STUDY ON COLLECTION
OF
BASIC INFORMATION CONCERNING
SMART GRID/SMART COMMUNITY
INTRODUCTION
IN
THE FEDERATIVE REPUBLIC OF BRAZIL

FINAL REPORT

March 2012

Japan International Cooperation Agency (JICA)
Tokyo Electric Power Services CO., LTD (TEPSCO)

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Abbreviations and Acronyms

Organization

ABINEE	Brazilian Electronic and Electrical Association
ABRADEE	Associação Brasileira de Distribuidores de Energia Elétrica
AES	Applied Energy Services in USA
AMPLA	AMPLA (Distribution Company in Rio de Janeiro)
ANATEL	English：National Agency of Telecommunications Portuguese：Agencia Nacional de Telecomunicacoes
ANEEL	E：Electric Power National Agency P：Agencia Nacional de Energia Eletrica
BNDES	Banco Nacional de Desenvolvimento Economico e Social
CCEE	E：Chamber for the Commercialization of Electric Power P：Câmara de Comercialização de Energia Elétrica
CEAL	Companhia Energética de Alagoas (Distribution Company subsided by Eletrobras)
CEEE	Companhia Estadual de Energia Eletrica (Electric Power Company in Rio Grande do Sul)
Celesc	Centrais Eletricas de Santa Catarina (Electric Power Company in South Catarina)
Celg	Centrais Elétrica de Goiás (Electric Power Company in Goiás)
Cemig	Companhia Energética de Minas Gerais (Electric Power Company in Minas Gerais)
CESP	Companhia Energética de Sao Paulo (Electric Power Company in Sao Paulo)
CEB	Cia Energética de Brasilia (Electric Power Company in Brazilia)
CMSE	Comitê de Monitoramento do Setor Elétrico
CNPE	Conselho Nacional de Política Energética
COPEL	Companhia Paranaense de Energia
CPFL	Companhia Paulista de Força e Luz (Electric Power Company in Sao Paulo)
CRC	Coast Resort City
CTA	Curitiba branch office
CTEEP	Companhia de Transmissão de Energia Elétrica Paulista
Duke Energy Brasil	Duke Energy Brazil (Electric Power Company in USA)
Eletrobras	Eletrobras
ENDESA	Empresa Nacional de Electricidad (Spanish Company subsided by ENEL in Italy)
EPE	E：Energy Research Company P：Empresa de Pesquisa Energética
EPRI	Electric Power Research Institute
INMETRO	E：Instituto Nacional de Metrologia (Private Electric Power Company) P：Normalização e Qualidade Industrial
Light	Group Light (Private Electric Power Company)
MCTI	E：Ministry of Science, Technology and Innovation P：Ministerio Da Ciencia, Technologia e Inovacao
MDIC	E：Ministry of Development, Industry and Commerce P：Ministério do Desenvolvimento, Indústria e Comércio Exterior
MOF	E：Ministry of Finance P：Ministério da Fazenda
MME	E：Ministry of Energy and Mines P：Ministerio de Minas e Energia
Novatrans	Novatrans (Laboratory in Swiss)

Others

ACL	The Free Market (the ACL)
ACR	The Regulated Market (the ACR)
AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
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
CIP	Contribution for Financing the Public Lighting Service
COFINS	Contribuicao para o Financiamento da Seguridade Social
CPI	Consumer Price Index
CPP	Critical Peak Pricing
CT	Current Transformer
DAS	Distribution Automation System
DEC	Duration of outages per consumer per year
DG	Distributed Generation
DR	Demand Response
EMS	Energy Management System
ESS	System Service Charges
EV	Electrical Vehicle
FEC	Frequency of outages per consumer per year
FEP	Front End Processor
FIRR	Financial Internal Rate of Return
FIT	Feed-in Tariff
GIS	Geometrical Information System
GIS	Gas Insulated Switchgear
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
HA	Home Automation;
HAN	Home Area Network
HEMS	Home Electricity Management System
ICMS	Tax on Circulation of Merchandise and Services
ICT	Information and Communication Technology
IGP-M	Market General Price Index calculated by Getúlio Vargas Foundation
IPP	Independent Power Producer
LBS	Load Break Switches
MAE	Wholesale Market for Electric Power
MCH	P：Micro/Mini Central Hidroelétrica (Less than 1 MW)
M-RTU	Master Remote Terminal Unit
OH	Over Head
ONS	P：Operador Nacional do Sistema Elétrico
OPGW	Optical Ground Wire
PC	Primary Concentrator
PCH	P：Pequena Central Hidroelétrica (1MW～30MW)
PDE	Plan for Expansion of Energy
PIS	P：Programas de Integracao Social e de Formacao do Patrimonio do Servidor Publico
PLC	Power Line Carrier
PROINFA	Alternative Energy Sources Incentives Program
PT	Potential Transformer

PV	Photovoltaic
P&D	Pesquisa e Desenvolvimento
RF	Radio Frequency
RGR	Global Reversal Reserve
RPS	Renewable Portfolio Standard
RTU	Remote Terminal Unit
R&D	Research and Development
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SC	Secondary Concentrator
SCADA	Supervisory Control and Data Acquisition
SHP	Small Hydropower
SIN	National Interconnected System
SMS	Short Message Service
TFSEE	Electric Energy Service Inspection Fee
TOU	Time of Use
UG	Under Ground
UHF	Ultra High Frequency
USAID	United States Agency for International Development
VHF	Very High Frequency
WAN	Wide Area Network
WHM	Watt Hour Meter

Chapter 1 Outline of Study

1.1 Background

The situation of electric power supply and demand in Brazil was tight temporarily because of short hydro generation due to a drought in the past, but power plants were added so that Brazil could get out of the peril. The demand is estimated approximately twice increase in the next decade because of strong economic growth, the Soccer World Cup and the Olympic Games to be held in 2014 and 2016, respectively. 70% of the power plants in Brazil are hydro making use of rich water resources in Amazon region, but concerning the future power source development, hydro power plant development seems difficult from the viewpoint of environmental preservation so that mass introduction of renewable energy such as wind and solar energy is deemed essential. In Brazil, the government established renewable energy promotion program (PROINFA) in 2002 publishing renewable energy purchase prices of power companies at the very early stage. Consequently, 3,300MW micro-hydro, biomass and wind power generation was developed in the first phase and it is planned that 10% of annual domestic energy consumption can be covered with renewable energy by 2025 in the second phase. Since small capacity dispersed power sources such as solar power generation are installed at each consumer and connected to distribution network, measures to stabilize the system with smart grid become necessary.

