rate.

Table 4.7-3 COPEL's Tariff Review in 2012

Descrição	Receita Requerida R$ mil	Impacto na Revisão %	Part. Receita %
Parcela A	4.584.535	8,97%	76,02%
Encargos Setoriais	853.170	1,72%	
Transmissão	554.278	0,97%	
Compra de Energia	3.177.087	[illegible]	
Parcela B	1.446.269	-10,56%	23,98%
Custos Operacionais + Anuidades	945.068	-3,55%	
Remuneração	278.907	-3,38%	
Depreciação	281.268	-3,78%	
Receitas irrecuperáveis	39.110	-0,32%	
Diferencial de X (Delta X)	(28.158)		
Índice de produtividade	(20.634)		
Outras Receitas	(49.292)	0,47%	
Parcela A + Parcela B	**6.030.804**	**-1,59%**	**100%**
Alocação de Subsídios na Tarifa	0	1,48%	
Reposicionamento Economico	**6.030.804**	**-0,11%**	
Componentes Financeiros	(44.077)	-0,72%	
Reposicionamento com Financeiros		-0,84%	
Financeiros Retirados do IRT anterior		0,19%	
Efeito Médio p consumior		**-0,65%**	

(Source: COPEL Distribution's material)

TEPSCO TEPCO

In the 2013 tariff review (Table 4.7-4), Component A decreased 14.36% and Component B decreased 0.07% so that the total decreased 14.47%. In Component A, the rural area generation plant charge, 7.73%, was excluded and the decrease of power purchase from the generation plants whose invested asset depreciation was finished except COPEL's was 1.38%. Similarly, the decrease of transmission charge because of transmission facility depreciation expiration was 5.25%. These decreases were based on the federal government decision and adopted to every distribution company. In addition, the cross-subsidy from urban customers to rural customers in the previous year (1.48%) was changed to the ANEEL's direct subsidy. Thus, the COPEL consumers can enjoy 14.44% price reduction in 2013.

4.7.5 Present COPEL's Tariffs

Based on the review above, COPEL's new tariffs are published by the ANEEL shown in Table 4.7-5 (for residential use only because there are too many pages).

Table 4.7-4 COPEL's Tariff Review in 2013

Descrição	Receita Requerida R$ mil	Impacto na Revisão %	Part. Receita %
Parcela A	3.724.610	-14,36%	72,09%
Encargos Setoriais	390.189	7,73%	
Transmissão	240.194	-5,25%	
Compra de Energia	3.094.227	1,38%	
Parcela B	1.441.869	-0,07%	27,91%
Custos Operacionais + Anuidades	945.068	0,00%	
Remuneração	278.907	0,00%	
Depreciação	281.268	0,00%	
Receitas irrecuperáveis	34.567	-0,08%	
Diferencial de X (Delta X)	(28.076)	0,00%	
Índice de produtividade	(20.573)	0,00%	
Outras Receitas	(49.292)	0,00%	
Parcela A + Parcela B	**5.166.479**	**-14,44%**	**100%**
Alocação de Subsídios na Tarifa	0		
Reposicionamento Economico	**5.166.479**	**-14,44%**	
Componentes Financeiros	(44.077)	0,00%	
Reposicionamento com Financeiros		-14,44%	
Financeiros Retirados do IRT anterior		0,00%	
Efeito Médio p consumidor		**-14,44%**	

(Source: COPEL Distribution's material)

Table 4.7-5 COPEL's New Tariffs for Residential Use

ANEXO I - TARIFAS DE APLICAÇÃO – COPEL-DIS

TARIFAS APLICADAS À BAIXA TENSÃO

QUADRO A - MODALIDADE TARIFÁRIA CONVENCIONAL

SUBGRUPO/CLASSE/SUBCLASSE	TUSD	TE			
		TE	BANDEIRA VERDE	BANDEIRA AMARELA	BANDEIRA VERMELHA
	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh
B1 - RESIDENCIAL	117,16	125,42	125,42	140,42	155,42
B1 - RESIDENCIAL BAIXA RENDA					
Parcela do consumo mensal de energia elétrica inferior ou igual a 30 (trinta) kWh	38,20	42,94	42,94	48,19	53,44
Parcela do consumo mensal superior a 30 (trinta) kWh e inferior ou igual a 100 (cem) kWh	65,48	73,61	73,61	82,61	91,61
Parcela do consumo mensal superior a 100 (cem) kWh e inferior ou igual a 220 (duzentos e vinte) kWh	98,22	110,41	110,41	123,91	137,41
Parcela do consumo mensal superior a 220 (duzentos e vinte) kWh	109,14	122,68	122,68	137,68	152,68
B2 - RURAL	72,19	77,28	77,28	86,52	95,77
B2 - COOPERATIVA DE ELETRIFICAÇÃO RURAL	58,13	62,22	62,22	69,66	77,10
B2 - SERVIÇO PÚBLICO DE IRRIGAÇÃO	70,30	75,25	75,25	84,25	93,25
B3 - DEMAIS CLASSES	115,40	123,54	123,54	138,32	153,09
B4 - ILUMINAÇÃO PÚBLICA					
B4a - Rede de Distribuição	59,42	63,61	63,61	71,22	78,83
B4b - Bulbo de Lâmpada	65,28	69,88	69,88	78,24	86,60

QUADRO B - MODALIDADE TARIFÁRIA BRANCA

SUBGRUPO/CLASSE /SUBCLASSE	TUSD			TE											
				PONTA				INTERMEDIÁRIO				FORA DE PONTA			
	PONTA	INTER-MEDIÁRIO	FORA DE PONTA	TE	BANDEIRA VERDE	BANDEIRA AMARELA	BANDEIRA VERMELHA	TE	BANDEIRA VERDE	BANDEIRA AMARELA	BANDEIRA VERMELHA	TE	BANDEIRA VERDE	BANDEIRA AMARELA	BANDEIRA VERMELHA
	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh
B1 - RESIDENCIAL	256,05	163,46	70,86	197,85	197,85	212,85	227,85	118,83	118,83	133,83	148,83	118,83	118,83	133,83	148,83
B2 - RURAL	166,33	105,86	45,38	121,92	121,92	131,16	140,41	73,22	73,22	82,46	91,71	73,22	73,22	82,46	91,71
B2 - COOPERATIVA DE ELETRIFICAÇÃO RURAL	133,93	85,23	36,54	98,16	98,16	105,60	113,04	58,96	58,96	66,40	73,84	58,96	58,96	66,40	73,84
B2 - SERVIÇO PÚBLICO DE IRRIGAÇÃO	161,96	103,07	44,18	118,71	118,71	127,71	136,71	71,30	71,30	80,30	89,30	71,30	71,30	80,30	89,30
B3 - DEMAIS CLASSES	306,94	193,84	80,75	194,89	194,89	209,67	224,44	117,05	117,05	131,83	146,60	117,05	117,05	131,83	146,60

ANEXO II - BASE TARIFÁRIA ECONÔMICA – COPEL -DIS

QUADRO A - MODALIDADE TARIFÁRIA CONVENCIONAL

SUBGRUPO/CLASSE/SUBCLASSE	TUSD	TE
	R$/MWh	R$/MWh
B1 - RESIDENCIAL	115,80	128,23
B1 - RESIDENCIAL BAIXA RENDA		
Parcela do consumo mensal de energia elétrica inferior ou igual a 30 (trinta) kWh	38,64	44,88
Parcela do consumo mensal superior a 30 (trinta) kWh e inferior ou igual a 100 (cem) kWh	66,24	76,94
Parcela do consumo mensal superior a 100 (cem) kWh e inferior ou igual a 220 (duzentos e vinte) kWh	99,36	115,41
Parcela do consumo mensal superior a 220 (duzentos e vinte) kWh	110,40	128,23
B2 - RURAL	71,36	79,02
B2 - COOPERATIVA DE ELETRIFICAÇÃO RURAL	57,45	63,62
B2 - SERVIÇO PÚBLICO DE IRRIGAÇÃO	69,48	76,94
B3 - DEMAIS CLASSES	114,07	126,31
B4 - ILUMINAÇÃO PÚBLICA		
B4a - Rede de Distribuição	58,73	65,04
B4b - Bulbo de Lâmpada	64,52	71,45

QUADRO B - MODALIDADE TARIFÁRIA BRANCA

SUBGRUPO/CLASSE/SUBCLASSE	TUSD			TE		
	PONTA	INTERMEDIÁRIO	FORA DE PONTA	PONTA	INTERMEDIÁRIO	FORA DE PONTA
	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh	R$/MWh
B1 - RESIDENCIAL	251,43	161,01	70,59	201,45	121,58	121,58
B2 - RURAL	163,29	104,23	45,17	124,13	74,91	74,91
B2 - COOPERATIVA DE ELETRIFICAÇÃO RURAL	131,47	83,92	36,37	99,95	60,32	60,32
B2 - SERVIÇO PÚBLICO DE IRRIGAÇÃO	158,99	101,49	43,98	120,87	72,95	72,95
B3 - DEMAIS CLASSES	301,10	190,66	80,22	198,43	119,75	119,75

(Source: ANEEL)

ANNEX I shows that there are three categories: green, yellow and red flags. This categorization is new and will be on trial this year and implemented more substantially next year. This policy was introduced because recent drought causes generation cost increases with thermal generation needs. Therefore, the federal government decided to announce green, yellow or red flags one month before depending on the drought situation. Green flag means enough water for hydro-generation, yellow flag requiring attention and red flag shortage of water. ANNEX II shows normal tariffs excluding three flags.

4.8 Control Center

There are 3-layer control centers in COPEL as shown in Figure 4.8-1.

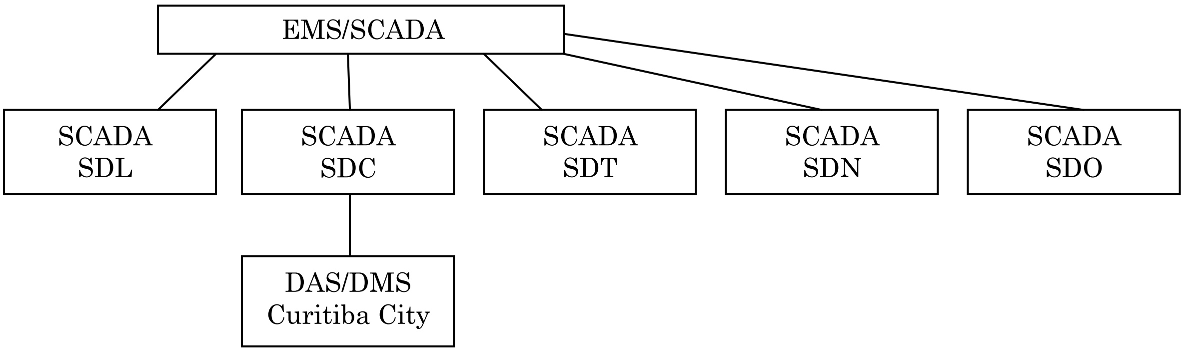


Figure 4.8-1 Existing 3-layer Control Center in COPEL

(Source: Survey team)

One EMS/SCADA has been installed in Control Center in Curitiba to manage all power generation plants in COPEL and 500kV / 230kV transmission network.

SCADA installed to each region (5regions) has monitored and controlled 138 / 69kV substations and LBS's in the region. The SCADA was installed more than 10 years ago so that the system is old and the capacity is not sufficient to monitor and control the increasing substations and LBS.

DAS/DMS has been applied to Curitiba City area as a pilot project. Modification is needed based on the pilot project and the international experience.

4.9 Organization Structure for Distribution System in Project Area

Since COPEL is at the smart grid introduction stage, the management organization structure of smart grid is not established. Therefore, there is no difference between personnel required for operation and maintenance between smart grid area installed and not installed. The existing organization structure for distribution system in Project Area is described below.

4.9.1 Operation Structure of Distribution System

The distribution system of COPEL is operated in five distribution control centers which belong to five Distribution Superintendences. The operation area is shown in Figure 4.9-1.

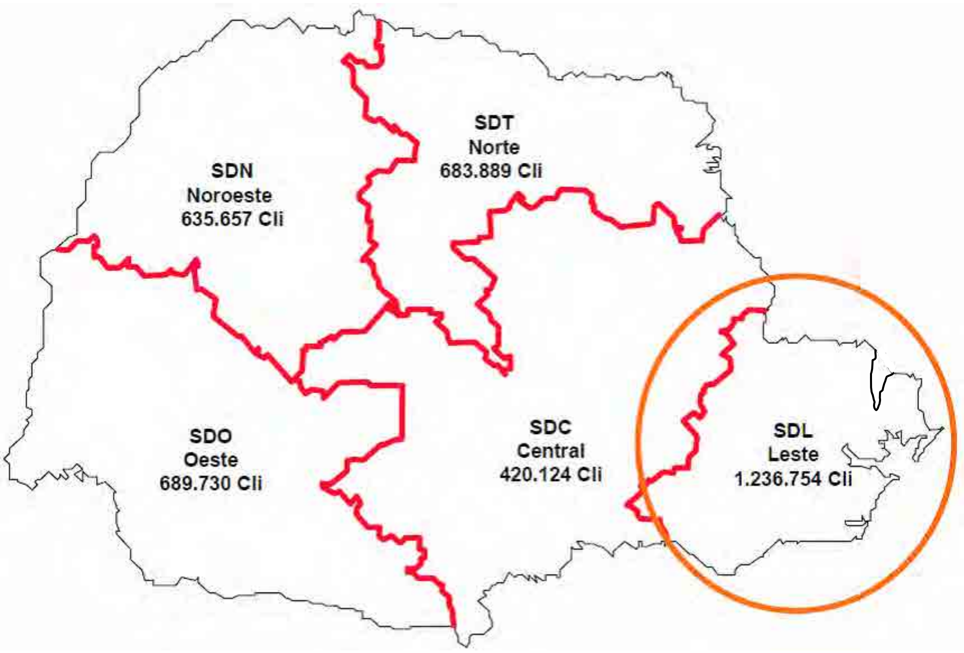


Figure 4.9-1 Distribution System Operation Area in COPEL

(Source: COPEL SDL)

In the existing distribution system of COPEL, all the distribution substations in the Curitiba Metropolitan Area, covering 29 municipalities and others, are monitored and controlled by the distribution control center which belongs to Regional East Distribution Superintendence (hereinafter referred to as SDL). The area enclosed with the orange circle in Figure 4.9-1 is a control area in charge of SDL and the detail area of SDL is shown in Figure 4.9-4. The distribution system in the proposed candidate project areas is also monitored and controlled by the distribution control center. At the distribution control center, there are four control boxes and one supervisor box, and in each control box, an engineer monitors and controls each charged area's substations shown in the following figure. The 138/69/34kV level facilities are monitored and controlled at the distribution control center. At present, only a few switches such as LBS and reclosers in Curitiba and Fazenda Rio Grande Cities are operated at the distribution control center.

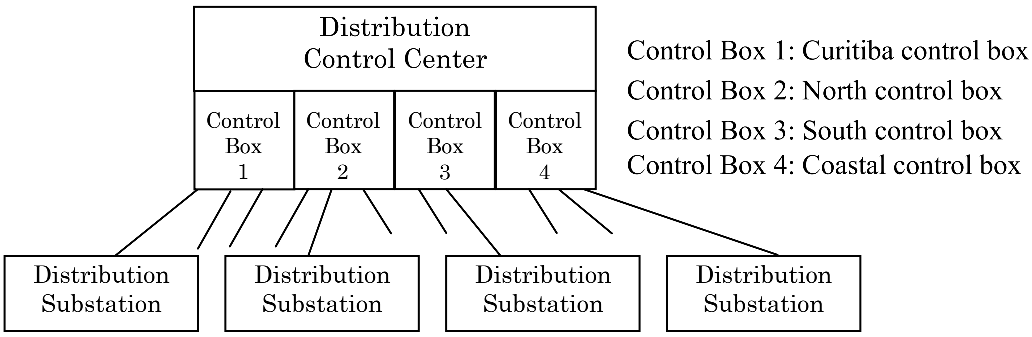


Figure 4.9-2 Structure for Existing Distribution Operation

(Source: JICA Survey Team)

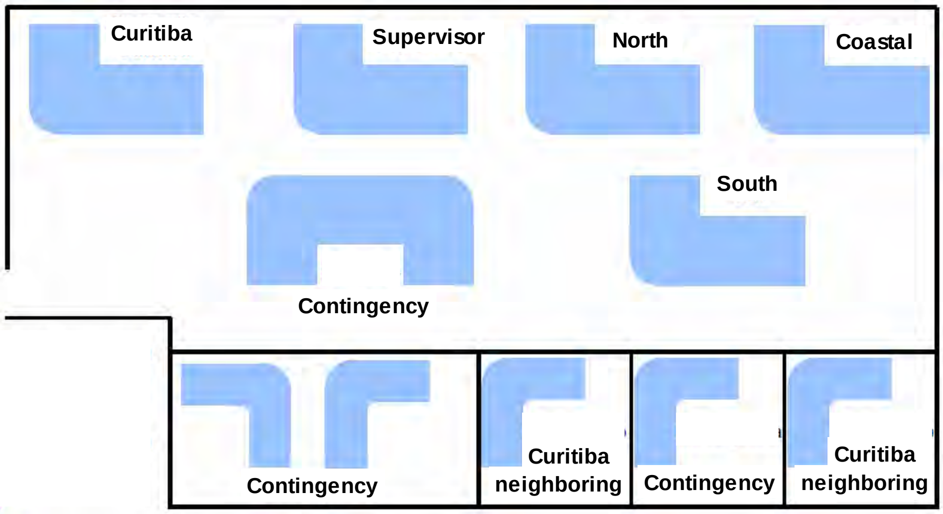
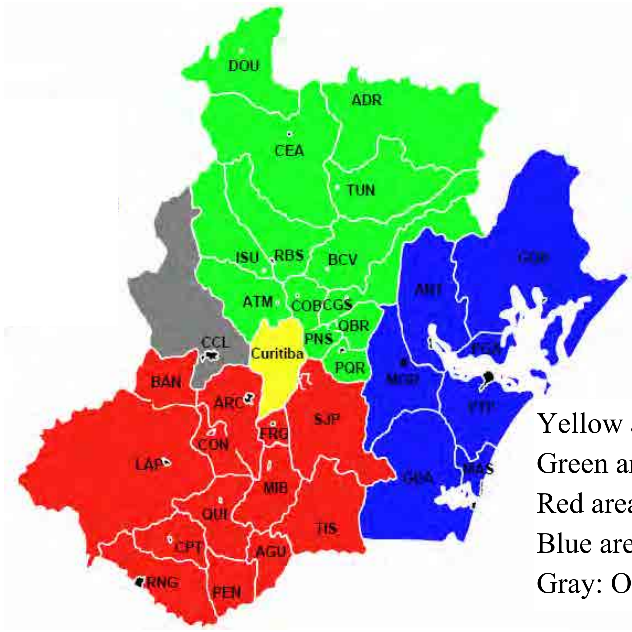


Figure 4.9-3 Layout of Control Boxes in COPEL SDL

(Source: COPEL SDL)

The Curitiba control box, North control box, South control box and Coastal control box, which are shown in Figure 4.9-2, monitor and control the yellow, green, red and blue areas of the following figure respectively.



Yellow area: Curitiba control box
Green area: North control box
Red area: South control box
Blue area: Coastal control box
Gray: Outside the service area

Figure 4.9-4 Distribution System Operation Area in COPEL SDL

(Source: COPEL SDL)

There are 30 engineers at the distribution control center and they operate in three shifts. The working system of the three shifts is shown in Table 4.9-1.

Table 4.9-1 Working System of Power System Operation Center

Working Time	Number of Staff Members		
	Supervisor	Operator	Emergency Standby
7:00-15:00	1	4	2
15:00-23:00	1	4	2
23:00-7:00	1	2	0

(Source: JICA Survey Team)

The main role of operation center is as follows.

- Distribution facilities operating (order→on/off)
- Site worker control
- Distribution facilities data management
- Facility operation recording
- System map updating
- Facility operation procedure updating
- Customer service control
- Trouble shooting

There are eight displays in the control box, and the operator contacts the construction or maintenance site by phone and relays to the site worker the contents of work.

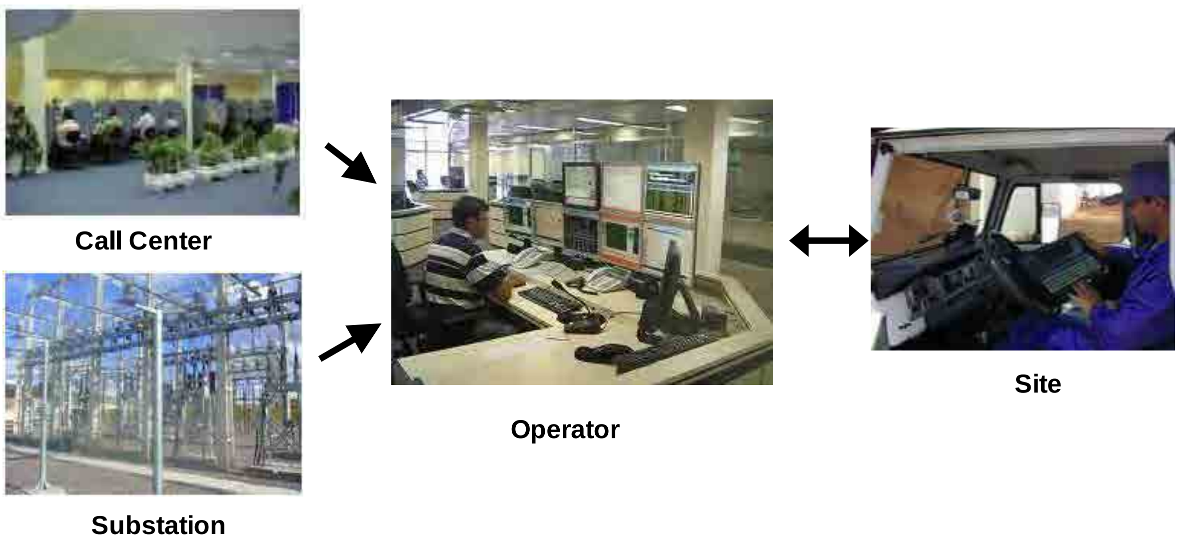


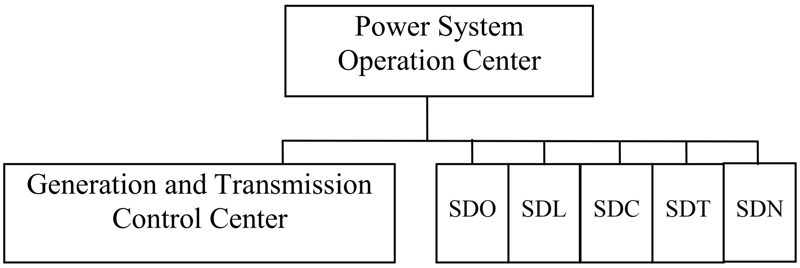
Figure 4.9-5 Information Connection Structure

(Source: Photo by COPEL SDL and Survey Team)

Figure 4.9-6 Distribution Control Center and Control Box

(Source: Photo by Survey Team)

Above 69kV level facilities are monitored and controlled at the power system operation center. There are one three generation and transmission control centers which covers the whole of Brazil, and five distribution control centers under the power system operation center as shown in the following figure with the cover area of each distribution control center shown in Figure 4.9-1.



SDO: Regional West Distribution Superintendence
SDL: Regional East Distribution Superintendence
SDC: Regional Central-South Distribution Superintendence
SDT: Regional North Distribution Superintendence

Figure 4.9-7 Structure for Existing Power System Operation

(Source: JICA Survey Team)

There are 74 engineers at the power system operation center and they monitor and control in three shifts. The working system of the three shifts is as follows.

Table 4.9-2 Working System of Power System Operation Center

Working Time	Number of Staff Members		
	Supervisor	Distribution Operator	Transmission Operator
6:30-14:30	1	3	3
14:30-22:30	1	3	3
22:30-6:30	1	3	3

(Source: JICA Survey Team)

4.9.2 Maintenance Structure of Distribution System

The distribution facilities of COPEL are maintained in maintenance centers which belong to five Distribution Superintendences. There are four maintenance centers in the Curitiba Metropolitan Area, which belong to SDL as shown in Figure 4.9-8. The number of each maintenance center is shown in Table 4.9-3.

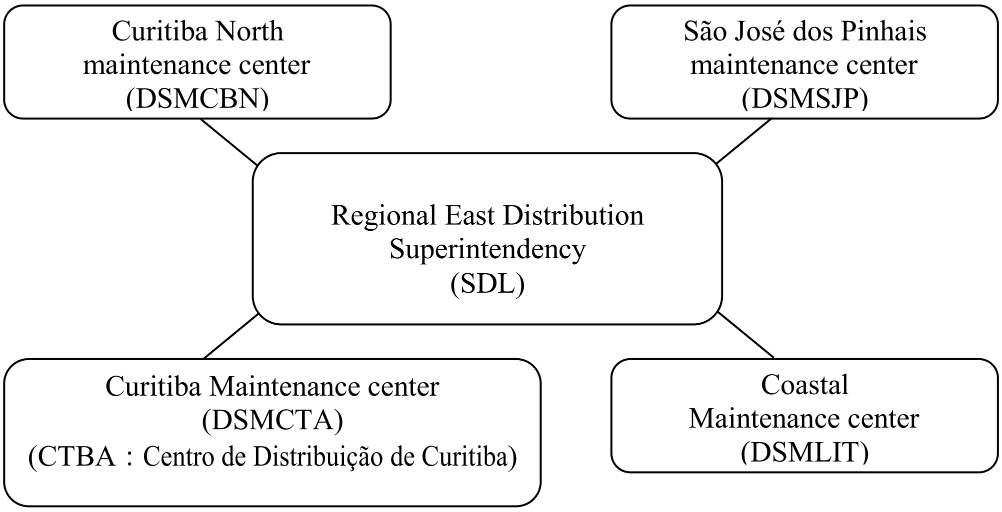


Figure 4.9-8 Existing Facilities Maintenance Structure in the Curitiba Metropolitan Area

(Source:COPEL)

Table 4.9-3 Number of each maintenance center

	VMACTA	VMACBN	VMASJP	VMALIT
Worker (dead line)	0	0	6	12
Worker (hot line)	15	10	10	5
Worker (underground)	17	0	0	0
Worker (other)	5	6	5	7
other (adm.etc.)	15	15	8	3
Total	52	31	29	27

(Source:COPEL)

The proposed candidate project areas are maintained at three maintenance centers, VMACTA, VMACBN and VMASJP. The main role of maintenance centers is as follows.

- New construction work
- Construction supervision
- Maintenance and inspection planning
- Distribution line patrol
- Maintenance and inspection of the distribution facilities

- Maintenance and inspection of the automation facilities
- Distribution facilities operating (work in the site)
- Fault point locating
- Fault point isolating
- Accident recovery work

Figure 4.9-9 Transformer Maintenance Building and Meter Testing Building

(Source: Photo by Survey Team)

Figure 4.9-10 Vehicles for Maintenance Work (Bucket Vehicle, Emergency Transformer Vehicle)

(Source: Photo by Survey Team)

The materials center and the examination center are situated next to the Curitiba Norte maintenance center. Moreover, 16 service offices exist in the Curitiba Metropolitan Area, with works corresponding to visitors and recovery works for accidents being performed.


Figure 4.9-11 Materials Center (Material for Transmission Tower and Distribution Pole)

(Source: Photo by Survey Team)

Moreover, in order to carry out maintenance of the installed smart grid facilities, there are 24 special engineers in Curitiba and Fazenda Rio Grande Cities aside from the existing facility maintenance engineers. The smart grid facilities maintenance is conducted by a team of two engineers.

The post responsible for construction, operation and maintenance is shown below.

Table 4.9-4 Responsible Post for Construction, Operation and Maintenance

	Post	Department	Division
Department director	Chief Distribution Office	-	-
Construction	Distribution Engineering Superintendence	Standardization, Geo-referencing and Construction	Projects and Constructions
Operation	Distribution Engineering Superintendence	Operation, Maintenance and Services	Operation and Protection Studies
Maintenance (13,8kV, 34,5kV)	Distribution Engineering Superintendence	Operation, Maintenance and Services	Distribution Maintenance and Quality Control
Maintenance (above 34,5kV)	Engineering Superintendence	Automation	Subtransmission Maintenance

(Source: JICA Survey Team)

Chapter 5 Selection of Smart Grid Projects

5.1 COPEL Needs

COPEL selected the candidates for COPEL smart grid project approximately 2 years ago based on the criteria which COPEL considered at that time. For this project, COPEL shows JICA Survey Team the candidates based on their previous selection. Table 5.1-1 shows COPEL's criteria with specifications. However, COPEL's criteria do not have priority, and so COPEL and JICA Survey Team discussed the priority of the criteria at first. Based on the discussion, it is clarified that reliability improvement of distribution line by improvement of SAIDI/SAIFI is the first priority, improvement of distribution loss is the second priority and improvement of voltage drop and power factor is the third priority because of COPEL's penalty payment, duties and unrecoverable cost related to loss based on the ANEEL regulations (described below). Additionally, it is also understood that COPEL has eager expectation of future demand restraint as a secondary effect by installing smart grid techniques and is very much interested in grid stability techniques for future issues in case renewable energy grid-connection is disseminated.

●ANEEL Regulations

- Regarding SAIDI/SAIFI, COPEL has duty to pay penalty to customers, if SAIDI/SAIFI are over values regulated by the ANEEL regulation (For details in 2.8 4 (1)).
- Regarding technical loss and non-technical loss, COPEL cannot recover the costs related to loss over the values regulated by the ANEEL regulation (For details in 2.7).
- Regarding voltage drop, COPEL has duty to pay penalty to customers, if voltage drop cannot satisfy the values and the rules regulated by the ANEEL regulation (For details in2.8 4 (2)).
- Regarding power factor, COPEL has duty to keep the power factor regulated by the ANEEL regulations (For details in2.8 4 (3)).

Table 5.1-1 COPEL criteria for Selection of Project Candidates

(Reference)
: Priority No.1
: Priority No.2
: Priority No.3
: Priority No.4

COPEL Criteria			Specification	
1	Por.	Subestacai Fonte	Meaning	Areas having 138 or 69kV/13k Substaions
	Eng.	Substation 138,69/13	Reason	It is understood that there is : a lot of demand related to distribution line (13kV).
2	Por.	Subestacao 34/13	Meaning	Areas having 34kV/13kV Substation
	Eng.	Substation 34/13	Reason	It is understood that there is : a lot of demand related to distribution line (13kV). However, priority is lower than the above.
3	Por.	Probabilidade de Perdas Comerciais > 0.5%	Meaning	Over 0.5% non-technical loss
	Eng.	Non-technical Loss > 0.5%	Reason	Reduction of non-technical loss is necessary. However, 0.5% does not have numerical reason
4	Por.	Multa – DEC-FEC / DIC-FIC	Meaning	SAIDI and SAIFI
	Eng.	SAIDI/SAIFI	Reason	Reliability improvement of distribution line is necessary, because COPEL has duty to pay penalty to customer, if SAIDI/SAIFI is over the values regulated by the ANEEL regulation.
5	Por.	Regulacao de Tensao na Rede	Meaning	Voltage Drop
	Eng.	Voltage Drop	Reason	Voltage drop is improved in long distance distribution line and in distribution line which is difficult for COPEL staff to reach.
6	Por.	Correcao de Reativo na Rede	Meaning	Power Factor
	Eng.	Power Factor	Reason	Efficiency of supplying power energy is improved by improvement of power factor.
7	Por.	Densidade de Carga > 20MW	Meaning	Expected over 20MW future demand
	Eng.	Future Demand > 20MW	Reason	Facility investment is restrained by peak shift with installation of smart grid techniques and expansion such as installing new transformers and so on is expected by smart grid project.
8	Por.	Densidade de Consumidores>20000	Meaning	No. of Customers ＞ 20000
	Eng.	The number of Contracts	Reason	It is understood that there is a lot of demand.
9	Por.	Inadimplencia>0.3%	Meaning	Non-payment Ration ＞ 0.3%
	Eng.	Non-payment Ratio	Reason	Profit is improved by reduction of non-payment ratio.
10	Por.	Acessantes Geracao	Meaning	Grid-connection of Standby Generators
	Eng.	Grid-connection	Reason	Impact of grid-connection of dispersed generators is mitigated and grid stability is kept.

(Source: JICA Survey Team based on COPEL's material and interview)

5.2 Evaluation of Applied Technique Priority

Based on the criteria shown in Table 5.1-1, high potential smart grid techniques are extracted and Table 5.2-1 shows the result of evaluation with the criteria shown in Table 5.1-1 and extracted high potential smart grid techniques. Based on the result of Table 5.2-1, DAS/DMS and protection relay of earth fault for SAIDI/SAIFI, AMI for non-technical loss, DAS/DMS for voltage drop and power factor, and DR and EMS/PV/Battery for the future demand and grid-connection, all have high potential.

Table 5.2-1 Evaluation of Applied Technique Priority

COPEL Criteria		Applied Technicques							
		DAS	Protection relay for earth fault	AMI	DR	EMS/PV/ Battery	EV	BEMS	HEMS
1	Substation 138,69/13	◎	◎						
2	Substation 34/13	◎	◎						
3	Non-technical Loss > 0.5%			◎					
4	SAIDI/SAIFI	◎	◎						
5	Voltage Drop	◎							
6	Power Factor	◎							
7	Future Demand > 20MW	◎			◎	○	○	○	○
8	The numbers of Contracts	◎	◎						
9	Non-payment Ratio			◎					
10	Grid-connection					◎	○		

* ◎: Excellent, ○: Good

(Source: JICA Survey Team)

Next, impacts of applied techniques are evaluated by putting weight on COPEL's criteria based on the result of Table 5.2-1. Additionally, necessity of law preparation is evaluated as well and the total score is calculated to evaluate the impacts quantitatively. The result is shown in Table 5.2-2.

Based on the result of Table 5.2-2, DAS/DMS has the highest score (46), and so the priority of DAS/DMS is No.1.

Table 5.2-2 Evaluation of Applied Smart Grid Technique Impacts

Evaluation Items (Weights*) / Applied Technicques	Improvement of DL Reliavility	Improvemnet of Efficiency					Grid Stability	CO2 Emission Reduction	Subtotal	Necessity of Law Preparation	Total
	SAIDI	LOSS	Voltage Drop	Power Factor	Facility Investment	Human Resource					
	(5)	(4)	(3)	(3)	(2)	(2)	(2)	(1)		(-1)	
DAS	**A**	**A**	**B**	**B**	**B**	**C**	D	**C**	**46**	Not Necessary	**46**
	3	**3**	**2**	**2**	**2**	**1**	0	**1**		0	
Protection Relay for Earth Fault	**A**	D	D	D	**C**	**C**	D	**C**	**20**	Not Necessary	**20**
	3	0	0	0	**1**	**1**	0	**1**		0	
AMI	D	**A**	D	D	D	**A**	D	D	**18**	Not Necessary	**18**
	0	**3**	0	0	0	**3**	0	0		0	
DR	D	D	D	D	**A**	**C**	D	**B**	**10**	**Necessary**	**9**
	0	0	0	0	**3**	**1**	0	**2**		**-1**	
EMS/PV/Battery	**C**	D	D	D	D	D	**A**	**A**	**14**	**Necessary**	**13**
	1	0	0	0	0	0	**3**	**3**		**-1**	
EV	D	D	D	D	D	D	**B**	**B**	**6**	Not Necessary	**6**
	0	0	0	0	0	0	**2**	**2**		0	
BEMS	D	D	D	D	**C**	D	D	**C**	**3**	Not Necessary	**3**
	0	0	0	0	**1**	0	0	**1**		0	
HEMS	D	D	D	D	**C**	D	D	**C**	**3**	Not Necessary	**3**
	0	0	0	0	**1**	0	0	**1**		0	

* Points: A: Excellent(3), B: Good(2), C: Fair(1), D: No impact(0)

(Source: JICA Survey Team)

5.3 Project Priority Based on Criteria

The priority of projects and the installation plan is shown in Table 5.3-1 and Figure 5.3-1.

Table 5.3-1 Proposed project and Installation plan of Smart Grid project in COPEL

	Explanation Chapter and item	Proposed project and Installation plan	
		1st Installation (2014-2017)	2nd Installation (Expansion) (2018- 2019)
1. DAS /DMS	6.2.2 in Chapter 6 6.3.2 in Chapter 6 6.3.5 in Chapter 6	1 Control center Distribution equipment for Curitiba Metropolitan Area (23 cities)	Distribution equipment for Curitiba City
2. Protection relay for earth fault	6.3.3 in Chapter 6 6.3.4 in Chapter 6	50 substations (Curitiba Metropolitan Area and Curitiba City)	
3. AMI	6.2.2 in Chapter 6 6.3.6 in Chapter 6	120,000 residential customers in Curitiba City	100,000 residential customers in Curitiba City
4. EMS / renewable power / Battery	-	Study	Continue to study
5. DR	-	Study	Continue to study
6. EV	-	Study	Continue to study
7. BEMS	-	Study	Continue to study
8. HEMS	-	Study	Continue to study

(Source: JICA Survey Team)

Proposed projects based on COPEL's needs and evaluation results are of DAS/DMS, Protection relay for earth fault and AMI.

DAS/DMS and protection relay for earth fault is recommended for application to the Curitiba Metropolitan Area (23 cities) and Curitiba City.

Smart meter for AMI is recommended to apply to 30% of residential customers in Curitiba City based on the following discussion.

- It is risky as first application to install the smart meter to more than 50% of customers

- The pilot project has been implemented in Fazenda Rio Grande, so that less than 10% of customers with access to a smart meter mean the same trial level as the pilot project.

- The preferred percentage of customers in the project is 20% to 30%, therefore 30% will be decided upon in order to increase effectiveness

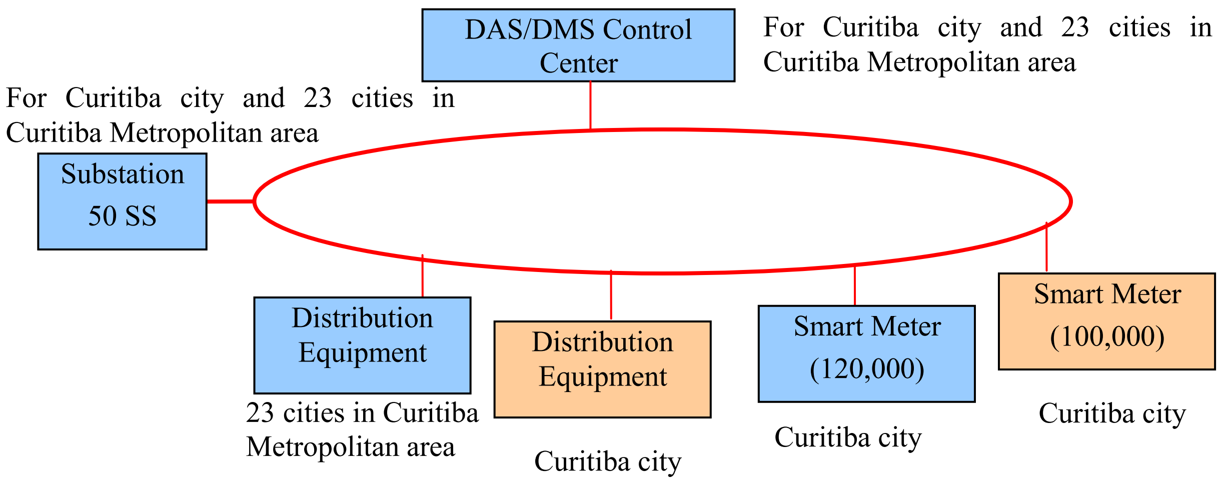


Figure 5.3-1 Concept of Proposed Projects

(Source: JICA Survey Team)

Chapter6 Overview of Smart Grid Project

6.1 Basic Information

6.1.1 Selection Process and Result for Project Area

At the outset of the study, according to the Minutes of Meetings on "the Preparatory Survey on Introduction of Smart Grid Project in Curitiba Metropolitan Area" agreed between JICA and COPEL in October 2012, the target area was defined as 23 municipalities in Curitiba Metropolitan Area (Região Metropolitana de Curitiba)[1], excluding Curitiba, Fazenda Rio Grande, and Campo Largo.

During the first survey by the JICA Survey Team in February 2013, the team reviewed socio-economic and electricity indicators and suggested the scenario to start with 10 municipalities; DAS/DMS and Relay for 10 municipalities, models SAS and EMS/ renewable power/ battery, AMI, power-charge network of Electric Vehicle (EV), BEMS, and HEMS in some municipalities in the Curitiba Metropolitan Area, and then in the future all these components are expected to expand in other areas.

Comments of the COPEL in March 2013 to the team's suggestion were as follows.

- All the 23 municipalities are the target for DAS/DMS (and protection relay) at once.
- AMI for large consumers and SAS, EMS, BEMS and HEMS components are excluded from the Project components.

Based on the request of COPEL, the team and COPEL discussed the matter of project area during the second trip of the team to Brazil in April 2013 and determined below.

- ◆ Target area of DAS/DMS component: Curitiba City where the distribution control center is located and 23 municipalities where distribution equipment including protection relays is installed.
- ◆ Target of the AMI pilot project for low voltage consumers is Curitiba City.

Thus, the project target area is finally defined as **23 municipalities and Curitiba City**.

6.1.2 Basic Information

Summary of socio-economic and electricity data of the project target area, i.e., Curitiba City and 23 municipalities, are shown in Table 6.1-1.

[1] The Curitiba Metropolitan Area is currently defined as 29 municipalities by "Lei Estadual nº 139/2011"; however, three municipalities, Campo do Tenente, Rio Negro, and Piên, are also excluded in the Minutes of Meetings between JICA and COPEL in October 2012. Therefore, for this survey, 23 municipalities in total are targeted.

Table 6.1-1 Socio-economic and Electricity Indicators of Project Target Municipalities in Curitiba Metropolitan Area

	Socio-Economic Indicators									Electricity Indicators (Quantity ・Quality・Financial Cost)									
Municipalities 1)	Total Population	Urban Population	Rural Population	Area (Km²)	Population Density (habitants/Km²)	Distance to Capital (km)	GDP/capita (R$)	No. of Establishments 2)	Investment Amount 3) (Million R$)	No.of sales office	No.of Sub station	No. of Consumers	Electricity Consumption (MWH)	SAIFI (FIC) (No./Year per consumer)	SAIDI(DIC) (Hour/Year per consumer)	No. of Penalties (SAIFI,SAIDI)	Penalty (R$) (SAIFI, SAIDI)	Penalty (R$) (Voltege Drop)
1 Adrianópolis	6,376	2,060	4,316	1,341.33	4.68	134.90	9,860	71	340.00	0	1	2,254	4,842	43.03	26.29	2,893	22,299	—
2 Agudos do Sul	8,270	2,822	5,448	191.82	44.07	73.50	6,039	132	-	0	1	3,165	8,039	38.17	57.47	5,858	17,531	—
3 Almirante Tamandaré	103,204	98,892	4,312	191.11	551.81	15.15	5,926	1,088	-	1	1	32,516	135,275	16.52	29.30	10,490	78,551	24,798
4 Araucária	119,123	110,205	8,918	471.38	260.70	28.60	101,411	2,327	-	1	2	44,152	401,101	11.04	17.11	49,100	158,497	5
5 Balsa Nova	11,300	6,870	4,430	344.19	33.52	49.73	23,717	254	-	0	1	4,837	43,461	16.45	25.91	1,315	4,260	—
6 Bocaiúva do Sul	10,987	5,128	5,859	825.76	13.66	41.60	8,433	180	-	0	1	4,570	17,484	25.85	31.77	9,357	33,519	—
7 Campina Grande do Sul	38,769	31,961	6,808	540.63	72.89	32.24	12,876	688	15.00	0	1	15,566	80,824	18.88	49.68	16,485	72,367	—
10 Campo Magro	24,843	19,547	5,296	278.22	91.70	19.00	7,483	335	-	0	0	8,189	26,457	19.86	27.99	19,099	40,630	—
11 Cerro Azul	16,938	4,808	12,130	1,341.32	12.69	84.56	9,772	192	-	0	1	5,870	10,892	34.31	72.71	7,712	12,469	—
12 Colombo	212,967	203,203	9,764	197.81	1,099.28	17.30	7,547	3,474	-	1	2	73,728	345,686	12.17	15.45	79,683	155,793	1,269
13 Contenda	15,891	9,231	6,660	300.57	54.20	49.00	9,384	224	-	0	1	5,751	19,465	12.28	17.87	3,457	6,476	—
14 Curitiba	1,751,907	1,751,907	-	435.50	4,079.87	-	24,720	58,833	1.62	7	22	744,070	4,158,448	5.91	7.81	427,533	1,264,211	2,735
15 Doutor Ulysses	5,727	929	4,798	787.32	7.22	131.45	13,662	48	-	0	0	2,059	2,648	-	-	-	-	—
17 Itaperuçu	23,887	19,956	3,931	320.16	76.75	30.76	7,418	357	-	0	0	7,803	28,419	15.89	20.63	1,097	3,318	—
18 Lapa	44,932	27,222	17,710	2,097.75	21.61	72.10	13,840	987	210.00	0	2	16,379	100,585	19.26	30.62	11,868	35,293	—
19 Mandirituba	22,220	7,414	14,806	381.39	60.11	45.70	10,044	597	-	0	2	8,633	47,298	23.91	31.22	15,280	51,526	—
21 Pinhais	117,008	117,008	-	61.14	1,952.65	8.90	20,129	3,181	-	1	1	43,461	303,192	8.74	11.46	52,692	116,006	418
22 Piraquara	93,207	45,738	47,469	225.22	426.35	22.52	5,489	754	-	1	1	26,224	85,363	16.31	25.97	27,495	69,967	2,287
23 Quatro Barras	19,851	17,941	1,910	181.27	112.59	25.10	27,510	412	4.30	1	1	7,394	88,723	11.53	18.02	14,652	68,672	425
24 Quitandinha	17,089	4,887	12,202	446.40	38.90	71.10	6,973	212	-	0	1	6,380	17,769	21.88	39.72	8,389	22,663	—
25 Rio Branco do Sul	30,650	22,045	8,605	816.71	37.77	28.36	16,613	423	625.00	1	1	10,797	469,569	32.44	91.81	24,219	82,024	688
27 São José dos Pinhais	264,210	236,895	27,315	944.28	289.38	18.60	41,217	5,965	1.54	1	4	99,551	973,207	10.37	17.09	100,014	270,844	481
28 Tijucas do Sul	14,537	2,285	12,252	671.93	22.15	67.10	10,944	292	-	0	1	6,125	18,100	14.98	22.98	3,284	12,637	—
29 Tunas do Paraná	6,256	2,792	3,464	671.71	9.91	79.21	10,162	115	-	0	2	2,196	14,414	30.71	76.55	9,554	50,263	—
Total Area	**2,980,149**	**2,751,746**	**228,403**	**14,064.91**	**211.89**	**–**	**–**	**81,141**	**1,197.46**	**15**	**50**	**1,181,670**	**7,401,261**	**20.02**	**33.28**	**972,115**	**2,854,918**	**33,116**

Source: Population Statistics-IBGE "Census 2010", Area-ITCG, Population Density and Poverty Rate (2010)、GDP per Capita (2009)-IBGE/IPARDES, NO. of Establishements-RAIS(2011), Investment Amount - Secretaria de Estado do Planejament e Coordenação Geral, and Electricity Indicators -COPEL(2012).