Concerning electric and distribution facilities, since the distribution losses are 7.3% and relatively high, especially in northern cities and Rio de Janeiro, the non-technical losses exceed 20% in some case. Accordingly the reduction of non-technical losses is an urgent issue. Further in Brazil the average SAIDI (18.4hours) in 2010 is 100 times of SAIDI (10minutes) in Japan, then the quality and reliability of distribution system is an important matter to be improved. It is strongly requested to provide smart grid to improve the non-technical losses and reliability of distribution system in Brazil.

The Ministry of Mines and Energy organized a working group to promote smart grid in 2010, continuing the discussion, collecting and studying information of policies in each country of Europe, the U.S. and Japan towards concrete smart grid introduction programs. In addition, it has been started that the elements of smart community (smart city) are incorporated into urban development plans at the state level and there is a possibility that smart grid/ smart community introduction progresses at an accelerated rate in the future of Brazil.

1.2 Purpose of Study

The purpose of study is to collect and analyze the information of current introduction / plan of Smart Grid and Smart Community in Brazil, so that JICA can arrange the basic document to prepare high priority projects in order to support Brazil.

1.3 Contents of Study

The study team visited the Brazilian government, related organizations and major distribution companies in 5 cities (Brasilia / Rio de Janeiro / Sao Paulo / Curitiba / Manaus) in order to survey the introduction and future plan of Smart Grid and renewable energy. In addition, the team also surveyed problems to connect to the distribution network and the basic data to formulate model projects.
Overview of the survey results is summarized as follows.

1.3.1 Overview of Power Sector in Brazil

The Ministry of Energy and Mines (MME) has the overall responsibility for policy setting in the electricity sector while ANEEL (Electric Power National Agency), which is linked to the MME, is responsible for Brazilian electricity regulation and standard of specification.
The National Energy Policy Council (CNPE) 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 National Power System Operator (ONS) 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 Chamber of Electrical Energy Commercialization (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 ANEEL.
Finally, the Energy Research Company (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 planning activities.

Fig. 1.3.1 Organization of Power Sector in Brazil

1.3.2 Activities of Smart Grid in Brazil

At present the federal government has not decided the policies about smart grid yet. The MME has created a working group for smart grid within the ministry and studied. However, the MME is planning to create a new working group expanding the members to other related ministries and agencies and to decide smart grid policies.
The other related ministries and agencies in addition to ANEEL closely related to the MME are considered as follows.

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

Outside of the government, ABRADEE, an association of the distribution companies in Brazil, is working for smart grid actively under the approval of the ANEEL. However, the above MME working group is limited to the government and ABRADEE, distribution companies or even national or state distributors cannot be members of the MME Working Group as long as they are operators. The new MME working group is within the government deciding policies as regulators. In order to study, a smart grid survey team was dispatched to the USA and Europe. Also they have intention to investigate the smart grid in Japan.

1.3.3 Related Laws and Regulations

(1) The Alternative Energy Sources Incentive Program (PROINFA)

The Alternative Energy Sources Incentive Program -PROINFA, created on April 26th, 2002 by publication 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 financial 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 N 247, December 21, 2006

Resolution N 247 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 has over 500 kW of demand

<Wheeling fees discount>

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

(3) Time of Use Tariff

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.

(4) Net-metering

ANEEL is now studying a net-metering system. One of the main objectives is to reduce obstacles of distributed generation (up to 1 MW) connection to low voltage lines. In the United States, 44 states enforce this policy.

- 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.

1.3.4 Present Situation and Plan of Smart Grid in Brazil

A lot of distribution companies have carried out model projects of Smart Grid by using fund stored in ANEEL. The overview of project and plan is as follows.

(1) Eletrobras

- Parintins City (island) in the Amazon River has a plan to implement Smart Grid (Micro Grid) model project. The project consists of Automated Meter Reading (AMR) with smart meters, distributed generation (Photovoltaic: PV, etc.) and the existing diesel generator. The model project is supposed to operate up to the end of 2012.
- Maceio city in Alagoas state and a northern coast area in Piau state have plans to apply pilot projects of Smart Grid.

(2) AES Electropaulo

- Distribution Automation System (DAS) has been operated in Ipiranga area as trial.
- AMR has also been operated in Slum Morada do Sol area as trial.

(3) Light

In order to prevent theft of power, the existing Watt Hour Meters (WHM) have been exchanged to Smart Meters since 2009. DAS also has been operated in order to monitor vaults in underground network and reclosers in over head (OH) network.

(4) AMPLA

AMPLA has a plan to apply a pilot project of Smart Grid to Buzios City as smart city. The project is supposed to implement from July of 2011 to June of 2014 and the scope / specification will be decided from now on. (Smart meter, Electrical Vehicle :EV, etc)

(5) CPFL(Compania Paulista de For a e Luz)

CPFL has a plan to implement DAS and AMR with Smart Meter.

(6) COPEL(Compania Paranaense de Energia)

DAS has been operated in the southern area (Fazenda Rio Grande) of Curitiba as trial. COPEL want to upgrade the functions. For AMR, 7000 units of smart meters were also installed to Foz de Londrina near Iguacu. Furthermore, a model project of AMR will be implemented to large customers in Fazenda Rio Grande.

(7) CEMIG(Compania Enrgetica de Minas Gerais)

According to a literature, Smart Grid of Lagoas area (80,000 customers) in Belo Horizonte is supposed to be implemented as City of Future in accordance with the development budget of ANEEL in 2011. The major scope consists of AMR, DAS, communication network and connection of Distributed Generators.

1.3.5 Present Situation and Plans of Smart Community

Regarding the Smart Community Project, both MME and ANEEL have just concepts but no specific plan at present and they try to study in the near future.
The reasons are as follows.

- ✓ As there are many stake holders related to "Smart Community" such as different ministries, state governments, and many sectors like transport, water and sewage, and city planning, it is very complicated to coordinate them.
- ✓ As Smart Grid is related to a specific sector, Power Industry and MME think it should start from Smart Grid and will spread to the idea of Smart Community in the future.

But in fact, some states like Parana and Minas Gerais are planning and studying the concept of Smart Community. The study team collected the related information on the occasion of visit at the city office.

- ➢ **Parana State**
  They are planning Smart Community Project in Rio Grande and Morretes. The main contents are wide area project from the securities of water sewage, gas to school and hospital. That plan includes Photovoltaic introduction to the stadium of Soccer World Cup. Additionally Electric Vehicles are studied there.
- ➢ **Minas Gerais State**
  CEMIG is planning the combination of smart grid and Building Electricity Monitoring system (BEMS) for the condominium. Especially Mineirão area is the target of intelligent power supply such as Minas Solar 2014 mentioned Chapter 2, 2.10 including the photovoltaic power and electric vehicle.
- ➢ **Others**
  Japanese companies proposed the idea of the hybrid system with Electric Vehicle and battery in Sao Paulo and AMPLA (Rio de Janeiro).

1.3.6 Survey Result of Distribution sector in Brazil

(1) Distribution network

Distribution network in Brazil is normally OH network. Light in Rio de Janeiro has Under Ground (UG) network but the percentage is around 10% in the distribution networks. OH consists of radial network mainly and there are looped networks in part of the city area.

(2) Power Quality (Reliability): Outage duration per Customer Year (SAIDI)

Outage duration in Brazil is very long due to radial networks and no sectionalizers which can isolate the faulty section. When a fault occurs, the power supply of all the sections on 13.8kV feeder will be stopped so that the outage duration become long. Reclosers are installed in a part of area,so that the faulty section of the load side can be isolated automatically. However, the recloser cannot be installed in series due to the coordination of protection relays, because it is very difficult to coordinate the operating time of each relay by the periodical and/or atmospheric change of operating characteristics of the relays. Then the remarkable improvement to reduce the outage duration is not expected.

The SAIDI of many distribution companies is more than 10 hours that means around 100 times of Japanese SAIDI. The needs to reduce the SAIDI are very strong in Brazil.