Note: 1) Numbering of municipalities is in accordance with Figure 2.9-1

2) Business entities, such as shops, companies, the agriculture farm

3)Commitment investment amount in two years under the Parana State government investment incentive program (Parana Competitivo), as of 12/2012.

(Source: JICA Survey team)

TEPSCO TEPCO

6.2 Plan of the projects

6.2.1 Needs of the project

Needs of COPEL in this project are as follows.

1) Power reliability is inadequate, especially outage duration (SAIDI) resulting in monetary penalties and reduced income by power supply. Therefore, COPEL's needs are to improve economical profits and contribute to customer's satisfaction.

2) Voltage drop and power factor are inadequate, especially in the Curitiba Metropolitan Area due to long distance of overhead network. COPEL wants to improve the power quality.

3) SCADA to monitor/control substations has been applied for, for more than 10 years and the capacity does not have enough margins. In addition, the operators have to monitor/control many facilities which increase year by year. COPEL wants to replace the existing SCADA to new SCADA with larger capacity and better functions.

4) The existing earth fault protection relay in substations cannot detect earth fault with high impedance due to delta connection which means the current of earth fault is small. COPEL wants to apply more reliable protection relays.

5) COPEL wants to advance labor saving in order to improve company's profit.

6) Distribution loss in COPEL is lower than other power companies in Brazil; however the loss can still be improved upon, thus increasing economical profits of COPEL.

This project can help contribute and solve the problems to satisfy the needs of COPEL.

6.2.2 Outline of the project / System

1) The whole system

The whole system of the project recommended by the survey team is shown in Figure 6.2-1.

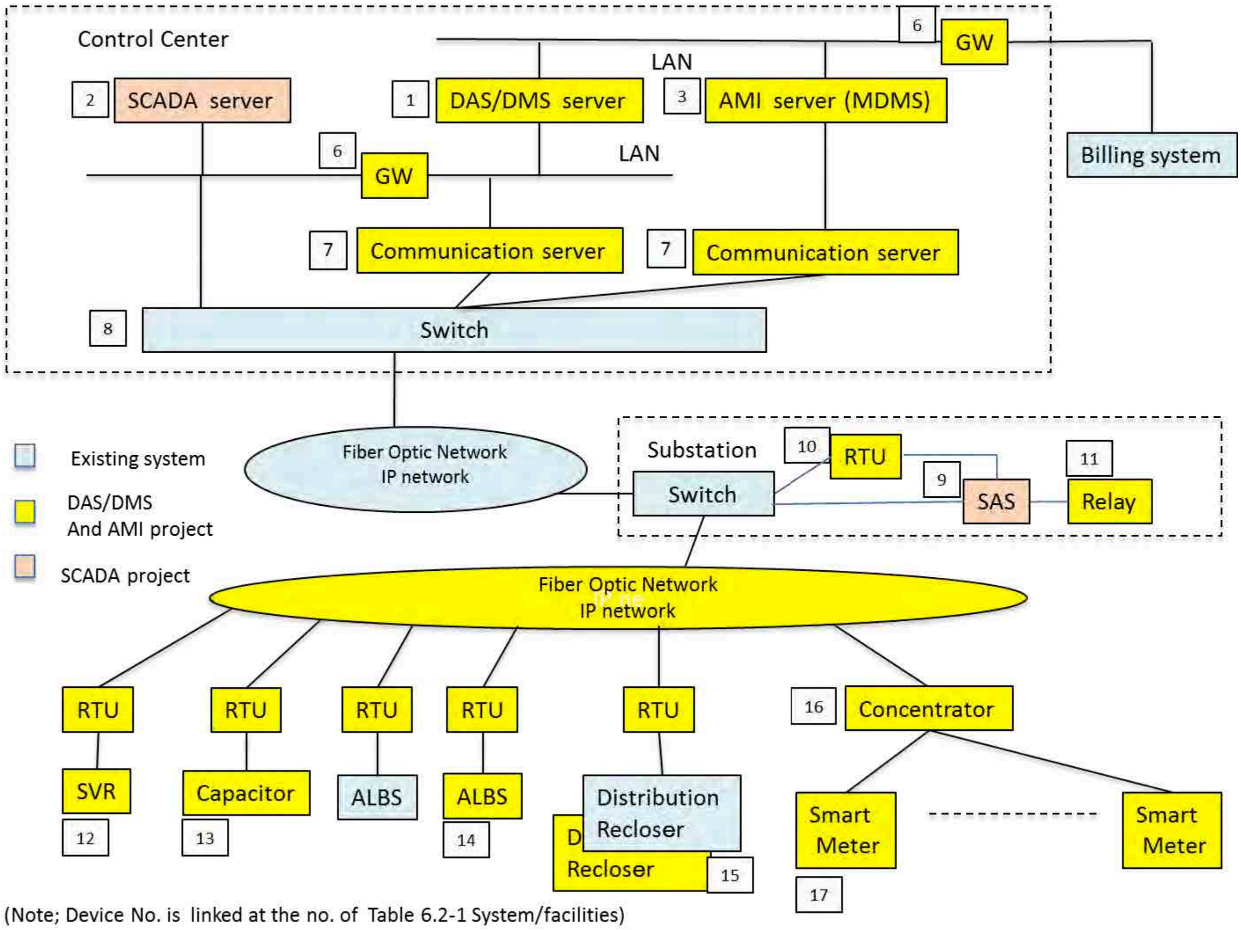


Figure 6.2-1 The whole system

(Source: JICA Survey Team)

The concept of the system is as follows.

(1) DAS/ DMS will monitor and control the distribution network including 13.8kV feeders of the substation in Curitiba City and the Curitiba Metropolitan Area (SDC Central).

(2) DAS/ DMS can be interfaced with SCADA installed in the same control center by using international protocol and GW on LAN.

(3) DAS/ DMS can expand the managed area from not only SDC Central but also to 4 regions (SDL Leste / SDT North / SDN Noroeste/ SDO Oeste).

(4) The existing equipment such as reclosers, LBS, etc., will be utilized as much as possible based on the detailed survey and design.

2) Scope

The scope of the project proposed by the JICA Survey Team is shown in system / facilities colored yellow in Figure 6.2-2. The number of equipment described in Figure 6.2-2 means the same as the number of Table 6.2-1.

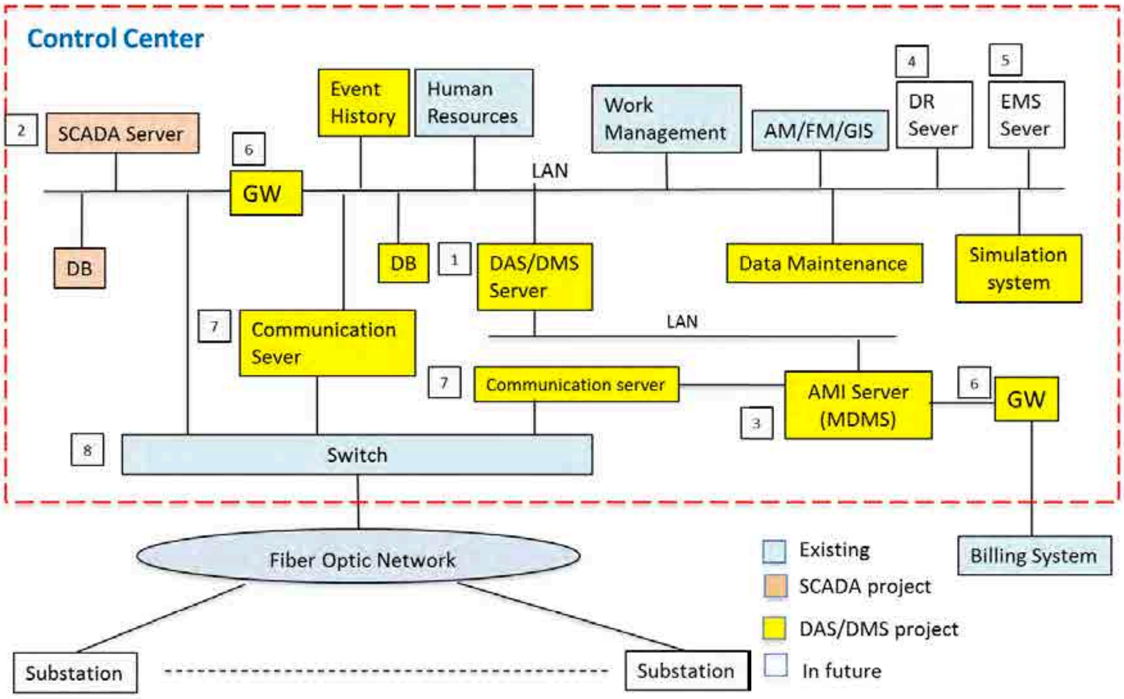


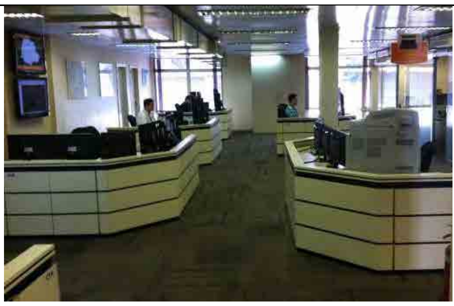
Figure 6.2-2 Control Center Facilities

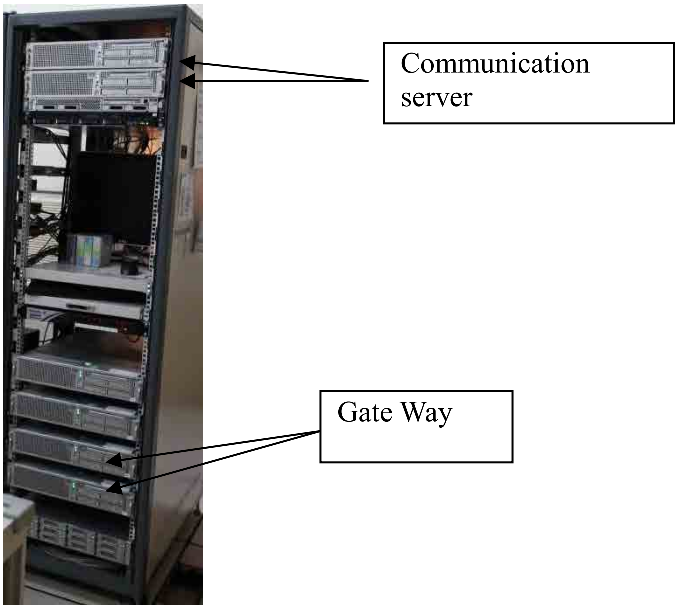
(Source: JICA Survey Team)

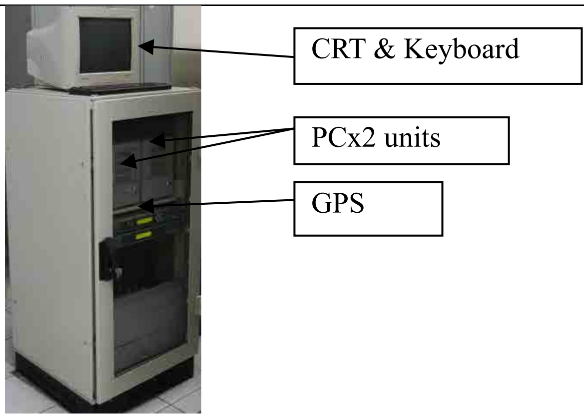
The major role of system and facilities is explained as shown in Table 6.2-1.

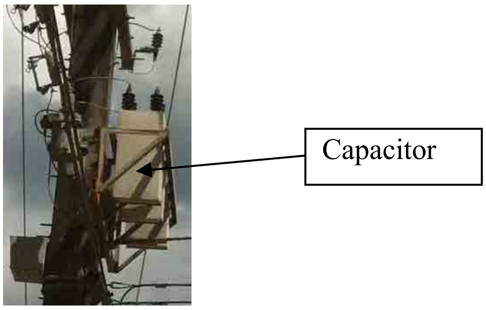
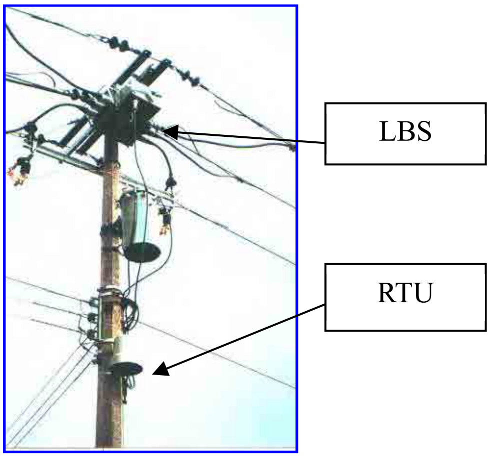
Table 6.2-1 Explanation of system and facility for the project

System / facilities	Explanation
1.DAS / DMS (Distribution Automation System / Distribution Management System)	DAS / DMS will control and monitor the distribution network mainly in order to improve the reliability of power supply. 
2.SCADA (Supervisory Control And Data Acquisition)	SCADA will control and monitor the transmission network and the substation mainly.

	
3.AMI (Automated Metering Infrastructure)	AMI server can calculate power consumption of customers based on smart meter's data. The calculated data will be sent to the existing billing system. 
4.DR (Demand Response)	DR server will be installed in the existing control center and can control the smart meters installed for AMI in order to cut the load in peak condition.  DR Terminal
5.EMS (Energy Management System)	EMS server can manage renewable energy (PV, etc.) and batteries in order to enable them to connect to the distribution network. 
6.GW (Gate Way)	The main function of GW is to exchange the protocol, so that the data-link between SCADA and DAS/DMS can be smoothly implemented.

	
7.Communication server	The major function of communication server is to carry out the interface between application server (DAS/DMS, AMI, etc.) and communication unit in order to divide the data gathered from M-RTU exactly. 
8.Switch	The existing communication units are of SDH (Synchronous Digital Hierarchy) and Layer 2 Switch which means high speed communication method. 
9.SAS (Substation Automation system)	SAS can monitor/measure/control all the data in substations through LAN and international protocol. The interface between SAS and the communication unit is easily available.

	
10.RTU (Substation for Remote Terminal Unit)	RTU receive data of SAS in the substation and send to control center through the communication switch . Refer to Table 6.3.3-1. 
11.Protection relay	Protection relays to detect earth fault precisely will be installed to each 13.8kV feeder at substation instead of the existing relays. Refer to Table 6.3.3-1. 

12.SVR (Step Voltage Regulator)	 SVR can compensate voltage-drop at distribution feeder by tap-change.
13.Capacitor	Power factor of distribution feeder is normally lagging due to the inductive load, especially overhead network. The power factor can be improved by installing the capacitors at a substation and on a distribution feeder. 
14.LBS (Load Break Switch) RTU (Remote Terminal Unit)	LBS can break load current. Automatic LBS can connect to RTU on the pole. Switch-power-supply and surge arrester are also installed on the pole. 
15.Recloser	Recloser can break fault current and re-close automatically in order to isolate the faulty section of the load side. Recloser is installed on pole and consists of breaker, CVT and protection relays in it. 
16.Concentrator	Concentrator can collect data from lots of smart meters and send them to Control center through optical fiber.

17.SM (Smart Meter)	A smart meter is an electronic watt-hour meter providing communication interface to transmit the data to the control center (AMI server).	

3) Analysis of necessary quantity

The necessary quantity of ALBS with RTU is calculated as follows based on the recommended network in 6.3.1 and Figure 6.2-3 / 6.2-4.

- In case of Curitiba city: 3 ALBS for main feeder + 3 ALBS for connection point = 4.5 ALBS/feeder

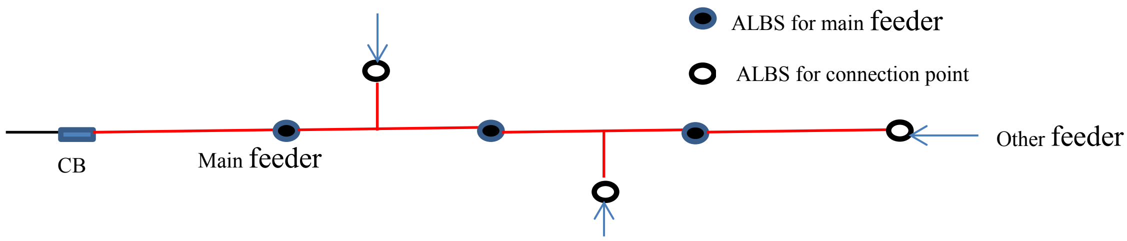


Figure 6.2-3 Arrangement of ALBS in distribution feeder in Curitiba city

- In case of Curitiba Metropolitan area:

  5 ALBS for main feeder + 3 ALBS for connection point = 6.5 ALBS/feeder

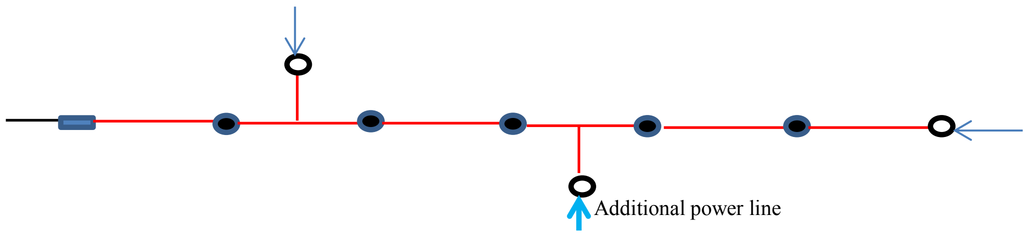


Figure 6.2-4 Arrangement of ALBS in distribution feeder in Curitiba Metropolitan area

Optical fiber is needed in Curitiba metropolitan area with the length required being the same as the length of main feeder. It is not necessary to install optical fiber in Curitiba city due to the utilization of the existing fiber.

Additional power line for connection point is planned as follows.

- In case of Curitiba city: no need because 3 connection points have been installed.
- In case of Curitiba metropolitan area: 3km/feeder is needed based on network design explained

before (6km/connection point is needed. 6km x 1/2 = 3km/feeder. There are 2 existing connection points in Curitiba Metropolitan area, so that one point has to be constructed and the length is 3 km.)

Capacitor bank and SVR is not needed in Curitiba city due to good power quality but the equipment is needed in Curitiba Metropolitan area with the required quantity planned as 1 unit / feeder.

The number of substations and facilities / equipment in Curitiba City and the metropolitan area is summarized as shown in Table 6.2-2.

Table6.2-2 Number of facility and equipment for each city in Curitiba area

	S/S	Feeder	RTU for Substation	Optical Fiber cable (Km)	Distribution line (OH Km)		O.H (ALBS+RTU)		Recloser		SVR		Capacitor Bank	
				additional	existing	additional	existing	additional	existing	Additional RTU	existing	additional	existing	additional
Adrianopolis	1	1	1	6.3	2.8	3	0	7	6	6	0	1	0	1
Agudos do sul	1	2	1	28.6	26.5	6	0	13	7	7	0	2	0	2
Almirante Tamandare	1	4	1	68.1	410	12	0	26	7	7	3	4	3	4
Araucaria	2	17	2	294.6	785	51	0	111	20	20	5	17	6	17
Balsa Nova	1	2	1	44.3	171	6	0	13	6	6	0	2	0	2
Bocaiuva Do Sul	1	2	1	61.2	180	6	0	13	4	4	0	2	0	2
Campina Grande Do Sul	1	3	1	91.5	356	9	0	20	9	9	4	3	1	3
Campo Magro	0	0	0	0	133	0	0	0	2	2	0	0	0	0
Cerro Azul	1	3	1	79.4	552	9	0	20	6	6	4	3	0	3
Colombo	1	9	1	163.3	501	27	0	59	16	16	6	9	6	9
Contenda	1	2	1	56.2	521	6	0	13	7	7	3	2	0	2
Curitiba	22	215	22	1073.4	3655	0	400	968	97	97	5	0	154	0
Doutor Ulysses	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Itaperucu	0	0	0	0	83	0	0	0	1	1	0	0	0	0
Lapa	2	9	2	284.7	1431	27	0	59	14	14	10	9	1	9
Mandirituba	2	8	2	308.9	654	24	0	52	9	9	5	8	0	8
Pinhais	1	3	1	102	665	9	0	20	7	7	1	3	11	3
Piraquara	1	6	1	91.3	286	18	0	39	10	10	1	6	3	6
Quatro Barras	1	7	1	120.2	283	21	0	46	13	13	2	7	5	7
Quitandinha	1	3	1	125.4	490	9	0	20	7	7	2	3	0	3
Rio Branco Do sul	1	3	1	136	175	9	0	20	12	12	9	3	2	3
Sao Jose Dos Pinhais	4	32	4	598.1	1146	96	0	208	55	55	8	32	14	32
Tijucas Do Sul	1	2	1	49.4	269	6	0	13	5	5	2	2	0	2
Tunas Do Parana	2	2	2	339.1	260	6	0	13	7	7	0	2	1	2
Total No.	50	335	50	4122	13273.8	360	400	1753	528	528	70	120	207	120
				*3	*2		*1		*5		*4		*4	

(Note) *1. ALBS with RTU; Curitiba City=4.5Units/Feeder, and Metropolitan Area=6.5Units/Feeder
*2. Optical Cable; the length =Main Feeder line length (Km)
*3. Additional Power line; Curitiba City=1Km/Feeder and Metropolitan Area=6Km/Feeder
*4. Capacitor Bank and SVR; Curitiba City=0 and Metropolitan Area=1/Feeder
*5. Recloser; Existing units

(Source: JICA Survey team)

Based on the above mentioned explanation, the scope and quantity of the recommended project is summarized as shown in Table 6.2-3.

Table6.2-3 Scope and quantity of recommended project

System / facilities	Quantity
DAS / DMS	1 system (Dual system)
AMI	1 system (Dual system)
RTU for Substation	50 sets
Protection relay and the adaptation work	50 sets
RTU	1,753 units
SVR	120 units
Capacitor	120 units
LBS	1,753 units
RTU for existing Recloser	528 units
Concentrator	2,200 units*
SM	220,000 units
OH distribution line (for loop)	360 km
Optical fiber	4122 km

*1 Concentrator is needed for 100 SMs based on experience.

(Source: JICA Survey team)

6.2.3 Consulting service

The following experts consulted for this project are required due to the first project in COPEL in order to achieve smooth construction/operation.

1) International engineer

- Project manager/Smart grid engineer
- DAS/DMS engineer
- Communication engineer
- Electrical engineer (Distribution Equipment)
- Electrical engineer (Substation and protection relay)
- Distribution network engineer
- AMI/Smart meter engineer

2) Local staff/engineer

Local staff/engineers are also needed to support the foreign engineer and carry out smooth conversation in Portuguese.

The engineering consultant that will be selected will execute mainly the works below:

- Implement the basic design for Control center of DAS/DMS and the function
- Implement the basic design for communication network and the method to communicate among control center, RTU, Concentrator and Smart meter.
- Implement the basic/detail designs for substation facilities including protection relay which can detect earth fault on delta connection transformer with reactance grounding.
- Implementing the basic and detail design for electrical equipment such as RTU, ALBS, SVR, Capacitor control and so on.
- Implement the basic design for the distribution network to install new ALBS and construct connection line.
- Implement the basic design for AMI system and the Smart meter/Concentrator.
- Provide the tender documents for Smart grid project.
- Implement the evaluation of tender and report the results to COPEL
- Support to the client in the scope of procurement of goods, services and works
- Control and supervision of the works to guarantee the conformity with the requirements of the contract.
- Support the client on works acceptance.
- Monitoring and approval of the implementation of environmental and social measures.
- Arrange the technical training for COPEL

The engineering schedule is attached in Appendix 6-1. For project organization, refer to attached information in Chapter 7 Clause 7.3

6.3 Basic Design

6.3.1 Distribution Network

1) Network Configuration (Sectionalization)

Network configuration in the Curitiba Metropolitan Area, specifically in urban area (Curitiba City), has a looped and sectionalized system, which can connect with adjacent feeders. However, most of LBS at connecting points with adjacent feeder are manual at present. Therefore, the network configuration in urban area (Curitiba City) has issues with regards to length of time taken to locate fault points and restore the distribution line isolating a faulted area according to operating duty of LBS. On the other hand, regarding the distribution network in suburban areas (other areas than Curitiba City: 23

Municipalities), although looped system with manual LBS is adopted in some areas close to substations, most of the network configuration in suburban areas (other areas than Curitiba City: 23 Municipalities) are a radial system.

In order to make an effective operation of DAS (Distribution Automation System), it would be very important to adopt Automatic Load Break Switch (ALBS) in the network configuration. The load current should be examined and balanced in each section of the network configuration providing the looped points effectively. However, in COPEL distribution system such an effective looped point system has not been established.

Therefore, the examination of the load current balance and the construction of looped points will be focused on in this study. As mentioned above, since the network configuration of urban area (Curitiba city) in the Curitiba metropolitan area is considerably different from the suburban areas (other areas than Curitiba city: 23 Municipalities), both areas will be examined respectively in order to find the most suitable network configuration in the Project for each area.

In addition, the network configuration suited for the future demand for the next 10 years is considered based on the assumption that the electricity demand grows 4~6% per year adopted in 2.4.2 Present Situation and Forecast of Demand and Supply in Curitiba Metropolitan Area. (Urban Area (Curitiba City): 4%, Suburban Area (Other Areas than Curitiba City: 23 Municipalities: 6%)

●**Urban Area (Curitiba City)**

Table 6.3.1-1 describes the characteristics of distribution system in the urban area (Curitiba City) analyzed based on COPEL’s answer to the team’s questionnaire. The network composition in the Project will be considered based on the existing network configuration which has 642 looped points in total and 3 looped points in each feeder on average, and saving installation cost, the existing network configuration and distribution facilities will be utilized as much as possible.

Table 6.3.1-1 Characteristics of Distribution System in Curitiba City

No. of SS	No. of Feeders	1 Feeder Average Length (km)	Average Peak Deamd (kW)	Average Maximum Current (A)	Average Voltage Drop (%)	Allowable Voltage Drop in Operation (%)	Outage Duration (Hours)	Average power Factor	No. of Looped points	Average Looped points in 1 Feeder
22	215	17	4,499	200	2.19	7.00	7.81	0.94	642	3.0

* Appendix 6-1 shows typical network configuration in the urban area as one of the references.

(Source: Created by JICA Survey Team based on COPEL answer)

Table 6.3.1-2 Transition of Current in Curitiba City

	Average Maximum Current (A)	Increasing Rate (%)
2012	200	—
2013	212	6
2014	225	6
2015	238	6
2016	252	6
2017	268	6
2018	284	6
2019	301	6
2020	319	6
2021	338	6
2022	358	6

(Source: Created by JICA Study Team)

Although there are 2 basic distribution facilities such as distribution line and Feeder Circuit Breaker (FCB) for the examination of network configuration here, FCB is selected in this study, because the FCB of same current capacity is used on the distribution feeder, on which different load current flows.

The current capacity of FCB of COPEL is 600A. Based on this current capacity, permissible current on one feeder is calculated to 480A as shown in the following formula considering the safety margin during the load current on a faulted line is divided into adjacent feeders.

FCB600A (Capacity) x 80% (Safety Margin) = 480A

On the other hand, the maximum average current of feeders in 2012 is 358A, as described in Table 6.3.1-2, therefore the additional loading current in one feeder to reinforce adjacent feeder at the time of power failure will be approximately 98A (480A-358A=122Ax80%). Accordingly, the maximum current in one of the divided sections in adjacent feeder should be less than 98A.

Considering the minimum SAIDI, it is desirable to minimize power outage area as much as possible. It is necessary to be interconnected to at least three adjacent feeders (270A / 98A = 2.8 times) to share the required load current by all non-fault sections, because the remaining capacity of one adjacent feeder is 98A and total required capacity is 270A (358A/4 sections x 3 sections) without the fault section.

From the above analysis, we conclude that the most suitable network configuration in the Project in the urban area (Curitiba City) should be “4 Sections with 3 Looped Points” as shown in Figure 6.3.1-1.

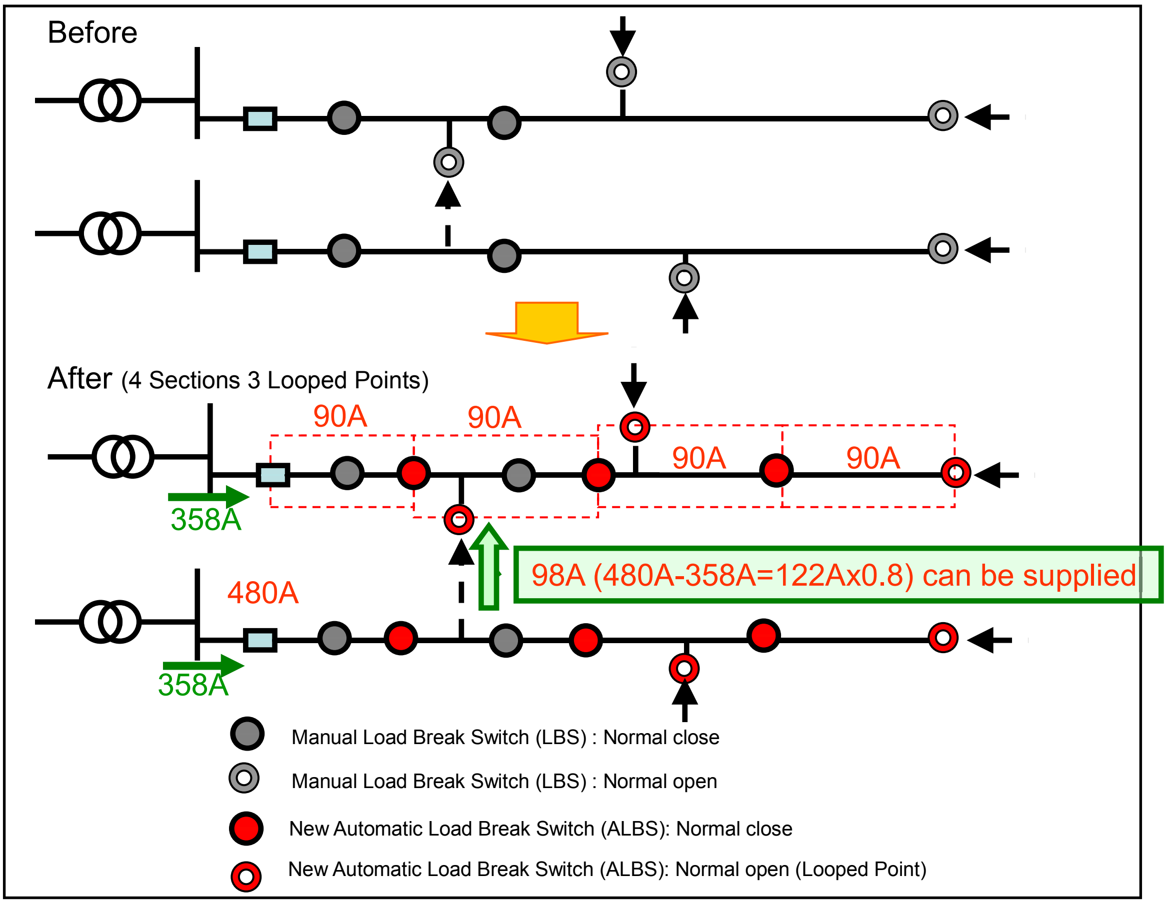


Figure 6.3.1-1 Overview of 4 Sections with 3 Looped Points

(Source: JICA Survey Team)

The effect by the minimizing power outage duration by the network configuration of so called "4 sections 3 looped points" is that power outage duration will be shortened to approximately 2 hours (25% of previous outage duration), because restoration in 3 of the 4 divided sections will be energized immediately compared with previous condition before installing ALBS .

●**Suburban Areas (Areas other than Curitiba City: 23 Municipalities)**

Table 6.3.1-3 describes the characteristics of the distribution system in the suburban areas (areas other than Curitiba City: 23 Municipalities) analyzed based on COPEL's answer to the questionnaire. The 2 remarkable characteristics of the suburban areas are that power outage duration and feeder average length is long. The long power outage duration means it takes a long time to locate and recover fault point. Also, the long feeder, results in longer duration of allocating fault point. Installing DAS (Distribution Automation System) into the area with such characteristics will greatly shorten the duration to detect the fault point, so that this will be the main focus of the examination on the network configuration of this area in the Project.

The improvement method to shorten the duration of locating failure point is effective setting of ALBS (Automatic Load Break Switch), that is to say effective network configuration by ALBS (Automatic Load Break Switch). Besides, the most suitable number of sections of 1 feeder will be examined according to the distribution system characteristics in the suburban areas (areas other than Curitiba City: 23 Municipalities), because the number of sections on one feeder affects the reduction of power outage duration as mentioned above.

Table 6.3.1-3 Characteristics of Distribution System in Suburban Areas (23 Municipalities)

No. of SS	No. of Feeders	1 Feeder Average Length (km)	Average Peak Deamd (kW)	Average Maximum Current (A)	Average Voltage Drop (%)	Allowable Voltage Drop in Operation (%)	Outage Duration (Hours)	Average power Factor	No. of Looped points	Average Looped points in 1 Feeder
28	120	103	3,551	163	4.50	7.00	33.81	0.91	298	2.4

* Appendix 6-2 shows typical network configuration in the suburban area as one of the references.

(Source: Created by JICA Survey Team based on COPEL answer)

Table 6.3.1-4 Transition of Current except Curitiba City (23 Municipalities)

	Average Maximum Current (A)	Increasing Rate (%)
2012	163	—
2013	170	4
2014	176	4
2015	183	4
2016	191	4
2017	198	4
2018*	192	4
2019	199	4
2020	207	4
2021	215	4
2022	224	4

*The year of 2018 is operation start date of the project and the improvement(0.91→0.98) by Capacitor is included.

(Source: Created by JICA Study Team)

As the target outage duration in the urban area (Curitiba City) is approximately 2 hours after installing ALBS (Automatic Load Break Switch), the amount of power loss per one section during power outage in the urban area (Curitiba city) can be calculated as follows;

【Precondition】

・The amount of power loss in all no fault sections is “0”, because the minimized power outage duration in all no fault sections after installing ALBS could be in a few minutes.

・The power outage in fault section is 2 hours.

The amount of power loss in fault section in the urban area (Curitiba city)

= 358A (Curitiba City in 2022) / 4 Sections x 2 hours = 179Ah

Assuming that the target in the suburban areas (other areas than Curitiba city: 23 Municipalities) is the same level as the amount of power loss in fault section in the urban area (Curitiba city) after installing ALBS, the network configuration in the suburban areas (other areas than Curitiba city: 23 Municipalities) needs 6 divided sections based on the following calculation.

The number of divided sections in the suburban areas (other areas than Curitiba city: 23 Municipalities) is "N",

・Current in fault section (A) : 224A (the suburban areas in 2022) / N

・Power Outage Duration (h) : 33.81h (from Table 6.3.1-3) – 33.81h x (N-1) / N

Based on the above,

The amount of power loss in fault section in the suburban areas (other areas than Curitiba city: 23 Municipalities) is

$224 / N \times (33.81 - 33.81 \times (N-1) / N) = 7{,}573 / N^2$

In case the target (the same amount of power loss in fault section between Curitiba city and 23 Municipalities) is same level,

7,573 / N2 = 179

N = 6.5

In addition, the feeder length of 1 section will be about 17.2km when it is divided in 6 sections, as the average feeder length is 103km. This would not be too long to locate the failure point and recover it in 6 hours, seeing as it is usually completed within 2~3 hours in mountainous regions of Japan where distribution lines are usually as long as dozens of kilometers. Thus, it should also be possible for COPEL if the same concept was adopted in the Project.

The number of looped points is examined based on the capacity of FCB as with the urban area (Curitiba City). However, since it will take a longer time to locate fault point and recover it due to the longer feeders compared with the urban area (Curitiba City), the duration of reinforcing to adjacent feeders will be longer compared with the urban area (Curitiba City). For this reason, the permissible current is 420A by assuming the safety margin for overload is 70% at the time of reinforcing the adjacent feeders.

FCB600A (Capacity) x 70% (Safety Margin for Overload) = 420A

The average maximum current of the feeders in the suburban areas (other areas than Curitiba city: 23 Municipalities) in 2012 is 224A as shown in Table 6.3.1-4, therefore the additional loading current in one feeder to reinforce adjacent feeders during power failure will be approximately 200A (420A – 224A) based on the current capacity of FCB.

However, a lot of the distribution lines having small permissible load current presently exist in the suburban areas (other areas than Curitiba city: 23 Municipalities), so it might be difficult to load the additional current to reinforce the faulted feeder during the fault. Therefore, the necessary number of the adjacent feeders in the network configuration of 6 divided sections is considered based on the model case in the suburban areas (other areas than Curitiba city: 23 Municipalities), which has 336MCM, 4/0AWG and 2/0AWG distribution lines in the first 2 divided sections, the middle 2 divided sections and the last 2 divided sections respectively as described in Figure 6.3.1-2.

From the result of this consideration, 255A (365Ax70%) in the middle 2 divided sections is the limitation of the reinforcing to adjacent feeders during power outage based on the consideration of the permissible current of 4/0AWG (365A) and the safety margin (70%) at the time of reinforcing to adjacent feeders. On the other hand, the passing current in the middle 2 divided sections is 149A based on the average maximum current of one feeder in the suburban areas (other areas than Curitiba city: 23 Municipalities) in 2022, so the possible reinforcing current to adjacent feeder in the middle 2 divided sections is 106A (255A-149A). Accordingly, the necessary number of the adjacent feeders in the network configuration of 6 divided sections is decided based on the possible reinforcing current (106A) in the middle 2 divided sections.

In addition, the average maximum current of one feeder in the suburban areas (other areas than Curitiba city: 23 Municipalities) is 224A in 2022 and the current of one divided section is 37.5A (224A/6sections), therefore the number of sections supplied by one adjacent feeder is 2 sections (37.5A x 2 Sections =75A < 106A), and in order to supply electricity to the first 2 divided sections and the last 2 divided sections as well, at least 3 adjacent feeders are necessary.

From the analysis above, the most suitable network configuration in the Project in the suburban areas (areas other than Curitiba City: 23 Municipalities) is “6 Sections with 3 Looped Points” which is shown in Figure 6.3.1-2.

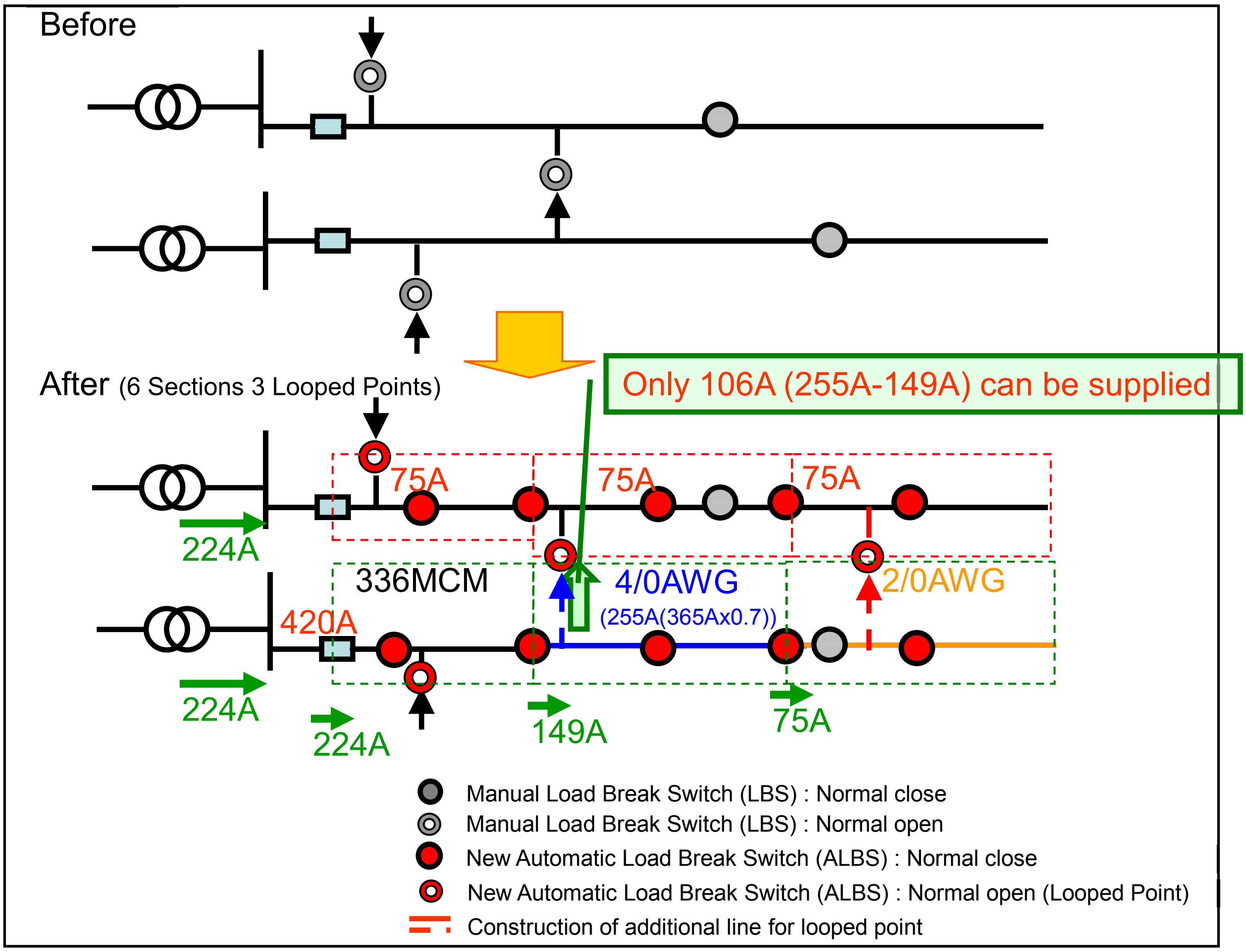


Figure 6.3.1-2 Overview of 6 Sections 3 Looped Points

(Source: JICA Survey Team)

2) Loop Formation

●Urban Area (Curitiba City)

As analyzed in 6.3.1 1) Network Configuration, the most suitable network configuration in the Project in the urban area (Curitiba City) is “4 Sections with 3 Looped Points”, and the average number of looped points in the area is 3 as shown in Table 6.3.1-1. For these reasons, it is considered most of the constructions at looped points would replace manual LBS (Load Break Switch) with ALBS (Automatic Load Break Switch).

In addition, the sizes of main distribution wires in urban area (Curitiba City) are 185mm^2 and 336MCM and their permissible load currents are 525A and 510A respectively. Based on this information, size up of distribution wire after installing DAS is examined however deemed unnecessary to size up.

Accordingly, it is not necessary to change to the bigger size of wire for additional distribution lines to make looped points in the urban area (Curitiba City).

●Suburban Areas (Other Areas than Curitiba City: 23 Municipalities)

The most suitable network configuration in the Project in the suburban areas (areas other than Curitiba City: 23 Municipalities) is “6 Sections with 3 Looped Points” analyzed in 6.3.1 1) Network Composition, and so the additional 1 looped point needs to be newly constructed, because the number of average looped points in 1 feeder in the area is 2. The distribution line needs to be extended in order to construct additional 1 looped point, and the extension length will be 3km/ feeder (6km / 2feeders) considering the number of feeders and size of the area (refer to Table 6.3.1-5).

Table 6.3.1-5 Radius in Supply Area in 1 Feeder in Suburban Areas

Total Area of 23 Municipalities	13,695 km2
No. of Feeder	123 Feeders
Supplying Area in 1 Feeder	111 km2
Radius in Supply Area in 1 Feeder	6 km

(Source: Created by JICA Survey Team based on COPEL Answer)

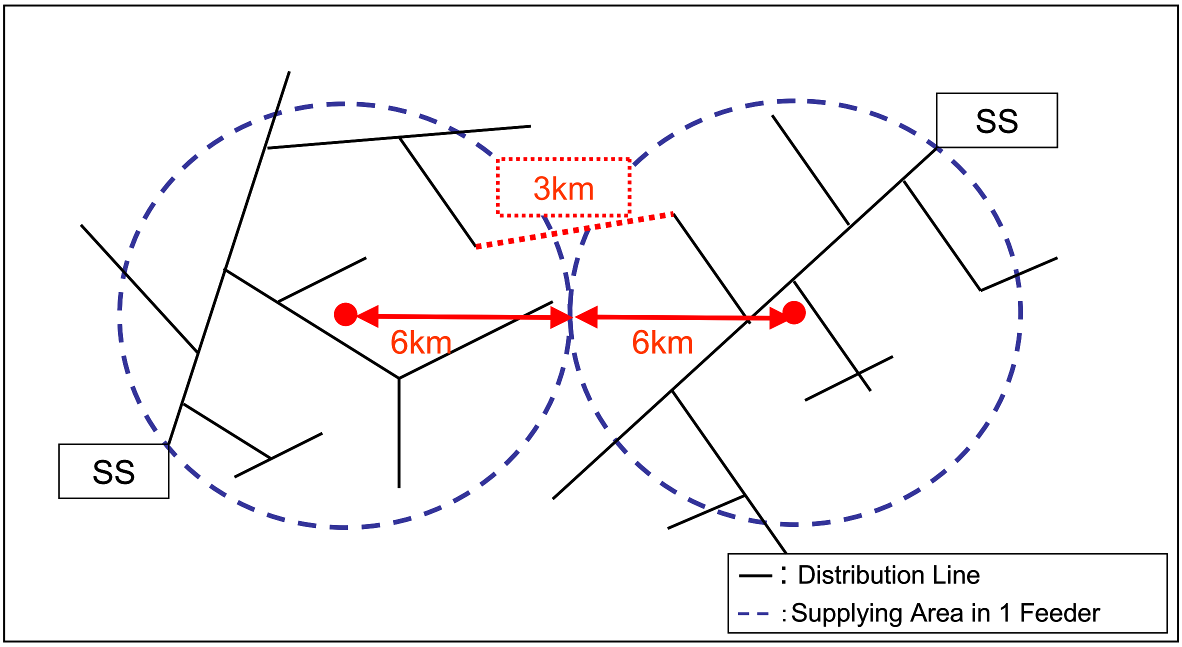


Figure 6.3.1-3 Concept Overview of Radius in Supply Area in 1 Feeder in Suburban Areas

(Source: JICA Survey Team)

6.3.2 Control Center

Control Center consists mainly of DAS/DMS server, AMI server, Communication server and communication device (LAN, Gate Way, etc.) as shown in Figure 6.3.2-1 and 6.3.2-2.

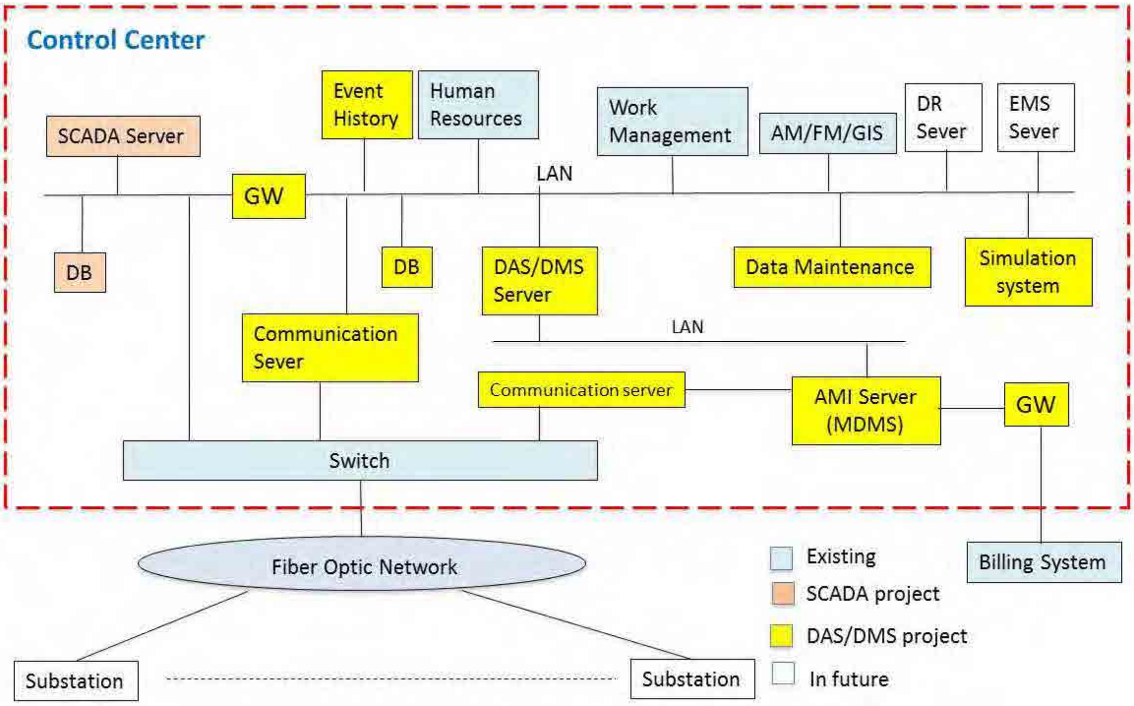


Figure 6.3.2-1 Concept of Control center

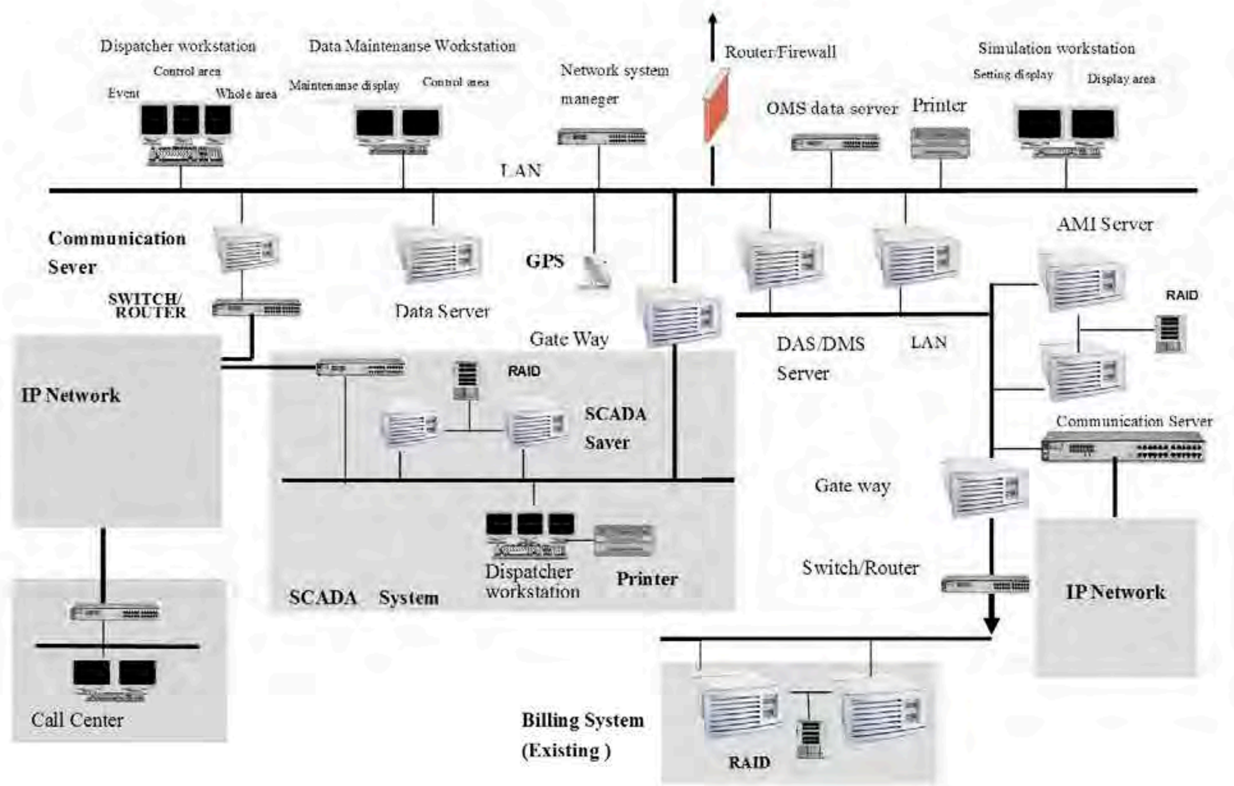


Figure 6.3.2-2 Configuration of Control Center

Map display

Distribution equipment can be monitored and controlled on this map display

Figure 6.3.2-3 Map Display

(Source: JICA Survey Team)

1) Basic Concept of DAS/DMS

- DAS/DMS will be installed in the existing operation center of Curitiba City and monitor / control distribution facilities (Substation / Automatic LBS / SVR / Capacitor for Var control / existing recloser) in 23 cities in the Curitiba Metropolitan Area and Curitiba City.

- DAS/DMS can manage 200,000 points (equipment) which consist of 20 measurements (V / I) and status data. There are 50 substations and 335 feeders in Curitiba area.

  50 x 2 banks x 20 points + 335 feeder x 10 points < 200,000 points

  Therefore, DAS / DMS can manage all the equipment in Curitiba area.

- In the future, the DAS/DMS can manage all the distribution facilities in Parana State due to enough capacity and high speed communication as shown in Figure 6.3.2-4.

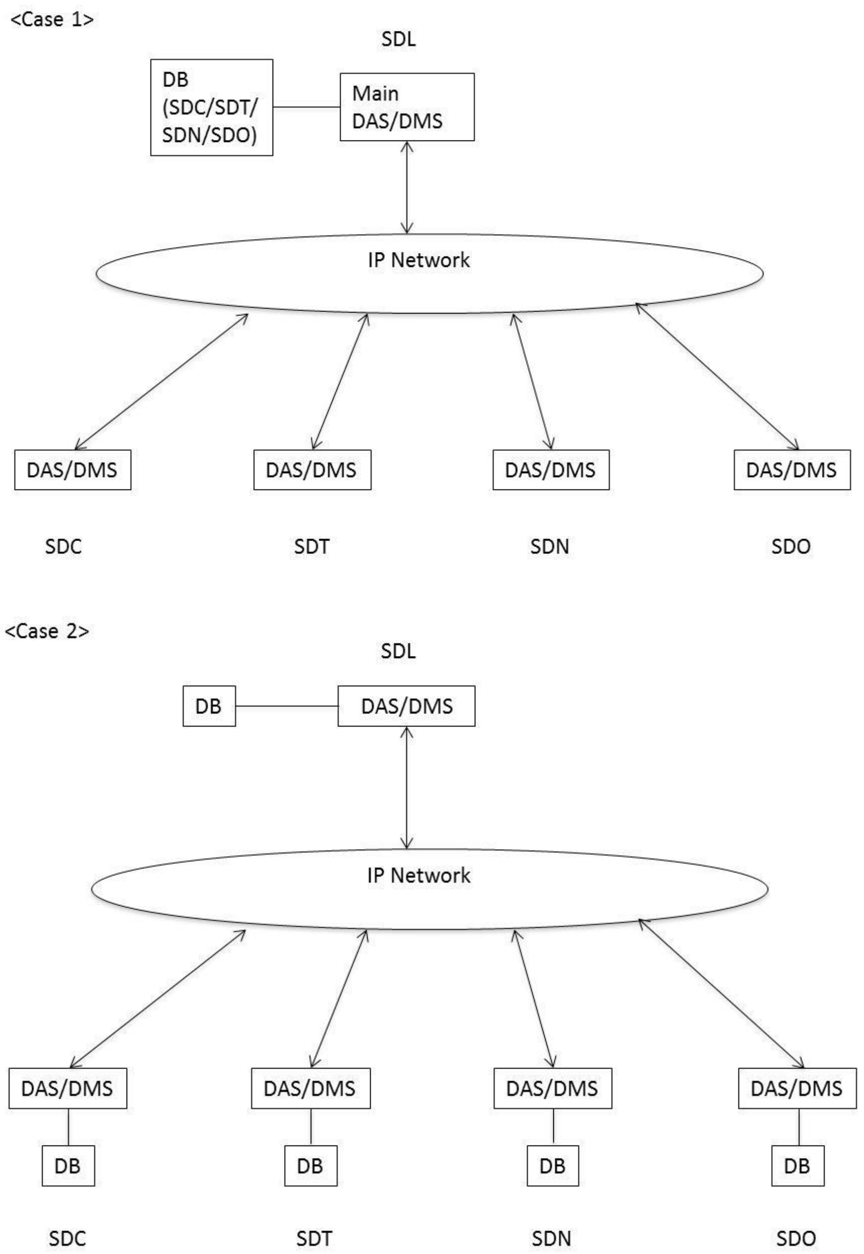


Figure 6.3.2-4 System configuration (Communication Case1 and Case2)

There are the following two cases to manage all the distribution facilities in Parana State and the comparison is shown in Table 6.3.2-1.

<Case 1>

At first, one (1) DAS/DMS with Data Base (DB) will be installed in SDL (Curitiba City area) and manage SDL as 1st stage. At the next stage, the DAS/DMS without DB will be installed to 4 branch offices (SDC / SDT / SDN / SDO) and can manage each area by receiving the data from the DB if the center of DAS / DMS in SDL cannot manage. Therefore, the investment of DAS

/DMS in branch offices can be saved.

<Case 2>

At first, one (1) DAS/DMS with DB will be installed in SDL as case 1. At the next stage, DAS/DMS with DB will be installed to 4 branch offices (SDC / SDT / SDN / SDO) and can manage the branch area easily. The DB can be stored with all the branch data, so that the DAS/DMS in 5 control centers can manage all the distribution facilities as dual system.

Table 6.3.2-1 Comparison for integrated system of control center

	1 integrated system (Case 1)	1 system / branch (Case 2)
Operation	Main DAS/DMS normally operate all the facilities in Parana State	Each DAS/DMS will operate the branch area
Multi-fault (a lots of fault happen)	Main DAS/DMS requests the branch DAS/DMS to operate and send the data to the branch DAS/DMS	Each DAS/DMS can operate the managed area by distributed treatment.
Maintenance	Easy in main DB	Revised data shall be sent to each DB
Cost	Low	High

- DAS/DMS will be installed to the control center in Curitiba and can monitor/control distribution facilities in the Curitiba Metropolitan Area including Curitiba City. SCADA also will be installed to the same control center in Curitiba City and can monitor/control distribution substations (69/13.8kV) in Curitiba metropolitan area. The DAS/DMS and SCADA will be connected by LAN in the control center as shown in Figure 6.3.2-1

2) Basic function of DAS / DMS

The function of DAS/DMS is as follows.

Table 6.3.2-2 Function of DAS/DMS

Function	Contents
1.Network Connectivity Analysis (NCA)	NCA conducts the required analyses and provides display of the feed point of various network loads. Based on the status of all the switching devices such as circuit breaker (CB), Ring Main Unit (RMU) and/or isolators that affect the topology of the network modeled, the prevailing network topology is determined. The NCA further assists the operator to know operating state of the distribution network indicating radial mode, loops and parallels in the network.
2.Switching Schedule & Safety Management	Control engineers prepare switching schedules to isolate and make a section of network safe before the work is carried out, and the DMS validates these schedules using its network model. Switching schedules can combine telecontrolled and manual (on-site) switching operations. When the required section has

	been made safe, the DMS allows a Permit To Work (PTW) document to be issued. After its cancellation when the work has been finished, the switching schedule then facilitates restoration of the normal running arrangements. The network component/connectivity model, and associated diagrams, will always be kept absolutely up to date
3.State Estimation (SE)	Providing a reliable estimate of the system voltages is mainly aimed at. This information from the state estimator flows to the control centers and database servers across the network. The variables of interest are indicative of parameters like margins to operating limits, health of equipment and required operator action. State estimators allow the calculation of these variables of interest with high confidence despite the facts that the measurements may be corrupted by noise, or could be missing or inaccurate. Even though we may not be able to directly observe the state, it can be inferred from a scan of measurements which are assumed to be synchronized. The algorithms need to allow for the fact that presence of noise might skew the measurements. In a typical power system, the State is quasi-static. The time constants are sufficiently fast so that system dynamics decay away quickly (with respect to measurement frequency). The system appears to be progressing through a sequence of static states that are driven by various parameters like changes in load profile.
4. Load Flow Application (LFA)	The load flow study usually uses simplified notations like a single-line diagram and focuses on various forms of AC power rather than voltage and current. It analyzes the power systems in normal steady-state operation
5.Volt-VAR Control (VVC)	VVC refers to the process of managing voltage levels and reactive power (VAR) throughout the power distribution systems. There could be loads that contain reactive components like capacitors and inductors (such as electric motors) that put additional strain on the grid. This is because the reactive portion of these loads causes them to draw more current than an otherwise comparable resistive load would draw. The erratic current results in both over-voltage/under-voltage violations as well as heating up of equipment like transformers, conductors, etc. which might even need resizing to carry the total current. A power system needs to control it by scheming the production, absorption and flow of reactive power at all levels in the system. A VVC application shall help the operator to mitigate such conditions by suggesting required action plans.
6.Load shedding Application	Distribution load shedding and restoration will be implemented due to bank/substation fault and peak deficits.
7.Fault Management & System Restoration (FMSR)	The DAS/DMS application receives faults information from the RTU in substation and processes the same for identification of faults and on running switching management application; the results are converted to action plans by the applications. The action plan includes switching ON/OFF the automatic load break switches (LBS).The action plan can be verified in study

	mode provided by the functionality. The automatic switching without the study can also be implemented due to operator request. When power is supplied to the load side of the faulty section, the automatic switching procedure to consider avoiding overload and voltage-drop can be implemented.
8.Load Balancing via Feeder Reconfiguration (LBFR)	To balance the loads on a network, the operator re-roots the loads to other parts of the network. A Feeder Load Management (FLM) is necessary to allow you to manage energy delivery in the electric distribution system and identify problem areas. A Feeder Load Management monitors the vital signs of the distribution system and identifies areas of concern so that the distribution operator is forewarned and can efficiently focus attention where it is most needed. Feeder Reconfiguration is also used for loss minimization
9.Distribution Load Forecasting (DLF)	Distribution Load Forecasting (DLF) provides a structured interface for creating, managing and analyzing load forecasts. Accurate models for electric power load forecasting are essential to the operation and planning of a utility company. DLF helps an electric utility to make important decisions including decisions on purchasing electric power, load switching, as well as infrastructure development.
10.Outage Management System (OMS)	OMS can implement Fault Detection, Isolation and Restoration (FDIR) function automatically. There are two fault detection methods which mean Voltage and Current sensing. OMS can implement the two methods in accordance with a request of Power Utility. Current sensing means the method to detect the faulty current and judge the faulty section by server and/or operator. Voltage sensing means the method to detect the faulty section by applying the distribution power (voltage). The faulty section can be automatically detected based on ON/OFF of feeder CB in substations.
11.Data Maintenance	Distribution network is daily changed due to increment of load (customers), so that easy data maintenance by operator (not manufacturer) is needed. The data maintenance can be implemented on display of off-line server by man-machine interface. The changed data including connection of substation and distribution network can be automatically reflected to on-line server by the request of operator.
12Simulation	Simulation of FMSR / LBFR / DLF /FDIR can be implemented on off-line server.
13.Standard based Integration	A lot of application software, which consist of GIS / AMI (MDMS) / DR / EMS / SCADA, etc., can be easily connected to DAS/DMS by using API and international protocol / communication (LAN / IEC 61850, etc.).

In case of DAS/DMS, the following functions are very important based on lots of experience for more than 20yeras.

(1) FDIR procedure (in OMS function)

Automatic operation to detect and isolate faulty section is needed to save operator's load due to lots of equipment and multi-faults. In case of SCADA, there are no problems due to fewer equipment and rare case of fault compared to DAS/DMS as shown in Table 6.3.2-3.

Table 6.3.2-3 Comparison between SCADA and DAS/DMS

	SCADA Mainly for transmission	DAS/DMS Mainly for distribution
Equipment / facilities for monitor and control	Fewer (ex: High voltage substation:30 Transmission line: 180 Distribution substation: 60)	Lots of equipment / facilities (ex: Substation: 60 – 200 Distribution line: 1000 – 3000 Distribution equipment: >10,000)
Feature of network	Fixed	Daily changed due to increasing customers
Normal work (No fault)	Very few (ex: one operation / day)	Many (ex: more than 100 operation / day)
Abnormal work (fault)	Very few (ex: several operation / year)	Many (ex: more than 10,000 / year)

When multi faults or bank faults occur due to disaster (heavy rain with thunder, etc.), operator cannot control lots of equipment to detect, isolate and restore for the faulty sections with exact and speedy procedure. Therefore, automatic operation is needed.

The SCADA has no function to make the FDIR procedure automatically, so that the system concept based on SCADA is not suitable for distribution network as shown in Table 6.3.2-3.

As for the FDIR procedure, there are the following 2 method and COPEL can select better procedure.

- DAS/DMS server makes the FDIR procedure and implement automatically.
- DAS/DMS server makes the FDIR procedure and implements up to automatic detection. In addition, the server displays the fault isolation and restoration procedure, so that operator can send the command of implementation after checking the procedure.

(2) Maintenance function

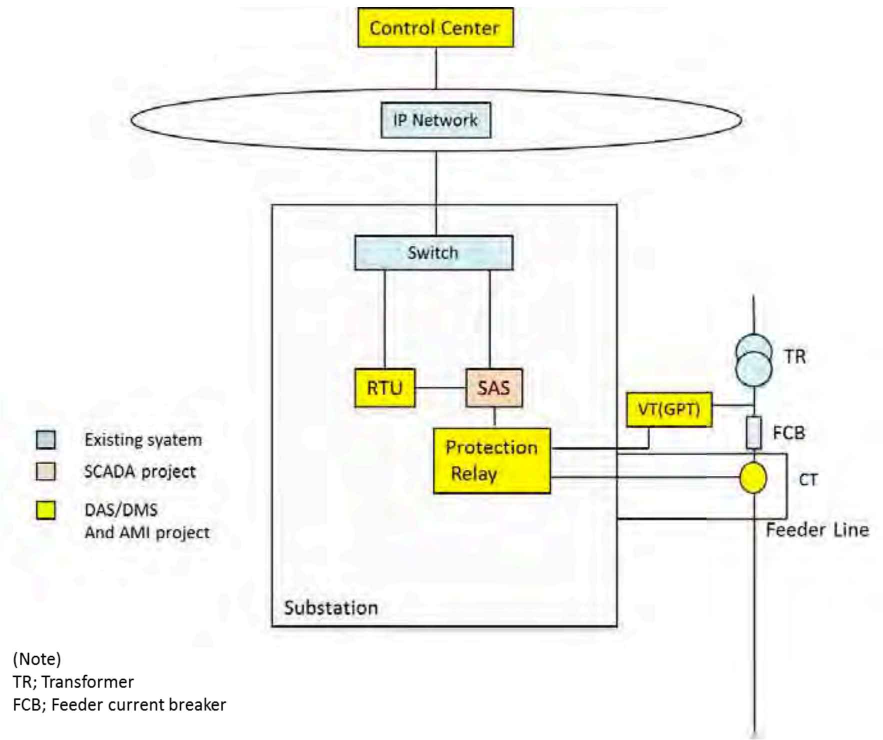
Distribution network changes daily due to increasing customers, repairing lots of equipment and so on. Therefore, the data maintenance is needed daily, so that easy work by COPEL’s employee is required without the help of manufacture which means to pay huge money.

When the distribution line/section increases, the network connection in the data-base has to be changed on the software. In case of SCADA, Power Company can ask the manufacture to change the software due to rare cases which means inexpensive cost. However, the change of distribution network is lots which means very expensive (more than the initial project cost), if Power Company will ask the manufacture.

DAS/DMS has the function of easy data-maintenance, so that COPEL's employee can easily change the software of distribution network on the console with man-machine interface.

6.3.3 Substation Facilities

Substation facilities regarding this project consist of Master RTU, SAS, communication facilities and additional protection relay as shown in Figure 6.3.3-1.



TR: Transformer CT: Current Transformer
FCB: Feeder Circuit Breaker

Figure 6.3.3-1 Construction of Substation

The major function is introduced in Table 6.3.3-1.

Table 6.3.3-1 Major Function of Substation Facilities

Facility/Works	Function & explanation
RTU	Functions of RTU are as follows. -Receive the command from the control center and send it to SAS. -Receive data from SAS and send the necessary data to the control center 
SAS	SAS has been developed by COPEL. Therefore, the data will be sent to SCADA through Layer 2 Switch. The data requested from RTU will also be sent to DAS/DMS server in control center. 
Switch	Existing facilities (SDH/Layer2 SW) can be utilized to send to SCADA. Additional Layer 2 SW for communication between RTU and DAS/DMS will be installed when DAS/DMS will be applied. 
Additional protection relay	Additional relay to detect earth fault will be installed and connected to SAS. CT to detect zero phases current will be installed to all the feeders in the substation. Voltage Transformer (VT) such as GPT (Grand Potential Transformer) to detect zero phase voltage will be installed to each bank in the substation.

	
Adaptation work	The existing data (Status of CB / Relay, telemetering data of Voltage/Current, etc.) and new protection relay will be connected to SAS by this adaptation work. New CT and VT (GPT) will be connected to the existing substation by outage work and the data (Vo / Io) will be connected to the new protection relay.  VT(GPT)

Functions of RTU installed in each substation are important in order to treat lots of data in server smoothly as follows.

- RTU sends the command to SAS
- RTU receives lots of data from SAS and classifies based on the priority
- High priority data such as status of CB /relay are sent to server in the control center
- The other data such as measurement of voltage / current are sent to the server for the spare time

6.3.4 Protection Scheme for 13.8kV Distribution Lines

1) Existing Protection Scheme for distribution lines

The existing protection scheme for 13.8 kV distribution line is over current (51) and earth fault (51N) protection which is provided in the auto-recloser as shown in Figure 6.3.4-1. The existing protection scheme has a weak point for high impedance earth fault. The major cause of fault on a distribution line is the earth fault caused by contact with the branches of plant, occasionally resulting in a high impedance earth fault. However the setting current of earth fault relay (51N) is restricted by the zero sequence current caused by unbalance of phase current or error current. According to the given data from COPEL, the error current is approximately 2A and on some feeders it comes to 5A maximum at primary value. Then setting current of earth fault relay is 25A at primary value. In case of high impedance earth fault, the earth fault current may be less than 10A where the earth fault impedance is approximately 2.4kohms. When the earth fault with high impedance at a fault point is not detected by the earth fault protection relays on the feeder, the earth fault may be extended to much more severe earth fault including fire disaster and distribution line may be damaged. In order to detect the high impedance fault, a protection scheme with more sensitive detection shall be provided.

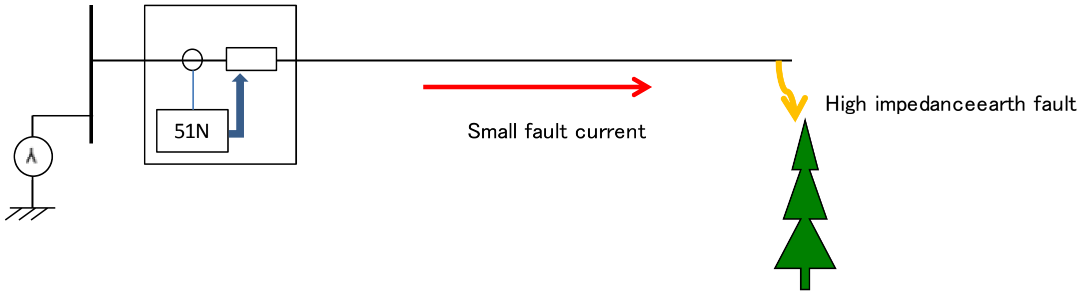


Figure 6.3.4-1 Existing earth fault protection in COPEL

2) Japanese earth fault protection system on the distribution feeder

In Japan, the connection of power transformer is star-delta connection which is the same as COPEL distribution system. However the earth system is no-grounding and providing GPT at 13.8kV busbar to feed small zero sequence current (I0) to be detected by the sensitive directional earth fault relay (67SEF) on the feeder. On the other hand, the COPEL distribution system provides earthen transformer which feeds about 2000A. It can supply much higher earth fault current to fault point compared to the Japanese system. However, with the COPEL system it is very difficult to detect the earth fault in case of high impedance earth fault because existing earth fault relay (51N) in Auto-Recloser can not detect the small earth fault current as shown in Figure 6.3.4-2 above.

The sensitive directional earth fault relay (67SEF) can detect the earth fault with very good current sensitivity because zero sequence impedance at source side is very high such as 10 Kohms in Japanese 6.6kV system and then detected V0 is very large. Accordingly in Japanese system, earth fault can be detected sensitively.

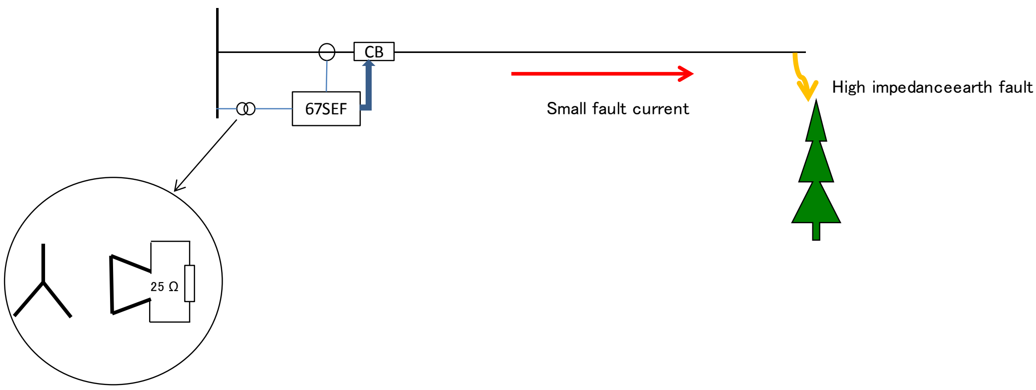


Figure 6.3.4-2 Earth fault protection in Japanese distribution system

3) Candidates of protection schemes

For sensitive detection, sensitive earth fault relay (51SEF), sensitive directional earth fault relay (67SEF), over voltage protection relay (64N), current differential scheme (87N) are considered.

Sensitive earth fault relay (51SEF)

More sensitive over current with lower current setting can be applied, but the minimum setting of the 51SEF will be 6 to 7 A considering error current on the distribution line.

Sensitive directional earth fault relay (67SEF)

If voltage signal can be used, more sensitive detection is possible. In the existing substations VT is not provided on 13.8 kV distribution lines. In such cases additional VTs shall be provided on each section of 13.8 kV busbar, improving sensitivity from 2 to 5 A.

Overvoltage protection relay (64N)

As with 67SEF, overvoltage relay can be applied to 13.8kV lines, but an overvoltage relay cannot segregate the faulted line. It may then be possible to apply as final back up function on 13.8kV busbar or fail safe function for 67SEF.

Current differential scheme (87N)

Technically, it is possible to provide 87N to detect leakage current on the line. This protection scheme has been used to the protection scheme for high voltage transmission lines, however a very complicated system would be necessary if it is applied to distribution line.

4) Recommended Protection Scheme

Considering the characteristics mentioned above, directional earth fault relay (67SEF) will be applied to 13.8 kV distribution line protection scheme. Consequently, a typical setting range of 67SEF will be as follows.

Current setting: 0.2 – 20% of rated current in minimum 0.1% step

Characteristics angle setting: -90 - +90 deg. (Operating angle should be characterized. angle +/-87deg)

Voltage setting: 0.5 – 100% of rated voltage in minimum 0.1% step

For VT and CT, a set of VT with broken delta winding shall be provided on each 13.8 kV busbar section and CTs shall be provided on each 13.8 kV line.

For 67SEF, the latest type of numerical relay will be used. Considering the cost and future application of SAS in which current IEC 61850 standard will be applied, the Intelligent Electronic Device (IED) should be used as Bay Control Unit (BCU). In the IED, almost all control and protection functions are integrated all in one as shown in Figure 6.3.4-3.

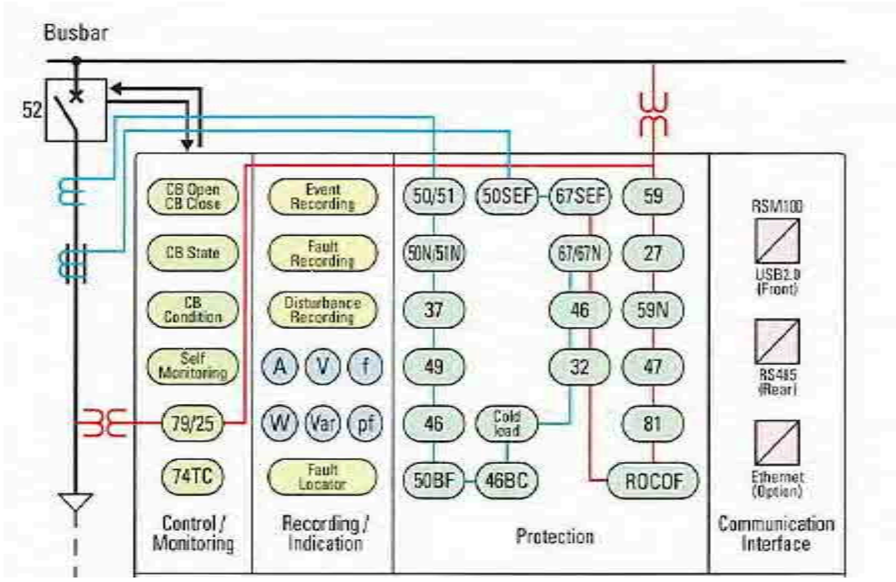


Figure 6.3.4-3 Configuration of Bay Control Unit

(Source: JICA Survey Team)

6.3.5 Installation into Overhead Line Network

1) Recloser

In the Curitiba Metropolitan Area, 577 reclosers have been installed as of the year 2012 (refer to Table 4.3-2) in order to locate faulted point and separate the section of failure point from un-failed sections. Over current relay (51/51N) provided in a recloser detects a fault point and dis-connects the section with a fault from non-fault sections, coordinating the operating time to the protection relays at substation. However, the coordination with substation is difficult and no more than 3 reclosers are installed within 1 feeder in COPEL. The longer it takes to locate failure points, the longer the duration of power outage becomes, hence, it is effective to increase the number of sections in 1 feeder in order to shorten the time taken to locate failure points. However, recloser has installation limitation in 1 feeder for the above reason. Accordingly, COPEL has enhanced reduction in power outage time by adopting ALBS (Automatic Load Break Switch) to increase the number of sections, which can be installed with more than one recloser in each feeder.

Avoiding installing reclosers and ALBS (Automatic Load Break Switch) to main distribution line together is advisable, since it raises the possibility of damage to distribution facilities by delaying fault clearance of distribution line, due to high possibility of malfunction caused by difficulty of coordination of each protection relay. Therefore, we would like to advise installation of ALBS (Automatic Load Break Switch) into main distribution line, which has no limitation on the number of installable units per feeder, and to reuse existing recloser for protection of branch feeder in terms of effective utilization of the existing distribution facilities as much as possible.

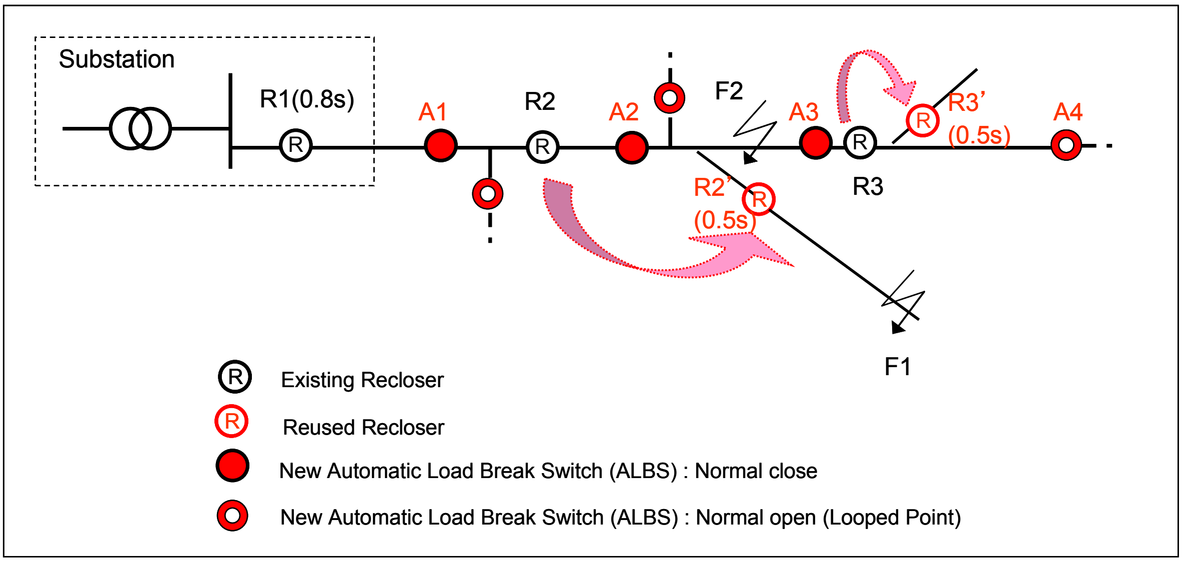


Figure6.3.5-1 Concept Overview of Reusing Recloser

(Source: JICA Survey Team)

The setting value of OC relay in the reused recloser for protecting branch distribution line is decided by considering the time coordination between other reclosers, based on minimum fault current at the end of feeder and operating characteristic curve of OC relay provided by manufacturer in the same way described in 4.3.3 1) Facility and Design. Concretely, in the case of R2' in Figure 6.3.5-1, based on the existing time coordination described in 4.3.3 1) Facility and Design, the setting value of OC relay in R2' should be selected in order to trip minimum fault current at the end of distribution line after R2' in 0.5 second. Regarding R1 and R3', the setting values of OC relays are selected in the same way as R2' and their trip times are 0.8 second and 0.5 second.

Once fault occurs, automatic network facility operation by DAS works as follows to separate fault section.

【Case 1: Fault Point of F1】

A. When the fault occurs at F1 described in Figure 6.3.5-1, R2' trips in 0.5 second by OC relay which detects fault current.

B. After the trip of R2', R2' is reclosed in 5 seconds. In the case of permanent fault at F1, the distribution line after R2' goes into power outage after re-trip of R2'.

【Case 2: Fault Point of F2 】

A. When the fault occurs at F2 described in Figure 6.3.5-1, R1 trips in 0.8 second and A1/A2/A3 are opened.

B. After the trip of R1, R1 is reclosed in 5 seconds. Then, A1 is closed and A2 is closed.

C. In the case of permanent fault at F2, A2 is opened again and locked. A4 is closed to supply electricity to section between A3 and A4.

2) Voltage Regulator (VR)

The purpose of VR is to compensate voltage drop. The average voltage drop in the urban area (Curitiba City) and the suburban areas (areas other than Curitiba City: 23 Municipalities) in FY 2012 was 2.19% (302V = 13.8kV x 2.19%) and 4.50% (621V = 13.8kV x 4.50%) respectively as in Tables 6.3.1-1 and 6.3.1-2. Table 6.3.5-1 shows the results from the analysis of trend in voltage drop for the next 10 years based on the assumption that the electricity demand grows 4~6% (Urban Area (Curitiba City): 6%, Suburban Area (other areas than Curitiba city: 23 Municipalities: 4%) per year adopted in 2.4.2 Present Situation and Forecast of Demand and Supply in the Curitiba Metropolitan Area and distribution line in the Urban Area is 185mm2 and one in the Suburban Area is the same as Figure 6.3.1-4. The voltage drop in normal operating condition, which is 7% (966V = 13.8kV x 7%) in Table 2.8-6, would be satisfied in the urban area (Curitiba City), but voltage drop in the suburban areas (areas other than Curitiba City: 23 Municipalities) is predicted to exceed the standard value in approximately 1 years from the commencement of operation in the Project which may start to operate in 2018. Therefore, one unit of VR is proposed to be installed on each distribution feeder in the suburban areas in this study.

In addition, based on the interview with COPEL, the international bid is conducted for purchasing the voltage regulator in general and when a foreign company participates in the bid, it needs to get approval of authorized organizations such as LACTEC, USP, CEPEL and EFEI. There are 2 local companies in Brazil; Cooper and Toshiba.

Table 6.3.5-1 Prospect for Voltage Drop

	Voltage Drop (V)	
	City (Curitiba City)	Local Area (23 Municipalities)
Increasing Rate	6%	4%
2012	302	621
2013	328	688
2014	356	759
2015	386	832
2016	417	908
2017	451	987
2018*	486	916
2019	524	995
2020	563	1,078
2021	605	1,164
2022	650	1,253

*2018 is the year of starting to operate the Project and the improvement(0.91→0.98) by Capacitor is included.

(Source: JICA Survey Team)

3) Capacitor Bank

The main purpose of installing capacitor is to improve power factor. The required values for the power factor in Brazil are shown in Table 2.8-9, and COPEL is responsible for maintaining the power factor higher than 0.92. In existing network, COPEL utilizes fixed type capacitor bank mainly, however there are a few self-control types which can switch on/off in pre-set time delay. Although COPEL take several countermeasures to improve power factor, the average power factor in the urban area (Curitiba city) is 0.94 as shown in Table 6.3.1-1, which is within the standard value, however, that of the suburban areas (other areas than Curitiba City: 23 Municipalities) is 0.91 which does not satisfy the standard. Therefore, it is proposed to install one unit of capacitor (600kVAR based on COPEL standard) on each feeder in 23 municipalities. Capacity and installation point on actual capacitor bank will be decided based on the characteristics of feeder in detailed design.

In addition, based on the interview with COPEL, the domestic bid is conducted for purchasing the capacitor bank in general, because there are 2 companies in Brazil; Cooper and ARTECHE, which can supply high quality production and economical price compared with imported production. Foreign companies can participate in the bid however, as long as they get the approval of authorized organizations such as LACTEC, USP, CEPEL and EFEI.

6.3.6 Smart Meter(SM)

In case the SM will be applied to residential customers, economical evaluation is needed due to the large investment. Survey Team analyzed and suggested there are economic benefits as stated in chapter 9.

It is therefore effective to apply smart meters to residential customers also providing the following benefits.

- DR can be easily applied due to installation of SM by AMI, so that peak load can be reduced and the construction of power generation can be saved by peak-shift or peak-cut.
- When TOU is established as a Brazilian law, the SM installed by AMI can be applied easily.
- Renewable energy (PV) will be applied to residential customers after completion of suitable FIT in Brazilian regulation, so that the distributed generator (PV) will increase and the control will be needed through the SM.

The SM consists of electrical watt-hour meter, communication device and switch for ON/OFF of the load.

Table 6.3.6-1 Specification and current situation of meter in Curitiba

Type		Single-phase		Dual-phase		Three-phase	
		Mechanical	Electrical	Mechanical	Electrical	Mechanical	Electrical
Rate	Voltage	120V		240V		120V,240V	
	Maximum current	Rated current:15A Maximum current: 100A				Rated current:15/30A Maximum current: 120/200A	
	Frequency	60Hz					
amount		322836	29957	194169	35022	140442	18876
Accuracy		Class 1					
Maker		Landis-Gyr,ELO,ELSTER,					
Price		80RS	40RS	- *	- *	300RS	150RS

* Price data could not be surveyed.

The summary of specification idea is shown in Table 6.3.6-2.

Table 6.3.6-2 Basic Specification of Smart Meter (Example)

		1Phase-2Wire	3Phase-4Wire
Connection		direct	direct
Rate	Voltage	120V,240V	240V
	Maximum current	Rated current;15A Maximum current;100A	Rated Current: 15/30A Maximum current: 120/200A
	Frequency	60Hz	
Accuracy	Active energy	class 1	
Measurement	Item	Active/Reactive energy (Import, Export)	
Monitoring	Item	Voltage(Vrms), Current(Arms)	
TOU	Item	Active energy (Import)	
	Tiers	Mini. 3	
Load Profile	Capacity	40days	
	Interval	15, 30, 60min	
Log Recording	Capacity	300 events	
	Record event	Supply failure	
		Reset	
		Irregular	
		Disconnect operation	

(Source: made by JICA Survey Team)

1) Switch

Switch can break the load of the customer remotely.

2) Measurement and monitoring

The current watt-hour meter only enables measurement of power consumption of active energy, but SM enables measurement of voltage and current, as well as power consumption of active energy.

Measurement of supply voltage to house or factory within specified range can be confirmed, so that it is used for optimum voltage supply operation.

On the other hand, measuring current can be realized current value which is consumed by house or factory, and can contribute to minimizing power consumption by means of visible encouragement.
Of course, it is possible to encourage consumers to save energy by making the active energy seeable.

3) TOU

Used when the time of day tariff system is established.

4) Freeze

Indicates the billing reset date.

5) Load Profile

Indicates the demand measurement.

6) Log Recording

Indicates the function to record and save events concerning the smart meter.

Concentrator is capable of connecting 500 sets of SMs per concentrator. However, bad communication conditions can cause poor performance.

6.3.7 Installation of Renewable Energy (Photovoltaic Power)

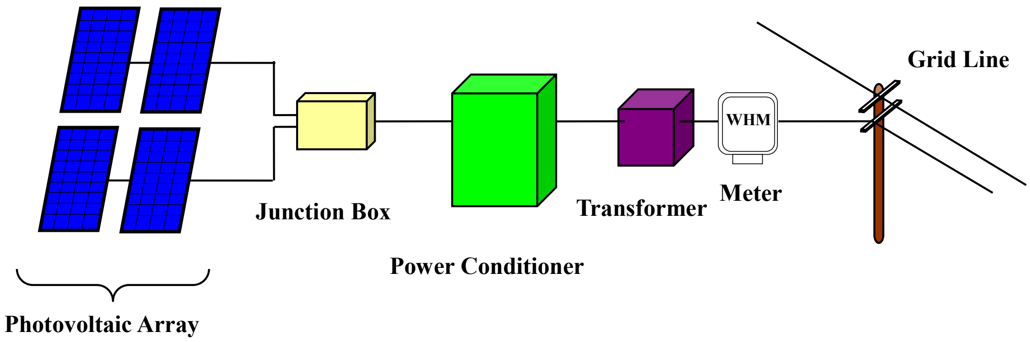
COPEL does not have much experience in Photovoltaic Power (PV) systems at this moment. The only experience is PV system installed in Fazenda Iguaçu Substation as one of COPEL's smart grid projects. In Fazenda Iguaçu Substation, the generated power of the PV system is consumed only in the substation for auxiliary service power and two different types of inverters are tested to examine the interference with each other. This test is performed to collect the data for the approval of inverters when COPEL is requested to connect the inverter to their grid in near future.

Although the technology of EMS (Energy Management System) is not highlighted in this study, the considerable issues related to grid-connected PV system is described, referring to the system in Japan only for information to COPEL in this section.

The following pages explain outline of grid-connected PV system and considerable technical items.

●Outline of Grid-connected PV system

Grid-connected PV system utilizes many facilities such as power conditioner, etc. and is connected to distribution line through grid-connected transformer in general as shown in Figure 6.3.7-1.



Facility	Overview
Photovoltaic Array	Group of PV panels
Junction Box	Box for gathering wires from PV array
Power Conditioner	Facility converts DC power from PV array to AC power with control for maximizing DC power
Transformer	Facility converts voltage of PV array to connect grid
Meter	Facility measures amount of sellable output of PV array

Figure 6.3.7-1 Basic Outline of Grid-connected PV system

(Source: JICA Survey Team)

●Considerable Technical Examination Items for Grid-connected PV system

When PV system is provided with the distribution grid, firstly a preliminary technical examination should be necessary. Negative impact should be examined when PV system is connected to distribution line.

Major issues for distribution grid in case of connecting PV system to grid are voltage fluctuation and islanding operation.