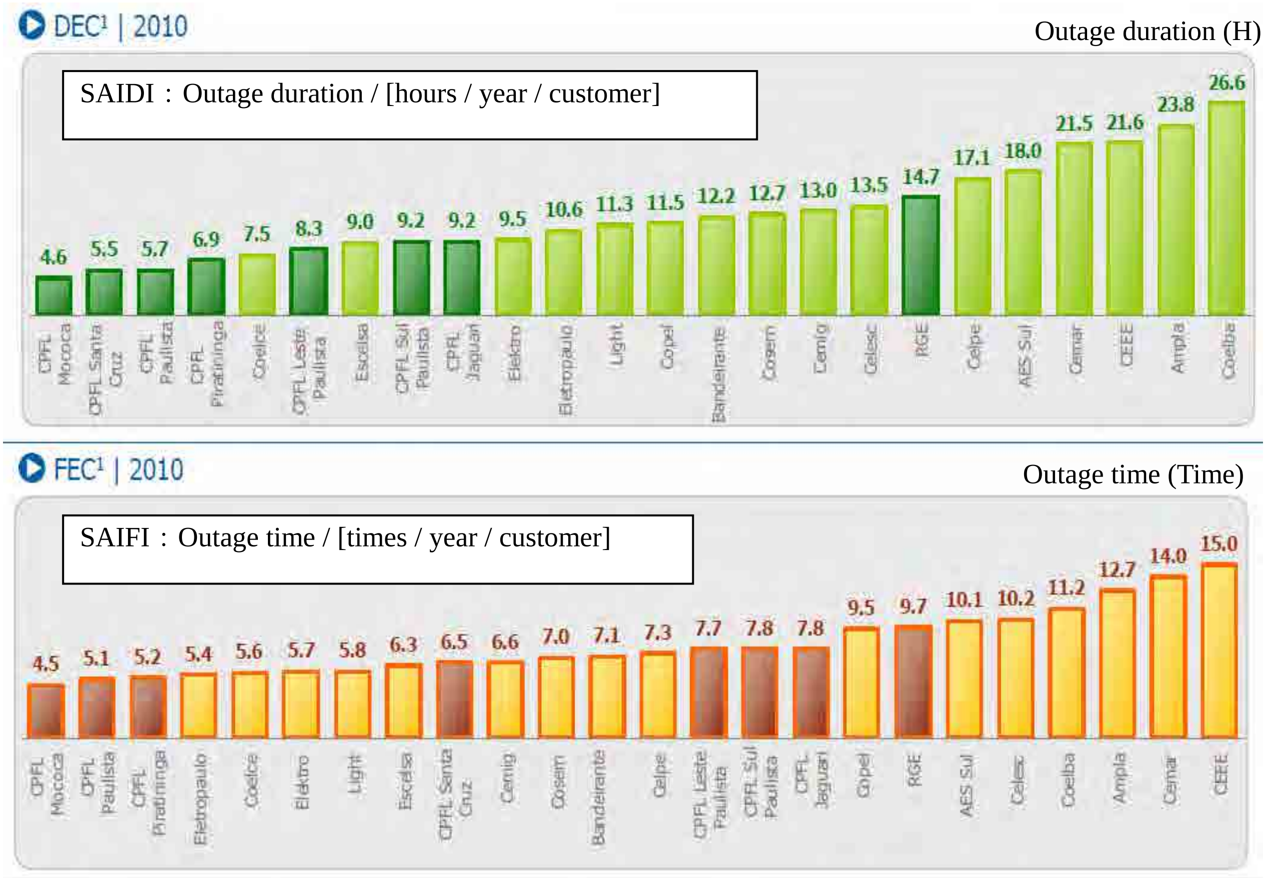


Fig. 1.3.2 SAIDI and SAIFI in Brazil

(3) Distribution loss

< Technical Loss >

Distribution line in northern and rural areas are well maintained by Distribution Companies, but the lines are too long so that the technical loss is large. Especially in Amazon area, there are a lot of towns in jungle so that transmission lines are not installed due to the increment of technical loss and the big investment. Diesel generators were installed and the power has been supplied to the towns and the surroundings. The technical loss is around 8%.

Technical losses in southern cities such as COPEL are low, but they make an effort to reduce the technical loss by improvement of power factor.

< Non-Technical loss >

Non –Technical loss is large in northern city and poverty area of big city, so that AMR with smart meter has been positively installed in order to improve the non-technical loss by theft. (Non-technical loss: 32% in Eletrobras in Amazones state, 39% in AES Eletropaulo, 14.9% in Light)

In order to prevent the thefts, many companies installed the few WHM on the top of pole near 13.8kV line. The cost is higher (1.5 times) than normal WHM.

(4) Power Shortage

Recently, distribution companies have no experience of outage by power shortage due to enough power and low consumption per customer. However, the consumption will increase year by year due to the Soccer World Cup and Olympic Games but the new development of hydraulic generation cannot be proceeded due to the problems of the environment.

Therefore, renewable energy is needed and power companies will apply positively by utilizing ANEEL fund storing 1% of the profits. There are many kinds of renewable energy such as PV, small wind power, small hydraulic power, biomass, etc. Especially, wind power generation has increased since several years ago so that the industry of wind power grew up. PV is expected to the next industry of wind power and the positive application has been implemented since 2011. The PV will be installed on the roofs of the World Cup stadiums as a definite plan.

These distributed generators will be connected to the distribution network and have already been connected in a part of area as trial. As a large quantity of the distributed generators will be connected to the distribution network, Smart Grid is needed in order to solve the connection problems.

(5) Energy Efficiency

A load curve in Brazil has a big difference between Peak and Off-Peak loads as shown in Fig 1.3.3 so that the application of TOU or the Peak-cut by Demand Response (DR) or the Peak-shift by visual display is needed. The peak comes out in a time-frame using shower after people come back home. In addition, Air Conditioning is also included in the peak load as large consumption, especially in Sao Paulo and Rio De Janeiro. This Peak-Shift is effective so that the construction of power generation can be deferred. Recently, White tariff system as shown in Fig 1.3.4 will be considered as TOU in order to decrease the peak load.

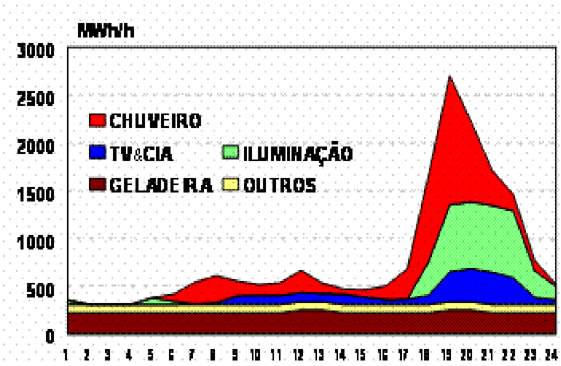


Fig. 1.3.3 Typical load curve in Brazil

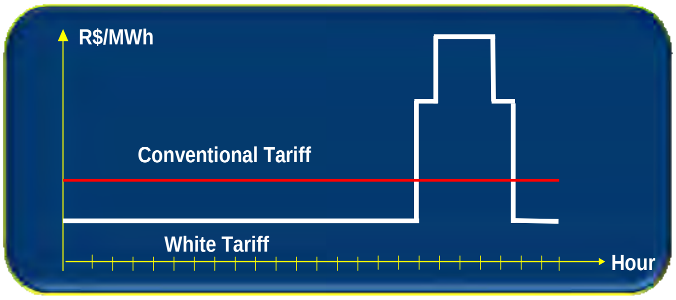


Fig. 1.3.4 White tariff system (Example)

Distribution companies in city area such as COPEL want to make effective the office and site work. Geographical Information System (GIS) (Off-line) and Call-Center system have been applied but more effective system including fault detecting procedure is needed.

1.3.7 Functions of Smart Grid needed in Brazil

High priority functions of Smart Grid in Brazil are as follows.

(1) Application of DAS in order to improve reliability of power supply
(2) Application of Auto Meter Reading (AMR) / Advanced Metering Infrastructure (AMI) in order to reduce non-technical loss
(3) Energy efficiency in order to reduce Peak load
  - Peak-Cut by DR
  - Peak-Shift by visual display or TOU
(4) Application of renewable energy (especially PV) in order to prepare for increment of power consumption

1.3.8 Model Project

(1) Area of Model Project

The candidates of model project and reason to be selected are as follows.