1) Voltage Fluctuation

Generally the distribution grid has power transformer connected to distribution grid, therefore at the connection point of grid-connected PV system, voltage fluctuation occurs by impedance of transformer and fluctuation of generated power from PV system which may be affected by climate condition etc. As a countermeasure to voltage fluctuation, control system with batteries will be applied.

2) Islanding Operation

Technically it is possible to operate so called *Islanding Operation* when the generated power by PV is balanced to consumption. During *Islanding Operation* it may cause an accident risk such as electric shock to public or maintenance worker and damage to facilities. Therefore, *Islanding Operation* is prohibited in Japan for safety reasons. In Brazil, *Islanding Operation* is also inhibited in ANEEL Procedimentos de Distribuicao de Energia Eletrica no Sistema Eletrico Nacional – PRODIST. In addition, in order to prevent *Islanding Operation*, we have applied the protection relay, or other measures.

Accordingly, preliminary technical requirements examination, about measurement of voltage fluctuation and preventing islanding operation, etc., is important. The following table explains the outline of technical requirements in the grid-interconnection code in Japan as an example. Although Japanese electric power companies conduct preliminary technical examination of grid-connected PV system according to this grid-interconnection code, required examination items in practical business are changed slightly, case by case depending on installing condition. (Low-voltage: 100/200V, Medium-voltage: 6.6kV, Extra-high-voltage: over 22/33kV)

Table 6.3.7-1 Grid-interconnection Code in Japan

Parameter		Measures for equipment			
		Low-voltage distribution line	Medium-voltage distribution line	Spot network distribution line	Extra-high-voltage distribution line
1. Power		Less than 50 kW in principle	Less than 2,000 kW in principle	Less than 10,000 kW in principle	–
2. Electric system		Same as that of grid connected in principle.			
3. Power factor	Common	Not less than 85% at receiving point and no leading power factor when viewed from grid.			
	With reverse flow	Not less than 80% when it is necessary to prevent voltage rise. When small-output inverter is used or power factor at receiving point is proper, power factor is not less than 85% when generator's reactive power is controlled, and not less than 95% if not controlled.		–	Value at which grid voltage can be kept correct.
	Without reverse flow	Not less than 95% when generator is connected with grid via inverter.	–		
4. Protection coordination	Common	OVR and UVR (combination with generator's protection is possible)			
			OVGR (combination with generator's protection is possible or it can be omitted under certain conditions)	–	OVGR (combination with generator's protection is possible or it can be omitted under certain conditions) DSR (for synchronous generator or it can be omitted under certain conditions) and current differential relay (neutral grounding system)
		DSR (for synchronous generator or it can be omitted under certain conditions)	DSR (for synchronous generator)		
	With reverse flow	OFR, UFR, and islanding operation detector (one or more passive and active methods)	OFR (can be omitted in dedicated line), UFR, and transfer trip system or islanding operation detector (active method) (can be omitted under certain conditions)	–	OFR (not affected by voltage change) and UFR (not affected by voltage change) or transfer trip system
	Without reverse flow	Inverter: RPR, UFR, and reverse charge detection function or islanding operation detector (one or more passive and active methods) Synchronous/induction generator: UFR, islanding operation detector (passive method), UPR (can be omitted if generator output < on-site load), and RPR (can be omitted if islanding operation detector is fitted)	RPR (can be omitted if received power > inverter output and islanding operation detector can detect in high speed) and UFR (can be omitted if dedicated line and RPR enables high-speed detection and protection)	URR and RPR (can be replaced by network protector's function) (generator is disconnected in a certain period if reverse power is detected in all circuits)	OFR, UFR, and RPR (if OFR and UFR cannot detect and protect)
	Fault prevention when circuit is reclosed	–	Installation of line voltage detector at the feeder panel of distribution substation (can be omitted under certain conditions)	–	Installation of line voltage detector at the feeder panel of distribution substation (can be omitted under certain conditions)

	Automatic load and power generation control	–	Introduction of automatic load control if interconnected conductors or transformer may be overloaded when generator is disconnected.		
					Use of power generation control by overload detector in principle for connection with extra-high voltage line rated at not less than 100 kV
	Other	Power supply shall be prohibited during power interruption and for given time after recovery.	Reverse flow shall be prevented at a transformer bank of distribution substation (if reverse power flow exists).	–	–
		As a rule, transformer shall be installed to prevent DC current flowing from inverter to grid (it can be omitted under certain conditions).			
5. Voltage variation		Introduction of automatic voltage adjustment if low-voltage consumer's voltage may be out of regulation (101 ± 6 V and 202 ± 20 V) (it can be omitted under certain conditions). If it is difficult, distribution line shall be reinforced.	Use of automatic load control if generator connects with general distribution line and when it is disconnected, low-voltage consumer's voltage may be out of regulation (101 ± 6 V and 202 ± 20 V) (it can be omitted under certain conditions). If it is difficult, distribution line shall be reinforced or generator shall be connected with dedicated line. Use of automatic voltage control if reverse flow may cause low-voltage consumer's voltage to be out of regulation (101 ± 6 V and 202 ± 20 V). If it is difficult, distribution line shall be reinforced or generator shall be connected with dedicated line.	Introduction of automatic load control if disconnection of generator may cause grid voltage to be out of regulation (within 1 to 2% of normal voltage).	Introduction of automatic voltage control if interconnection with generator may cause grid voltage to be out of regulation (within 1 to 2% of normal voltage).
		Synchronous generator: Use of amortisseur winding and automatic synchronizing function. Inductive generator: Use of current-limiting reactor if instantaneous voltage drop at parallel connection may cause grid voltage to be out of regulation (within 10% of normal voltage in low voltage, high voltage, and spot network; within ±2% in extra-high voltage). If it is difficult, synchronous generator is employed.			
		Self-excited inverter: Use of automatic synchronizing function. Separately excited inverter: If instantaneous voltage drop at parallel connection may cause grid voltage to be out of regulation (within 10% of normal voltage in low voltage, high voltage, and spot network; within ±2% in extra-high voltage), self-excited type shall be used (in case of low-voltage distribution line, necessary reinforcement shall be considered).			
6. Short-circuit capacity		Installation of current-limiting reactor (for AC generator)	Installation of current-limiting reactor		
7. Liaison system		–	Installation of dedicated telephone line for safety and security communication between grid operator's office or power station and the owner of generation system	Installation of dedicated telephone line for safety and security communication between grid operator's office or power station and the owner of generation system	
8. Meeting		The owner of generation system and grid operator shall have sincere talks about interconnection.			

(Source: Grid-interconnection Code in Japan: JEAC 9701)
(Remarks) OVR: Over Voltage Relay, UVR: Under Voltage Relay, OVGR: Over Voltage Ground Relay, DSR: Directional Short circuit Relay, OFR: Over Frequency Relay, UFR: Under Frequency Relay, RPR: Reverse Power Relay

6.3.8 Telecommunication Facilities

The telecommunication facilities can be classified into three classes as shown in the following table and figure, which are WAN1, WAN2, and NAN. WAN1 is the network between the control centers and substations, WAN2 is the network between the substations and RTUs/concentrators, NAN is the network for the last one mile.

Table 6.3.8-1 Telecommunication network for this project

Network		Path
WAN1	Wide Area Network 1	Control Centers – Substations
WAN2	Wide Area Network 2	Substation – Switch/Concentrator
NAN	Neighborhood Network	Concentrator - Meter

(Source: JICA Survey Team)

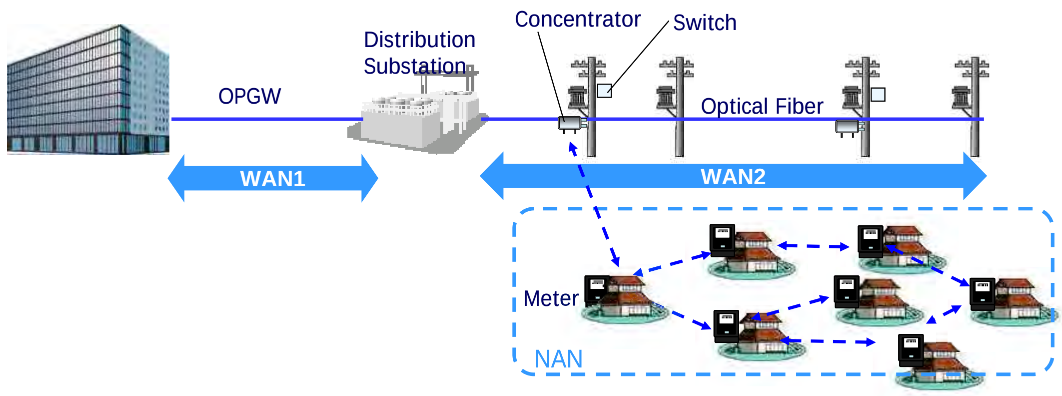


Figure 6.3.8-1 Telecommunication network for this project

(Source: JICA Survey Team)

(a) WAN1 (Control Center to Substations)

Concerning WAN1, COPEL already has the telecommunication facilities (IP/SDH), naturally, the existing facilities will be used for this project.

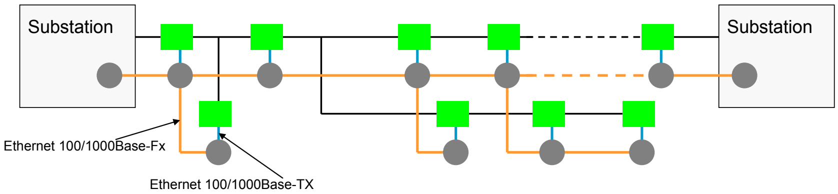
(b) WAN2 (Substations to RTUs on feeders / Concentrators)

The following functions are required for WAN 2.

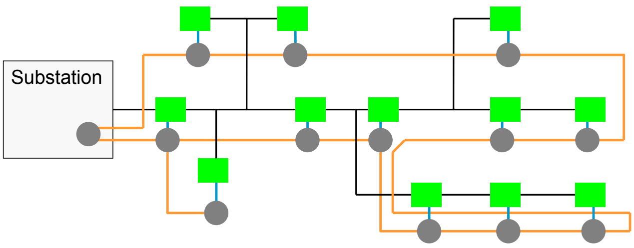
- ✓ High Transmission Speed for the Metering of many of the RTUs on the feeders
- ✓ Easy Designing and flexibility of the network
- ✓ Sustainability at the time of disaster
- ✓ Providing a telecom line for AMI between the substations and concentrators

In consideration of the high transmission speed communication, the communication media should be the optical fibers. In addition, the transmission paths should be composed of more than two physical routes to avoid disruption of communications during times of disaster and maintenance.

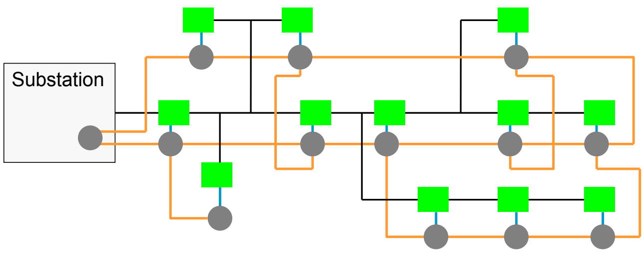
The optical multi-hop system has nodes that have the routing table to indicate the next node for the incoming data and also has some physical connections to the neighbor nodes. These nodes exchange the connection information with each other, and generate their routing tables automatically from that information. If one communication path breaks down, the node can transfer data to the destination node by using the other available bypath. The following figures show the topology of the optical multi-hop system.



(a) Tree topology



(b) Ring topology



(c) Mesh topology

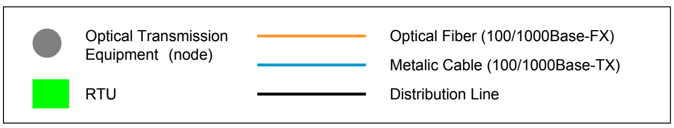


Figure 6.3.8-2 Topology of Optical multi-hop System

(Source: JICA Survey Team)

Another candidate of transmission system for DAS/DMS is PON (Passive Optical Network). A PON is a point-to-multipoint, fiber to the premise network architecture in which unpowered optical splitter are used to enable a single optical fiber to serve multiple premises. A PON consists of an OLT (Optical Line Terminal) and a number of ONUs (Optical Network Units) near end users. A. an OLT is a device which serves as the service provider endpoint of a PON. An ONU is a device that transforms incoming optical signals into electrical signals at a customer's premises in order to provide telecommunication services. Downstream signals are broadcast to all premises sharing multiple fibers. Upstream signals are combined using a multiple access protocol, usually time division multiple access (TDMA). There are two standards: IEEE 802.3h (GE-PON) and ITU G.984 (G-PON). A PON is popular to serve internet access to a number of premises all over the world.

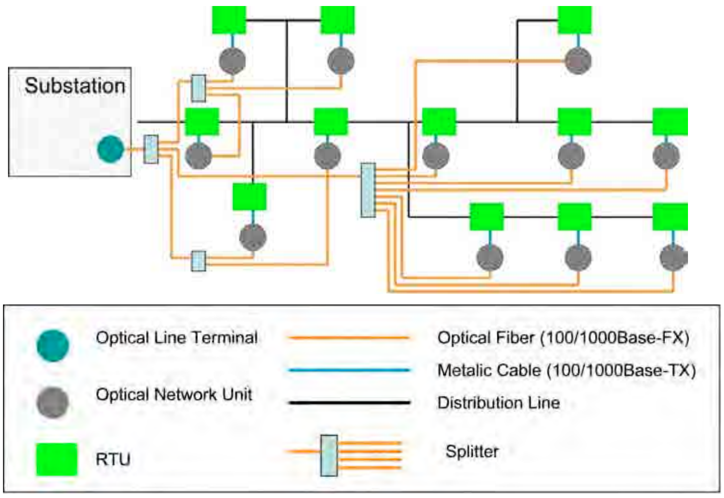


Figure 6.3.8-3 Topology of PON (Passive Optical Network) System

(Source: JICA Survey Team)

However, PON is designed for commonly-used internet service, not for DAS/DMS. On the other hand, optical multi-hop system is designed for DAS/DMS. Thus, in terms of reliability, redundancy, cold start, and supply continuity, Optical multi-hop system is recommended for DAS/DMS. The table 6.3.9-1 summarizes the comparison of PON and Optical multi-hop System.

Table 6.3.8-2 Comparison of PON and Optical multi-hop System

	PON (Passive Optical Network)		Optical Multi-hop System	
Reliability /Redundancy	×	Each node has only one route to the substation. When a root path of the network is cut, all the nodes lost connection.	◎	Each node has some routes to the substation. In the case that one route between a node and substation is down, a node is available by using another route.
Fiber Cores	×	The system spends many fiber cores	○	The system needs only one/two core.
Cold Start	△	Approx. 30 sec	○	<5s
Supply Continuity	△	The system designed for telecom services, and the production period is short due to the evolution speed of telecommunication technology. In addition, PON depends on a few chip manufactures.	○	The system was designed for DAS/DMS, and the production period is long. Using only generic parts.
Maintenance	△	Detection of fault section is difficult. Management of fiber cores is difficult.	○	Detection of fault section is easy. Management of fiber cores is easy.
Designing	△	Network design is difficult.	○	Network design is easy.

(Source: JICA Survey Team)

There are no optical fibers between the substations and distribution equipment on the MV feeders except for a few areas in the Curitiba metropolitan area at present. Thus, new distribution optical fiber cables need to be installed for this project. These optical fiber cables should be conformed to the COPEL standard ETME-01, that is based on ABNT NBR 13488:2005 (refer to Appendix 6-4).

The following table summarizes the outline design for WAN2.

Table 6.3.8-3 Telecommunication outline design for WAN2

Communication Media	Optical Fiber
Transmission Method	Optical Multi-hop System
Interfaces to RTU/Concentrator	IP

(Source: JICA Survey Team)

(d) NAN

There are two ways to implement the telecommunication system for last one mile. The first one is by using the public telecommunication network, and the second is to construct a new telecommunication network by COPEL. Table 6.3.8-4 shows the comparison between the GPRS
of the telephone company and COPEL's network. As for the initial costs, the public network is lower than the private network. However, the public network will result in running costs to the utility, and has some security and business continuity problems.

Thus, a private network is recommended for NAN. In addition, a 900MHz band RF Mesh is recommended for main telecommunication system of NAN because it has achieved satisfactory results in other countries. Table 6.3.8-5 summarizes the outline design for NAN.

Table 6.3.8-4 Comparison between the GPRS of the telephone company and COPEL's network

	GPRS	COPEL's Network (Optical + RF Mesh)
Reliability	△	○
Security	△	○
Congestion	△	○
Guaranty (10 years)	△	○
Initial Cost	○	△
Connection Cost	×	○

(Source: JICA Survey Team)

Table 6.3.8-5 Telecommunication outline design for NAN

Communication Media	Radio
Transmission Method	RF Mesh

(Source: JICA Survey Team)

6.3.9 Fault Detecting

There are 2 (two) fault detecting procedures; voltage sensing and current sensing methods as shown in Figure 6.3.9-1 and Figure 6.3.9-2.

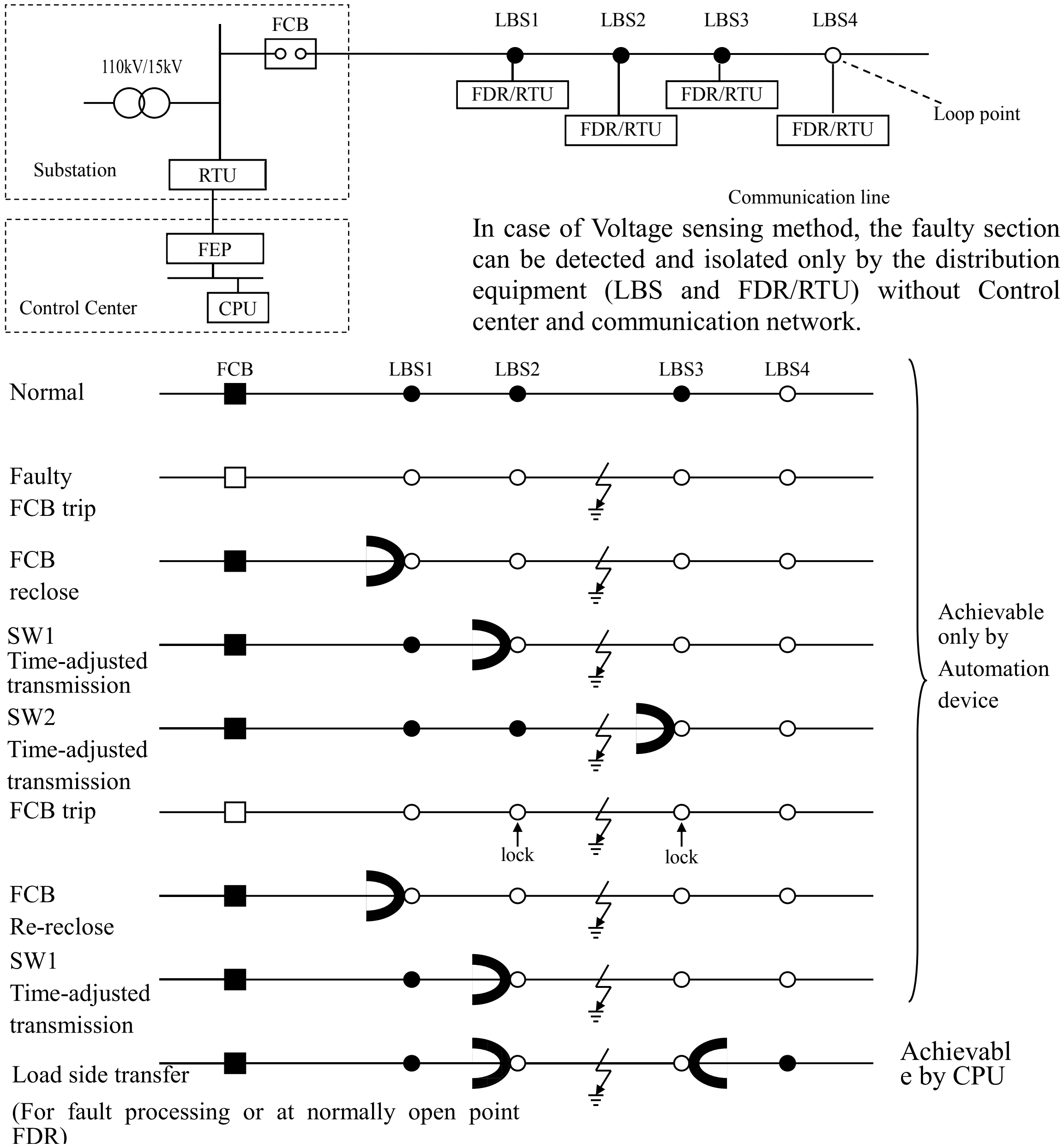


Figure 6.3.9-1 Voltage sensing method

(Source: JICA Survey Team)

Load Break Switches (LBS) with fault detecting relay are closed successively to detect a fault section and can isolate the fault section without a server and communication network as shown in Figure 6.3.9-1

The fault detection system using a server is the same as the above-mentioned method. However, power recovery to the load side of fault section is provided by logical decision of the server of DAS/DMS. Specifically, power is supplied to the load side section from another interconnected distribution line. In this process, load balances and voltage drops are calculated based on logical decision of the server, and a recovery procedure is provided to the operator. Once the operator confirms the procedure, the server is directed to operate switches by the operator. It is noted that the switches can be operated automatically without operator's decision.

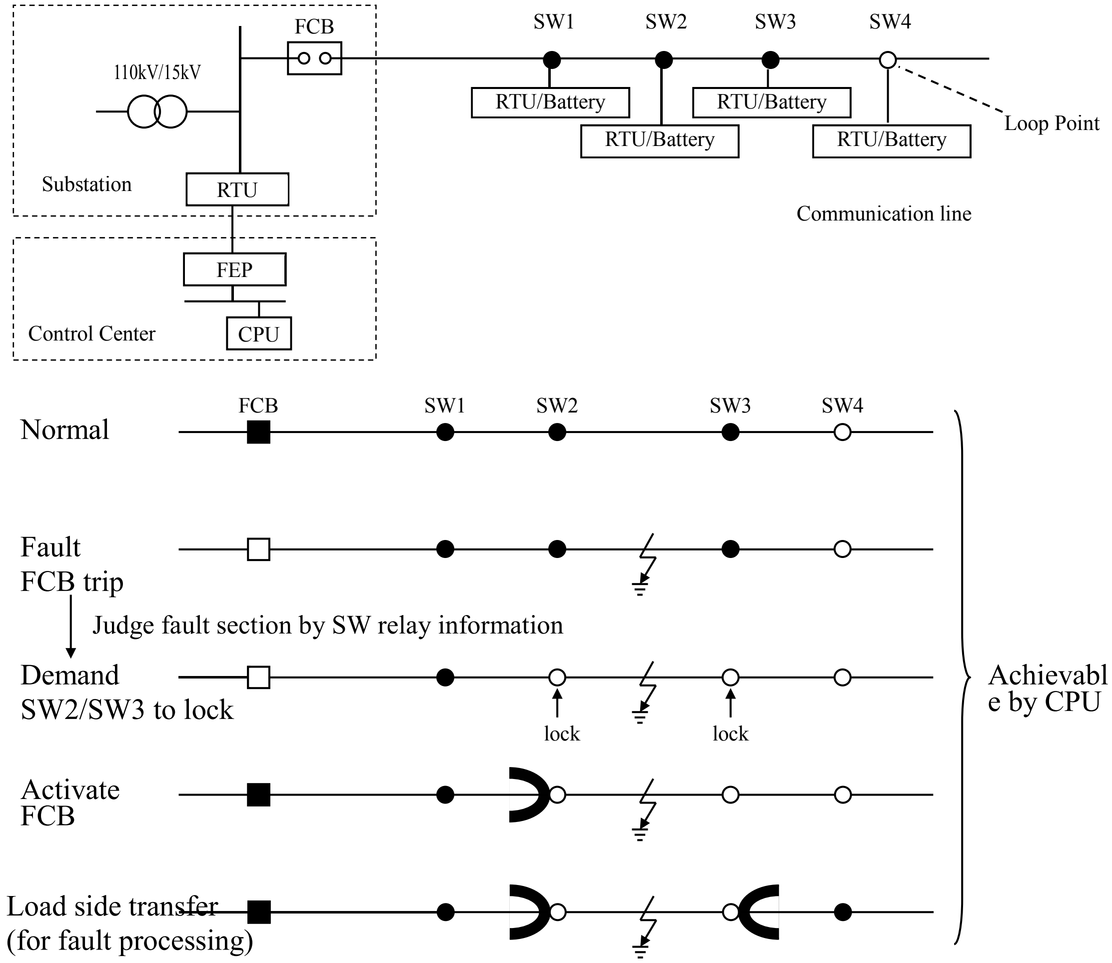


Figure 6.3.9-2 Current sensing method

(Source: JICA Survey Team)

The current sensing method is to detect the faulty current when the fault occurs. Therefore, the server and communication network are needed to detect and isolate the faulty section.

The comparison is introduced as shown in Table 6.3.9-1.

Table 6.3.9-1 Comparison of Current and Voltage Sensing Method

		Current system		Voltage system	
FCB operation		○	1 time	△	2 times ・Fault may be expanded due to fault current that flows twice. ・Damage in FCB and LBS
Fault detection		×	Unreliable ・Fault current is small due to delta connection and reactor earth, so that the fault detection by current is difficult.	◎	Reliable ・ The following additional equipment is needed. - VT (GPT) in bank - CT and Protection relay in MV feeder in SS
Redundancy		×	Low ・Fault section cannot be judged or separated in case of failure in server or communication infrastructure.	◎	High Fault detection / isolation is available without the server and communication network
Recovery time		○	Relatively slow (due to necessity of operator work)	◎	First
Maintenance		△	・Batteries are needed due to operation of LBS on no-voltage. ・Battery must be replaced every 3 to 5 years.	◎	Maintenance free (no batteries required)
Cost	Control center	○	-	○	-
	Distribution equipment	×	For every LBS (RTU) ・Earth fault detection (Sensor to detect Vo and Io, Earth fault detecting relay) ・Short circuit detection (CT and OC relay) ・batteries and the chargers	○	Battery and the charger are not necessary

(Source: JICA Survey Team)

Distribution network of COPEL is mainly OH and the connection of the substation transformer of 13.8kV side is delta with reactor earth. The system is similar to Japanese distribution network and the earth fault is small, so that the voltage sensing method based on Japanese experience is suitable for COPEL.

Study team will propose the revised Voltage sensing method suitable for COPEL whose concept is as follows. The fault detecting procedure is explained as shown in Figure 6.3.9-3.

- COPEL applies instantaneous reclosing, so that the ALBS maintain the closed condition for the instantaneous reclosing duration. (Many faults such as those caused by tree-contact are instantaneous. The faults can be quickly recovered by this function.)
- ALBS will open after a few seconds from detecting no-voltage. The power to open the ALBS will be supplied from power storage unit (ex: capacitor) charged in RTU but the required power is small due to the removal of the latched pin in ALBS
- After the second reclosing, the fault detecting procedure is the same as Voltage sensing method.

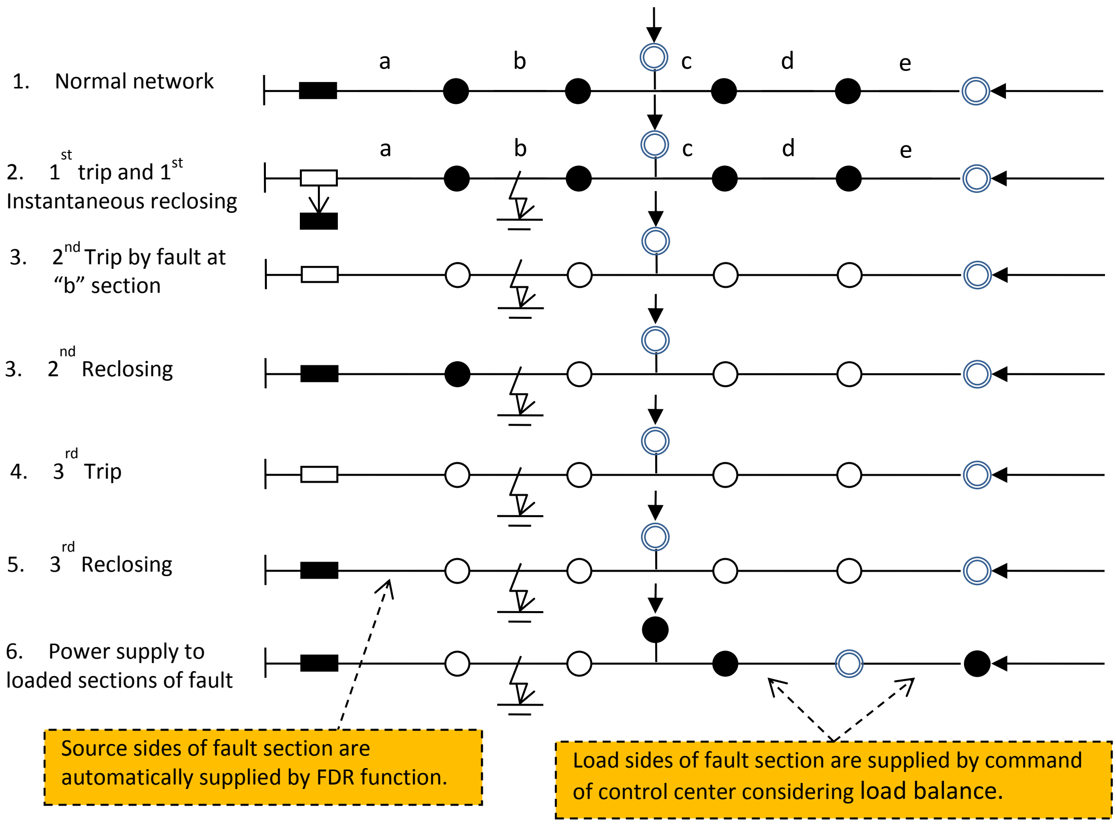


Figure 6.3.9-3 Proposed fault detecting procedure for COPEL

(Source: JICA Survey Team)

6.4 Procurement and Installation Plan

6.4.1 Installation Method Statement

In the smart grid project, the method statements for four key facilities are described as follows.

1) 13.8 kV Interconnection Lines

According to the requirement of COPEL, XLPE insulated wire will be applied to interconnection between distribution lines. The insulated wire line as shown in attached picture will be used. The size of conductor will be chosen according to the load current flow on the interconnection line.

Figure 6.4-1 13.8 kV Interconnection line
(Source: Photo by Survey Team)

2) Load Break Switch (LBS) and Remote Terminal Unit (RTU)

In this project, the standard LBSs are used. The method statement applied to the existing system can also be applied to this project. The example of installation work is shown in the attached picture.

Figure 6.4-2 Installation of LBS and RTU

Figure 6.4-3 RTU on a pole
(Source: Photo by Survey Team)

3) Installation of Fiber Optic Cable

In this report, the overhead fiber optic cable, outdoor type splicing enclosure and splicing facilities are proposed. The communication equipment itself is included in DAS. Here only fiber optic cable and enclosure as communication route are described. The fiber optic cable is hung on each tower and pole by fixing accessories and fiber optic cables are spliced at an enclosure. Figure 6.4-4 shows the structure of overhead fiber optic cable. The cable can be supported on towers or poles by tension wire.

The fiber optic cable can be connected in an enclosure every 1 to 2 km depending on the cable length or junctions at RTUs. It is possible to take out necessary cores from cable without cutting the other cores as per the structure shown in Figure6.4-5 which shows the structure of an enclosure (4 cable type). The fiber optic cable can be connected and/or branched in the enclosure which can be fixed on tower or pole.

Figure 6.4-7 shows the installation work on pole. Using a truck with bucket, it is possible to carry out effective and safety work on the pole.

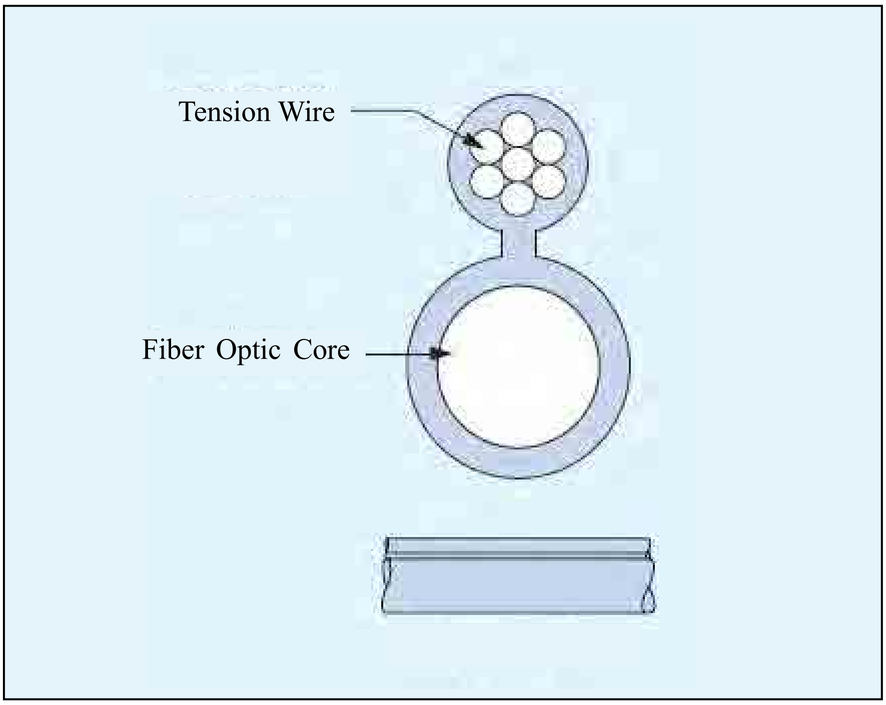


Figure 6.4-4 Overhead Fiber Optic Cable

(Source: Survey Team)

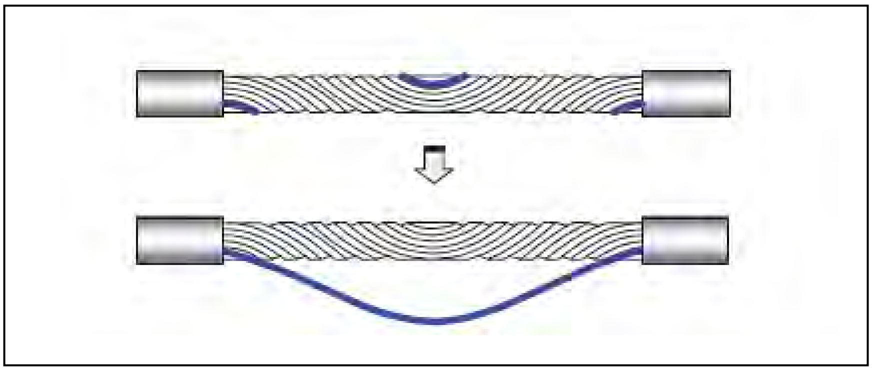


Figure 6.4-5 Fiber optic cable

(Source: Survey Team)

Figure 6.4-6 Enclosure for Splicing (4 cable type)

(Source: JICA Survey Team)

Figure 6.4-7 Installation Work at a pole

(Source: Photo by Survey Team)

On the other hand, if an additional fiber optic cable for branching or new routing is necessary in the future, the installation method to use would be spiral tube as shown in the picture. This method is very useful for adding new cables and has been used in the installation method of fiber optic cable in Japan.

4) Protection relays for 13.8 kV distribution feeders

In the existing system, the over current (51) and earth fault relay (51N) element which are provided in the auto-recloser have been used for 13.8 kV feeder protection relay. However the setting value of earth fault relay (51N) shall be larger than error current (Io) on the residual circuit and then the sensitive detection required to find the high impedance earth fault is not possible. In order to improve the sensitivity of the existing earth fault protection, it is recommended to provide the sensitive directional earth fault relay (67SEF) which is provided separately from an auto-recloser. In addition, considering the future provision of SAS which applies IEC61850 standard, it is recommended that Intelligent Electronic Device (IED) for Bay Control Unit (BCU) with control and protection elements all in one unit be adopted.

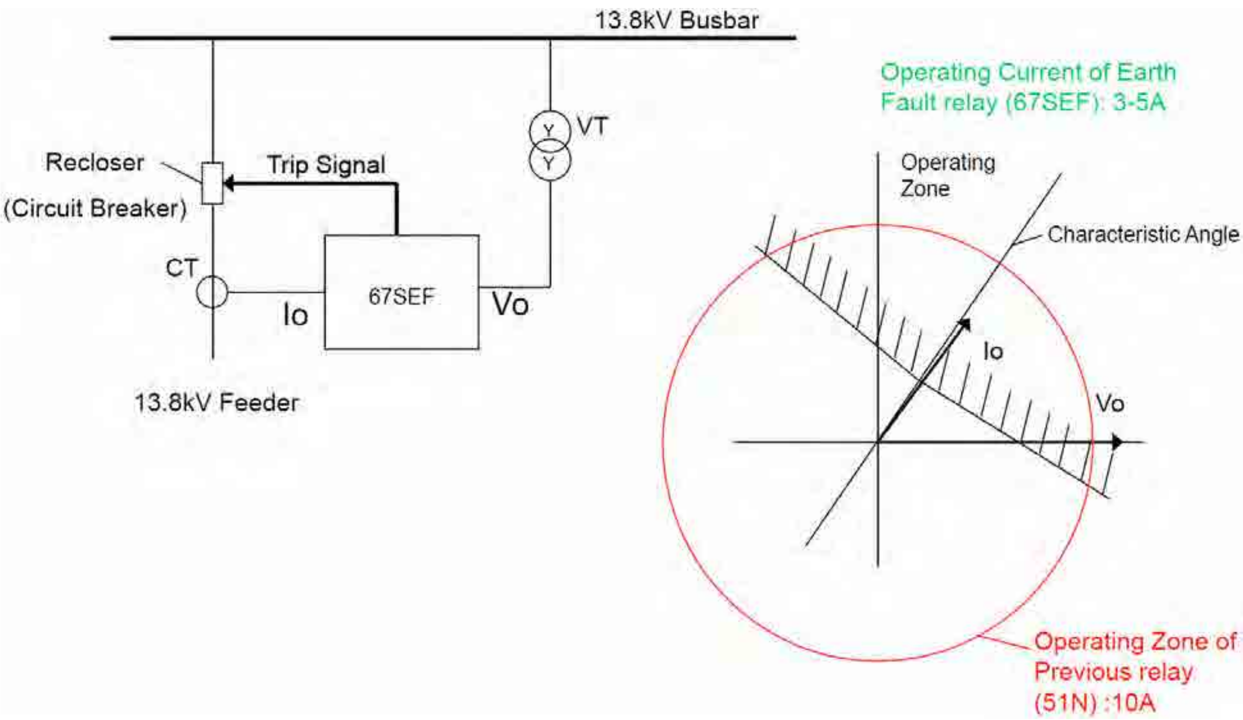


Figure 6.4-8 Existing earth fault protection and proposed directional earth fault relay

(1) Installation of CVTs

In the existing auto-recloser, CT and VTs are provided, but considering accuracy and characteristics of CTs, it is recommended that separated CT and VTs for measuring and protection relays be provided. To install the CT and VTs it is necessary to provide the iron base near the recloser at switchyard. In case of Sao Jose dos Pinhais SS for instance, the existing iron base can be used for CTs. For the other substation where the existing iron base is not available, new iron base similar to the picture will be provided.

Figure 6.4-9 Installation of CVT at existing substation

(Source: Photo by Survey Team)

(2) Installation of IED

Considering the busbar configuration of 13.8kV of COPEL, provision of five or six sets of the IEDs on each bus section in the separated cubicles at the substation control room is recommended. The mounting of swing rack cubicle to the IEDs as shown in Figure 6.4-10 is recommended.

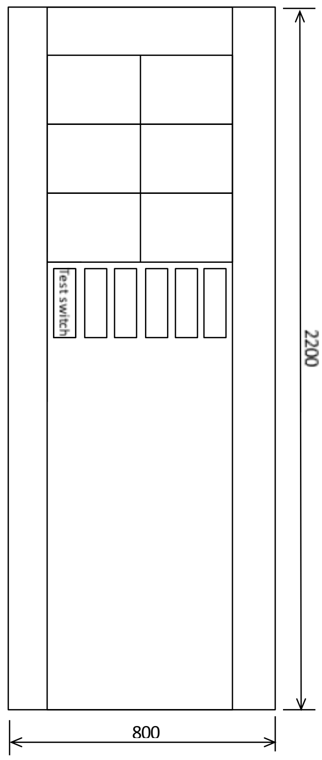


Figure 6.4-10 Swing Rack Cubicle for 67SEF

(Source: Survey Team)

6.4.2 Procurement and Transportation/Installation Schedule

1) Packaging

There are 2 (two) packaging ideas which are of

- 1 (one) package
- Lots of packages for each piece of equipment

It can be expected that lots of packages would reduce the project cost, but the interface for control center system, substation facilities and lots of distribution equipment is very difficult as a first project despite being specified in detail. In addition, when the system performance test between the control center and field equipment is implemented, trouble is likely to occur and the responsibility among many manufacturers is not clear based on the following actual experience.

In case of 1st system in Japan, Japanese power company requests manufacturers of control center / RTU with communication / LBS to develop new system / equipment jointly with money of the Power Company. The interface test between control center and RTU/LBS is implemented in the factories and the sites. Normally, problems will be discovered and the manufacturer repairs the problems in the factory. These works will be repeated under surveillance of the Power Company. From 2nd system, the system and equipment will be supplied separately.

In case of 1st system in Asian Power Company (APC), APC implemented tender with the separated packages between DAS/DMS and RTU/LBS. Lots of problems between the control center of European manufacturer and RTU/LBS of Asian manufacturers were discovered in site test after the installation. European and Taiwanese manufacturers denied any responsibility through their respective lawyers. It took more than 1 year and the manufacturer responsible for the problems had still not been made fully clear. APC asked Asian manufacturer in the weaker position to make the repairs resulting in the operation schedule being postponed by more than 2 years.

The Survey Team is afraid that the completion of the project will be postponed and the system will not be operated because of similar troubles.

Based on the above mentioned experience, the following project package is recommended applying both benefits of the packaging idea.

1st stage (first project):

1(one) package including all the system and equipment

2nd stage (Expansion of the project):

Lots of packages separated for each piece of equipment after confirmation of the interface on 1st stage

2) Method of Procurement for Smart Grid Project

For the method of procurement in the project, the making of a packaged international tender as Turn Key project is strongly recommended. One reason is that there is no major contractor to take and coordinate such a Smart Grid project. The other reason is that it is very difficult to maintain the quality if the system is divided into several sub-systems. Also the installation work shall be included together in equipment supply in order to make good coordination between equipment design/supply and installation work. Packaged tender may contribute to increase of total quality and unify responsibility for overall project.

(1) Preliminary design stage before tender

Owner/Consultant will do overall design regarding Smart Grid System and if tender is divided into each equipment level, Owner/Consultant should do detail interface design and specify in tender specification. It means taking responsibility in overall design and taking risks in interfacing. Also that skillful designers should be prepared for preliminary design and may take cost and time to prepare them.

(2) Tender stage

The cost of equipment may be decreased if the system is divided in equipment basis because any design and engineering cost is not included in cost of equipment. However the cost of preliminary design, detail design and engineering cost will be necessary in from the Owner's side.

(3) Detail design stage by Contractors

The divided Contractors only design and supply their equipment. The Owner should do the overall design and interface co-ordination, however, it may take much time, cost and manpower. Also the Owner should take any risk for the overall design.

(4) Installation stage

During installation, it is very important to give instructions to installation contractor. If the system is divided into several pieces of equipment, the installation design should be done from the Owner's side.

(5) Commissioning stage

Each Contactor may perform the commissioning for their equipment but any contractor may not take responsibility for total commissioning including interface. When interface problem arises, the Owner engineer should solve the problem at Owner's cost and risk.

(6) Guarantee Stage

During guarantee period, if any incompliance has occurred, Owner engineer should investigate the problem and make appropriate recovery plan and repair and/or improve the system. If the allover system is packaged in one, all responsibilities will be taken by Contractor and they will investigate, study, re-design and repair/improve.

(7) Operation Stage

If any problem occurs during operation, the Owner should make investigation and study to solve the problem for maintenance with Owner designer continuously. However, if the contract of one package is taken, the Owner can contact the manufacturer and ask for investigation with an order. Any continuous design organization is not required.

Table 6.4-1 Advantage and Disadvantage of Packaged and Divided Project

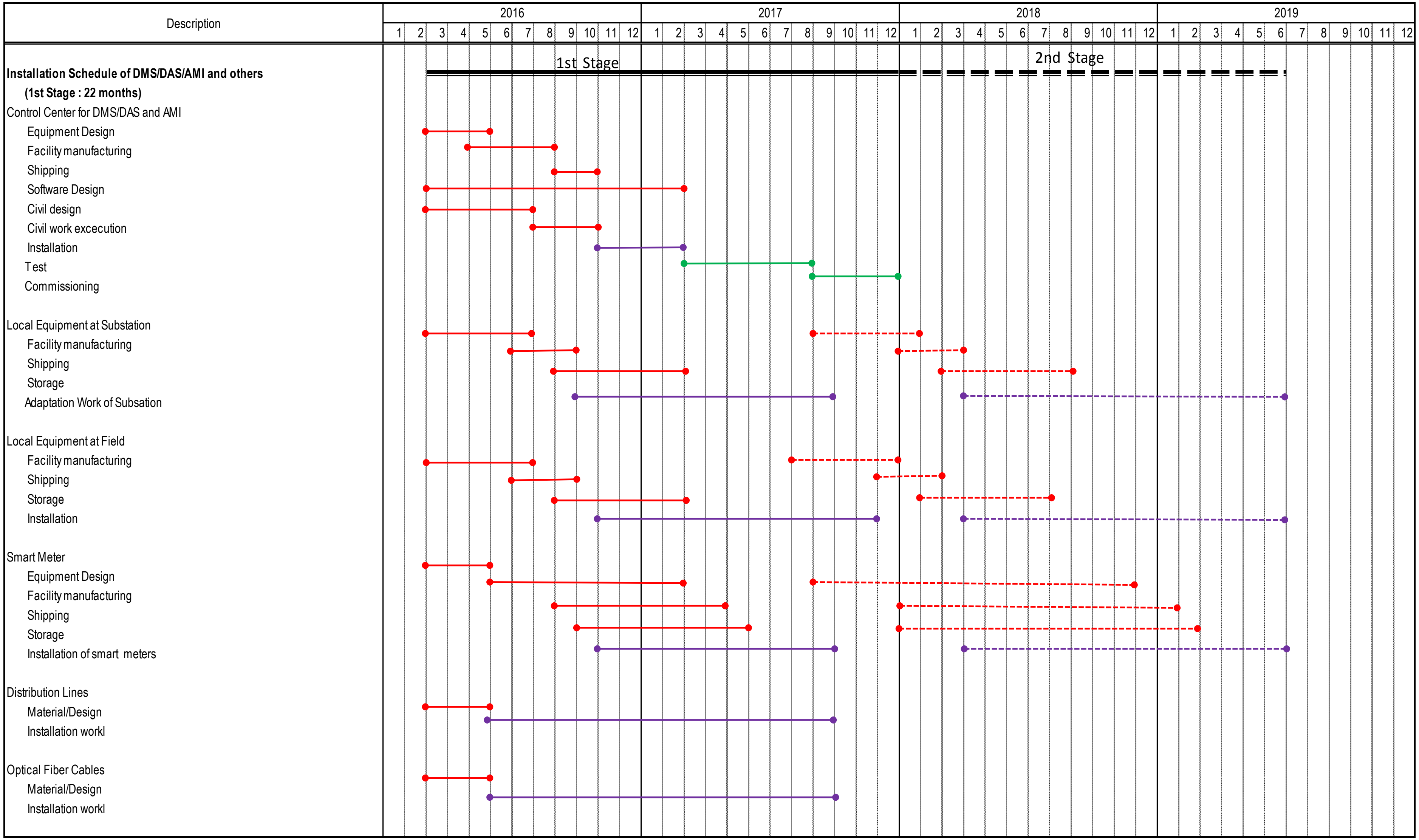
Description	One Package Project		Divided Project	
Stage	Advantage	Disadvantage	Advantage	Disadvantage
Preliminary design stage	Less manpower and time	-	-	Engineering and time
Tender stage	Specification requirement and responsibility is clear.	Cost is higher than divided tender	Less cost	It takes detailed engineering for interface coordination.
Detail design stage	Interface coordination can be completed by Contractor.	-	-	Owner should have organization to make interface coordination.
Installation stage	Ditto	-	-	Owner should do installation design and take the responsibility of interface.
Commissioning stage	Ditto	-	-	Owner should perform the commissioning which is not included in Contractors' equipment.
Guarantee Stage	Contractor will take all responsibility regarding overall system.	-	-	Owner should take investigation and action or repair/improvement relating to the interface.
Operation Stage	Owner ask contractor to investigate and repair/improve the problem with order.	-	-	Owner should maintain design organization continuously.

(Source: JICA Survey Team)

3) Implementation Schedule

The implementation schedule of transportation and installation works is attached hereafter. Any special method is not required for transportation and delivery to the site.

Table 6.4-2 Implementation Schedule for Smart Grid Project

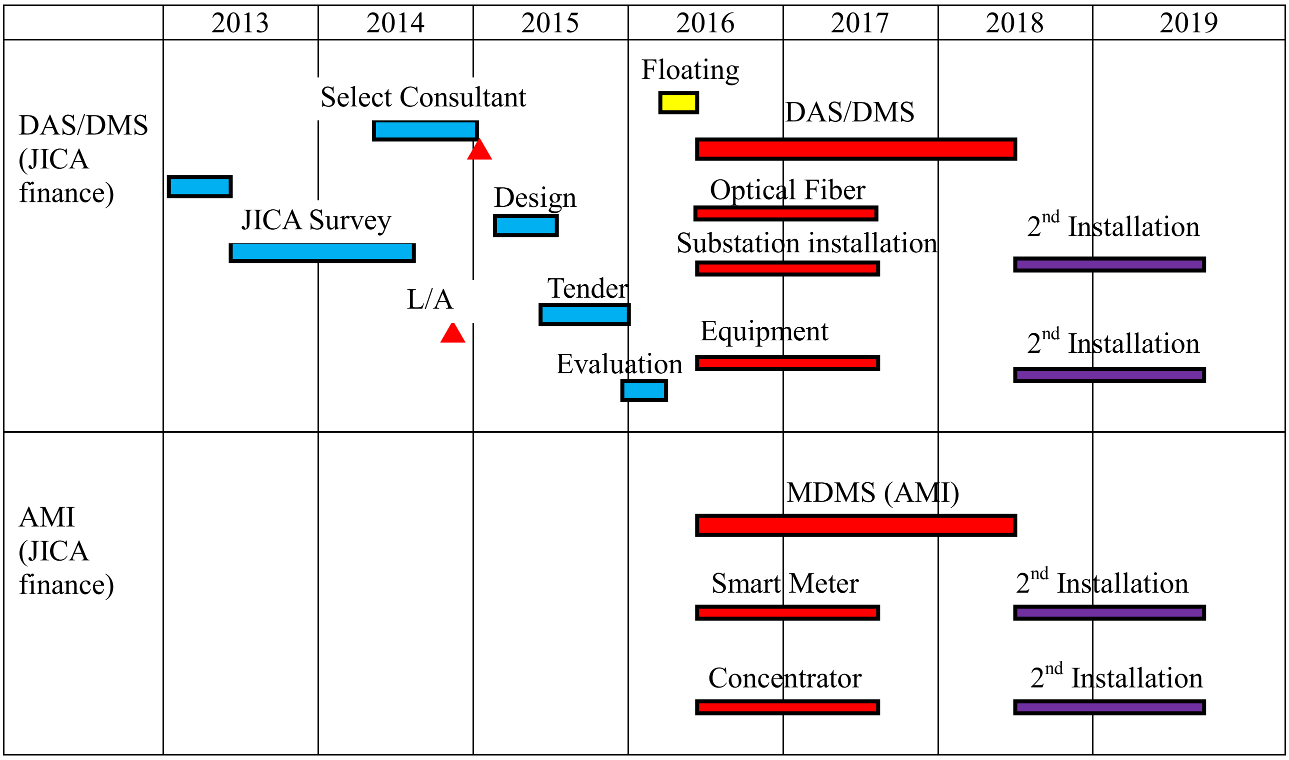


(Source: JICA Survey Team)

6.5 Project schedule

Outline of the project schedule including the related project (SCADA) is introduced in Table 6.5-1. The detail schedule is explained in attached document.

Table 6.5-1 Project schedule



(Source: JICA Survey Team)

The construction schedule is calculated based on the following condition.

***1**: 1.5months are needed as adaptation work of one substation due to installation of GPT in each bank, installation of CT for each 13.8 kV feeder which also install new protection relay.

5 crews can be worked as assumption. (5 crews x 12 month) / 1.5SS = 40 SS/year

Curitiba Metropolitan Area: 28 SS as 1st Installation < 40SS

Curitiba City area: 12SS as 1st Installation and 10 SS as 2nd Installation

***2**: 1 day is needed to install OH unit. 5 crews can work as assumption.

1 unit x 5 crews x 12 month x 20 days/month = 1,200 units / year

Curitiba Metropolitan Area: 1,000 units as 1st Installation < 1,200 units

Curitiba City: 753 units as 2nd Installation

***3**: 6 SM can be exchanged from the existing WHM to SM for one day. There are 5 crews/in each branch. There are 3 branches in Curitiba City area.

6 units x 5 crews x 3 branches x 12 month x 20 days = 24,000 units/year

Outsourcing of SM installation is needed: 5 times of 5 crews if possible.

5 times x 24,000 units = 120,000 units / year

120,000 customers in Curitiba City (648,000 customer in Curitiba City) as 1st Installation < 120,000

100,000 customers in Curitiba City as 2nd Installation

Based on JICA standard, it takes 12 months for the selection of consultant and 18 months for tender with PQ.

Chapter7 Implementation Plan of Smart Grid Project

7.1 Condition of Project Implementation Organization

7.1.1 Present Structure of Project Implementation Organization

COPEL Distribution takes charge of the implementation organization of Smart Grid Project in the Curitiba Metropolitan Area. Electromechanical and Automation Maintenance Department (hereinafter referred to as DMEA) which belongs to Distribution Engineering Superintendence (SED) becomes the main responsibility section for project implementation. The present organization structure of the COPEL Distribution is shown in the following figure.

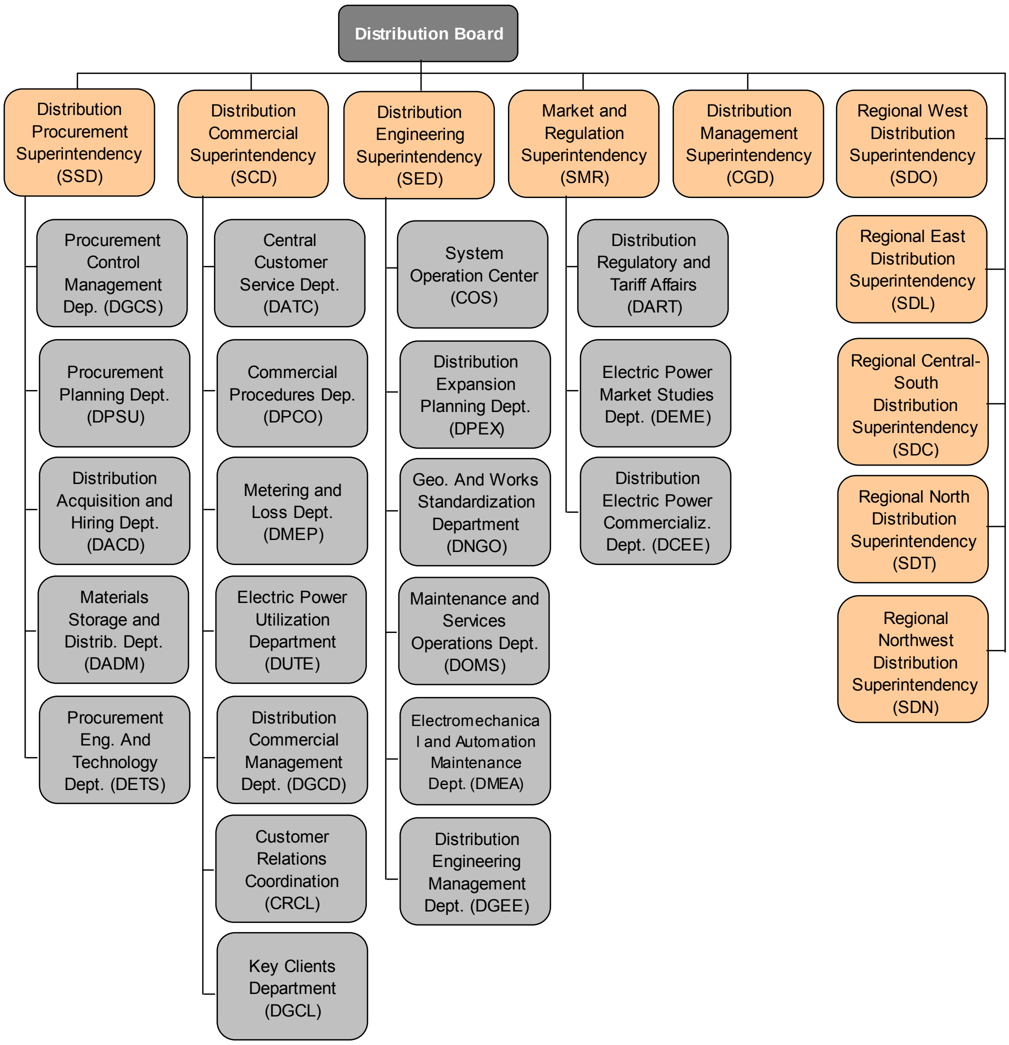


Figure 7.1-1 Organization Chart of COPEL Distribution

(Source: COPEL Distribution)

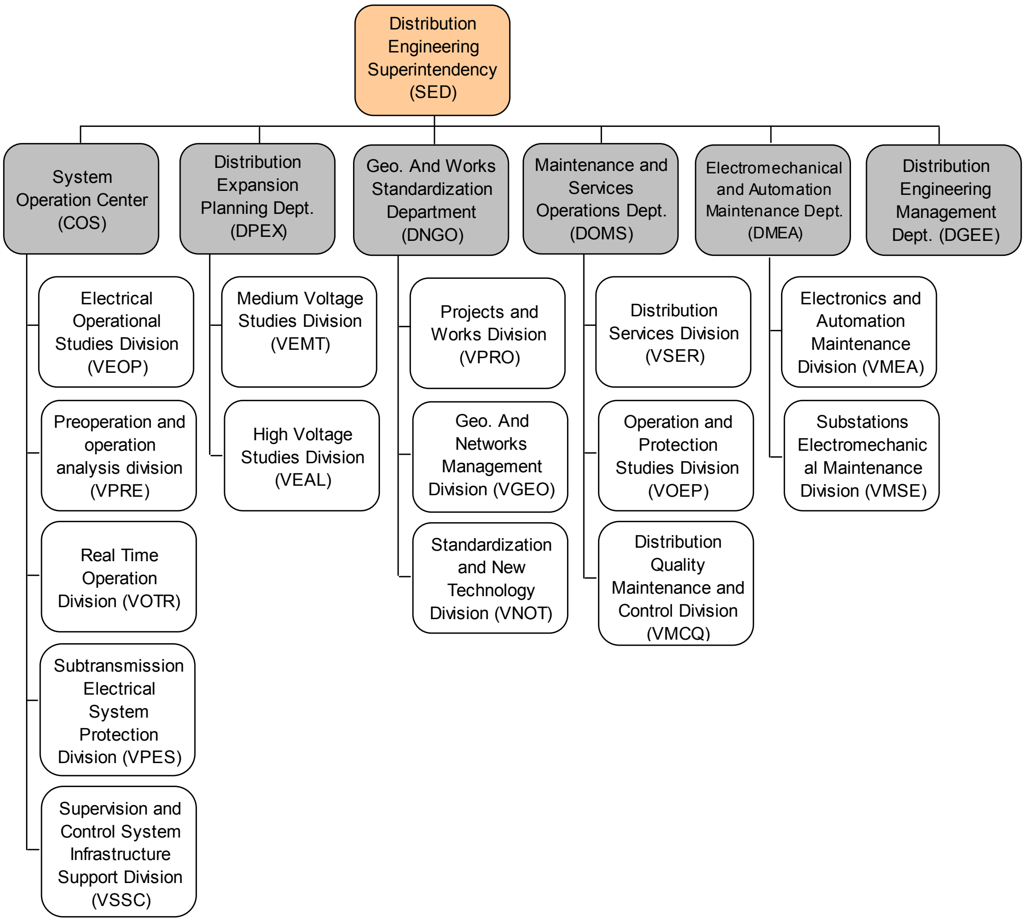


Figure 7.1-2 Organization Chart of SED

(Source: COPEL Distribution)

The organization revision will be planned by COPEL Distribution for the structural reinforcement for the smart grid project. Although the division name may be changed, there will be no change in the fundamental role and the DMEA will continue to have the responsibility for implementation of the Smart Grid Project in the Curitiba Metropolitan Area.

In addition to the members of the DMEA, the following sections offer the implementation support of the Smart Grid Project under management of the DMEA.

- Procurement Control Management Dep. (DGCS): Procurement of the facilities and materials
- Metering and Loss Dept. (DMEP): Specification of AMI, Installation plan of AMI
- Distribution Expansion Planning Dept. (DPEX): Distribution system analysis, Distribution planning
- Geo. And Works Standardization Department (DNGO): Management of mapping system, Standard management
- Maintenance and Services Operations Dept. (DOMS): Distribution system protection
- Distribution Engineering Management Dept. (DGEE): Maintenance of distribution facilities

COPEL Telecommunications takes charge of the installation of the communication facilities such as optical fiber and transmission equipment for the last one mile, described in chapter 6.3.8. The present organization structure of the COPEL Telecommunications is shown in the following figure. The Department of telecomm infrastructures and transmission Engineering becomes the main responsibility section for project implementation for the installation of the communication facilities.

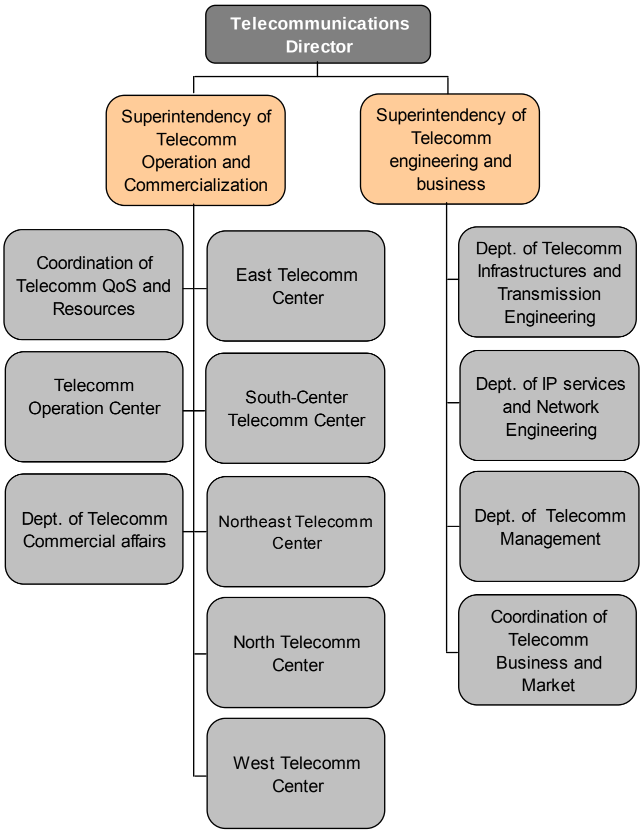


Figure 7.1-3 Organization Chart of COPEL Distribution

(Source: COPEL Telecommunications)

7.1.2 Operation and Maintenance Organization for Smart Grid Project Facilities

The distribution control center which belongs to the Regional East Distribution Superintendence (SDL) operates the Smart Grid Project facilities. The DAS/DSM will be installed at the distribution control center and the operators control the installed facilities on the control monitors.

Three maintenance centers, Curitiba maintenance center, Curitiba Norte maintenance center, São José dos Pinhais maintenance center, which belong to the Regional East Distribution Superintendence (SDL), maintain the Smart Grid Project facilities. The maintenance area of each maintenance center is shown in the following table and the map is shown in Figure 4.9-4.

Table 7.1-1 Maintenance area of each maintenance center

Maintenance center	Municipalities
Curitiba Norte maintenance center (VMACBN)	Adrianópolis
	Almirante Tamandaré
	Bocaiúva do Sul
	Campina Grande do Sul
	Campo Magro
	Cerro Azul
	Colombo
	Doutor Ulysses
	Itaperuçu
	Pinhais
	Piraquara
	Quatro Barras
	Rio Branco do Sul
	Tunas do Paraná
Curitiba maintenance center (VMACTA)	Curitiba
São José dos Pinhais maintenance center (VMASJP)	Agudos do Sul
	Araucária
	Balsa Nova
	Campo do Tenente
	Contenda
	Fazenda Rio Grande
	Lapa
	Mandirituba
	Piên
	Quitandinha
	Rio Negro
	São José dos Pinhais
	Tijucas do Sul

(Source: Created by JICA Survey Team)

7.2 Project Implementation Organization Capability for Project Implementation

7.2.1 Experience of Project Implementation Organization

In COPEL Distribution, nine projects were registered in the ANEEL's list from 2011 to 2012 as shown in the following table. A project scale is one million R$ to five million R$, and the total is twenty-five million R$.

Table 7.2-1 Registered Project into ANEEL

Project Title	Project Cost	Registration Date
Development of a computational tool for power flow analysis and short circuit in systems containing FACTS controllers.	R$ 740,920	2009/8/25
Air monitoring technology for inspections of substations, lines and transmission and distribution networks of electric power using digital infrared monitoring system and visual.	R$ 2,146,900	2009/8/26
Integrated Forecast System of Electric Power Market.	R$ 4,842,856	2009/8/25
Development of proximity sensor's series of head of distribution network as an accessory of safety helmets.	R$ 763,732	2009/8/25
Methods and Algorithms to Improve the Management Efficiency of Maintenance in Distribution Systems.	R$ 1,359,800	2009/8/31
Knowledge Management System to Support the Operation in Electric Power Systems' real-time.	R$ 2,995,158	2011/1/31
Development of Products for the Cleaning of Living Line Equipment.	R$ 752,960	2011/2/14
Development of Methodology for Real-Time Evaluation of the Effects of Atmospheric Discharges in Distribution Networks.	R$ 3,911,863	2011/7/15
Crambe oil evaluation as insulating fluids in transformers and agro-industrial culture development.	R$ 3,501,712	2012/6/4
Development of ceramic material for decontamination of mineral insulating oil with polychlorinated biphenyls, PCBs.	R$ 2,116,557	2011/9/2
Development of ceramic material for decontamination of mineral insulating oil with polychlorinated biphenyls, PCBs.	R$ 2,034,589	2012/7/30
DEVELOPMENT OF PROCESS FOR THE DESTRUCTION OF PCBS IN MINERAL INSULATING OIL.	R$ 1,874,331	2012/7/10
Portable Pulsed Voltage Controller for Photovoltaic Systems of Electric Power Generation.	R$ 2,253,324	2012/12/20
AUTOMATIC REAL-TIME PROTECTION MANAGEMENT SYSTEM	R$ 5,149,512	2012/10/1

(Source: Created by JICA Survey Team)

Moreover, two smart grid projects are being carried out in Curitiba City and Fazenda Rio Grande, thus the COPEL Distribution has experience of project implementation. The project scale is shown in the following table.

Table 7.2-2 Ongoing Smart Grid Projects

Project	Term	Number of Stage	Total Amount	Division
Fazenda Rio Grande	2012-2015	2(study, implementation)	30-40 million R$	VMEA
Curitiba City	2013-2014	1(implementation)	40 million R$	VMEA

(Source Created by JICA Survey Team)

Furthermore, COPEL Distribution itself is studying the installation of the SCADA system and is planning the completion in 2015. From the above situation, it can be said that COPEL can satisfactorily implement the Smart Grid Project in the Curitiba Metropolitan Area because COPEL Distribution has sufficient experience of smart grid and other projects by itself.

7.2.2 Personnel for Project Implementation Organization

In COPEL Distribution, DMEA takes charge of the distribution automation system project, as described in Chapter 7.1.1. Moreover, the members of DMEA have experience of the smart grid project, as described in Chapter 7.3. It is possible to have necessary manpower for the plan and design of the Smart Grid Project in the Curitiba Metropolitan Area by posting them appropriately.

In addition, COPEL Distribution has a plan to change the organizational structure and DMEA's formation, which may increase the number of staff for implementation of the future smart grid projects. The present personnel belonging to DMEA are shown in the following table.

Table 7.2-3 Member of DMEA

Department	Division	Class	Number	Total
DMEA	VMEA	Engineer	18	29
		Technician	11	
	VMSA	Engineer	11	22
		Technician	11	

(Source: Created by JICA Survey Team)

The present organization structure of the Regional East Distribution Superintendence (SDL) is shown in the following figure.

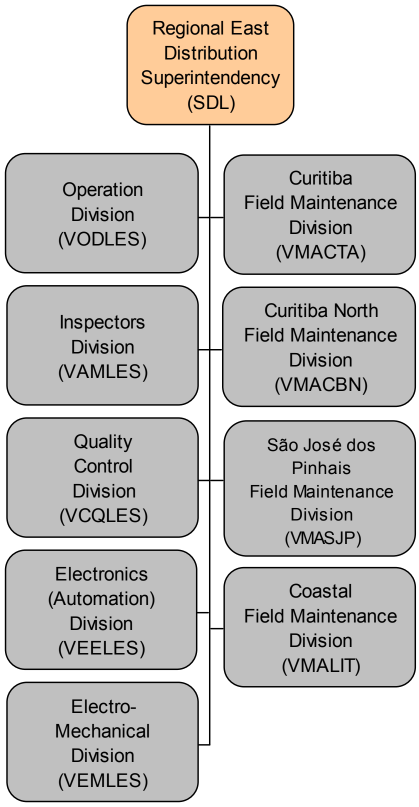


Figure 7.2-1 Organization Chart of SDL

The present personnel belonging to SDL is shown in the following table.

Table 7.2-4 Member of SDL

Department	Division	Number	Total
SDL	VODLES	76	334
	VAMLES	8	
	VCQLES	39	
	VEELES	26	
	VEMLES	46	
	VMACTA	52	
	VMACBN	31	
	VMASJP	29	
	VMALIT	27	

The number of distribution line maintenance personnel in the Smart Grid Project Area in the Curitiba Metropolitan Area (VMACTA, VMACBN, VNASJP) is 572 including the associated companies as shown in the following table. The workers who can do hot line work and dead line work can do the construction work for the smart grid projects. The total number of these workers is 41 in COPEL Distribution and 90 in associated companies, 131 in total. In addition, the construction work is carried out by 2 workers. Therefore, in the Curitiba Metropolitan Area, 65 crews can be engaged in the construction work of the distribution line at present.

Table 7.2-5 Numbers of Maintenance People for Distribution Lines in Curitiba Metropolitan Area

COPEL				Associated company (Total number of four company)	
	VMACTA	VMACBN	VMASJP		
Worker (dead line)	0	0	6	Worker (dead line)	51
Worker (hot line)	15	10	10	Worker (hot line)	39
Worker (underground)	17	0	0	Worker (underground)	12
Technician	5	6	5	Worker (tree cutting)	126
				Worker (clean)	267
				Worker (tree collection)	3
Total	37	16	21	Total	498

(Source: Created by JICA Survey Team)

From the above situation, it can be said that COPEL has sufficient personnel available to carry out the Smart Grid Project in the Curitiba Metropolitan Area.

7.2.3 Technical level for Project Implementation Organization

In COPEL, the contract commission of construction and the purchase agreement of facilities are based on the (international) bid. The bid information is released on the home page of COPEL Distribution along with the following standards. The tenderers can access the bid information and facilities standards through the Internet.

- Technical Standard of COPEL (Norma Técnica Copel : NTC)
- Technical Specification of COPEL (Especificação Técnica Copel : ETC)
- Manual and Guideline of COPEL (Manual de Instrução Técnica Copel : MIT)

COPEL Distribution owns four maintenance centers in the Curitiba Metropolitan Area. The role of the maintenance centers is not only to maintain the distribution facilities but also to check and repair the facilities and manage and control the materials. The following vehicles for maintenance and construction of distribution facilities are used.

Table 7.2-6 Vehicles for Maintenance

Type	Class	Number of vehicle
Vehicle for work at height	16m	200
	32m	2
Vehicle with transformer	7MVA	1
	30MVA	2

(Source: Created by JICA Survey Team)

Moreover, the installed facilities are checked at the maintenance center for quality control. The facilities of Fazenda Rio Grande project and Curitiba City project are also being checked at the maintenance center and the facilities of the Smart Grid Project in the Curitiba Metropolitan Area will be checked at the maintenance center.

In addition, in respect of personnel training, COPEL Distribution has training facilities for the construction and maintenance of the distribution facilities, and trains the distribution technicians for the improvement of the construction and maintenance capability.

From the above situation, it can be said that COPEL has sufficient technical capabilities available to carry out the Smart Grid Project in the Curitiba Metropolitan Area.

Figure 7.2-2 Testing Facilities for Checking the Installed Facilities (LBS and RC)

(Source: Photo by Survey Team)

Figure 7.2-3 Safety Equipment and Insulated Equipment

(Source: Photo by Survey Team)

Figure 7.2-4 Training Facilities

(Source: Photo by Survey Team)

7.3 Project Implementation Structure

There are three cases of the organizational structure for the distribution projects which are shown in the following table.

Table 7.3-1 Project Implementation Structure

Case	Financed Campany	Project Implementation organization	Remarks
Case 1	COPEL Holding Co	COPEL Distribution COPEL Telecomminucations	It have tax implications for transfering funds between COPEL Holding Co, and COPEL Distribution or COPEL Telecomminucations
Case 2	COPEL Distribution COPEL Telecomminucations	COPEL Distribution COPEL Telecomminucations	It needs two financed campanies, COPEL Distribution and COPEL Telecomminucations, for yen loan.

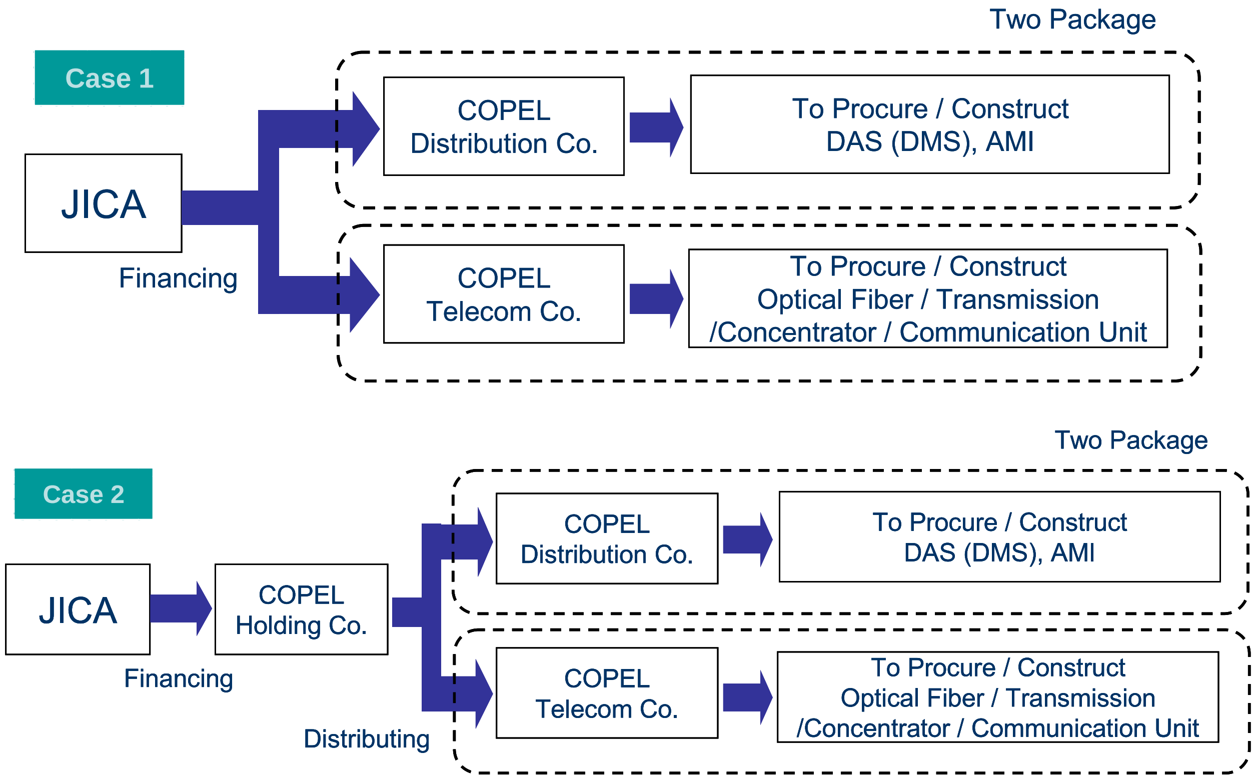


Figure 7.3-1 Image of financing flow

(Source: Created by JICA Survey Team)

Each organizational structure for the distribution projects is shown in Figure 7.3-2 and Figure 7.3-3. In order to define clear responsibility for the project, the making of a project team as task force is recommended.

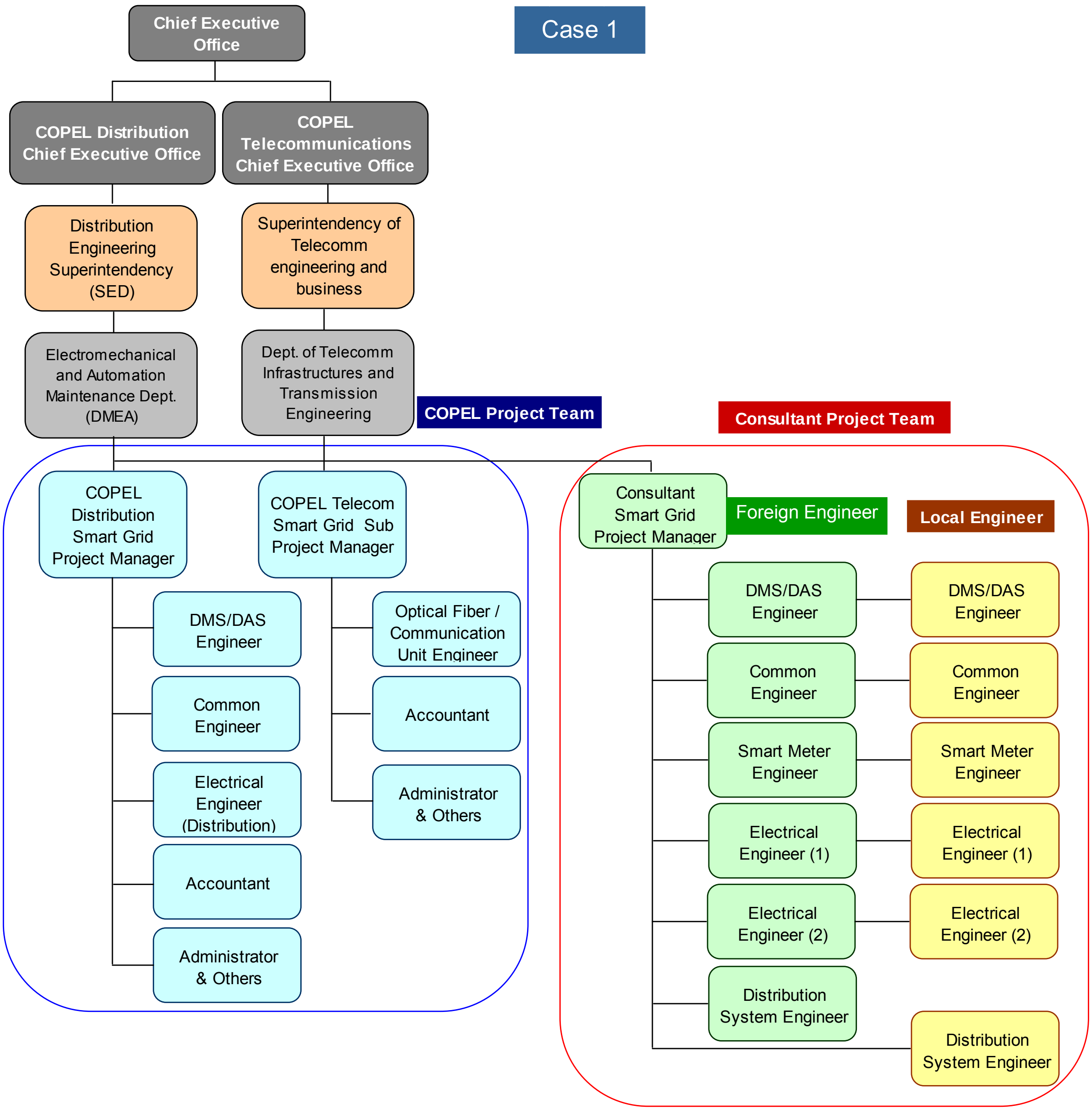


Figure 7.3-2 Organizational Structure for the Distribution Projects (Case1)

(Source: Created by JICA Survey Team)

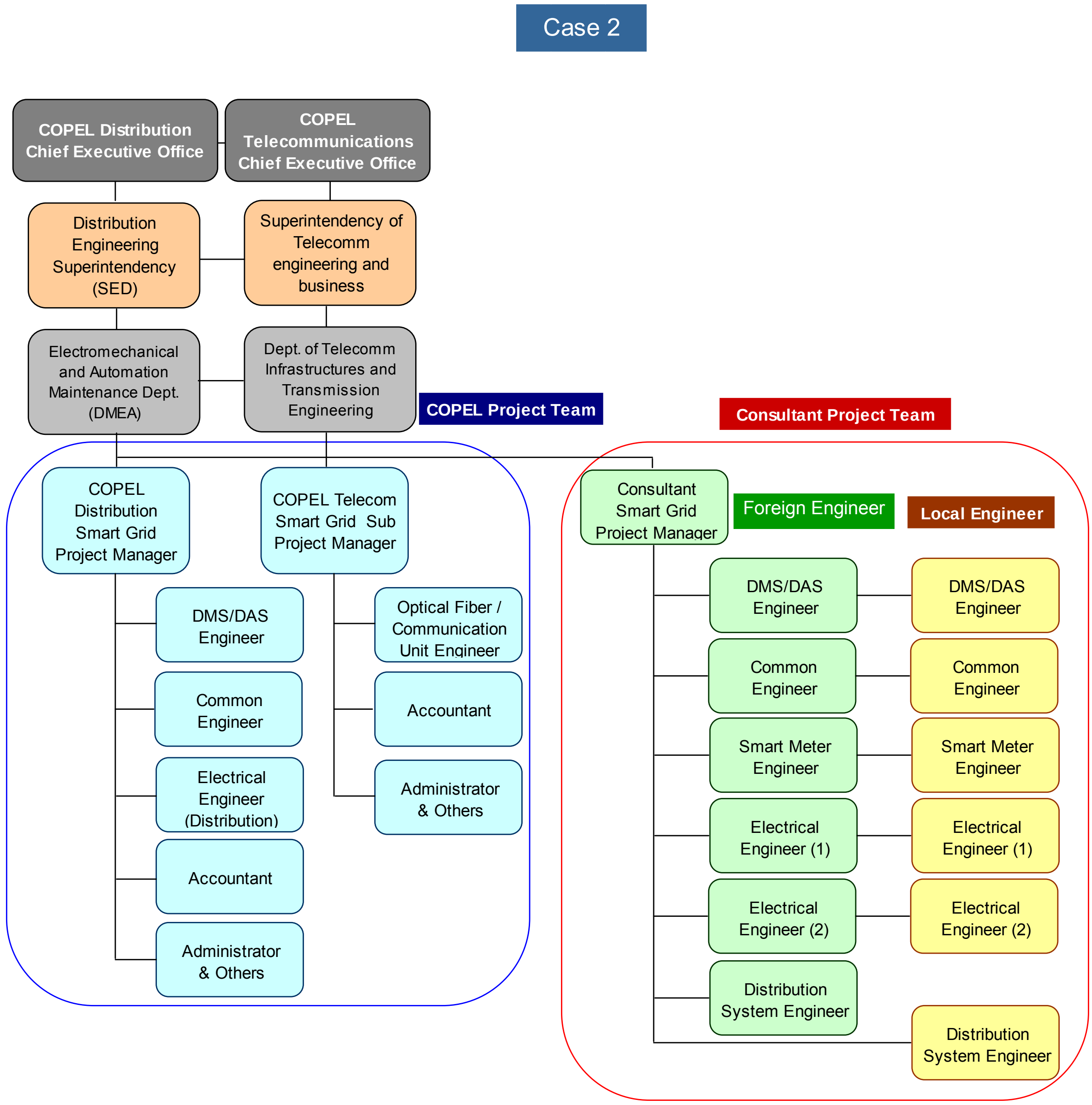


Figure 7.3-3 Organizational Structure for the Distribution Projects (Case2)

(Source: Created by JICA Survey Team)

7.4 Financial Situation of Implementation Entity

7.4.1 Profit and Loss

1) COPEL Holdings (Consolidated)

COPEL's consolidated profit and loss table is shown in Table 7.4-1. Operating revenues and costs are increasing from 2009 to 2012. Operating profits decreased from 2009 to 2010, increased from 2010 to 2011 and decreased from 2011 to 2012. Anyway, the operating profits continued (the account is in the black). From 2009 to 2011 non-operating profit/ loss was in the black, but in 2012 it was in the red.

Table 7.4-1 Profit and Loss of COPEL Consolidated (1,000R$)

Year	2009	2010	2011	2012
Op. revenues	**6,250,140**	**6,901,113**	**7,776,165**	**8,532,217**
Sales to customers	2,059,554	2,213,403	2,330,828	2,625,509
Sales to distributors	1,209,157	1,288,001	1,439,831	1,623,507
Grid system use	1,975,117	2,272,421	2,762,368	2,831,101
Construction	601,880	663,534	741,726	788,260
Lease & rents	0	103,686	88,909	0
Other op. income	404,432	360,068	412,503	663,840
Op. costs	**5,207,005**	**5,968,143**	**6,472,671**	**7,542,738**
Power purchase	1,816,848	1,972,275	2,152,545	2,807,735
Grid use charges	553,174	592,741	632,518	772,361
Personnel & mana.	630,917	811,514	982,653	1,246,599
Pension & health	85,243	124,221	150,845	182,878
Materials	80,224	84,124	85,610	69,816
Services	228,579	350,906	391,433	410,059
Depreciation & Am.	509,230	542,992	553,165	550,588
Provisions & Rev.	0	362,776	289,655	218,796
Construction	601,614	662,887	731,443	771,912
Other op. costs	701,176	463,707	502,804	511,994
Sub. earning equity	**14,327**	**99,337**	**55,654**	**11,040**
Op. prof./ loss	**1,057,462**	**1,032,307**	**1,359,148**	**1,000,519**
Non-op. profit/ loss	**6,735**	**348,425**	**224,768**	**-27,821**
Current prof./ loss	**1,064,197**	**1,380,732**	**1,583,916**	**972,698**

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

However, current profit continued from 2009 to 2012 although it decreased from 2011 to 2012.

2) COPEL Distribution

Profit and loss table of COPEL Distribution (subsidiary company) is shown in Table 7.4-2. Operating revenues and costs are increasing from 2009 to 2012. Operating profits increased from 2009 to 2011, but the operating account became a loss in 2012. Current account was shown to be in the black from 2009 to 2011, but became red in 2012. According to the accounting staff of COPEL Distribution, the reasons are highlighted by the following two issues.

(1) Change of Asset Assessment Method by ANEEL

The asset assessment method was changed by the ANEEL and so COPEL Distribution had to include the decrease of assets as costs.

(2) More Early Voluntary Retirements than Estimated

COPEL Distribution have asked voluntary early retirement of employees, but the retirements in 2012 were more than expected and COPEL Distribution had to pay their benefits so that the expenses increased.

Table 7.4-2 Profit and Loss of COPEL Distribution (1,000R$)

Year	2009	2010	2011	2012
Op. revenues	**4,420,923**	**4,939,328**	**5,490,064**	**5,892,171**
Sales to customers	1,960,175	2,104,950	2,233,335	2,490,638
Sales to distributors	57,879	64,471	91,789	155,463
Grid system	1,801,832	2,117,454	2,505,499	2,500,075
Construction	545,882	599,634	606,620	665,601
Lease & rents	57,177	53,755	56,058	0
Other op. income	-2,022	-936	-3,237	80,394
Op. costs	**4,316,069**	**4,577,731**	**5,038,081**	**5,968,827**
Power purchase	2,037,970	2,170,875	2,365,587	2,939,447
Grid use charges	434,171	468,723	505,869	648,501
Personnel & manag.	554,202	546,834	657,382	824,102
Pension & health	76,624	86,359	104,234	126,187
Materials	53,478	60,132	66,018	48,296
Services	255,958	277,437	307,494	320,135
Depreciation & Am.	167,516	180,701	193,969	192,344
Provisions & Rev.	103,515	106,913	122,332	118,986
Construction	545,882	599,634	606,620	665,601
Other op. costs	86,753	80,123	108,576	85,228
Op. prof./ loss	**104,854**	**361,597**	**451,983**	**-76,656**
Non-op. prof./ loss	**65,940**	**378,910**	**256,721**	**5,644**
Current prof./ loss	**170,794**	**740,507**	**708,704**	**-71,012**

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

The loss account in 2012 is therefore considered temporary.

Operating revenues of GET (Generation and Transmission), DIS (Distribution), and TEL (Telecommunication) in 2012 were R$ 2,243 million, R$ 5,892 million, and R$ 172 million, respectively, so that Distribution company's revenue scale is the largest. However, Operating Profits of GET, DIS, and TEL in 2012 were R$ 885 million, R$ -77 million, and R$ 33 million, respectively.

7.4.2 Balance Sheet

1) COPEL Holdings (Consolidated)

COPEL's consolidated balance sheet is shown in Tables 7.4-3 and 7.4-4. Total assets are increasing from 2009 to 2012. Non-current assets are more than current assets, which fluctuated increasing from 2009 to 2012, and property, plant and equipment are the largest (almost a half) in the non-current assets.

Table 7.4-3 Balance Sheet of COPEL Consolidated (1) Assets (1,000R$)

Year	2009	2010	2011	2012
Total Assets	**16,312,903**	**17,859,432**	**18,842,019**	**21,211,554**
Current Assets	**3,612,114**	**4,157,790**	**3,702,013**	**4,699,255**
Cash & equivalents	1,518,523	1,794,416	1,049,125	1,483,137
Bonds & securities	365,243	534,095	582,019	635,501
Collaterals & escrow accounts	5,047	64,078	2,668	36,812
Trade account receivable (Customers)	1,071,986	1,162,627	1,368,366	1,489,173
Dividends receivable	5,135	5,851	17,906	9,555
CRC to State	49,549	58,816	65,862	75,930
Accounts receivable concession	44,070	54,700	80,626	361,404
Other receivable	133,002	161,069	161,313	235,281
Inventories	112,102	121,424	103,802	124,809
Income tax & social cont.	270,558	158,213	215,381	193,158
Other current taxes recoverable	31,933	37,536	50,357	49,491
Prepaid expenses	4,966	4,965	4,588	5,004
Non-current Assets	**12,700,789**	**13,701,642**	**15,140,006**	**16,512,299**
Long-term Assets	**3,807,275**	**4,805,293**	**5,659,868**	**6,302,904**
Financial investments	64,298	33,431	100,142	171,761
Trade account receivable	51,932	43,729	32,452	26,171
CRC to State	1,205,025	1,282,377	1,280,598	1,308,354
Judicial deposits	159,012	400,699	430,817	574,473
Accounts receivable concession	1,828,220	2,423,345	3,236,474	3,402,597
Advance to suppliers	0	9,902	0	0
Other receivable	16,949	5,322	17,223	31,560
Income tax & social cont.	0	12,341	18,714	19,995
Other noncurrent taxes recoverable	83,957	84,862	77,912	120,189
Deferred income tax& social con t.	397,882	507,710	465,536	647,804
Receivable from other parties	0	1,575	0	0
Investments	**405,653**	**483,450**	**549,158**	**543,036**
Property, plant & equip.	**6,659,648**	**6,663,945**	**7,209,123**	**7,871,849**
Intangible assets	**1,828,213**	**1,748,954**	**1,721,857**	**1,794,510**

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

Total liabilities and equity are increasing from 2009 to 2012 as they are equal to the total assets because of balance sheet. Equity is much more than liabilities (equity's share is approximately 60% of the total liabilities and equity, but it is decreasing from 64.5% in 2009 to 58.9% in 2012).