1) Candidate of model project
a. Curitiba City
b. Maceio City

2) Reasons to be selected as candidate
a. The power company shall be the public sector.
b. The project shall be under planning and not started yet.
c. The company has intention to proceed the project with JICA fund.
d. The show window effect is expected by the model project in Brazil.

(2) Overview of Model Project

1) System Configuration of Model Project
System configuration of model project is shown in Figure 1.3.5

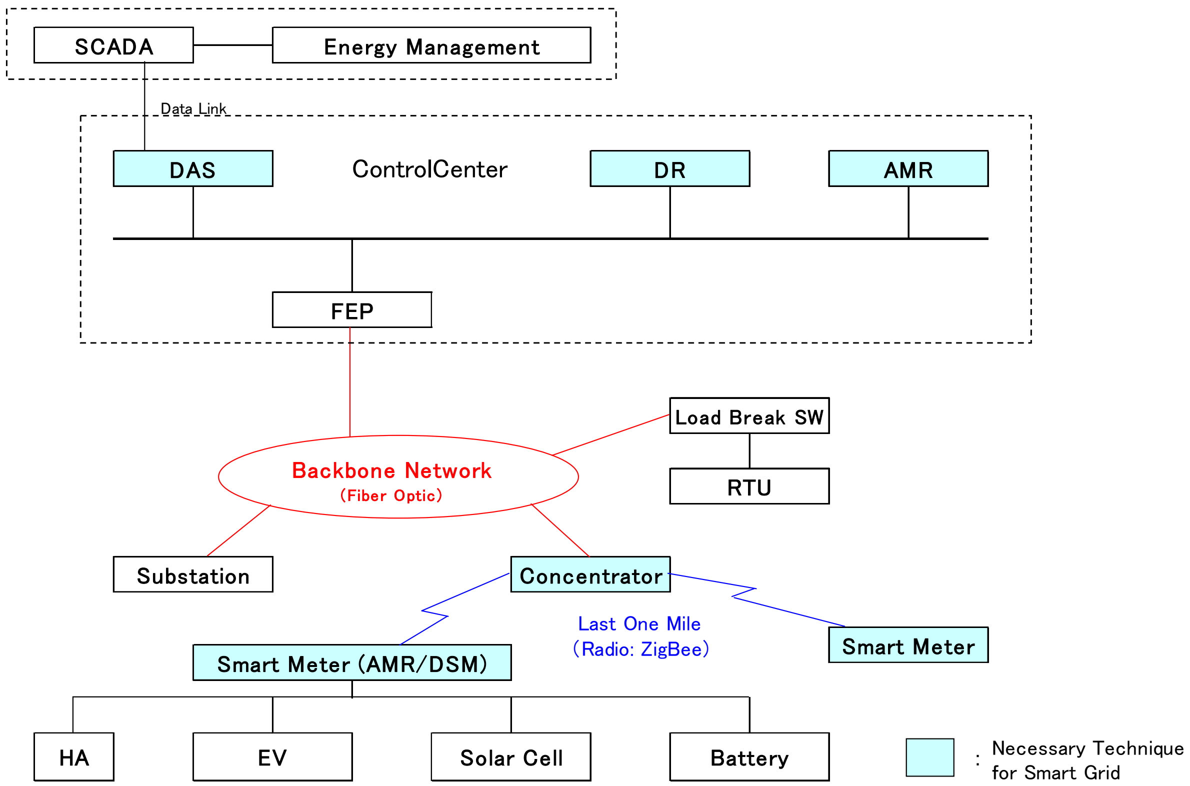


Fig. 1.3.5 System Configuration

2) Total Project Cost
Total costs of both projects are shown in Table 1.3.1 and 1.3.2 for Curitiba City and Maceio City respectively.

Table 1.3.1 Total Project Cost of Curitiba City

Equipment	Quantity	Unit Price	Total Cost (Million US$) (Quantity x Unit Price)
Control Center	1 system	-	7
Substation equipment Distribution Equipment	24 SS 1,000 sets	0.2 Million US$ 15,000 Million US$	4.8 15.0
Smart Meter	70,000 sets (700,000sets)	100 US$	7.0 (70)*
Capacitor	220	45,000 US$	9.9
Fiber Optic Cable	0	6,000 US$/km	0
Others（Design, Spare Tax etc.）	50 %	-	21.9 (53.4)*
Total	-		65.5 (160.1)*

Table 1.3.2 Total Project Cost of Maceio City

Equipment	Quantity	Unit Price	Total Cost (Million US$) (Quantity x Unit Price)
Control Center	1 system	-	7
Substation equipment Distribution Equipment	2 SS 70 sets	0.2 Million US$ 15,000 Million US$	0.4 1.1
Smart Meter	10,000 sets (104,200sets)	100 US$	1.0 (10)*
Fiber Optic Cable	700km	6,000 US$/km	4.2
Others（Design, Spare Tax etc.）	50 %	-	6.9 (11.4)*
Total	-	-	20.6 (34.1)*

*: Cost in case that all of the existing meter will be exchanged to smart meter in the first year.

(3) Economical Benefits.

Economical benefits are is shown in Table 1.3.3 below.

Table 1.3.3 Overview of economical benefits for 2 model areas

Economical Effect	COPEL Curitiba City	Eletrobras Alagoas Maceio City
Reduction of Blackout Time	600min.→120min. （22 Million US$）	960min→192min （6.4 Million US$）
Reduction of Technical Losses	6.6%→4.82% (420 Million US$)	8.42%→6.82% (70 Million US$)
Reduction of Non-Technical Losses	1.5%→0.45% (260 Million US$)	23.03%→6.9% (705 Million US$)
Peak cut/shift by Demand Response	840 MW (168 Million US$)	110 MW (22 Million US$)

(4) Economical Analysis

Financial Internal Rate of Return (FIRR) calculated in both projects according to economical benefits and costs are shown as follows.