In regard to liabilities, non-current liabilities are much more than current liabilities. The share of non-current liabilities in the total liabilities is 67.3% in 2012 (approximately 70% in 2009 and 2011 and 61% in 2010).

Table 7.4-4 Balance Sheet of COPEL Consolidated (2) Liabilities and Equity (1,000R$)

Year	2009	2010	2011	2012
Total Liabilities and Equity	**16,312,903**	**17,859,432**	**18,842,019**	**21,211,554**
Current Liabilities	**1,723,323**	**2,536,801**	**2,058,821**	**2,847,818**
Payroll, social charges &acc.	206,957	175,584	224,095	384,150
Suppliers	543,529	612,568	747,453	1,136,359
Income tax & social cont.	124,505	153,249	151,790	170,189
Other tax liabilities	325,990	378,871	288,457	290,896
Loans and financing	81,698	83,095	116,487	274,009
Debentures	54,195	621,157	0	0
Dividend payable	90,806	163,634	135,744	204,780
Post-employment benefits	22,505	24,255	36,037	25,819
Customer charges payable	29,523	56,105	70,511	56,498
R&D & energy efficiency	121,005	155,991	156,915	159,599
Payable concession	38,029	40,984	44,656	48,477
Other accounts payable	84,581	71,308	86,676	97,042
Non-current Liabilities	**4,065,217**	**4,026,805**	**4,713,670**	**5,866,238**
Associated & subsidiary companies	0	0	0	0
Suppliers	175,796	144,936	108,462	100,996
Tax liabilities	131,650	32,252	152	0
Deferred income tax & social cont.	901,084	887,218	648,266	615,924
Loans and financing	784,144	1,280,982	2,057,985	2,987,546
Debentures	753,384	0	0	0
Post-employment benefits	352,976	384,208	432,838	502,423
R&D & energy efficiency	90,493	90,732	94,649	104,561
Payable concession	312,626	340,099	370,442	399,080
Other accounts payable	2,953	0	53	0
Provisions for legal claims	560,111	866,378	1,000,823	1,155,708
Shareholders' Equity	**10,524,363**	**11,295,826**	**12,069,528**	**12,497,498**
Attributed to controlling shareholders	**10,295,998**	**11,030,123**	**11,826,694**	**12,232,992**
Capital	5,298,340	6,910,000	6,910,000	6,910,000
Equity valuation adjustments	1,660,634	1,559,516	1,457,081	1,350,002
Legal reserves	428,912	478,302	536,187	571,221
Profit retention reserve	2,908,112	2,056,526	2,838,551	3,337,295
Unrealized revenue reserve	0	0	0	0
Additional proposed dividends	0	25,779	84,875	64,474
Accumulated profits (losses)	0	0	0	0
Attributed to minority shareholders	**228,365**	**265,703**	**242,834**	**264,506**

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

In non-current liabilities, loans and financing are the largest and their share in non-current liabilities is 50.9% in 2012, but it increased from 19.3% or 37.8% including debentures in 2009. Thus, loans have become important in liabilities.

According to the Quarterly Report of COPEL, the Company's debt profile in December 2012 is shown in Table 7.4-5. Foreign currency is overwhelmingly small (only 1.8%). In domestic currency, debt from Banco do Brasil (and other) is the most (48% in domestic currency) and debentures (bonds) are the second largest (31.6%).

Table 7.4-5 Debt Profile of COPEL Consolidated (1,000R$)

Category	Source	Short-term	Long-term	Total
Foreign Currency	National Treasury	3,311	56,029	59,340
	Eletrobras	6	5	11
	Total	3,317	56,034	59,351
Domestic Currency	Eletrobras- COPEL	54,204	178,841	233,045
	FINEP	2,014	27,511	29,525
	BNDES	33,131	353,967	387,098
	Banco do Brasil and other	168,624	1,373,235	1,541,859
	Debentures	12,719	997,958	1,010,677
	Total	270,692	2,931,512	3,202,204
Total		274,009	2,987,546	3,261,555

(Source: COPEL's Quarterly Report Dec. 2012)

In "COPEL 2009 Management and Sustainability Annual Report," it is written that COPEL's national long-term rating and its fourth issuance of debentures was 'AA' (bra) according to Fitch Ratings Agency in 2009. In addition, it is described that corporate rating of COPEL was 'Aa1.br', according to Latin America Moody's in the Brazilian scale. In addition, COPEL was rated "AA+" by Fitch Ratings in 2011.

2) COPEL Distribution

COPEL Distribution's balance sheet is shown in Tables 7.4-6 and 7.4-7. Total assets are increasing from 2009 to 2012. Non-current assets are more than current assets. The share of non-current assets in total assets is decreasing from 74.2% in 2009 to 67.4% in 2012. In the non-current assets, long-term assets are the largest, accounting for 77.9% in 2012 (increasing from 67.0% in 2009). In the long-term assets, accounts receivable related to concession are the largest, accounting for 51.5% in 2012 (increasing from 39.5% in 2009 to 52.6% in 2011 and decreasing a little). CRC to State is the second largest accounting for 28.3%, but decreasing from 43.4% in 2009. Intangible assets are as large as CRC to State accounting for 22.0% in non-current assets, 2012, but decreasing from 32.9% in 2009. It is noteworthy that COPEL Distribution has no property, plant and equipment. Instead, it has accounts receivable related to concession. For reference, properties, plants and equipment of COPEL GET, DIS, and TEL are R$ 6,635 million / R$ 0 / R$ 319 million in 2012.

Liabilities and equity of COPEL Distribution are increasing from 2009 to 2012 as total assets increase. In total liabilities and equity, equity is the largest accounting for 40.9% in 2012, but the share was decreasing from 54.6% in 2009. Non-current liabilities are the second largest accounting for 36.6% in 2012 and the share increased from 25.9% in 2009. Current liabilities account for 22.5% in 2012 and the share increased a little from 19.5% in 2009.

Table 7.4-6 Balance Sheet of COPEL Distribution (1) Assets (1,000R$)

Year	2009	2010	2011	2012
Total Assets	**5,586,303**	**6,708,119**	**7,629,993**	**8,812,803**
Current Assets	**1,439,645**	**1,963,891**	**2,150,339**	**2,876,268**
Cash & equivalents	192,468	669,079	647,783	1,126,361
Bonds & securities	19,429	30,813	33,735	158,837
Restricted investments (Collaterals)	197	201	5	34,293
Trade account receivable	835,215	931,463	1,104,328	1,200,251
Dividends receivable	0	-	0	0
CRC to State	49,549	58,816	65,862	75,930
Accounts receivable concession	0	-	0	0
Other receivable	95,047	127,198	95,030	126,686
Inventories	76,170	83,893	69,579	84,995
Income tax & social cont.	145,091	30,685	87,484	35,868
Other current taxes recoverable	24,988	30,089	44,871	31,460
Prepaid expenses	1,491	1,654	1,662	1,587
Non-current Assets	**4,146,658**	**4,744,228**	**5,479,654**	**5,936,535**
Long-term Assets	**2,779,383**	**3,451,017**	**4,229,128**	**4,626,774**
Financial investments	24,195	26,280	38,211	78,934
Trade receivable (Customers)	50,921	43,729	32,363	26,172
CRC to State	1,205,025	1,282,377	1,280,598	1,308,354
Judicial deposits	87,360	147,895	185,994	276,541
Accounts receivable concession	1,097,120	1,637,888	2,225,203	2,383,262
Advance to suppliers	0	0	0	0
Other receivable	4,611	3,280	3,172	4,036
Income tax & social cont.	0	0	0	0
Other noncurrent taxes recoverable	71,775	64,303	64,827	60,663
Deferred income tax& social cont.	238,376	245,265	398,760	488,812
Investments	**4,250**	**4,232**	**4,012**	**4,012**
Property, plant & equipment	**0**	**0**	**0**	**0**
Intangible assets	**1,363,025**	**1,288,979**	**1,246,514**	**1,305,749**

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

In current liabilities, loans and debentures account for approximately 50% in 2012, in particular, debentures increased a great deal in 2012.

In equity, accumulated profits/ losses were zero from 2009 to 2011. It seems profits are absorbed by the parent company or shareholders. However, they become minus in 2012 reflecting the loss (red) in current 2012 profit and loss.

Table 7.4-7 Balance Sheet of COPEL Distribution (2) Liabilities (1,000R$)

Year	2009	2010	2011	2012
Total Liabilities and Equity	**5,586,303**	**6,708,119**	**7,629,993**	**8,812,803**
Current Liabilities	**1,090,066**	**1,449,633**	**1,708,165**	**1,987,053**
Payroll, social charges &acc.	139,562	118,790	151,184	259,725
Suppliers	433,800	444,987	531,187	694,903
Income tax & social cont.	0	0	0	0
Other tax liabilities	202,146	254,811	214,128	205,330
Loans and financing	12,490	17,950	17,619	164,788
Debentures	0	0	0	12,719
Dividend payable	111,268	355,968	508,695	371,863
Post-employment benefits	15,501	16,811	24,612	18,004
Customer charges payable	25,732	52,475	66,464	49,262
R&D & energy efficiency	106,761	140,381	140,918	142,936
Payable concession	0	0	0	0
Other accounts payable	42,806	47,460	53,358	67,523
Non-current Liabilities	**1,444,762**	**1,941,675**	**2,255,993**	**3,224,230**
Associated & subsidiary companies	658,724	715,539	781,031	851,237
Suppliers	0	0	0	0
Tax liabilities	48,311	11,553	0	0
Deferred income tax & social cont.	0	32,563	66,057	0
Loans and financing	147,224	525,711	708,607	609,941
Debentures				997,958
Post-employment benefits	241,546	262,728	295,899	326,987
R&D & energy efficiency	70,565	64,447	60,126	61,211
Payable concession	0	0	0	0
Other accounts payable	0	0	0	0
Provisions for legal claims	278,392	329,134	344,273	376,896
Shareholders' Equity	**3,051,475**	**3,316,811**	**3,665,835**	**3,601,520**
Capital	2,624,841	2,624,841	2,624,841	2,624,841
Capital reserve	0	0	0	0
Equity valuation adjustment	11,464	13,463	8,657	1,230
Legal reserve	82,274	108,500	135,294	135,294
Profit retention reserve	237,684	570,007	883,575	883,575
Unrealized revenue reserve	0	0	0	0
Additional proposed dividend	95,212	0	13,468	0
Accumulated profits (losses)	0	0	0	-43,420

(Source: COPEL's Financial Statements and Quarterly Report Dec. 2012)

7.5 Operation and Maintenance Structure after Project

The operation and maintenance structure (O&M structure) after the Project is considered based on the existing organization structure in COPEL.

1) Proposed O&M Structure

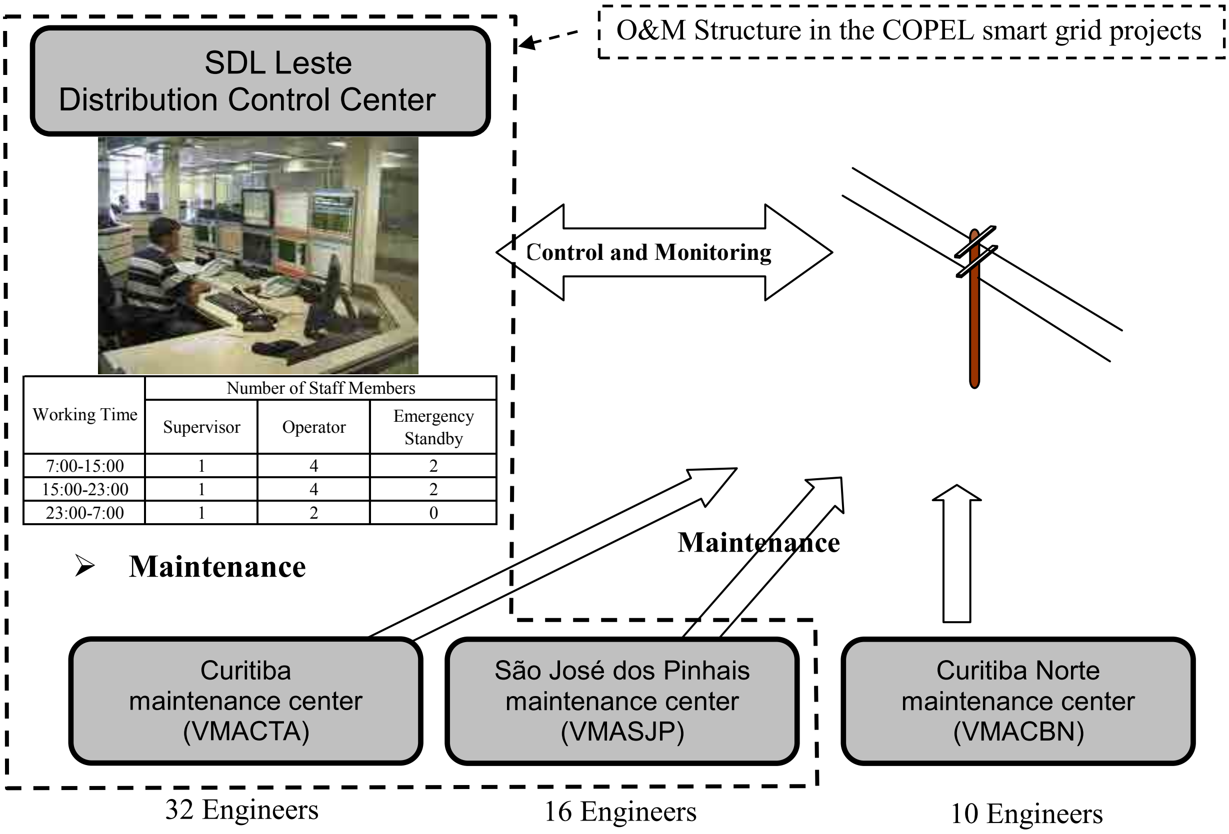
In the O&M structure of the COPEL smart grid projects (Curitiba and Fazenda Rio Grande), the distribution control center belonging to the SDL Leste conducts monitoring of the distribution lines through installed control panels, and the maintenance centers (VMACTA and VMASJP) belonging to the Superintendencia de Distribuicao Leste (SDL) conducts maintenance of the distribution lines in its territory.

For operation and maintenance after the Project, conducting by the similar O&M structure of the COPEL smart grid projects, because the O&M structure of the COPEL smart grid projects can be utilized after the Project by adding one maintenance center (VMACBN). Namely, the control panel under the Project will be installed in the same distribution control center belonging to the SDL Leste and its distribution control center will conduct monitoring of the distribution lines and give orders (e.g. orders for sending maintenance staff to fault section, confirmation of fault condition and recovery work, etc.) at power accident. In addition, normal maintenance and power accident recovery work at fault point after the Project will be conducted by 3 maintenance centers (VMACTA and VMASJP in the COPEL smart grid projects + VMACBN) these belong to the Superintendencia de Distribuicao Leste (SDL) which manages the target areas of the Project.

Figures 7.5-1 and 7.5-2 show the proposed O&M structure after the Project for normal condition and power accident.

【Normal Condition】

- **Control and Monitoring**



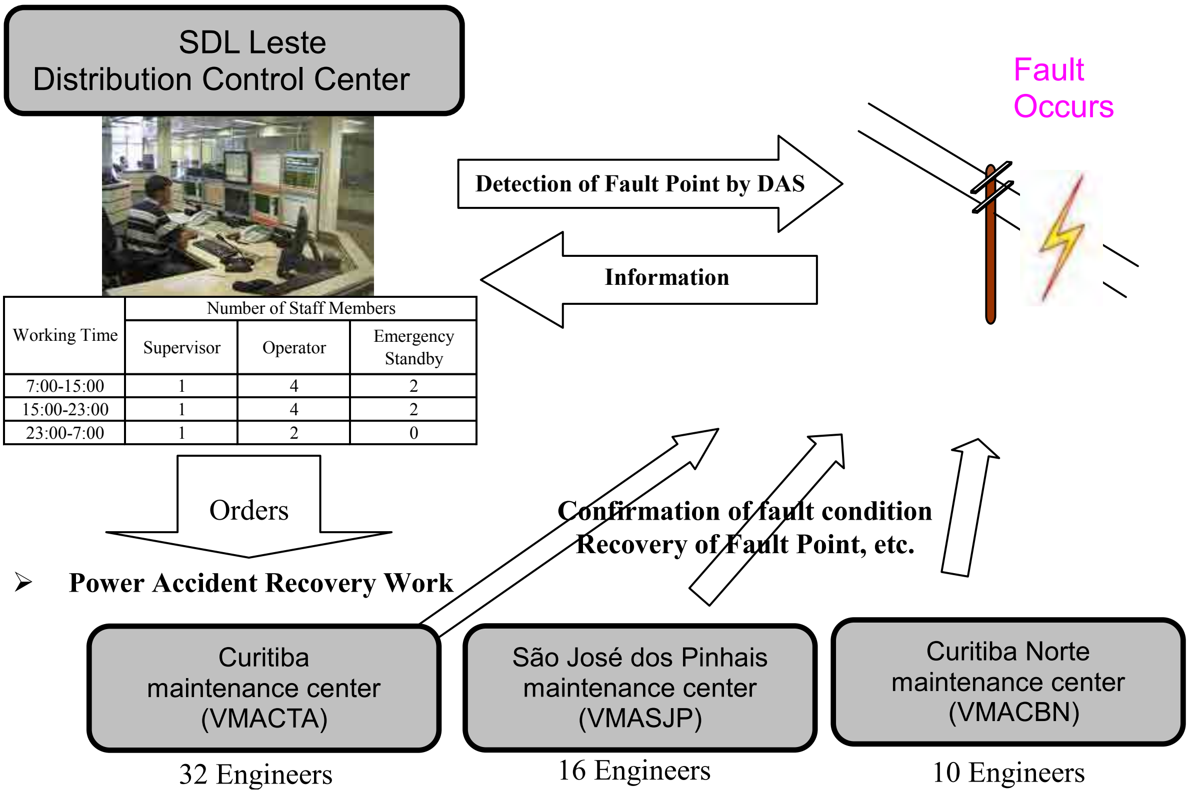
Working Time	Number of Staff Members		
	Supervisor	Operator	Emergency Standby
7:00-15:00	1	4	2
15:00-23:00	1	4	2
23:00-7:00	1	2	0

Figure 7.5-1 Proposed O&M Structure in Normal Condition

(Source: Created by JICA Survey Team)

【Power Accident】

- **Gathering Information and Order**



Working Time	Number of Staff Members		
	Supervisor	Operator	Emergency Standby
7:00-15:00	1	4	2
15:00-23:00	1	4	2
23:00-7:00	1	2	0

Figure 7.5-2 Proposed O&M Structure in Power Accident

(Source: Created by JICA Survey Team)

Table 7.5-1 Increased/Reduced/Not necessary Works after the Project based on Existing Works in Operation Center and Maintenance Center

Distribution Control Center		Maintenance Center	
Daily Work	Distribution facilities operating (order→on/off)	Daily Work	New construction work
	Site worker control		Construction supervision
	Distribution facilities data management		Maintenance and inspection planning
	Facility operation recording		Distribution line patrol
	System map updating		Maintenance and inspection of the distribution facilities
	Facility operation procedure updating		Maintenance and inspection of the automation facilities
	Customer service control		Distribution facilities operating (work in the site)
Accident	Trouble shooting	Accident	Fault point locating
	Site worker control		Fault point isolating
	—		Accident recovery work

: Increased Working Volume
: Reduced Working Volume
: Not necessary

(Source: Created by JICA Survey Team Based on Interview with COPEL)

2) Manpower

Regarding the above proposed O&M structure, it is necessary to consider the manpower in the distribution control center and maintenance center separately based on the existing works shown in Table 7.5-1.

A. Distribution Control Center

As described in Table 4.9-1, Figure 7.5-1 and Figure 7.5-2, the distribution control center is operated on 24-hour schedules by 3 shifts in the existing condition. As described in Table 7.5-1, when DAS is installed under the Project, Management and monitoring of the distribution lines is simplified. For example, some daily works (distribution facilities data management, facility operating recording, system map updating and customer service control) will be conducted automatically by DAS and their working volumes will be reduced, which occupy a large portion in general. At accident, necessary hours for trouble shooting and site worker control will be reduced because of reduction of outage duration by DAS, thus the working volume of these 2 works at power accident will be reduced as well. In addition, site worker control for distribution facilities operating (open/close of LBS) in the site will not be necessary because this operation will be conducted remotely by DAS. By contrast, the working volumes of distribution facilities operating and facility operation procedure updating are likely to be increased. Distribution facilities operation is conducted by request to maintenance staff in the site from distribution control center under the existing condition, but it will be able to be conducted by only on/off of ALBS in distribution control center after installing DAS and the frequency of the on/off of ALBS should be increased due to increasing the number of ALBS. The facility operation procedure is required to be updated according to the on/off of ALBS. Thus, also the working volume of the facility operation procedure should be increased. Therefore, by comparing reduced working volumes and increased working volume, the working volume in the distribution control center can be reduced comparatively and the man power in the existing distribution control center is enough to manage DAS.

B. Maintenance Center

As described in 4.9.2 Maintenance Structure of Distribution System, 4 maintenance centers such as VMACBN, VMASJP, VMACTA and VMALIT showed in Figure 5.9-8 conducts maintenance works described in Table 7.5-1 in the Curitiba Metropolitan Area. Among them, the Project is covered by only 3 maintenance centers (VMACBN, VMACTA, and VMASJP). In addition, each work in 3 maintenance centers is shown in Table 7.5-1 and the daily work of distribution facilities operating will be not necessary by the Project, because the distribution facilities operating will be conducted remotely by DAS. By contrast, the working volume of maintenance and inspection of the automation facilities will be increased, because of increasing the number of ALBS. However, maintenance and inspection might not be necessary even if many ALBS are installed under the Project, because the

DAS will monitor periodically if ALBS work correctly or not. The durable period of ALBS is more than 20 years and the troubles of ALBS occur less frequently in Japan due to simple mechanism. Regarding power accident, fault point locating and fault point isolating are shortened dramatically by DAS. Thus, vastly improved working volume at power accident would be able to be shifted to the maintenance and inspection of ALBS with another way of maintenance and inspection of ALBS being to outsource it to COPEL sub-contractors. Therefore, the man power in the existing maintenance center is enough to maintain distribution lines after installing DAS.

Accordingly, the manpower in the above proposed O&M structure is not required to be changed from the existing condition.

3) Technical Level

Regarding the above proposed O&M structure, it is necessary to consider the technical level in the distribution control center and maintenance centers separately as well.

A. Distribution Control Center

At present, the distribution control center is conducting the operation and trouble-shooting to handle power accidents by collating enormous system information to Geometrical Information System (GIS) and monitoring system. After installing DAS, most of the remaining works shown in Table 7.5-1 can be conducted automatically by DAS as described in 4) Man Power. In addition, even for the works (Distribution facilities operating and Facility operation procedure updating) increased their working volumes, their works would be simple such as on/off of ALBS and confirmation and updating of outputted information of facility operation procedure from DAS. At power accident, the way to order will be slightly changed before and after the Project, thus the existing technical level of the order is enough. Therefore, it is very easy for the operators to take appropriate actions without high skill and knowledge after installing DAS compared with the previous system.

B. Maintenance Center

As described in 7.2.3 Technical Level of Implementation Organization, the maintenance center of COPEL carries out the acceptance test of facilities for the smart grid projects in Curitiba City and Fazenda Rio Grande in addition to the maintenance of distribution facilities in the field, and there is not a big difference in installing facilities between the COPEL smart grid projects and the Project. Therefore, COPEL already has basic skills and technical knowledge related to installing facilities and maintenance under the Project. Additionally, the maintenance centers have also conducted fault point locating and the fault point isolating with power accident according to order from the distribution operation center. After the Project, the necessary technical skills for the fault point locating and the fault point isolating at power accident are completely the same. Accordingly, necessary technical knowledge and skills for new DAS in maintenance centers are still sufficient both for normal condition and power accident.

Accordingly, the technical level in the above proposed O&M structure is not required to be changed from the existing condition.

4) Considerable Points

As described in 3.3 Present Situation and Plan of Smart Grid in Curitiba Metropolitan Area, COPEL is conducting the smart grid projects in Curitiba City and Fazenda Rio Grande, which are similar to the Project and their O&M structure can be utilized for the O&M structure under the Project as described above. In addition, as explained above, COPEL already have enough man power and technical skill for the proposed O&M structure. Therefore, the proposed O&M structure may not have any problems after the Project.

However, COPEL does not have actual operation experience of the latest DAS because it has only limited operation experiences in small technical area of the existing automated distribution system installed by COPEL, and the big difference in the systems between the COPEL smart grid projects and the Project is fault point locating at power accident. It means that the system in COPEL smart grid projects can not locate fault point automatically, but the system (DAS) in the Project can. Therefore, COPEL does not have actual experience of trouble shooting after the DAS locates fault point automatically. In addition, new control panel will be installed under the Project and the knowledge of operation of it would be very important for COPEL. Therefore, the following 2 trainings procedures will be very helpful for COPEL.

A. Simulation training for trouble shooting after the DAS installed under the Project locates fault point.
(e.g. How to send the command from control center to maintenance center, etc.)

B. Operation training for new control panel
(e.g. How to operate distribution facilities (on/off) and How to update facility operation procedure, etc.)

Additionally, the assumed conductors for above 2 trainings are as follows.

A. International consultants selected by COPEL

B. Installing manufacturers of new control panel

Chapter8 Environmental and Social Considerations on Project Site

8.1 Survey Outline

8.1.1 Project Components and Environmental and Social Considerations

The concept of Smart Grid Project is presented in Figure 8.1-1 and Table 9.1-1 which show each project component of "Smart Grid Project in Curitiba Metropolitan Area (hereinafter referred to as "the Project") and its description in view of environmental and social considerations. The target area of the project in Scopes 1- 3 is 24 municipalities and Project Component 4 is only in Curitiba City.

As explained in this table, the project components necessary to be considered in terms of environmental and social impacts are identified as:

- ✧ Construction works: installation of equipment in substations and distribution lines
- ✧ Disposal of old equipment

The construction works at substations and distribution lines do not require the land acquisition and resettlement of residents since there is neither new substation construction nor expansion of substations due to the project. In this sense, serious environmental and social impacts due to this project are not predicted.

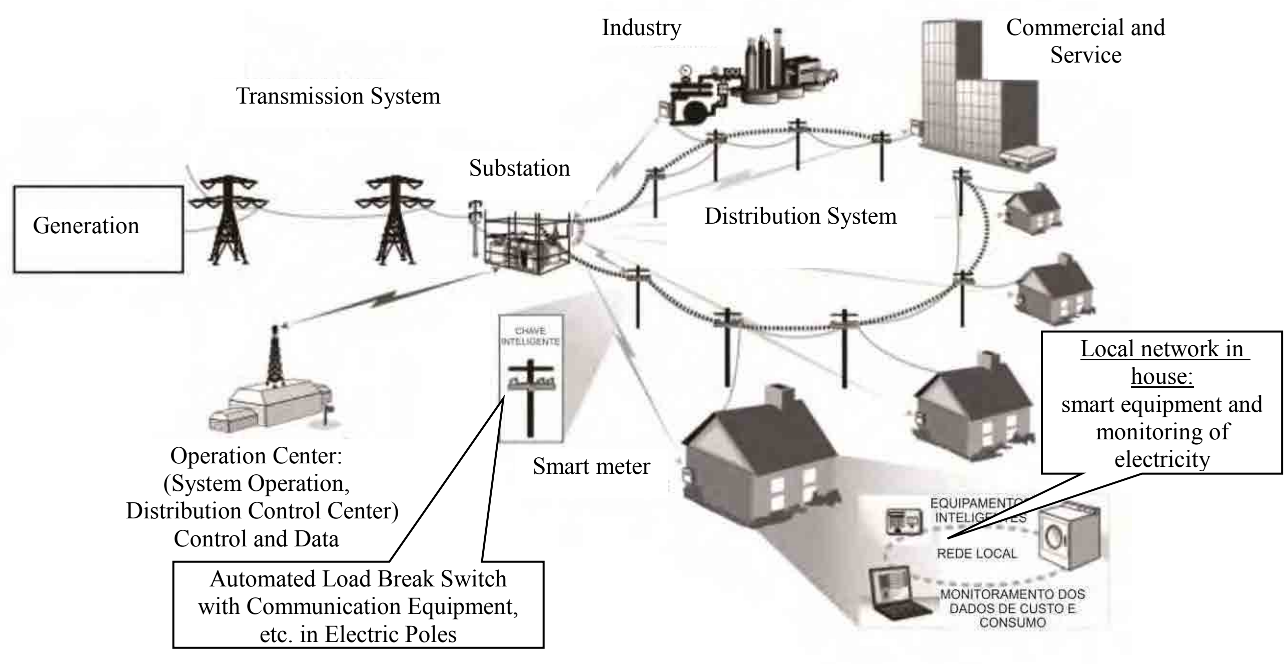


Figure 8.1-1 Conceptual Image of Smart Grid Project

(Source: Elaborated by Ecotécnia Ltda, originally from GAO 2013)

Table 8.1-1 Project Components and Description in relation to Environmental and Social Considerations

Project Scope	Description
1. Facilities for Distribution Control Center · Replacement of Software System (DAS: Distribution Automation System) · Installation of communication equipment, etc.	◆ Replacement of the software and equipment in the space in the existing Distribution Control Center -Work stations (PCs) -Server -Inter-connection to communication equipment ◆ No need for expansion work of the space in the Distribution Control Center ◆ Disposal of old equipment such as existing work station, control cables and miscellaneous items is necessary.
2. Facilities for Substations Installation of · Master Remote Terminal Unit (MRTU) · Relay, Current Transformer (CT)/Ground Potential Transformer (GPT) · Communication Equipment if necessary, etc.	◆ Installation of new equipment such as MRTU, relay, communication line inside the buildings in the existing substations ◆ Installation of CT/GPT with bases at switchyard of the substation ◆ No need for new substation construction and, basically, no need for expansion of the space of the existing substation ◆ Disposal of old equipment such as control cables and miscellaneous items is necessary.
3. Facilities for Distribution lines Installation of: · Automatic Load Break Switch (ALBS) · Remote Terminal Unit (RTU) · Communication Equipment · Voltage regulator · Capacitor Construction work of : · Extension of 13.8/34.5kV Distribution Lines · Extension of Optical fiber cable	◆ Installation of new equipment on the distribution lines or replacement of the existing equipment ◆ Construction work for extension of distribution line 13.8/34.5kV is necessary to connect between the two distributions lines coming from different feeders. ◆ Construction work for extension of the optical fiber cable to connect RTU (under the distribution line) ◆ Disposal of old distribution lines, scraps of iron and concrete, and others is necessary
4. Advanced Metering Infrastructure (AMI) Installation of · Smart meters (first phase 20,000, second phase 200,000) of low voltage electricity users in Curitiba City (Pilot Project) · AMI servers in Distribution Control Center	◆ Installation of new smart meters as a replacement of the old ones ◆ Installation of AMI servers in the existing space of the Distribution Control Center ◆ No need for construction work ◆ Disposal of old meters is necessary.

(Source: JICA Survey Team)

8.1.2 Highlights of Survey

In relation to waste disposal of old equipment and extension of distribution line, legal framework at each level of federal, state, and municipal levels is reviewed, respectively. In the case of this project, the project area is limited to only the State of Paraná, and most probably large scale impacts due to the project scope are not predicted. Therefore, local governments, i.e., state and municipal regulations, are more critically reviewed.

In case of extension of distribution lines, it will be determined finally only at the time of detailed design. Thus, it cannot be assessed at this moment. For the survey, therefore, general principles and actual experiences of COPEL will be reviewed upon extension of distribution line. Basically, it is assumed that there is no necessity to extend the distribution line in Curitiba city because it has already developed distribution network. Thus, extensions of distribution lines are examined in case of 23 municipalities except for Curitiba.

The project target area is extensive, comprising of 24 municipalities and the total area is 14,064.91km^2. Given the purpose and period of the survey, while general environmental and social information is reviewed in this whole area, more details in 10 municipalities around Curitiba City (Admirante Tamandaré, Araucária, Campina Grande do Sul, Colombo, Mandirituba, Pinhais, Piraquara, Quatro Barras, São José dos Pinhais, and Rio Branco do Sul) are analyzed in terms of environmental and social regulatory information. Except Mandirituba, these municipalities are Central Urban Nuclear (NUC) in the Curitiba Metropolitan Area, which are more developed and densely populated compared to the other municipalities of the project target in the Curitiba Metropolitan Area.

Among all the substations in the project target area, 4 municipalities selected from 10 municipalities are examined as examples: a municipality with industrialized area (Sâo José dos Pinhais), a municipality of densely populated area (Colombo), a municipality with less populated area (Rio Branco do Sul), and a municipality with population density between Colombo and Rio Branco do Sul (Admirante Tamandaré). Potential area where examples of distribution lines planned to be extended are also examined around the area of three substations.

Consumer survey is conducted in Curitiba City by sampling of residential consumers at sales offices and some institutions, in order to have consumers' opinions on introduction of Advanced Metering Infrastructure (AMI) and information of what kind of domestic electric appliances they are using during the peak hour.

Stakeholder meeting is not conducted at this time because:

-Environmental and social impacts are predicted to be temporary in many cases and relatively small in scale.

-Extension of distribution line will be planned later at detailed design stage; therefore, actual location and scale of the project work on this component is unknown at this preparatory survey stage.

8.1.3 Project Alternatives

1) Substations and Extension of Distribution Line

It is difficult to identify alternatives in order to achieve the project objective, enhanced reliability and reduction of power outage time and frequency for this type of project. In terms of environmental aspect, the Project components have minimal influence to environmental and social issues since the main components are upgrade of equipment and extension of distribution lines, considered as relatively small construction work. In general practice, actual location of distribution line extension will be designed along with the road in public land and to avoid any type of environmental protected areas at detailed design stage.

2) Option of "Without Project"

Annual growth rates of electricity demand in COPEL service area in the past ten years were 4 to 6 %. In the future, IPARDE predicts real economic growth rate in the State of Paraná will be about 4% until year 2016. Thus, the economy in the Curitiba Metropolitan Area is assumed to increase by more or less 4 % per year during the same period.

In this situation, without this project, the percentage of distribution loss and outage duration and frequency will not be improved at the same level by other means. In order to respond to increase in demand, new construction or expansion of the existing power plant and substations may be necessary in the future. New construction or expansion of power plant may cause more environmental cost compared to the Project.

8.2 Environmental and Social Consideration System and Organizations

8.2.1 Legal Framework

In Brazil, at the federal government level, the Constitution in 1988 stipulates environmental protection in one chapter. Prior to it, the Law on National Policy of the Environment (Política Nacional do Meio Ambiente Lei No. 6.938) was established in 1981, and it has been a basis of current legal framework for the environmental protection policy. The Law on National Policy of the Environment established "National System of Environment" (SISNAMA: Sistema Nacional do Meio Ambiente) for environmental and social considerations of development projects comprises the federal level authorities such as the Federal Government Council, Ministry of Environment (MMA: Ministério do Meio Ambiente), National Council of Environment (CONAMA:Conselho Nacional do Meio Ambiente) and Brazilian Institute of Environment and Renewable Natural Resource (IBAMA: Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis) under MMA, National Water Agency (ANA: Agência Nacional de Águas) and also other federal, state, and municipal government organizations. In the case of this project, most related laws, decrees, and resolutions are listed in Table 8.2-1, but it is not limited only to them.

Regulations on Environmental License and necessity of Environment Impact Assessment (EIA) are stipulated by the CONAMA Resolution No.1 in 1986 for the first time and then several times it has been revised to date. CONAMA Resolution No. 237 in 1997 stipulates the jurisdiction of federal, state, and municipal government authorities, respectively. These resolutions articulate that the Project executing agency must obtain the environmental license in each phase of the project such as:

- License of Prevision (LP: Licença Prévia) : in the phase of project planning
- License of Installation (LI: Licença de Instalação) : in the phase of project implementation
- License of Operation (LO: Licença de Operação) : in the phase of project operation

According to these CONAMA resolutions, activities which require environmental license in the electric power sector are; power generation plants of more than 10MW with any type of primary energy source, hydroelectric power by dam with more than 10MW capacity, and more than 230kV transmission line. This Project does not fall into any of these categories.

Also, according to CONAMA resolution, as a principle, the federal government authority is involved in environmental clearance if the project potentially affects the federal environment protection area or more than one state. The Project work is implemented in an area within one state without affecting areas across other states, and is considered to have no possibility of affecting any federal level environmental protection areas. Conducting any development project in a federal environmental protection area is prohibited and even if 13.8/34.5kV distribution lines are newly constructed near such an area, there is almost no possibility of affecting the areas. Thus, the authorities that provide approval for environmental clearance and monitor the project are local authorities only at the state and municipal governments.

Regarding the federal law on waste disposal, there are “National Politics of Solid Residue Lei No. 1.428” and also decree No.7.404. Also, in terms of protection of forest, there are “Forest Code Lei No.12.651” and “Atlantic Forest Law Lei No. 1.428”.

Table 8.2-1 List of the Federal Laws and Regulations on the Environment Protection

Date of Legislation (day/month/ year)	Type and No.	Title /*Content*
Environment Protection Policy in General		
31/08/1981	Lei No.6.938	National Policy of Environment (Política Nacional do Meio Ambiente)
12/02/1998	Lei No.9.605	Lei de Crimes Ambientais (Environmental Crime Law)
18/07/2000	Lei No.9.985	National System of Conservation Unit (Sistema Nacional de Unidades de Conservação)
Environment License and Environmental Impact Assessment (EIA)		
23/01/1986	Resolução No. No.1	CONAMA Resolution *Environmental License – Norms and Procedure – Basic Criteria and General Directions for Environmental Impact Study (EIA)*
19/12/1997	Resolução No.237	CONAMA Resolution *Environmental License : Competence of Federal government, State, and Municipalities, List of Activities subject to obtain license, Environmental Study, Environmental Impact Study, and Environmental Impact Report*
27/06/2001	Resolução No.279	CONAMA Resolution *Establish procedure for simplified environment license for electric work with potential small environment impact*
Environment Protection in Specific Issues in relation to the Project		
12/05/2012	Lei No.12.651	Forest Code (Código Florestal)
22/12/2006	Lei No.1.428	Law on Atlantic Forest Law (Lei da Mata Atlântica)
02/08/2010	Lei 12.305	National Politics of Solid Residue (Politica Nacional de Resíduos Sólidos)
2010	Decreto No.7.404	*Decree for regulating a National Policy for Solid Residue*
25/1937	Lei No. 25.1937	*Decree for organizing protection of historic heritage and national artistic*

(Source: Elaborated by JICA Survey Team)

Table 8.2-2 shows major laws and resolutions of state government of Paraná related to the project. Procedures to obtain environmental license and forest authorization are at first stipulated in “SEMA resolution No. 31” in 1998. “Conjoint Resolution SEMA/IAP No. 9” in 2010 states environmental clearance more specifically according to the type of power sector projects.

With respect to waste disposal, each organization should prepare the plan of waste management and disposal implementation according to the type of equipment. If the waste is hazardous so that it directly impacts nature and human beings, it should require special treatment. COPEL has an internal regulation to formulate “Management Plan of Solid Waste (PGRS)” in case of the project with a certain scale of civil work. As the Project does not require large scale civil work and disposal of equipment mainly consisting of old cables and iron and concrete scraps, it is not necessary to prepare such a management plan.

State governments conduct zoning for appropriate land use and establish environment protection areas. In case of the State of Paraná, including the Curitiba Metropolitan Area, there are water source areas for the Iguaçu Fall which is a world natural heritage site and federal environmental protection area. Those areas are also critical as water supply in the Curitiba Metropolitan Area and the state government established the laws and regulations on the management of such an area, as Environmental Protection Areas (APA: Área de Proteção Ambiental) or Territorial Unit of Planning (UTP: Unidade Territorial de Planejamento). There are state decrees for each APA and UTP.

Table 8.2-2 List of State Laws and Regulations on the Environment Protection

Date of Legislation (day/month/ year)	Type and No.	Title <*Content*>
Environment License and Environmental Impact Assessment (EIA)		
24/08/1998	Resolução No.31	SEMA Resolution (Resolução SEMA) *Environment License , Environmental Authorization, Forest Authorization, Announcement of Provision for Dismemberment and Installment in Rural Field*
Year 2009	Resolução No.51	Resolution *Exemption of environmental License and authorization of small-scale projects and activities with low environmental impact*
03/11/2010	Resolução No.09	Conjoint Resolution SEMA/IAP (Resolução Conjunta SEMA/IAP) *Procedure of Environment License , Environmental Authorization, Forest Authorization and so on, related to generation, transmission, distribution of the electricity*
Environment Protection in Specific Issues in relation to the Project		
Year 2002	Decreto Estadual No. 6.674	State Decree *Procedures, Norms, and criteria of Treatment of Solid Waste*
Year 1999	Decreto Estadual No. 808	State Decree *Declaration for protecting "Manancias" (Water Sources)*
Year 1998	Lei Estadual No. 12.248	State Law *Establishment of Integral System of Management and Protection of Water Sources*
Year 1995	Lei Estadual No. 11.054	State Forest Law (Lei Florestal do Estado)
Year 1995	Lei Estadual No. 11.067	State Law *Prohibited activities in terms of utilization, destruction, hunting, collection of the fauna that are threatened by extinction*
Year 2003	Lei Estadual No. 14.037	State Law *State Code of protection of animals*

(Source:Elaborated by JICA Survey Team)

Municipal governments have "Organization Law (Lei Orgânica)," which is a basic law that is considered as each city's constitution. These laws state the promotion of environmental protection and control of environmental pollution. Each municipality has the right to ask the Project executing organization to provide them "Provisional Study of Impact on Neighborhood" (EIV: Estudo Prévio de Impacto de Vizinhança) for any development project, apart from environment impact study required by IAP for provision of environmental license. In case of other 10 municipalities around Curitiba, Pinhais, Araucária, Campina Grande do Sul, Quatro Barras and Piraquala established the municipal law on environmental protection policy and/or environmental licenses. In case of Curitiba City, there are terms of reference of EIV, defined by the municipal law No. 11.266 established in 2004.

In general, it should be noted that the State of Paraná regulates that it is obligatory for each municipality to formulate a development master plan (Plano Diretor) once every 10 years. This is currently not the case with municipalities in other states in Brazil. In this sense, existing municipal environmental regulation also examined carefully in order to avoid any conflict between the project works and existing legal framework. Upon constructing the extension of distribution, in some cases it might be necessary to pay attention to this document.

In relation to the Project components, according to COPEL, there was no case to receive a request for

EIV by the municipal governments for extension of 13.8/34.5kV distribution lines. Therefore, the request for EIV by municipal governments is hardly predicted. In addition, extension route of distribution line is relatively easily checked with existing municipal governments' plan such as "Plano Diretor".As a conclusion, at this moment, no critical issues are identified in legal requirement of municipal governments.

8.2.2 Organizations and Procedure for Environmental Clearance

1) Clearance Procedure for Local Authority

As for construction works of the Project conducted in 23 municipalities except for Crutiba, environmental approval from IAP under State Secretariat of Environment and Water Resources (SEMA) is required. In case of construction work in Curitiba City, approval of the municipal environmental authority is only required.

Reviewing the regulation "Conjoint Resolution SEMA/IAP No. 9 in 2010" under the Decree by State Secretariat of Environment and Water Resources of State of Paraná (SEMA: Secretaria de Estado do Meio Ambiente e Recursos Hídricos) and Environmental Institute of Paraná (IAP : Instituto Ambiental do Paraná), this resolution states the procedure of environmental clearance in detail for the power sector projects such as generation, transmission, and distribution.

According to this resolution, in case of 13.8/34.5kV distribution line construction environmental license is not required to be obtained at each phase. Moreover, any type of environmental study is not prerequisite, even such as Simplified Environmental Report (RAS: Relatório Ambiental Simplificado). RAS can be considered generally equivalent to the Initial Environmental Examination (IEE).

Environmental authorization by submission of documents in Table 8.2-3 is required in case of cutting of native species, while it is not necessary in case of cutting of exogenous species[1].

Table 8.2-3 Documents Required for Environmental Permission in Case of Distribution Line Construction of 13.8/34.5kV

Type of Environmental Permission	Documents to be submitted
Environmental Authorization (Autorização Ambiental)	a) Request of Environmental Authorization b) Simple Registration of Various Civil Works c) Undertakings of Basic Project and Content - Plan and /or Sketch of delimitation and characteristics of existing forest typology and demarcation of each property affected by the project- Project situation plan d) Announce for properties which are cut and/or suppressed e) Receipt of Payment of Environmental Tax f) Copy of Notes of Technical Responsibility of Residing professionals

(Source: Art.17 in "Resolução Conjunta SEMA/IAP No. 9/2010")

[1] Interview to Department of Environmental Management in COPEL.

2) Organization and Procedure in COPEL

COPEL had the Chief Environment and Corporate Citizenship Office (DMC) established in 2009 for environmental and social considerations for new projects and social responsibility activities as a public company (Refer to Figure 8.2-1). Among the electric power companies in Brazil, COPEL is the first one that delegates environment and social issues to directorate level. This office coordinates all the social and environmental activities in COPEL and COPEL's subsidiaries such as COPEL Generation and Transmission, COPEL Distribution, and COPEL Telecommunications. In total, there is 143 staff in this office as of February 2012.

Under this office, Superintendence of Environmental Engineering is in charge of obtaining the environmental license and conducting environmental impact study upon the implementation of new projects. 96 staff members are working for the SEA. Working together with Superintendence in charge of the project implementation, SEA assures the process of acquiring the environmental license. In SEA, Department of Environmental Management (DGEA) undertakes the work of obtaining environmental license. Coordination Office of Planning and Environmental Study (CPMA) under SEA is in charge of conducting necessary environment study for the project. COPEL usually contracts with external organizations in case of EIA study whose scope is extensive; however, they conduct simple environmental study such as RAS (IEE) by themselves since COPEL has enough capacity with expert staffs in each field such as biodiversity, fauna, forest, biology, etc.

According to COPEL, in general, estimated period of time for environmental authorization is 80 days, counting from internal preparation of document and submission of the document to the local authorities to the acquisition of the authorization. In case of authorization of cutting trees, 140 days is estimated. It appears the estimated period necessary for authorization differs depending on the local authority involved. In case of authorization of only Curitiba Municipal Institution, it appears faster than the case of state government institutions.

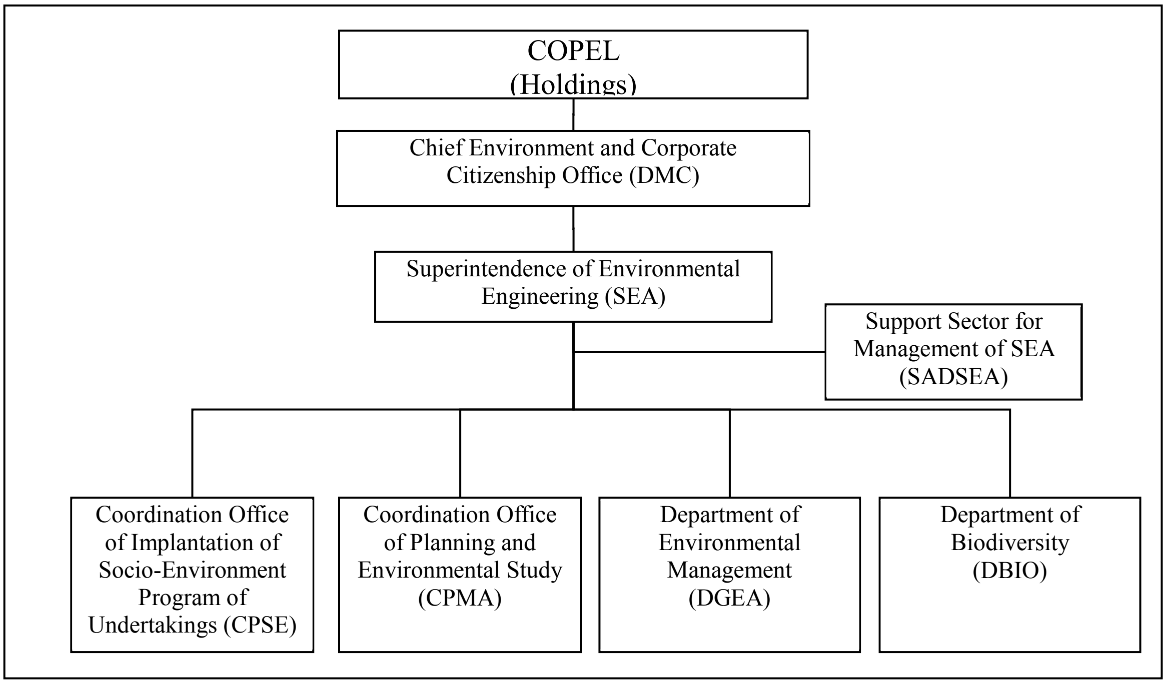


Figure 8.2-1 COPEL Organization Chart in Relation to Environmental Consideration for the Project

(Source: COPEL, as of February, 2013)

8.3 Natural and Social Environment in the Project Area

8.3.1 Natural Environment

1) Protection Areas

In the Curitiba Metropolitan Area, there are some environmental conditions that restrict the use and occupation of the soil. Such areas are Environmental Protection Area (APA), Territorial Unit of Planning, and Water Source Interest Areas of Public Water Supply.

Environmental Conservation Areas are established at federal, state, and municipal levels. The Federal Government law, Lei No. 9985 National System of Natural Conservation Units (SNUC) states two groups of conservation areas. One is “Units of Integral Protection (Unidades de Proteção Integral)” where occupation of human beings is totally prohibited and it is only allowed to use resources there indirectly for the survey or eco-tourism purpose. The other is “Units of Sustainable Use (Unidades de Uso Sustentavel)” where occupation of human being and use of natural resources are permitted in a sustainable manner.

There are 21 Conservation Areas in the Curitiba Metropolitan Area: 2 federal protection areas, 18 state protection areas, 1 municipal protection area (refer to Figure 8.3-1). Under the SNUC, those are 7 units of integral protection and 14 Units of Sustainable Use. Among all APAs, 5 APAs (17 to 20 APAs in Figure 8.3-1) are described as Water Source Area for the Curitiba Metropolitan Area.

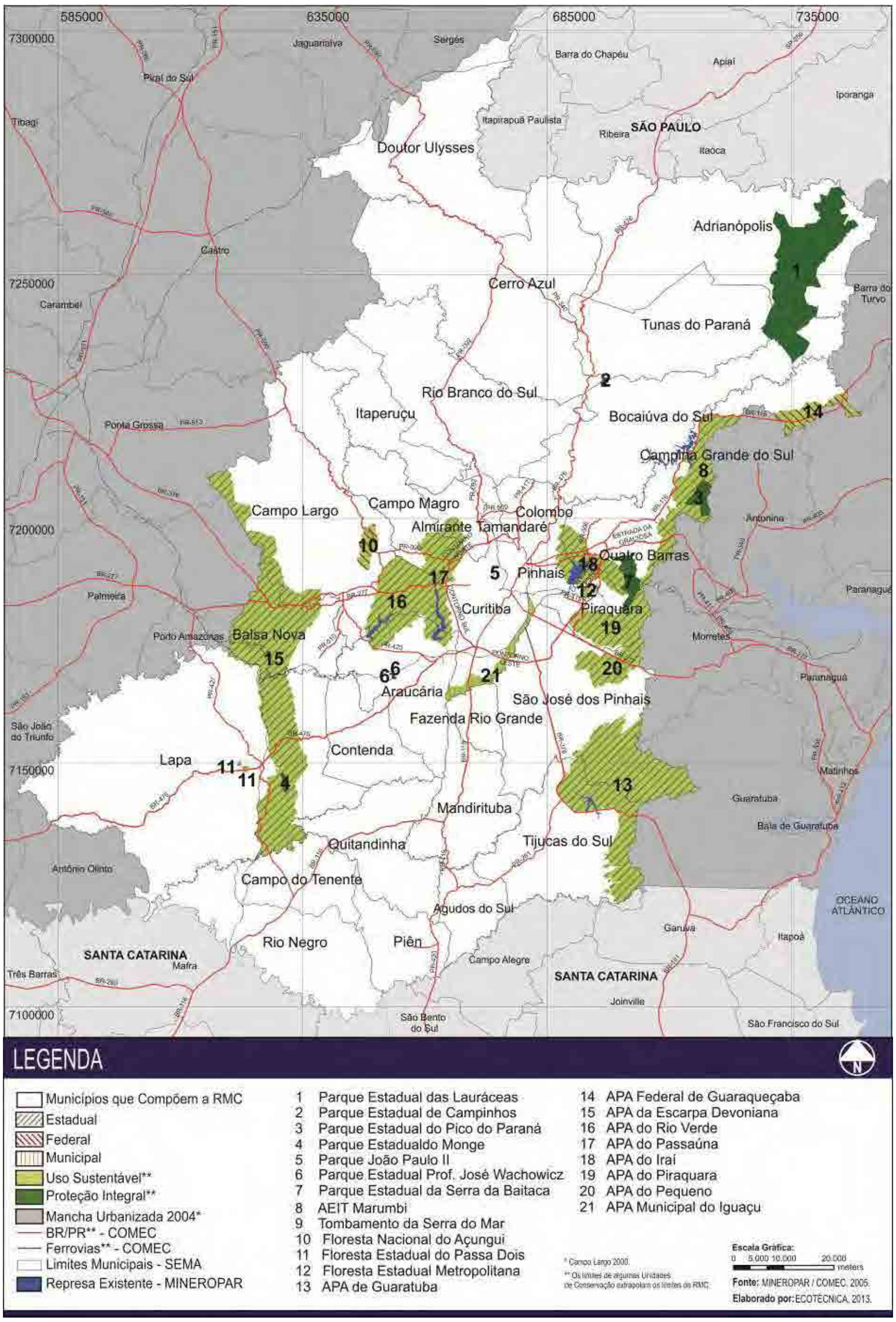


Figure 8.3-1 Environment Protection Areas in Curitiba Metropolitan Area

(Source : Elaborated by Ecotécnia, Ltda, originally from COMEC)

2) Vegetation

A major part of the Curitiba Metropolitan Area is characterized by Mixed Ombrophious Forest (Floresta Ombrófila Mista). The area is also famous for Paraná-Pine Forest (Florestas com Araucária) in mixed Ombrophilous Forest, which is a part of "the biome Atlantic Rain Forest (o bioma Mata Atlãntica)" which was comprised of Dense Ombrophilous Forest and Seasonal Forest. Paraná-pine is a native species, typical of highland areas and grows up to 30 meters height and 1-2 meters in diameter.[2] It is on the Red List of Endangered Species in the State of Paraná. It is generally prohibited to cut Paraná-pines except for some conditions, and penalties can be imposed on those who cut them without permission. Figure 8.3-2 below shows the coverage of vegetation in the Curitiba Metropolitan Area.

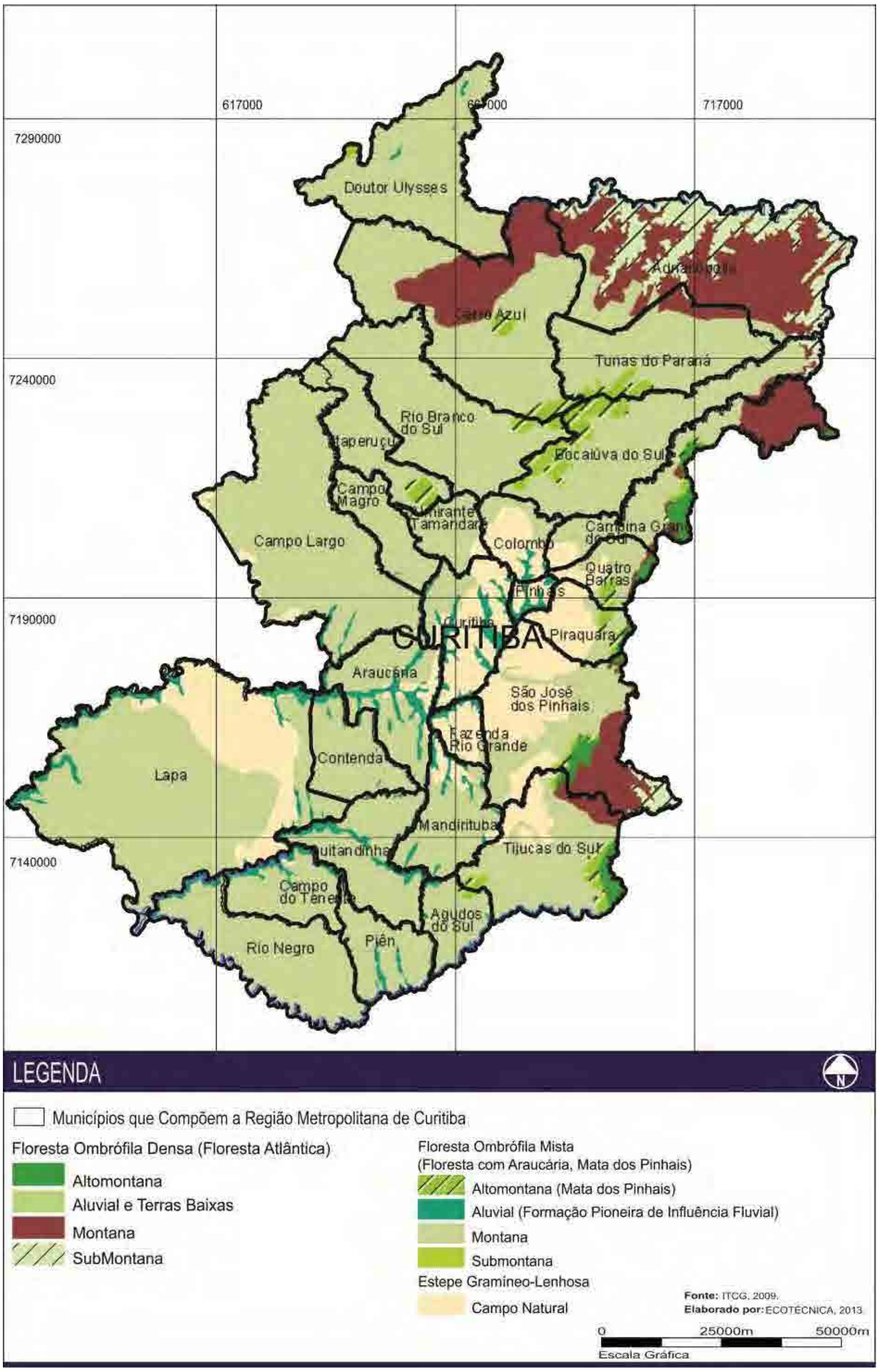


Figure 8.3-2 Vegetation in Curitiba Metropolitan Area

(Source: Elaborated by Ecotécnia Ltda, originally from ITCG)

[2] Eduardo Fenianos "Manual Paraná-Nosso Estado em Suas Mãos ", p18.

8.3.2 Social Environment

In terms of ethnic minority in the Curitiba Metropolitan Area, according to National Foundation for Indians (FUNAI: Fundação Nacional do Índio), two places are officially registered as indigenous communities (Kakané Porã and Karugu). Nearly 200 indigenous people live in these communities. According to IBGE, 2,693 indigenous people live in Curitiba City; however, they are living sporadically and already adapted to urban life.

In Brazil, there are communities called "Quilombola" which consists of slaves escaped from plantations during the 16th to 19th Centuries. These communities have also adapted and incorporated into the current Brazilian society although they are still under some protection stipulated by the law.

Figure 8.3-3 shows the location of indigenous communities and Quilombora in the Curitiba Metropolitan Area.

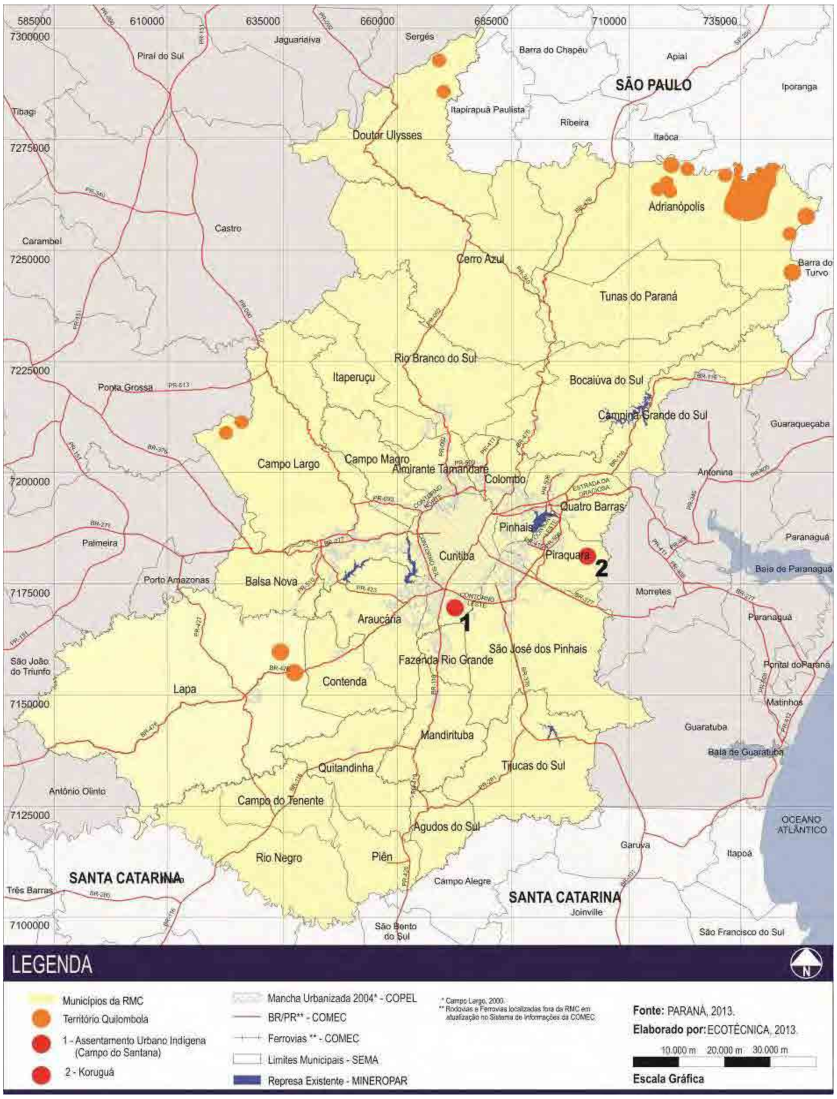


Figure 8.3-3 Indigenous Community and Quilombolas in Curitiba Metropolitan Area

(Source: Elaborated by Ecotécnia Ltda, originally from COMEC 2006)

8.4 Environmental and Social Impacts

8.4.1 Scoping and Further Survey/Review Points

As a result of information collection and discussion with personnel in the environmental sections, i.e., CPMA and DGEA of SEA in COPEL, scoping of the Project impacts was summarized in Table 8.4-1. As seen in this table, 14 out of 31 check items are identified as having possible minor negative /positive / unknown impacts at the moment, either or both of pre-/during construction stage and operation stage of the Project. No significant impact is predicted in any issues. Only minor negative impacts can occur during the construction of distribution line extension and waste disposal.

Table 8.4-1 Result of Scoping and Further Survey Points

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Brief Description *(Reasons for Rating)*	Further Survey Points
		Pre-/ during Construction Stage	Operation Stage		
Social Environment					
1	Involuntary Resettlement	D	D	Project Scope does not require resettlement.	
2	Local economy such as employment and livelihood, etc.	B+	D	**【During construction】** Employment of temporary local workers during construction can be increased. **【Operation】** No increase of employment is predicted.	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document.
3	Land use and utilization of local resources	D	D	Project components do not influence land use and utilization of local resources.	
4	Social organizations of social infrastructure and local decision-making and so on.	D	D	Project components do not require the intervention in such infrastructure.	
5	Existing social infrastructures and services	C	B+	**【During construction】** Extension of distribution line is conducted generally on the existing roads and bridges. In case of extending the distribution line over the road, it should be coordinated with other governmental agency in charge of the roads. Extension over railway is very limited, thus most probably it is not necessary to coordinate with railway authority. **【Operation】** Operation cost on energy of social services such as schools and hospitals can be reduced by shutting down or downsizing their own existing independent generating facilities, etc., as a result of improving reliability of	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document. ・Information on result of electricity consumer survey

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Brief Description *(Reasons for Rating)*	Further Survey Points
		Pre-/ during Construction Stage	Operation Stage		
				electricity supply from the grid by the Project.	
6	The poor, indigenous and ethnic people	C	D	Distribution line may pass through such community. However, the project components do not affect such vulnerable groups in particular.	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document. ・Percentage of poor household in Curitiba City ・Information on result of electricity consumer survey
7	Misdistribution of benefit and damage	D	D	Characteristics of the Project do not cause such misdistribution.	
8	Cultural heritage	C	D	Even in urbanized areas, there is a possibility of affecting cultural heritage. However, considering the project components, most probably, the level of impacts are predicted to be rather minor scale.	・Location of cultural heritages
9	Local conflict of interests	D	D	Characteristics of the Project do not cause local conflicts.	
10	Water Usage / Rights	D	D	Characteristics of the Project do not influence water usage/rights.	
11	Right of Way	C	C	**【Pre-construction】** Distribution line construction is usually conducted along the road;	・Information on operation policy for social consideration at the time of pre-construction: any document review and interview with COPEL and construction company. ・Site survey in selected municipalities
12	Sanitation and Public Health	D	D	Project components do not require civil work in a large scale in terms of area and content; therefore no necessity of workers' camp area. Accordingly, the project does not cause any problem of sanitation and public health of workers and residents near the construction sites.	
13	Hazards (Risk) Infectious diseases such as HIV/AIDS	D	D	Civil work component of the Project does not incur the increase of many immigrant workers outside of Project area. Thus, no risk is predicted.	
14	Working Environment and	B-	B-	**【During construction】**	

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Brief Description *(Reasons for Rating)*	Further Survey Points
		Pre-/ during Construction Stage	Operation Stage		
	Accidents			The risk of work accident is related to construction equipment operation and movement of special vehicles. 【Operation】 At the time of periodic maintenance of distribution line and equipment, there is a work accident risk during that time.	・Information on accident risk management of COPEL and construction companies by interview and through the document review. ・Site survey on any construction or maintenance site
Natural Environment					
15	Topography and Geographical features	B-	D	**【During construction】** Civil work of construction of new post requires soil compact. Thus topography can be different at the time of project implementation although it would be at very small scale.	・Information on operation policy for environment consideration during construction work: any document review and interview to COPEL and construction company
16	Soil Erosion	D	D	Civil work of the Project does not cause soil erosion.	
17	Groundwater	D	D	Civil work of the Project does not affect groundwater.	
18	Hydrological Situation	D	D	Civil work of the Project does not affect hydrology.	
19	Coastal Zone (Mangroves, Coral reefs, Tidal flats, etc.)	D	D	No coastal zone exists in Project Area.	
20	Flora, Fauna and Biodiversity	C	C	**【During construction & Operation】** With respect to the flora, during construction and maintenance of distribution line may require cutting trees. In terms of influence on fauna and biodiversity, no large influence is predicted by the Project.	・Information on operation policy for environment consideration for flora during construction work: document review and interview with COPEL and construction company. ・Site survey in selected municipalities.
21	Meteorology	D	D	Scale of the civil work of the project does not influence on the climate.	
22	Landscape	B-	B-	Construction of new posts, distribution lines and equipment changes the appearance of landscape.	・Site survey in selected municipalities.
23	Global Warming	D	B+	**【Operation】** Reduction of distribution loss and outage hour can contribute to the increase of power supply.	・Result of calculation on reduction of CO^2 emission due to the Project.
Pollution					
24	Air Pollution	B-	D	**【During construction】** Distribution line extension work can cause dust although it is considered to be rather small scale.	・Information on operation policy for environment consideration during construction work: document review and

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Brief Description (Reasons for Rating)	Further Survey Points
		Pre-/ during Construction Stage	Operation Stage		
					interview with COPEL and construction company ・Relevant law, decree, and standard. ・Site survey on any construction or maintenance site.
25	Water Pollution	C	D	【During construction】 It is uncertain until location of distribution line extension points. Depending on the location of distribution line, excavation work to install the pole, or unwillingly spilling the oil of machines, etc. may influence the water nearby	Ditto
26	Soil Contamination	D	D	Civil work of the project does not contaminate the soil.	
27	Waste	B-	B-	【During construction】 Waste disposal of old distribution equipment such as lines, insulators, load break switch, etc. Also, there will be residue produced by civil work. 【Operation】 During maintenance work, waste of cable, oil, and grease may be produced.	Ditto
28	Noise and Vibration	B-	D	【During construction】 Use of equipment for civil work of distribution line can cause noise and vibration.	Ditto
29	Ground Subsidence	D	D	No ground subsidence can occur due to the project.	
30	Offensive Odor	D	D	No offensive odor can be produced by the project work.	
31	Bottom sediment	D	D	Civil work of the Project does not cause bottom sediment of the river, lake, and so on. .	

Rating:
A+/-: Significant positive/negative impact is expected.
B+/-: Positive / negative impact is expected to some extent.
C: Extent of impact is unknown (Further examination is needed, and the impact could be clarified later at the time of detailed design stage).
D: No impact is expected.

(Source:Elaborated by JICA Survey Team)

8.4.2Analysis on Environmental and Social Impacts

Table 8.5-2 shows the result of further survey/review on items focused by scoping. In fact, there were no changes of rating to each item after the review at this moment. All the items rated as “B” or “C” were further surveyed and reviewed through interview, document review, and site survey. As a result, all evidences support the rating result in the previous scoping. A reason for rating "C" is due to the lack of information on detailed design at this moment ; however, those items are predicted to be minor even if there is some impact.

Table 8.4-2 Result of the Survey/ Review on Environmental and Social Impacts

Project Title : Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	**Impacts**	**Rating**		**Further Survey Points**	**Result**
		Pre-/ during Construction Stage	Operation Stage		
Social Environment					
1	Local economy such as employment and livelihood, etc.	B+	D	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document.	➢ Although volume of distribution line extension will be determined finally later, direct employment of labor is expected for construction work. ➢ Also, because most construction materials and equipment can be procured locally, direct economic impacts on local economy are expected.
2	Existing social infrastructures and services	C	B+	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document. ・Information on result of electricity consumer survey	➢ According to COPEL, operation policy to construct distribution line is always to coordinate with other social infrastructure and there was no conflict in the past experience. ➢ In case of constructing the distribution lines in relation to other infrastructures, ✓ Across the road: coordination with the authority in charge. ✓ Across the railway: the length of railway line in Project area is very limited. ✓ Over the river: it is generally along the existing bridge. ➢ According to survey result of electricity consumers such as a clinic and educational institutions, all respondents said they would economize their electricity consumption if they can have access to information through smart meters.
3	The poor, indigenous and ethnic people	C	D	・Information on the past experiences of similar project component by interview with COPEL, construction company, etc. and review on document. ・Percentage of poor	➢ In interview with COPEL, there was no critical issue in construction of distribution line in these areas in the past experiences. ➢ They are rather isolated areas. Possibility of distribution line extensi1on

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Further Survey Points	Result
		Pre-/ during Construction Stage	Operation Stage		
				household in Curitiba City ・Information on result of electricity consumer survey	in these areas may be low. ➢ Poverty rate in Curitiba City is 4.9% in Year 2010. If poor household was selected and they have no equipment of visualizing the information of electricity, consideration for those household to provide such equipment may be considered. ➢ According to survey result of residential consumers from relatively low –income area, all respondents said they would economize their electricity consumption if they can have access to information through smart meters.
4	Cultural heritage	C	D	・Location of cultural heritages	➢ At this moment, there is no map of heritage locations in the Curitiba Metropolitan Area. Upon determining the route of distribution extension, this should be noted. However, impacts by the project are predicted to be minor.
5	Right of Way	C	D	・Information on operation policy for social consideration at the time of pre-construction: any document review and interview with COPEL and construction company. ・Site survey in selected municipalities	➢ Interview with construction company and COPEL, distribution line is almost always constructed along the road in public land. This is operation policy of COPEL. As a rare case, in rural area, distribution line may pass the private land. In this situation, it is necessary to have approval from land owner. In such a case, no compensation is usually necessary. Since the project target area entails rural area, it cannot be concluded that there is no such case at this moment.
6	Working Environment and Accidents	B-	B-	・Information on accident risk management of COPEL and construction companies by interview and through the document review. ・Site survey on construction or maintenance site	➢ According to a construction company, based on the recommendation of the norms of safety in work place, they provide necessary individual protection equipment for their workers. Also, they have safety meetings to mitigate accidents periodically. These were confirmed during the site visit of improvement of distribution line in Colombo in the Curitiba Metropolitan Area.
Natural Environment					

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Further Survey Points	Result
		Pre-/ during Construction Stage	Operation Stage		
7	Topography and Geographical features	B-	D	· Information on operation policy for environment consideration during construction work: any document review and interview to COPEL and construction company	➢ Considering civil work is distribution line extension along the road, although some impact can be observed due to excavation of soil for installation of new electric poles, such impact is not in a large scale.
8	Flora, Fauna and Biodiversity	C	C	· Information on operation policy for environment consideration for flora during construction work: document review and interview with COPEL and construction company. · Site survey in selected municipalities.	➢ According to COPEL and construction company, operational policy for extension of distribution line is not to pass any type of protection areas in the past experiences. ➢ Distribution line extension work does not require large scale intervention. However, location of extension route cannot be confirmed at this moment. ➢ During the site survey in 4 municipalities, to examine one distribution extension route which can be considered in the future is verified and it was not necessary to cut a tree in this location. One area is not necessary to construct distribution extension.
9	Landscape	B-	B-	· Site survey in selected municipalities.	➢ During the site survey in four municipalities, no particular issue was observed on distribution lines. Due to nature of facilities, some impacts are on the landscape; however, it is within the scale of normal practices and rather minor.
10	Global Warming	D	B+	· Result of calculation on reduction of CO2 emission by the Project	➢ After the project operation, reduction of CO2 emission is estimated to be about 70,000 ton CO2 by technical loss reduction and reduction of outage duration. (refer to Chap 9, 9.4)
11	Air Pollution	B-	D	· Information on operation policy for environment consideration during construction work: document review and interview with COPEL and construction company · Relevant law, decree, and standard. · Site survey on any construction or maintenance site	➢ Primary emission is particle matters from the civil works such as excavation of the soil to install the post. Secondary emission is from combustible from vehicles during construction at the Project site, although it is relatively minor.
12	Water Pollution	C	D	Ditto	➢ In case that location of distribution line extension is

Project Title：Smart Grid Project in Curitiba Metropolitan Area in Brazil					
No.	Impacts	Rating		Further Survey Points	Result
		Pre-/ during Construction Stage	Operation Stage		
					near the river or over the bridge, it may have a minor impact, but it is temporary and minor.
13	Waste	B-	B-	Ditto	➢ During the site visit to Maintenance Center of COPEL in Curitiba Norte (Pólo Atuba), it was confirmed that old equipment in part was collected there and recycled or sold for other use. ➢ COPEL has an operational policy of the procedure of waste disposal, and manages the waste based on it.
14	Noise and Vibration	B-	D	Ditto	➢ During construction, noise and vibration can be reduced to some extent temporarily and also only during working hours, Therefore the impact is not in a large scale.

Rating:
A+/-: Significant positive/negative impact is expected.
B+/-: Positive / negative impact is expected to some extent.
C: Extent of impact is unknown (Further examination is needed, and the impact could be clarified later at the time of detailed design stage)
D: No impact is expected.

(Source:Elaborated by JICA Survey Team)

8.4.3 Mitigation Plan and Environmental Monitoring

As examined in 8.4.2, most negative impacts occur during the construction period and its scale is not so significant. Also, those impacts can be minimized by enforcing the appropriate procedure.

COPEL possesses a series of manuals such as “MIT 16909 Procedures of Cutting Trees”, “MIT 163101Manual of Procedures for Executing Civil Work” and others applied during construction and operation.

In terms of daily working procedures, environmental and social considerations on almost all items are incorporated. Procedures in their work place, including for Construction Company under the contract with COPEL are enforced. .

In this situation, special mitigation and monitoring plan specifically for the project and thus additional cost for them is not required in general.

8.5 Findings of Interview Survey to Consumers in Curitiba City

8.5.1Objective and Survey Method

One of the proposed project components is introduction of AMI to 30% of total residential consumers in Curitiba City. In order to have opinions of consumers on introduction of AMI, the survey by interview was conducted by Ecotécnica Ltd (subcontractor of JICA survey team) for residential consumers and also some other type of low voltage consumers such as commercial institutions, clinics, educational institution, and service companies.

In this survey, more samples are collected in the category of residential consumers. The interview was conducted at two COPEL Sales Offices, on May 6th in 2013, in Curitiba City at Centro and Sítio Cercado. These two places are selected to have respondents who have different levels of income. Consumers at Centro Office tend to have relatively higher income, while ones at Sítio Cercado, which is located in suburban area in Curitiba City, tend to have relatively lower income[3]. The number of interviewees total 48 (23 in Centro and 25 in Sítio Cercado).

As for interview to institutions of low voltage consumers, 8 institutions (3 commercial institutions, 2 service companies, 2 education institutions, and 1 clinic) are interviewed on May 6th and 10th, 2013.

8.5.2Constraints of the Survey

Since the introduction of AMI to low voltage consumers was still under discussion as to whether or not it is incorporated, this interview survey attempts to gain initial insight into the opinions of those considering the introduction of AMI to low voltage consumers. In addition, due to time and budget constraints, a limited number of samples are collected at only a part of Curitiba city. Therefore, in this survey, statistical analysis is not conducted in detail, for example, about whether or not the difference in answer can be attributed to the background and characteristics of interviewees. In future, further study with increased number of samples in different locations and characteristics may be necessary when examining what kind of demand response system is effective, together with established tariff system, advanced domestic electric appliances and others factors.

8.5.3Major findings

Major findings are summarized as follows (for more details, refer to Appendix 8-1):

- Opinions on Introduction of AMI
  - ✓ Majority of residential respondents are in favor of introduction of AMI, if there is no additional

[3] According to Curitiba Agency of Development S.A. (Agencía Curitiba of Development S.A.), in 2010 monthly average nominal income in Centro is 3.34 times higher than the same in Sítio Cercado (R$934.95).

cost on their side (83% in Centro and 100% in Sítio Cercado). All institutional consumers have interest in access to information of electricity consumption.

- ✓ Answer varies between residential respondents in each location regarding a question "If you will pay for visualizing equipment, how much you think you would pay?" In Centro, 39% consumers do not want to pay any cost for that and 44% consumers can pay up to R$25. In Sítio Cercado, 68% consumers do not want to pay such additional cost and only 20% consumers can pay up to R$25.
- ✓ Answers of institutional respondents to the same question in the above, educational and commercial institutions would not pay any expense. One service company said that they would pay up to R$25 and other said they would pay up to R$50.
- ✓ It should be noted that regarding the above question, upon being asked questions by interviewers, the interviewees may not be conscious of the benefit possibilities of economizing the expenses during the year. These could prove to be larger than this investment cost on equipment. If the calculation of this benefit had been shown to interviewees, there might have been a chance that their answer would have been different.

- ➢ Opinions on Demand Response
  - ✓ Majority of residential respondents think that they would economize the electricity consumption, if AMI is introduced (87% in Centro and 100% in Sítio Cercado). As for institutional consumers, all of them think they would economize it.
  - ✓ Answer varies between residential respondents in each location about a question "Would you accept, suppose there is an agreement between COPEL and consumers that COPEL cut energy supply some specific electric appliances at home during peak hour, in exchange for providing some benefit to consumers" (78% in Centro and 38% in Sítio Cercado).
  - ✓ Answers of institutional respondents to the same question in the above, one clinic and two commercial companies said "Yes" while two educational institutions and two service companies said "No".
- ➢ Use of Electric Appliances During Peak Hour

Most used electric appliances in residences during peak hour in February (summer in Curitiba, percentage of total respondents) are shown in Table 8.5-1. In case of commercial and service institutions, electric equipment in use during the peak time are computer, TV/DVD, air conditioner, and fan as well as lights.

Table 8.5-1 Electric Appliances during Peak Hour in February

Location	**Centro**	**Sítio Cercado**
10h-11h	Radio (28%):	TV/DVD (22.74%)
19h-20h	TV/DVD (67.7%)	TV/DVD(63.65%)

(Source: Interview Survey result by Ecotécnica Ltd.)

As a result, uses of any domestic electric appliances which require relatively large electricity consumptions such as air conditioner were not identified. In fact, traditionally many people in Curitiba do not use air conditioner during summer and winter in their residence. Rather, they tend to use the fan during summer and portable heater during winter[4].

Five most commonly used electric appliances in residences during peak hour 19h-20h in February are shown in Table 8.5-2. Examining this table, it can be seen that together with TV/DVD, computer and washing machine, the use of shower consumes relatively higher amounts of electricity.

Table 8.5-2 Five most commonly used electric appliances during peak hour 19h-20h in February

Location	**Centro**	**Sítio Cercado**
No.1	TV/DVD (25.35%)	TV/DVD (35.71%)
No.2	Shower (23.94%);	Computer (28.57%);
No.3	Washing Machine (19.72%)	Shower (21.44%).
No.4	Computer (15.49%)	Washing Machine (7.14%);
No.5	Radio (9.86%).	Iron (7.14%)

(Source Survey result by Interview of Ecotécnica Ltd.)

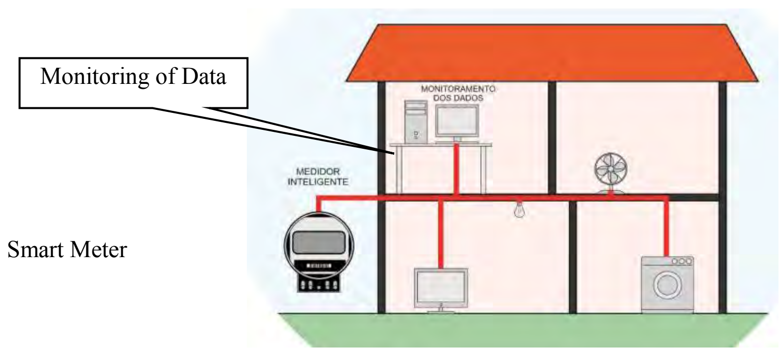


Figure 8.5-1 Conceptual Image of Network in House of Smart Grid Project

(Source: Elaborated by Ecotécnia Ltd,)

[4] Interview result to local company and Marketing Department of COPEL

Chapter 9 Economic Effects of Project

9.1 Approximate Estimate of Project Investment Costs

The investment costs of the project are estimated based on the prices of facilities and instruments such as RTU, reclosers, smart meters and ALBS necessary for the project. In addition, costs of their installation / test / training and consulting are estimated. Furthermore, taxes such as customs duties of imported instruments, Cofins, PIS and ICMS are added. Finally, general administration costs and contingency costs are estimated (5% for each).

These investment costs are distributed annually based on the project deployment plan.

Table 9.1-1 shows DAS/DMS part of the project investment cost contents. The total investment cost of DAS/DMS is approximately R$ 334 million. Taxes account for approximately 29.6% of the total investment cost. Since there are so many taxes in Brazil, it is better to try to reduce these taxes. There are various tax reduction or exemption programs. For example, REIDI (Regeme Especial de Incentivos para o Desenvolvimento da Infraestrutura)[1].

Table 9.1-1 DAS/DMS Investment Costs (Unit: R$ thousand)

Item		Total	2015	2016	2017	2018	2019	2020
I	Procurement / Construction	206,299	0	74,997	96,676	19,862	14,765	0
	Distribution Field Equipment	85,982	0	31,086	25,136	18,175	11,589	0
	13kV OH Line	41,400	0	18,182	23,218	0	0	0
	Optical Cable	33,718	0	14,225	19,493	0	0	0
	138/13.8kV Substation	19,344	0	7,918	8,967	0	2,459	0
	DAS	16,026	0	14	15,258	741	14	0
	AMI (Smart Meter & MDMS)	0	0	0	0	0	0	0
	Base cost	196,476	0	71,425	92,072	18,916	14,062	0
	Physical contingency	9,824	0	3,571	4,604	946	703	0
II	Consulting services	17,789	3,321	4,661	4,214	3,714	1,489	390
	Base cost	16,941	3,163	4,439	4,013	3,537	1,418	371
	Physical contingency	847	158	222	201	177	71	19
A. Total (I+II)		224,088	3,321	79,658	100,889	23,576	16,254	390
a	Land Acquisition	0	0		0	0	0	0
b	Administration cost	11,204	166	3,983	5,044	1,179	813	20
c	Tax	98,840	296	38,260	44,019	15,426	816	23
B. Total (a+b+c)		110,044	462	42,243	49,063	16,605	1,628	42
TOTAL (A + B)		334,132	3,783	121,901	149,953	40,181	17,882	432

(Source: JICA Survey Team)

This regime exempts PIC and COFINS. The objects include electric power assets as infrastructure. It is recommended that COPEL apply to such regimes in order to reduce investment costs.

The DAS/DMS investment costs above include OH distribution lines and their installation costs because although when the existing lines are exchanged according to the current capacity, it can enable the new lines to respond to the consumer increases so that it can contribute to the sales of COPEL and so COPEL should burden the costs with its budget.

[1] http://www.mme.gov.br/mme/menu/reidi.html

Table 9.1-2 shows AMI part of the project investment cost contents. The total investment cost of AMI is approximately R$ 129 million. Taxes account for approximately 27.2% of the total investment cost, less than that of DAS, but still high.

Table 9.1-2 AMI Investment Costs (Unit: R$ thousand)

	Item	Total	2015	2016	2017	2018	2019	2020
I	Procurement / Construction	86,014	0	32,626	47,770	5,618		0
	Distribution Field Equipment	0	0	0	0	0	0	0
	13kV OH Line	0	0	0	0	0	0	0
	Optical Cable	0	0	0	0	0	0	0
	138/13.8kV Substation	0	0	0	0	0	0	0
	DAS	0	0	0	0	0	0	0
	AMI (Smart Meter & MDMS)	81,919	0	31,073	45,495	5,351	0	0
	Base cost	81,919	0	31,073	45,495	5,351	0	0
	Physical contingency	4,096	0	1,554	2,275	268	0	0
II	Consulting services	3,209	725	606	754	828	296	0
	Base cost	3,056	690	577	718	789	282	0
	Physical contingency	153	35	29	36	39	14	0
A. Total (I+II)		89,223	725	33,233	48,524	6,446	296	0
a	Land Acquisition	0	0	0	0	0	0	0
b	Administration cost	4,461	36	1,662	2,426	322	15	0
c	Tax	35,091	70	11,257	22,936	779	49	0
B. Total (a+b+c)		39,553	106	12,919	25,362	1,102	64	0
TOTAL (A + B)		128,776	831	46,152	73,886	7,548	359	0

(Source: JICA Survey Team)

However, this estimate includes the following assumptions.

- Smart meters and concentrators are domestic products (no customs duties).
- At first, 120,000 smart meters as well as concentrators are invested in 2016 and remaining 100,000 SMs are invested in 2017.
- Although there is the Ministry of Communication's new tax exemption program[2], the application cannot be in time and taxes are not exempted in this estimate.

These two investments (DAS/DMS and AMI) above are summed and the total project investment costs are shown in Table 9.1-3. The total investment costs of the project are approximately R$ 463 million. Taxes account for approximately 28.9% of the total investment cost, less than that of DAS, but still high.

2 Act No. 12,715/2012

Table 9.1-3 Total Project Investment Costs (Unit: R$ thousand)

	Item	Total	2015	2016	2017	2018	2019	2020
I	Procurement / Construction	292,314	0	107,623	144,445	25,480	14,765	0
	Distribution Field Equipment	85,982	0	31,086	25,136	18,175	11,589	0
	13kV OH Line	41,400	0	18,182	23,218		0	0
	Optical Cable	33,718	0	14,225	19,493		0	0
	138/13.8kV Substation	19,344	0	7,918	8,967		2,459,016	0
	DAS	16,026	0	14	15,258	741	14	0
	AMI (Smart Meter & MDMS)	81,919	0	31,073	45,495	5,351		0
	Base cost	278,394	0	102,498	137,567	24,267	14,062	0
	Physical contingency	13,920	0	5,125	6,878	1,213	703	0
II	Consulting services	20,997	4,045	5,268	4,968	4,542	1,784	390
	Base cost	19,998	3,853	5,017	4,731	4,326	1,700	371
	Physical contingency	1,000	193	251	237	216	85	19
A. Total (I+II)		313,311	4,045	112,891	149,413	30,022	16,550	390
a	Land Acquisition	0	0	0	0	0	0	0
b	Administration cost	15,666	202	5,645	7,471	1,501	827	20
c	Tax	133,931	366	49,517	66,955	16,205	865	23
B. Total (a+b+c)		149,597	568	55,162	74,426	17,707	1,692	42
TOTAL (A + B)		462,908	4,613	168,053	223,839	47,729	18,242	432

(Source: JICA Survey Team)

9.2 Effect of Project

The following effects can be expected by applying the project.

1) Reduction of outage duration

2) Reduction of technical loss

3) Reduction of non-technical loss

4) Saving construction of power generation and the transmission

5) Reduction of operation / maintenance cost

6) Reduction of CO2 emission

7) Saving construction of substation

8) Expand to future project / business of COPEL

9.2.1 Effect of Outage duration reduction

1) Shortening of outage duration

As shown in Figure 9.2-1, if a fault occurs in Section 4 of the distribution line, the interruption will continue on all of the sections until the fault is recovered. If DAS/DMS is installed, only the faulty section will be isolated, and the other good sections can be supplied immediately so that outage duration can be reduced. The current fault detecting procedure is as shown in Table 9.2-1, whereas Table 9.2-2 shows fault detecting procedure after installation of DAS/DMS.

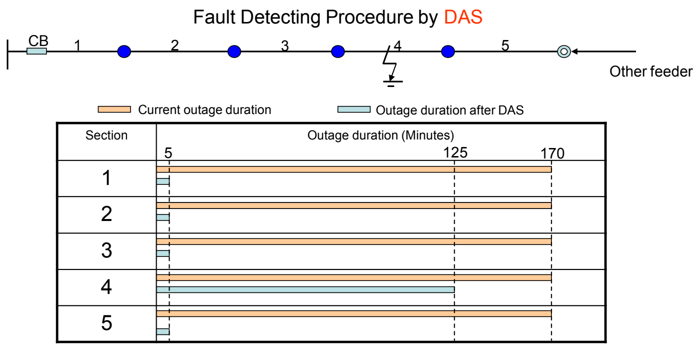


Figure 9.2-1 Effect of shortening interruption time by DAS/DMS

(Source: JICA Survey Team)

Table 9.2-1 Current fault detecting procedure

No	Fault handling works description	Fault handling time	
		Cumulative	Work time
1	Circuit Breaker (CB) trip	-	
2	Contact by phone from substation, informing occurrence of fault	5	+5
3	Forming of work team and rush off to site	25	+20
4	Check fault section	55	+30
5	Isolate fault section	60	+5
6	Check fault point in fault section	75	+15
7	Repair of fault point	135	+60
8	Repair work and check	145	+10
9	Electric supply test at repair section	150	+5
10	Recovery of commercial supply	170	+20

(Source: Created by survey team based on COPEL survey result)

Table 9.2-2 Fault detecting procedure after DAS/DMS installation

No	Fault handling works description	Fault handling time	
		Cumulative	Work time
1	CB trip	-	
2	Auto-detection of fault section by DAS, and auto isolation	5	+5
3	Forming of work team and rush off to site	15	+10
4	Check fault point in fault section	30	+15
5	Repair of fault point	90	+60
6	Repair work check	100	+10
7	Electric supply test at repair section	105	+5
8	Recovery of commercial supply	125	+20

(Source: Created by survey team based on COPEL survey result)

After DAS/DMS installation, the fault section (Section 4 in Figure 9.2-1) will be auto-isolated, and the other good sections (Area 1, 2, 3 & 5) will be supplied automatically. Restoration of the good sections will be within 5 minutes (about 1-2 minutes) and so the average interruption duration in all of the sections will be 29 minutes as shown in the calculation below.

(5 + 5 + 5 + 125 + 5) / 5 sections = 29 min/section

Meanwhile, based on the current system, interruption duration will be 170 min/section, which means the reduction rate is 80% as shown in the calculation below.