Table 1.3.4 Financial Internal Rate of Return for 2 model areas

Effect	Curitiba	Maceio
Cost Reduction and Increase of income.	US$ 809 million	US$ 701 million
Total Investment	US$ 66 million	US$ 20.6 million
Maintenance Cost	US$ 134 million	US$ 23.7 million
Financial Internal Rate of Return (FIRR)	21.2%	44.4%

1.3.9 Next Step

In Brazil, ABRADEE considerer that pilot projects of smart grid and smart meter will be carried out by 2016 and referring the result of those pilot projects, commercial plant will be started and completed by 2030.
In order to achieve results of pilot projects by 2016, SAPROF or similar actions shall be carried out with the agreement between the Japanese and Brazilian Governments made in 2012 considering two years for construction.
Based on the pilot projects carried out by Yen-loan and other pilot projects by other fund, it is recommended that the specifications of smart grid and meters will be decided and it will be applied to other commercial projects in Brazil. At the same time, it is expected that the Brazilian Government shall prepare applicable laws and regulations regarding smart grid and meter by 2016.

1.4 Study Team Members

The Study was implemented by the following members as shown in Table 1.4.1 below.

Table 1.4.1 Members of survey team

	Field in Charge	Name	Company
1	Leader / Distribution Planning and Smart Grid	Fujisawa Atsushi	Tokyo Electric Power Service Co. (TEPSCO)
2	Distribution Facilities Planning (Distribution Facilities)	Kuwahara Kenichi	Shikoku Electric Power Co. (SEPCO)
3	Distribution Facilities Planning (Distribution Network)	Miyazaki Teru	Tokyo Electric Power Co. (TEPCO)
4	Distribution Facilities Planning (Communication Network)	Kato Kiyotaka	TEPSCO
5	Economical Analysis	Aoyama Toru	International Development Associates

1.5 Study Schedule

1.5.1 1st Site Survey Schedule

The survey team visited and surveyed the Brazilian Government, the related organizations and major distribution companies in 5 cities (Brasilia / Sao Paulo / Rio De Janeiro / Curitiba / Manaus) from Nov. 22, 2011 to Dec 19, 2011 as shown Table 1.5.1.

Table 1.5.1 Schedule of the Primary Survey

Schedule (Date)	City	Visiting Site
Nov 22 /23	-	Traveling
24	Brasilia (Forum in Sao Paulo)	MME, JICA, Japanese Embassy
25		ANEEL
26, 27		(Adjustment of Documents
28		MDIC, MCTI
29		MME, Eletrobras, Forum in Sao Paulo
30	Sao Paulo	Hitachi, Forum
Dec 1		CPFL, Forum
2		AES Eletropaulo
3, 4	Rio De Janeiro	Traveling, Adjustment of Documents
5		Light
6		AMPLA
7	Curitiba	COPEL
8		COPEL, Parana State Government
9		Toshiba, L+G
10, 11	Manaus	Traveling, Adjustment of Documents
12		Eletrobras (Amazonas State Energy Distribution Company)
13		Traveling
14	Brasilia	ANATEL, ABRADEE forum
15		ABRADEE forum
16		MME, JICA
17,18,19	-	Traveling

1.5.2 2nd Site Survey Schedule

The survey team visited and surveyed the Brazilian Government, the related organizations and major distribution companies in 3 cities (Brasilia / Curitiba / Maceio) from Jan. 17th 2012 to Jan. 31st 2012 as shown Table 1.5.2.

Table 1.5.2 Schedule of the Second Survey

Schedule (Date)	City	Visiting Site
Jan /17, 18	-	Traveling
19	Curitiba	COPEL, Furukawa Electric
20	Itaipu	Electric Vehicle Survey
21		Itaipu Power Station
22	Maceio	Traveling
23		Eletrobras Alagoas (CEAL)
24	Brasilia	Traveling
25		MME
26		Seminor
27		Federal Brasilia Government and JICA
28		Traveling
29,30,31		Traveling

Map of Site survey and Model Project areas in Brazil

Chapter 2 Overview of Electricity Sector in Brazil

2.1 Electricity Industry System

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 MME has implemented and coordinated the power 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 was created. Furthermore, the ONS 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 to implement 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.

The electric power industry situation in Brazil divided in generation, transmission and distribution is explained as follows.

(1) Generation

ANEEL material shows that the total generation in Brazil is 485 TWh and the installed power is 116 GW (70% is hydro) in 2010. Eletrobras, national power corporation (the federal government owns 52% of the stocks and BNDES has 21% so that 78% of the shares are public and the remaining shares are private including free floating), has 37% (42.08GW) of the total generation capacity in Brazil and is the biggest supplier according to the Eletrobras annual report. It has 36 hydro, 126 thermal and two nuclear power plants. Among those, Tucuruí (8,370 MW), Brazilian part of Itaipu (7,000 MW), Paulo Afonso (3,984 MW), Xingó (3,162 MW), Angra 1& 2 (2,007 MW), Serra da Mesa (1,275 MW), Furnas (1,226 MW) and Sobradinho (1,050 MW) are mentioned as large and important plants. In spite of the privatization promotion, the reason why these power plants remained in hand 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 stocks are shared by the federal government at 48%, but 64 % of voting rights are owned by the government, is generating power with more than 5GW capacities of its fifteen power plants.

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: 63 generation plants (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 6.925GW capacities
- COPEL (Companhia Paranaense de Energia) in Parana State: 18 generation plants (17 hydro and one thermal) with 4.55GW capacities
- CELESC (Centrais Eletricas de Santa Catarina) in Santa Catarina State: 12 hydro plants with 83MW capacities

The sum of Eletrobras', Petrobras' and four state generation companies' capacities accounts for 58% 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: 11 power plants (six hydro and five thermal) with 6.977GW capacities
- AES (Applied Energy Services): two power plants (one hydro and one thermal) with 3.296GW capacities
- CPFL (Companhia Piratininga de Forca e Luz): 64 power plants with 2.658GW capacities
- Duke Energy Brazil: 2.237GW
- Endesa (Empresa Nacional de Electricidad): 13 power plants with 986.77MW capacities
- Light: three power plants with 130MW capacities

Table 2.1.1 Main Power Generation Companies in Brazil

Generation Company	Generation Capacity	Share	Public/ Private
Eletrobras	42.08GW	37%	public
Petrobras	More than 5 GW	4.4%	public
CESP	7.455GW	6.5%	public
Tractebel Energia	6.977GW	6.1%	private
Cemig	6.925GW	6.0%	public
Copel	4.55GW	4.0%	public
AES	3.296GW	2.9%	private
CPFL	2.658GW	2.3%	private
Duke Energy Brasil	2.237GW	2.0%	private
Endesa	986.77MW	0.9%	private
Light	130MW	0.1%	private

The number of generation companies registered in ONS is 100.

(2) Transmission

According to the MME, total length of high voltage transmission lines in Brazil is 97,349km in 2009 (Figure 2.1.1). Eletrobras shares 58,361.32km, which accounts for 60%.
Main state-owned transmission companies are as follows.

- CEMIG: 7,506km
- CEEE (Companhia Estadual de Energia Eletrica): 5,781km (Rio Grande do Sul State)
- COPEL: 1,880km
- CELESC: 4,000km (Santa Catarina State)

While the sum of these public transmission lines accounts for approximately 80% share, major private transmission companies are mentioned as follows.

- CEEP (Companhia de Transmissão de Energia Elétrica Paulista, a Colombian enterprise): 12,271km (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
- Novatrans: 1,278km

The number of transmission companies registered in ONS is 68.

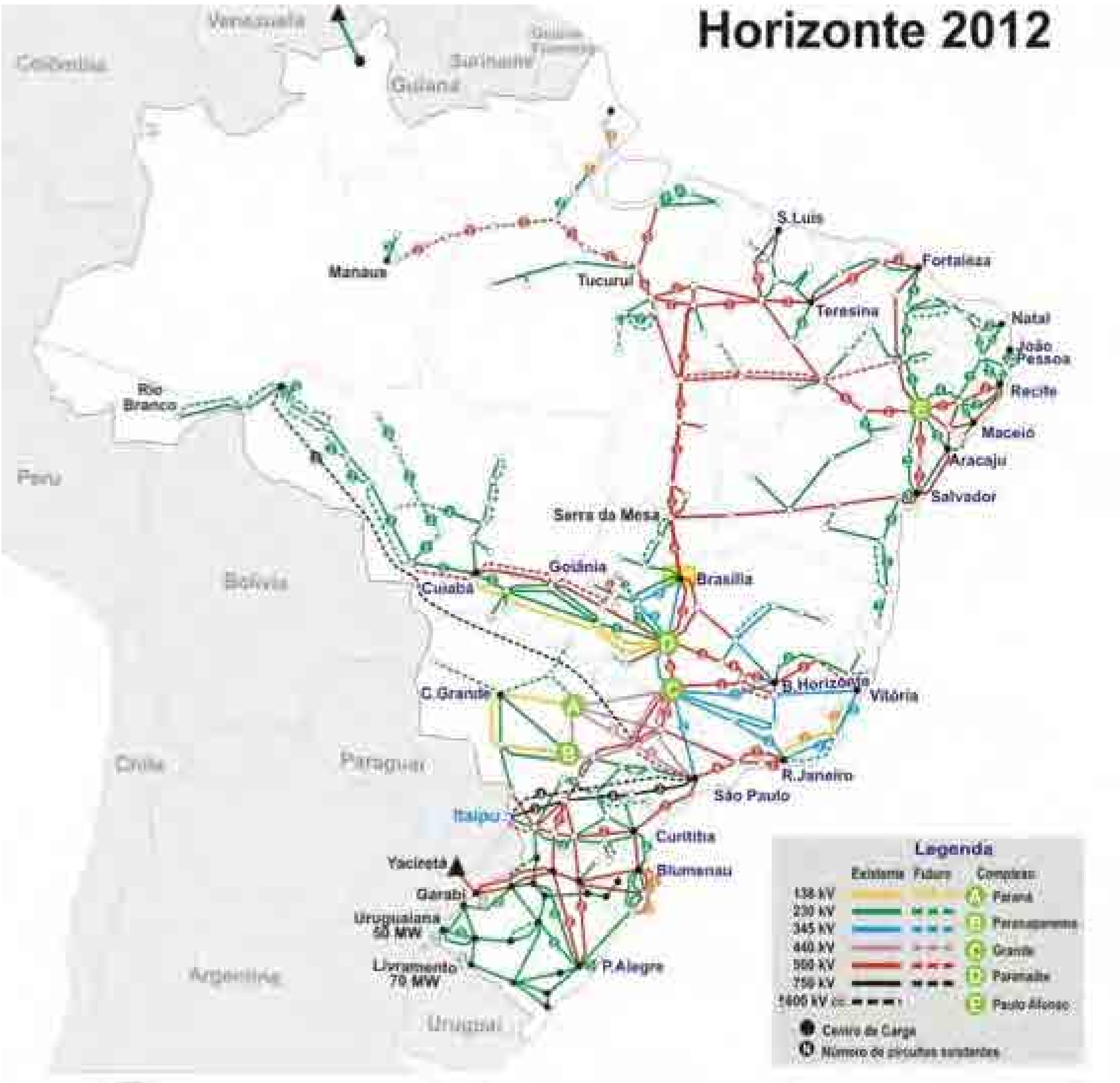


Fig. 2.1.1 Transmission Network in Brazil
(Source: Ivan Camargo, “Innovative Regulation for the Development of Smart Grids in Latin America” 2011)