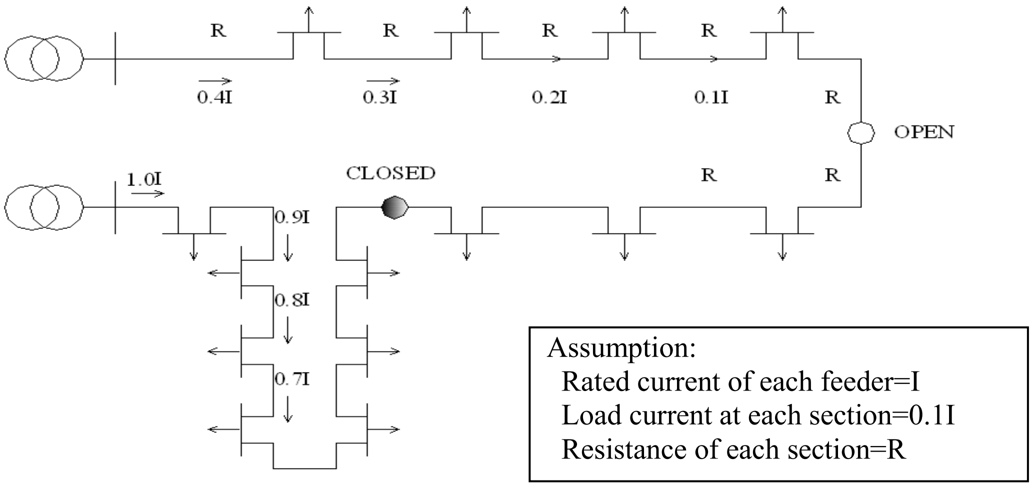
(29 min. / 170 min.) x 100% = 17% (≒ 20%)

9.2.2 Effect of Technical loss reduction

1) Improvement of load unbalance

The load condition can be monitored on a real time basis by DAS/DMS, and if overload is detected, the load can be split to the neighboring distribution feeders by DAS/DMS to improve the unbalance. Based on the typical calculation, the technical losses can be improved by about 32.5% on medium voltage line as one model network.

<Before application of DAS>



Total losses $= (0.4I)^2 .R+(0.3I)^2.R+(0.2I)^2.R+(0.1I)^2.R+$

$(1.0I)^2.R+(0.9I)^2.R+(0.8\ I)^2.R+\ldots\ldots+(0.1I)^2.R$

$= 4.15\ I^2.R$

(Source: JICA Study Survey Team)

<After installation of DAS>

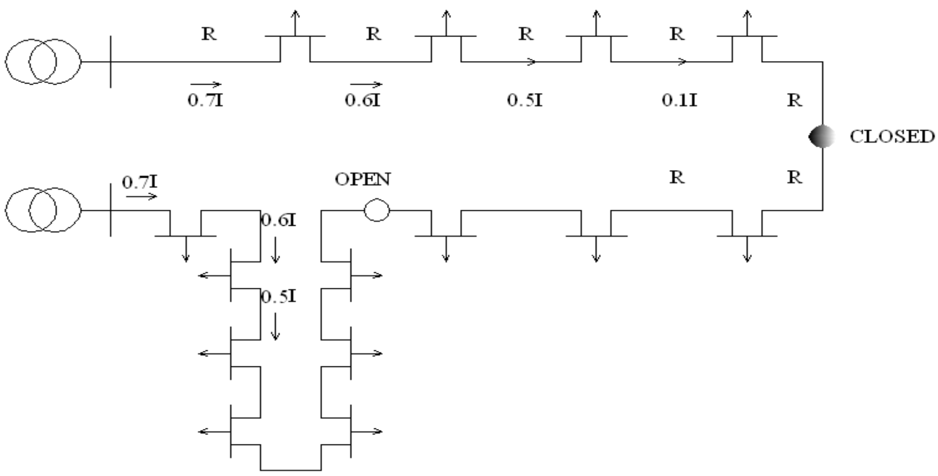


Figure 9.2-2 Calculation of load unbalance

(Source: JICA Study Survey Team)

Total losses $= 2((0.7I)^2 .R+(0.6I)^2.R +\ldots\ldots+(0.1I)2.R)$

$= 2.80\ I^2.R$

Effect of DAS = (4.15-2.80) *(100)/(4.15)

= 32.5%

Therefore, the technical loss can be reduced up to 0.98% (=3.0% x 0.325).

2) Improvement of power factor

In case Capacitors are installed to 13.8kV feeder, the power factor can be improved and the technical loss of 13.8kV feeder can also be reduced.

The principal of loss reduction by capacitor control is explained as follows.

The relationship among Reactive power Q, Active power P and Apparent power S is shown in Figure 9.2-3.

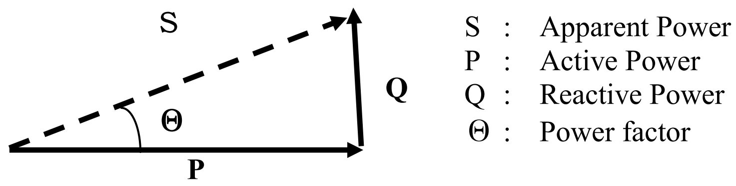


Figure 9.2-3 Relationship among S, P and Q

(Source: JICA Study Survey Team)

When a reactive power Q becomes larger by using motor load, the active power P will reduce and the load current will increase in case of requirement of the same power P such as motor loads, so that the loss by increasing the load current will increase.

Q is normally a lagging reactive power Q1/Q2 whose load consists of motor, light and so on. Therefore, if a leading reactive power Qc such as capacitors is added to the load side, the Q1 can be reduced to Q2, so that the loss can be reduced as shown in Figure 9.2-4.

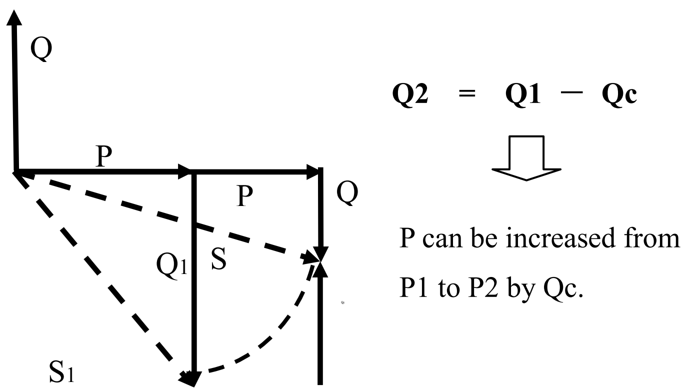
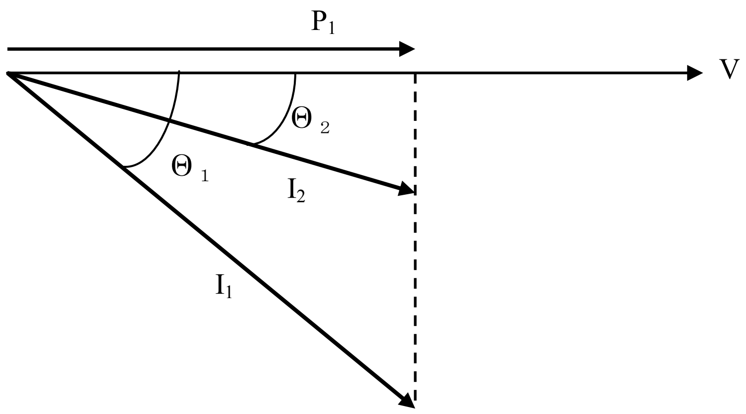


Figure 9.2-4 Improvement of Power factor by leading reactive power

(Source: JICA Study Survey Team)



$$\text{Loss reduction} = I1^2 \cdot R - I_2^2 \cdot R = (P_1 / V \cdot \text{Cos}\ \theta_1)^2 \cdot R - (P_1 / V \cdot \text{Cos}\ \theta_2)^2 \cdot R$$

$$= (P_1^2 / V^2) \cdot R\ (1/\cos^2 \theta_1 - 1/\cos^2 \theta_2)$$

R: Resistance of distribution line

V: Voltage between phases

Figure 9.2-5 Calculation of Loss Reduction

(Source: JICA Study Survey Team)

The loss can be improved around 17% per example case in which the power factor can be improved from 0.91 to 0.98 by installation and control of the Capacitor. In case that the condition of the reduced reactive power is assumed to continue during 20H, the actual reduction of loss is around 14.2% (17% x 20/ 24H) levels.

The location of capacitor is normally installed to around 2/3 load point, so that the improved percentage is around 9.5% (=14.2 x 2/3).

Power factor in Curitiba metropolitan area is shown as Table 9.2-3 and the average is around 0.91.

Table 9.2-3 Power factor in Curitiba metropolitan area

Power factor	< 0.85	0.86 – 0.9	0.91 – 0.95	0.96 <
No of feeder	37	71	130	116
Average	0.91			

(Source: COPEL Material)

DAS can control the capacitors installed in substations and overhead distribution networks in accordance with the real time monitoring of the power factor, so that the loss can be reduced up to around **9.5%**.

Therefore, the technical loss of MV can be reduced up to 0.28% (=3.0% x 0.095).

3) Improvement of voltage –drop by SVR

In case SVR will be installed on OH feeder, the voltage drop at the end of OH feeder will be improved and the loss in the load side line of SVR can be reduced.

SVR will be installed in OH feeder of COPEL metropolitan area whose related facilities are as shown in Table 9.2-4.

The voltage drop has occurred in OH feeder due to the long distance, so SVR is recommended to install at the middle of OH feeder as shown in Figure 9.2-6.

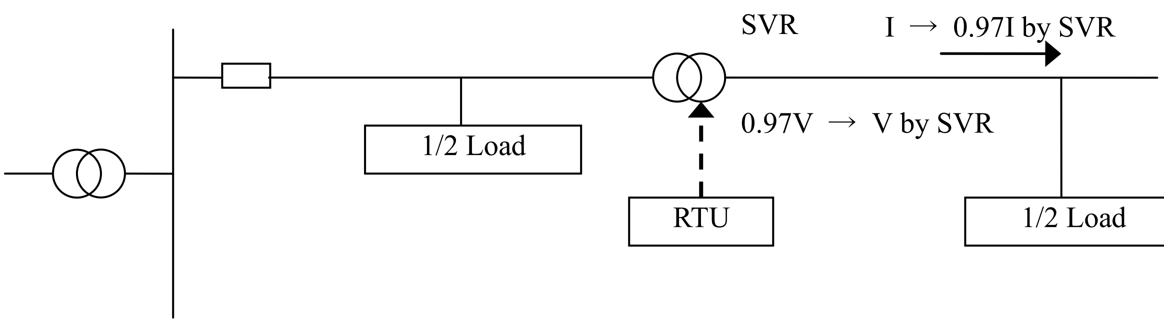


Figure 9.2-6 Model for calculation of Voltage -drop

When the voltage drop can be improved around 3% (Average voltage drop of Curitiba metropolitan area: 4.46%), 3% of the feeder current can be reduced, so that the technical loss of OH feeder can be improved around 10% [= $(9.7/ 10)^2$ = 0.94 → 6%].

As SVR will be installed at the middle of the OH feeder, half of 6% can be reduced.

The loss reduction rate is around 3% (= 6% x 1/2). Technical loss in Curitiba metropolitan area is around 6.4% in 2012, so that the medium loss is assumed as 3%.

Table 9.2-4 Data and effect in Curitiba metropolitan area in COPEL

Item	Data in North-Dakahlia
Nos. of 13.8kV OH feeder	358
Length of 13.8kV OH main feeder	3,639 km
Main feeder length on average	10.2 km
Technical Loss of OH feeder	6.4%
Technical loss of MV (assumption)	3.0% in 6.4%
Effect of loss reduction by SVR	0.09% (= 3.0% x 0.03)

(Source: JICA Survey Team)

Therefore, the technical loss in Curitiba metropolitan area can be reduced up to **0.09%** by installation of SVR.

Total technical loss is expected to reduce 1.35% (=0.98 + 0.28 + 0.09).

9.2.3 Effect of Non-Technical loss reduction

Non-technical loss can be further reduced by AMR and calculation as example based on other countries by the survey team was provided as reference so that non-technical loss of about 70% can be reduced.

AMR can detect both the trouble of meters or human error.

Smart Meter is more accurate than mechanical meter already installed and as works to measure the power consumption are not required for human due to direct assessment from the control center for AMR, it is effective in reducing losses.

At the same time, when the cover of smart meter is removed, it can be detected by the sensor, which prevents electricity stealing or provides early warning after stealing. And stealing by direct connection from the distribution line can be detected roughly by voltage drop and comparing the data of RTU for transformer and Smart Meter.

Table 9.2-5 Effect for reduction of non-technical loss

Non-technical losses		(a)Current loss in model divisions (by Indian case)	(b)Reduction by AMR	Target in model divisions
Meter	Non performing meter	0.28	0.28 (100%) *1	0
	Under performing meter	0.16	0.00 (0%) *2	0.16
	Defects of circuitry in CT/PT	0.80	0.80 (100%) *3	0
	Mistake of meter reader	1.42	1.42 (100%) *4	0
Theft	Pilferage by manipulation of meters	0.28	0.28 (100%) *5	0
	Energy theft by direct tapping	1.42	0.71 (50%) *6	0.71
	Direct connection without meters	1.02	0.51 (50%) *7	0.51
Total Non-technical losses		5.38 %	4.0 % (74%)	1.38%

*1: Non performing meter can be detected when Smart Meter dose not respond.

*2: Additional solution is required for this kind of loss reduction.

*3: Additional solution is required for this kind of loss reduction.

*4: Meter is correctly read by system without human errors. Current Meter has been measured every month.

*5: Manipulation of meter can be detected by the opening/closing sensor of meter cover.

*6: Additional solution is required for this kind of loss reduction.

*7: This type of theft can possibly be detected by comparing electricity amount data between the meter in RTU of DAS and Smart meters. However the accuracy of this theft detection would be as low as 50%.

(Source: Made by JICA Survey Team)

9.2.4 Saving construction of power generation and the transmission by peak shift and cut

It is not an effective way to construct power stations according to the peak demand. It is very important to make load curve even by the consumer side. One of peak suppress methods is peak shift and cut. It is possible to reduce the generating power from power stations to make their operation more efficient.

In order to make peak shift and cut, we can take the following two methods.

- The facilities such as AC whose interruption cannot give a serious impact on the operation in a building, commercial area, factory and school, will be cut.
- All power will be cut for private houses

DAS/DMS providing EMS functions may interrupt the power to control an area for 30minutes. If duration of peak shift is longer than 30 minutes, the interrupted area will be changed area to area alternatively. However, for consumers wanting to use power during the interruption, it is possible to do so with higher tariff to make peak cut/ shift effective.

It is expected that the peak load of residential consumer is 2kW (twice AC consumption of 1kW) considering the future extension of demand.

2kW x 220,000 x1/2 (Rotation) = 220MW

The peak hour of each residential customer is different, so that the saved power will be lower than 220MW.

The peak shift and cut control the load directory and in addition, it is possible to provide the indication of consumed power at each private house and restrict the use of power. However, it may cost to provide the power indication at each private house.

On the other hand, applying TOU, it is possible to restrict the power consumption of consumers.

9.2.5 Reduction of operation / maintenance cost

Existing Organization structure for distribution system in Project Area is described in 4.9 in Chapter 4 and the Operation and Maintenance Structure after Project is also introduced in 7.5 in Chapter 7.

DAS/DMS can detect the faulty section automatically, so that the maintenance crews required to detect the faulty section can be reduced.

In addition, DAS/DMS can manage the distribution network in real time and make many reports automatically, so that the number of employees available can be increased.

It is difficult to calculate the savings, but the effect should improve based on the comparison between COPEL and TEPCO, which has already installed DAS/DMS to all areas.

Table 9.2-6 Comparison of distribution employee between COPEL and TEPCO

	COPEL Distribution	TEPCO (2012)
No of customers	4 million	28 million
Sales power	23,284 (GWh)	268,230 (GWh)
Service Area	199,315 (km^2)	39,509 (km^2)
Distribution of Employees	7,169	5,522*

*No of Regular employees for distribution work

*No of employees for distribution include subsidiary company for distribution: 11,423

(Source: JICA Survey Team)

9.2.6 Reduction of CO2 emission

This smart grid project can contribute to reduction of CO2 emission based on the following effects.

(1) Effect for reduction of outage duration

(2) Effect for reduction of technical loss

The detail is introduced in 9.4.

9.2.7 Saving construction of substation

DAS/DMS can quickly switch a lot of loads of distribution feeder on occurrence of bank fault in substation. COPEL adopts maximum 70% operation of rated capacity and allowing 140% of rated capacity in emergency stop of one bank due to 2 banks as standard of COPEL substation as shown in Figure 9.2-7.

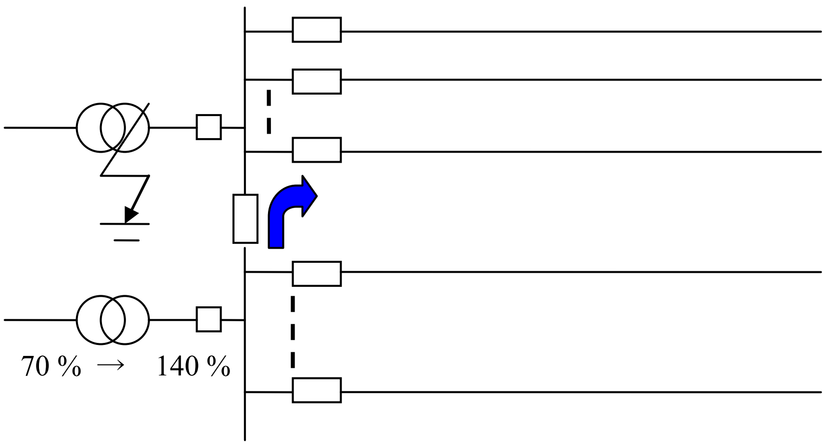


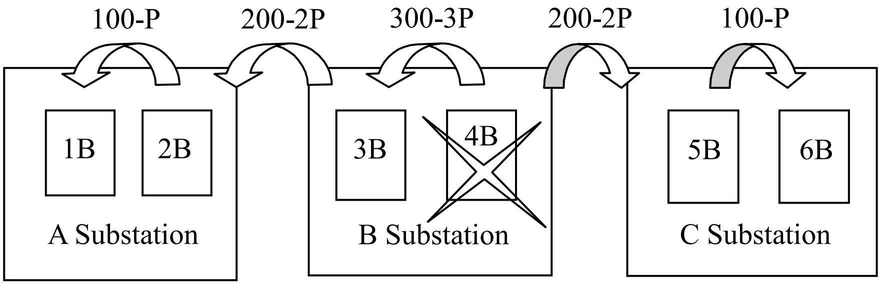
Figure 9.2-7 Concept of one bank fault in substation of COPEL

(Source: JICA Survey Team)

DAS/DMS allows raising of maximum operation level by quickly switching the loads of the fault bank.

Overload allowance is not considered in the raised maximum operation level because it normally takes less than a few hours to repair the bank accident.

By raising maximum operation level of bank of substation, average operation level can also be raised. As a result, new construction of substation can be saved by raising average operation level. After installation of DAS/DMS, maximum 83% of rated capacity can be allowed as explained in Figure 9.2-8.



While all banks operate at P% of rated capacity, a bank fault occurs at 4B.
Load of 4B can switch to other 5 banks by means of automatic load switching of DAS in distribution feeder side.
Total (500% - 5P %) can be switched (P ≦ 500 – 5P)
Maximum operation level can rise to 83% (P=500/6).

Figure 9.2-8 Explanation of raising operation level of substation

(Source: JICA Survey Team)

<Calculation condition for required substations after 20 years>

- Consumption of COPEL is of 7,401 GWh in 2012 and will increase with 6 % of grow rate.
- Average capacity of Power is around 844 MW [= 7,401 x 103 / (365 x 24)]. The required power after 20 years: 844 MW x (1.06)20 – 844MW = 1,863 MW
- The standard capacity of COPEL’s substation is 80MW (= 40MW x 2 bank).
- Effect by DAS / DMS is 13% (70% load → 83%)

If this project is not implemented, the number of substations required based on the load-increase, is about 33.

(40MW x 2 banks) x A SS x 0.7 = 1,863MW A = 33 substations

If this project is implemented,

(40MW x 2 banks) x B SS x 0.83 = 1,863 MW B = 28 substations

Therefore, the construction of 5 substations (= 33-28 substations) can be saved by this project.

9.2.8 Expansion of future project / business of COPEL

The communication network and smart meter will be installed during this project, so that the following project / business can be available in the future.

1) EMS:

The smart meter will be installed to customers, so that the renewable energy / batteries with the customer can be controlled through the smart meter and the communication network. Therefore, the initial investment for EMS can be saved due to utilizing the smart meter and communication network as shown in Figure 9.2-9.

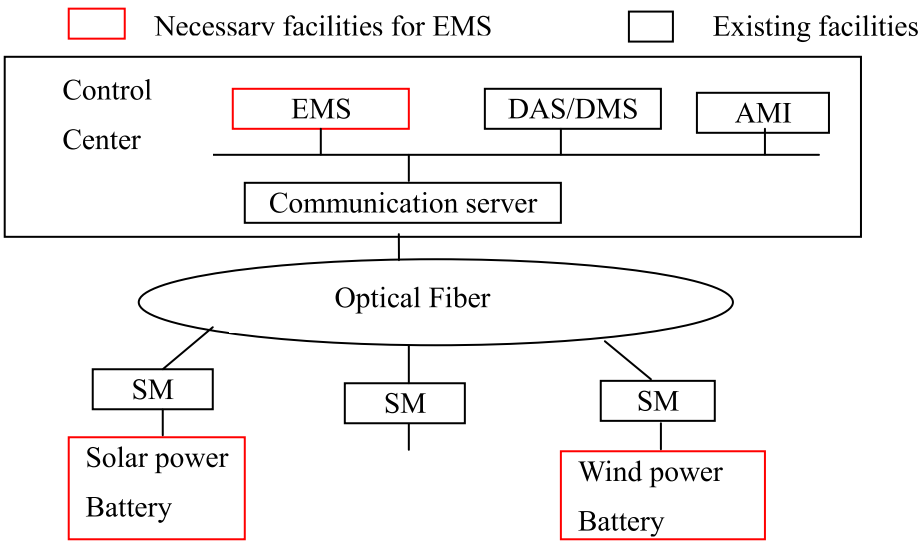


Figure 9.2-9 Expansion of EMS in existing system

2) The smart meter can be connected to **HEMS**, so that temperature control of AC (Air Conditioner) and battery control of **EV** etc. will be available in future.

3) New business such as satellite working / remote doctor etc. will be available by using optical fiber.

9.3 Economic Evaluation (IRR Estimates)

9.3.1 Financial Evaluation (FIRR Estimates)

Based on the project investment costs described in 9.1 and project effects explained in 9.2, the project can be evaluated with financial internal rate of return (FIRR) calculation.

1) DAS/DMS

The effects of DAS/DMS are calculated as follows.

(1) Outage Reduction

DAS/DMS can reduce 80% of outage duration. Therefore, the lost MWh income during the outage can be covered and so COPEL's sales income increases. The average outage durations per consumer in Curitiba City and the Curitiba Metropolitan Area excluding Curitiba City (23 municipalities) are 7.81 and 34.44 hours /consumer in 2012, respectively. Using sales income per consumption (R$/MWh) in 2012, number of consumers, and consumption (MWh) in the two areas, the sales income increases can be estimated through power supply duration and outage duration.

(2) Technical Loss Reduction

Total consumptions (MWh) of the two areas in 2012 are divided by 91.55%(=1-0.0845: total loss) and the total supply can be obtained. Technical loss reduction is 13.5% and so this rate and purchase price of power (R$ 115/MWh) are multiplied to the total supply so that technical loss reduction (power purchase cost reduction) can be estimated because demand does not change, but supply (purchase) can be reduced.

(3) Penalty Reduction

Penalties for SAIDI in the two areas are clarified and 80% of SAIDI duration can be reduced so that 80% of the penalties are assumed to reduce by DAS/DMS.

(4) Saving substations

According to 9.2.7 Saving Construction of Substations, DAS/DMS can reduce the needs of substations through the planned operation rates of substations from 70% to 83%. The results suggest that total of 33 substations can be reduced to 28 substations in twenty years so that 5 substations can be saved. It is assumed that one substation is saved every four years. One substation investment cost is estimated at approximately US$ 19 million according to COPEL.

Table 9.3-1 shows financial internal rate of return (FIRR) of DAS/DMS.

Table 9.3-1 DAS/DMS FIRR (Unit: R$ thousand)

Year	Investment	Outage Reduction	Technical Loss Reduction	Penalty Reduction	Substation Reduction	Cash flow
2015	3,783					-3,783
2016	121,901					-121,901
2017	149,953					-149,953
2018	40,181	3,079	7,801	660		-28,641
2019	17,882	3,264	8,269	700		-5,650
2020	432	4,623	20,004	1,313	19,000	44,508
2021		4,900	21,205	1,392		27,497
2022		5,194	22,477	1,475		29,146
2023		5,506	23,826	1,564		30,895
2024		5,836	25,255	1,658	19,000	51,749
2025		6,187	26,770	1,757		34,714
2026		6,558	28,377	1,862		36,797
2027		6,951	30,079	1,974		39,005
2028		7,368	31,884	2,093	19,000	60,345
2029		7,810	33,797	2,218		43,826
2030		8,279	35,825	2,351		46,455
2031		8,776	37,974	2,492		49,242
2032		9,302	40,253	2,642	19,000	71,197
2033		9,860	42,668	2,800		55,329
2034		10,452	45,228	2,968		58,648
2035		11,079	47,942	3,146		62,167
2036		11,744	50,818	3,335	19,000	84,897
2037	[illegible]	12,448	53,867	3,535		94,089
					FIRR=	9.44%

(Source: JICA Survey Team)

The FIRR is 9.4% and not so bad. However, this calculation includes the following assumptions.

- The legal depreciation lives of the instruments above vary from 5 years (computer software) to 37 years (overhead power lines), but short life products are often used over the depreciation life years and so this FIRR is calculated for 20 years without reinvestment of short life products.
- However, the negative residual values of longer life products (more than 20 years) need to be input as investment costs in the last calculation year (2037) and are therefore included.

2) AMI

The effects of AMI are calculated as follows.

(1) Meter Reading Cost Reduction

AMI can render meter-reading unnecessary so that its costs, R$ 1.5 per month per consumer can be excluded.

(2) Maintenance Cost Increase

Although AMI reduces meter-reading costs, postal invoice delivery cost is required because meter-reading works accompany invoice issues. However, this cost is estimated to be one third because it is assumed that other invoices of gas and sewage are sent together and the costs are shared.

(3) Non-technical Loss Reduction

This is similar to the technical loss reduction effect of DAS/DMS. However, 70% of non-technical loss (2.05% X 0.7 =1.435%) is reduced. In addition, non-technical loss is considered almost theft so that hidden income (sales income=R$ 245.8/MWh) is used instead of purchase cost in technical loss reduction.

Table 9.3-2 shows AMI FIRR calculation. The FIRR of AMI is 5.0%.

Table 9.3-2 AMI FIRR (Unit: R$ thousand)

Year	Investment	Postage cost	Maintenance cost	Non-technical Loss Reduct.	Meter Reading Cost Reduct.	Cash flow
2015	831					-831
2016	46,152					-46,152
2017	73,886	1,728	462	3,458	2,160	-70,458
2018	7,548	3,168	1,200	6,720	3,960	-1,237
2019	359	3,168	1,276	7,123	3,960	6,280
2020		3,168	1,279	7,550	3,960	7,063
2021		3,168	1,279	8,003	3,960	7,516
2022		3,168	1,279	8,483	3,960	7,996
2023		3,168	1,279	8,992	3,960	8,505
2024		3,168	1,279	9,532	3,960	9,045
2025		3,168	1,279	10,104	3,960	9,617
2026		3,168	1,279	10,710	3,960	10,223
2027		3,168	1,279	11,353	3,960	10,865
2028		3,168	1,279	12,034	3,960	11,547
2029		3,168	1,279	12,756	3,960	12,269
2030		3,168	1,279	13,521	3,960	13,034
2031		3,168	1,279	14,333	3,960	13,845
2032		3,168	1,279	15,193	3,960	14,705
2033		3,168	1,279	16,104	3,960	15,617
2034		3,168	1,279	17,070	3,960	16,583
2035		3,168	1,279	18,095	3,960	17,607
2036		3,168	1,279	19,180	3,960	18,693
					FIRR=	4.96%

(Source: JICA Survey Team)

If the costs of smart meters are shared with gas and water supply (and sewage) companies, COPEL Distribution's cost becomes one third, the FIRR of AMI becomes 14.4% shown in Table 9.3-3. In this case, maintenance costs become one third, too.

Table 9.3-3 AMI FIRR (Costs of smart meters are shared) (Unit: R$ thousand)

Year	Investment	Postage cost	Maintenance cost	Non-technical Loss Reduct.	Meter Reading Cost Reduct.	Cash flow
2015	831					-831
2016	15,847					-15,847
2017	43,699	1,728	158	3,458	2,160	-39,968
2018	3,322	3,168	595	6,720	3,960	3,594
2019	359	3,168	629	7,123	3,960	6,927
2020		3,168	632	7,550	3,960	7,710
2021		3,168	632	8,003	3,960	8,163
2022		3,168	632	8,483	3,960	8,643
2023		3,168	632	8,992	3,960	9,152
2024		3,168	632	9,532	3,960	9,692
2025		3,168	632	10,104	3,960	10,264
2026		3,168	632	10,710	3,960	10,870
2027		3,168	632	11,353	3,960	11,513
2028		3,168	632	12,034	3,960	12,194
2029		3,168	632	12,756	3,960	12,916
2030		3,168	632	13,521	3,960	13,681
2031		3,168	632	14,333	3,960	14,492
2032		3,168	632	15,193	3,960	15,352
2033		3,168	632	16,104	3,960	16,264
2034		3,168	632	17,070	3,960	17,230
2035		3,168	632	18,095	3,960	18,254
2036		3,168	632	19,180	3,960	19,340
					FIRR=	14.4%

(Source: JICA Survey Team)

3) Total Project FIRR

Above Tables 9.3-1 and 9.3-2 are integrated and FIRR of the total project is shown in Table 9.3-4.

FIRR is 8.5 %, that is, between 9.4 % of DAS/DMS and 5.0% of AMI.

Table 9.3-4 Total Project FIRR (Unit: R$ thousand)

Year	Investment	Revenues or Cost Reduction	Maintenance Cost Increase	Cash flow
2015	4,614	0	0	-4,614
2016	168,053	0	0	-168,053
2017	223,839	5,618	2,201	-220,422
2018	47,729	22,220	4,410	-29,920
2019	18,241	23,315	4,484	591
2020	432	56,451	4,487	51,531
2021		39,460	4,487	34,973
2022		41,590	4,487	37,103
2023		43,848	4,487	39,360
2024		65,241	4,487	60,754
2025		48,778	4,487	44,290
2026		51,467	4,487	46,980
2027		54,317	4,487	49,830
2028		76,339	4,487	71,851
2029		60,542	4,487	56,054
2030		63,936	4,487	59,449
2031		67,535	4,487	63,048
2032		90,350	4,487	85,862
2033		75,393	4,487	70,905
2034		79,679	4,487	75,191
2035		84,222	4,487	79,735
2036		108,038	4,487	103,550
2037	-24,238	94,142	4,487	113,893
			FIRR=	8.46%

(Source: JICA Survey Team)

9.3.2 Economic Evaluation (EIRR Estimates)

The method of Economic Internal Rate of Return (EIRR) estimates is similar to that of FIRR. However, there are differences between them as follows.

i) Benefits

While FIRR provides financial revenues as financial benefits, EIRR provides social benefits such as saving energy and cost reduction of customers. However, EIRR or cost-benefit analysis does not include indirect effects such as regional effects (industrial location increase) and multiplier effects. COPEL's income increase and cost reduction is not the object of cost-benefit analysis, but they are evaluated from the social viewpoints described below.

ii) Costs

The investment and operational costs are similar to those of FIRR. However, taxes are excluded from the costs of EIRR. In addition, foreign currency portion of investment costs is converted to border price multiplying conversion factor. The conversion factor in Brazil is assumed 0.91[3].

1) DAS/DMS

The benefits of DAS/DMS are calculated as follows.

(1) Outage Reduction

Consumers suffer from outages and so DAS/DMS can improve the damages or inconveniences of consumers caused by the outages. A willingness-to-pay survey to the consumers is necessary to clarify this improvement benefit, but it is not conducted. Therefore, the same average tariff (sales revenue) per consumer is used to recover 80% of outage revenues instead of consumer's willingness-to-pay price of electricity consumption during outages. This benefit is supposed to include standby power use cost of consumers during the outage durations. However, it is considered that this average tariff is a kind of minimum willingness-to-pay price so that the reduction of penalties imposed by the ANEEL for outages is additional damage recovery of customers.

(2) Technical Loss Reduction

The technical loss reduction by DAS/DMS can be considered savings of power supply. Therefore, social savings of power supply are equal to sales of saved power supply, namely COPEL's reduction of power purchase used in FIRR.

(3) Saving substations

The investment cost reduction of saving substations brought about by DAS/DMS can be considered customers payment reduction through tariff increase prevention.

(4) CO2 Emission Reduction

CO2 emission reduction described in 9.4 below can be converted to social cost reduction through international sales price of CO2 emission right. The price is assumed 0.42 euro/ tonCO2[4] (R$ 1.2054/tonCO2).

Table 9.3-5 shows the economic internal rate of return (EIRR) result of DAS/DMS. The estimated EIRR is approximately 14.1%.

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3 William J. Vaughan, Arthur H. Darling and Diego J. Rodriguez, "Uncertainty in the Economic Appraisal of Water Quality Improvement Investments: The Case for Project Risk Analysis" Inter-American Development Bank, July 2000.

4 ICE ECX Forward Price in London Market on June 6, 2013

Table 9.3-5 DAS/DMS EIRR (Unit: R$ thousand)

Year	Investment	Outage Reduction	Technical Loss Reduction	Penalty Reduction	Substation Reduction	CO2 Reduction	Cash flow
2015	3,318						-3,318
2016	80,708						-80,708
2017	102,871						-102,871
2018	22,914	3,079	7,801	660		24	-11,350
2019	15,746	3,264	8,269	700		25	-3,489
2020	385	4,623	20,004	1,313	19,000	95	44,651
2021		4,900	21,205	1,392		101	27,597
2022		5,194	22,477	1,475		107	29,253
2023		5,506	23,826	1,564		113	31,008
2024		5,836	25,255	1,658	19,000	120	51,869
2025		6,187	26,770	1,757		127	34,841
2026		6,558	28,377	1,862		135	36,931
2027		6,951	30,079	1,974		143	39,147
2028		7,368	31,884	2,093	19,000	151	60,496
2029		7,810	33,797	2,218		160	43,986
2030		8,279	35,825	2,351		170	46,625
2031		8,776	37,974	2,492		180	49,423
2032		9,302	40,253	2,642	19,000	191	71,388
2033		9,860	42,668	2,800		203	55,531
2034		10,452	45,228	2,968		215	58,863
2035		11,079	47,942	3,146		228	62,395
2036		11,744	50,818	3,335	19,000	241	85,139
2037	-23,878	12,448	53,867	3,535		256	93,985
						EIRR=	14.1%

(Source: JICA Survey Team)

2) AMI

The benefits of AMI are calculated as follows.

(1) Meter Reading Cost Reduction

This cost reduction can be considered customers payment reduction through tariff increase prevention.

(2) Non-technical Loss Reduction

Non-technical loss is considered almost theft so that hidden income becomes other usual customers benefit through tariff increase prevention. It also means that just tariff payment is conducted socially.

(3) Saving power generation plant construction

According to 9.2.4 saving construction of power generation and transmission by peak shift and cut, power generation plant construction can be saved through demand response. The effect is limited to approximately 30% of residential customers in Curitiba City, but 220 MW generation can be saved so that US$110 million as gas turbine generator investment and US$ 160 million as fuel costs in twenty years are assumed as saving effects.

Table 9.3-6 shows AMI EIRR calculation. The EIRR of AMI is 21.0%.

Table 9.3-6 AMI EIRR (Unit: R$ thousand)

Year	Investment	Postage cost	Maintenance cost	Non-technical Loss Reduct.	Meter Reading Cost Reduct.	Saving Generation	Cash flow
2015	727						-727
2016	34,867						-34,867
2017	49,651	1,728	349	3,458	2,160		-46,110
2018	6,720	3,168	845	6,720	3,960		-53
2019	302	3,168	912	7,123	3,960		6,701
2020		3,168	915	7,550	3,960		7,427
2021		3,168	915	8,003	3,960		7,880
2022		3,168	915	8,483	3,960		8,360
2023		3,168	915	8,992	3,960		8,869
2024		3,168	915	9,532	3,960		9,409
2025		3,168	915	10,104	3,960		9,981
2026		3,168	915	10,710	3,960		10,587
2027		3,168	915	11,353	3,960		11,229
2028		3,168	915	12,034	3,960		11,911
2029		3,168	915	12,756	3,960		12,633
2030		3,168	915	13,521	3,960		13,398
2031		3,168	915	14,333	3,960	648,000	662,209
2032		3,168	915	15,193	3,960	48,000	63,069
2033		3,168	915	16,104	3,960	48,000	63,981
2034		3,168	915	17,070	3,960	48,000	64,947
2035		3,168	915	18,095	3,960	48,000	65,971
2036		3,168	915	19,180	3,960	48,000	67,057
						EIRR=	21.0%

(Source: JICA Survey Team)

3) Total Project EIRR

Above Tables 9.3-5 and 9.3-6 are integrated and EIRR of the total project is shown in Table 9.3-7.

EIRR is 17.1%, that is, between 14.1% of DAS/DMS and 21.0% of AMI.

Table 9.3-7 DAS/DMS and AMI EIRR (Unit: R$ thousand)

Year	Investment	Benefits	Maintenance Cost Increase	Cash flow
2015	4,045	0	0	-4,045
2016	115,575	0	0	-115,575
2017	152,522	5,618	2,088	-148,993
2018	29,633	22,243	4,057	-11,447
2019	16,048	23,340	4,121	3,172
2020	385	56,545	4,123	52,038
2021		39,561	4,123	35,437
2022		41,697	4,123	37,573
2023		43,961	4,123	39,838
2024		65,361	4,123	61,238
2025		48,905	4,123	44,782
2026		51,602	4,123	47,478
2027		54,460	4,123	50,337
2028		76,490	4,123	72,367
2029		60,702	4,123	56,579
2030		64,106	4,123	59,983
2031		715,715	4,123	711,592
2032		138,541	4,123	134,417
2033		123,595	4,123	119,472
2034		127,894	4,123	123,770
2035		132,450	4,123	128,326
2036		156,279	4,123	152,156
2037	-23,878	142,398	4,123	162,153
			EIRR=	17.1%

(Source: JICA Survey Team)

9.4 Consideration on Effect of CO2 Emission Reduction

Effects of CO2 emission reduction according to installing DAS under Japanese Loan are as follows;

- Effect for Reduction of Outage Duration
- Effect for Reduction of Technical Loss

1) Effect for Reduction of Outage Duration

This effect is to reduce operation time of standby power plant possessed by customer for power outage according to reduction of outage duration by installing DAS and is calculated by the following formula. In addition, standby power plant is assumed as diesel generator using a heavy oil, as per Japanese standby power plants.

Reduced CO2 Emission of Diesel Generator – Increasing CO2 Emission of National Grid

■ Reduced CO2 Emission of Diesel Generator

Table 9.4-1 shows estimated power generation amount of standby diesel generator based on the following items;

- Total generation amount in target area in this study except residential customers, which is described in the statistics in Department of Statistics in Parana State Government.

  (The reason why residential customers are excluded, is that in general, they don't have standby power plants.)

- Objective index of operation of standby power plant, which is described in JBIC Investment Environment in India – Foresight and Challenge

  (The rate of generation amount of standby power plant in total generation amount in Brazil is 1.6% and the rate operating time only for power outage excluding maintenance, etc. of the preceding rate is 80%.)

Table 9.4-1 Estimated Power Generation Amount of Standby Diesel Generator

MUNICÍPIOS	Consumo					Power Generation Amount of Standby Diesel Generator (A) x 1.6% x 80%
	Setor Secundário (Mwh)	Setor Comercial (Mwh)	Rural (Mwh)	Outras Classes (Mwh)	Total (A) (Mwh)	(Mwh)
Adrianópolis	548	702	870	618	2,738	35
Agudos do Sul	452	1,045	3,534	798	5,829	75
Almirante Tamandaré	44,878	13,333	3,514	11,466	73,191	937
Araucária	443,528	55,479	8,623	20,893	528,523	6,765
Balsa Nova	71,877	5,538	4,190	2,097	83,702	1,071
Bocaiúva do Sul	7,191	1,467	2,707	1,359	12,724	163
Campina Grande do Sul	34,446	14,451	3,519	5,151	57,567	737
Campo Magro	4,498	2,855	3,623	2,635	13,611	174
Cerro Azul	1,833	1,078	2,936	1,573	7,420	95
Colombo	122,384	49,754	7,421	24,036	203,595	2,606
Contenda	4,169	3,466	5,130	2,124	14,889	191
Curitiba	1,097,907	1,367,632	1,157	380,872	2,847,568	36,449
Doutor Ulysses	35	201	1,001	511	1,748	22
Itaperuçu	9,963	2,962	1,149	2,405	16,479	211
Lapa	43,580	10,155	16,329	7,428	77,492	992
Mandirituba	19,713	5,179	10,088	2,686	37,666	482
Pinhais	111,145	46,091	100	50,747	208,083	2,663
Piraquara	15,817	9,857	2,640	13,563	41,877	536
Quatro Barras	62,764	5,518	1,144	5,457	74,883	959
Quitandinha	1,518	2,640	8,231	1,153	13,542	173
Rio Branco do Sul	11,733	5,023	2,416	5,904	25,076	321
São José dos Pinhais	595,917	127,825	17,827	41,493	783,062	10,023
Tijucas do Sul	1,190	3,294	7,264	1,646	13,394	171
Tunas do Paraná	7,295	2,727	265	747	11,034	141
Total						65,993

(Source: Department of Statistics in Parana State Government and JBIC Investment Environment in India – Foresight and Challenge)

Based on the result of Table 9.4-1, emission reduction on diesel generator can be calculated as per the following table.

Table 9.4-2 CO2 Emission Reduction on Diesel Generator

Iitems			Note
Diesel CO2 Emission Factor in Generation	0.8831	kgCO2/kWh	･0.0693kgCO2/MJ(A Heavy Oli):Ministry of the Environment in Japan ･1kWh=3.6MJ:Coversion Factor ･28.25% (Heat Efficiency):Yonden CDM Project
Power Generation Amount of Standby Diesel Generator	65,993	MWh	From Tabale 9.4-1
Reduction of Power Generation Amount of Standby Diesel Generator according to Reduction of Outage Duration	52,794	MWh	▲80% (From 9.2.1)
CO2 Emission Reduction (kg)	46,623,437	kgCO2	—
CO2 Emission Reduction (ton)	46,623	tonCO2	—

(Source: Created by JICA Survey Team)

From Table 9.4-1 and 9.4-2, the reduced CO2 emission of diesel generator is 46, 623 ton CO2.

■ Increasing CO2 Emission of National Grid

This can be calculated by the following formula, because increasing generation amount from national grid is the same amount of reduced power generation amount of standby diesel generator.

National Grid CO2 Emission Factor x increasing generation amount from national grid

= National Grid CO2 Emission Factor x Reduced Power Generation Amount of Standby Diesel Generator

= 0.0497 tonCO2/MWh (Table 9.4-2) x 52,794 MWh = 2, 624 tonCO2

Table 9.4-3 CO2 Emission Factor of National Grid in Brazil

	Monthly Average Factor (tCO_2/MWh)												Annual Average Factor (tCO_2/MWh)
2010	MONTH												YEAR - 2010
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	0.0211	0.0280	0.0243	0.0238	0.0341	0.0506	0.0435	0.0774	0.0907	0.0817	0.0869	0.0532	0.0512
2011	MONTH												YEAR - 2011
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	0.0262	0.0288	0.0208	0.0198	0.0270	0.0341	0.0308	0.0301	0.0273	0.0350	0.0356	0.0349	0.0292
2012	MONTH												YEAR - 2012
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	0.0294	0.0322	0.0405	0.0642	0.0620	0.0522	0.0394	0.0460	0.0783	0.0984	0.1636	0.1168	0.0686
Average (2010 - 2012)													**0.0497**

(Source: MCTI (Ministerio da Ciencia, Tecnologia e Inovacao), CO2 Emission Factors that need Brazil's National Interconnected System's average emission factor, such as corporate inventories.)

■ Total Reduced CO2 Emission for Reduction of Outage Duration

Reduced CO2 Emission of Diesel Generator – Increasing CO2 Emission of National Grid

= 46,623 tonCO2 - 2,624 tonCO2

= 43,999 ton CO2

2) Effect for Reduction of Technical Loss

This effect can be calculated by the following formula;

National Grid CO2 Emission Factor x Total Necessary Generation Amount in COPEL x Total Reduced Technical Loss

- National Grid CO2 Emission Factor

This factor utilizes 0.0497 tonCO2/MWh described in Table 9.4-2

- Total Necessary Generation Amount in COPEL

This is calculated based on total energy consumption in 24 municipalities and loss in transmission and distribution lines in COPEL like Table 9.4-4 and its amount is 8,084,392MWh.

Table 9.4-4 Total Necessary Generation Amount in COPEL

Total Energy Comsumption in 24 Municipalities	7,401,261	MWh
Loss in Transmission and Distribution Lines in COPEL (from Table 2.7-1)	8.45	%
Total Necessary Generation Amount in COPEL	8,084,392	MWh

(Source: Created by JICA Survey Team)

- Total Reduced Technical Loss

This utilizes 1.35% from 9.2.2.

- Total Reduced CO2 Emission for Reduction of Technical Loss

National Grid CO2 Emission Factor x Total Necessary Generation Amount in COPEL x Total Reduced Technical Loss

= 0.0497 tonCO2/MWh x 8,084,392MWh x 1.35%

= 5,424 tonCO2

3) Total **CO2 Emission Reduction**

1) Effect for Reduction of Outage Duration + 2) Effect for Reduction of Technical Loss

= 43,999 tonCO2 + 5,424 tonCO2

= 49,424 tonCO2