Table 2.1.2 Main Transmission Companies in Brazil

Transmission Company	Transmission Line Length	Share	Public/ private
Eletrobras	58,361.32km	60%	public
CTEEP	12,271km	12.6%	private
Cemig	7,506km	7.7%	public
CEEE	5,781km	5.9%	public
Alusa	5,464.5km	5.6%	private
Celesc	4,000km	4.1%	public
Copel	1,880km	1.9%	public
Novatrans	1,278km	1.3%	private

(3) Distribution

The private companies' share has advanced more in the distribution business. As a whole, the distributors in Brazil consist of 49 private distribution companies, state distribution corporations and local public distributors belonging to ABRADEE supplying electric power to the whole country except part of agricultural areas. Furthermore, electrification cooperatives and distribution cooperatives are supplying power in rural and agricultural areas of Amazon. The distribution companies from the first to seventh rank (in Table 2.1.1) as of 2007 supply a half of whole Brazil demands. Eletrobras has six distribution subsidiaries, but their service areas are Amazonas, Acre, Roraima and Rondonia States in northern region and Piaui and Alagoas States in northeast region, but they are not so attractive to the private and so remained unsold in concession bidding. According to the Eletrobras' annual report of 2008, the total supply power of Eletrobras was 11,157GWh which accounts for 2.8% of the total supply power, 392,764GWh in Brazil. In addition, Cemig, COPEL, CELESC, CELG (Centrais Elétrica de Goiás), CEEE and CEB (Companhia Energetica de Brasilia, a federal government enterprise) among the distribution companies in Table 2.1.3 are public and their summed supply power accounts for 27%.

Table 2.1.3 Top 20 Distribution Companies in Brazil

Rank	Distribution Co.	Area	Suply Power GW	Market share	Public/private
1	Eletropaulo	SP	31.677	12.57	Private
2	Cemig	MG	20.134	7.99	Public
3	Light	RJ	18.381	7.29	Private
4	CPFL Paulista	SP	18.294	7.26	Private
5	Copel	PR	17.479	6.94	Public
6	Celesc	SC	12.745	5.06	Public
7	Coelba	BA	10.614	4.21	Private
8	Elektro	SP	9.563	3.8	Private
9	Bandeirante	SP	7.865	3.12	Private
10	Celpe	PE	7.85	3.12	Private
11	CPFL Piratininga	SP	7.743	3.07	Private
12	Celg	GO	7.173	2.85	Public
13	Ampla	RJ	7.051	2.8	Private
14	AES Sul	RS	6.905	2.74	Private
15	RGE	RS	6.319	2.51	Private
16	CEEE	RS	6.287	2.5	Public
17	Coelce	CE	6.206	2.46	Private
18	Celpa	PA	4.739	1.88	Private
19	Escelsa	ES	4.287	1.7	Private
20	CEB	DF	3.991	1.58	Public

2.2 Governmental Policy and Regulation

2.2.1 Regulatory Organization of Electric Industry

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.

CNPE 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 CMSE monitors and evaluates power supply continuity and safety throughout Brazil.

ONS was established to operate, supervise and control power generation within SIN, and to manage

Brazilian power transmission grid. The ONS is under ANEEL's control and regulation.
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 ANEEL.
Finally, EPE was created in 2004 with the specific mission of carrying out studies and research in order to provide the market monitoring and long term planning.

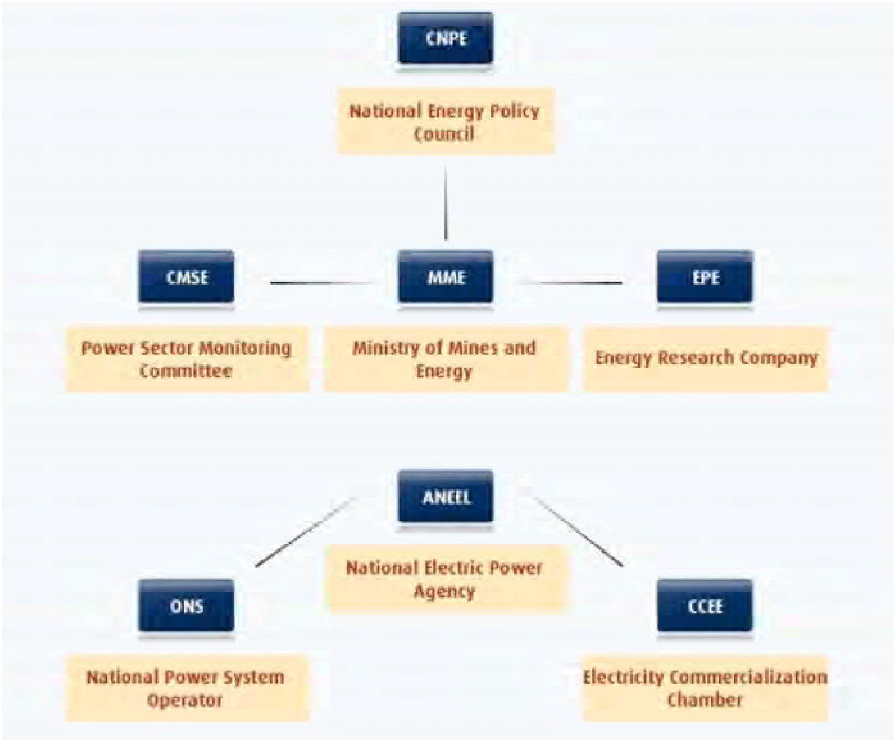


Fig. 2.2.1 Organization of Power Sector in Brazil

2.2.2 Electric Power Market Trade

The Brazilian electricity power trade is almost fully deregulated, which allows generators to sell their energy via freely negotiated contracts with consumers above 3 MW or via energy auctions to distribution companies. Under this model, distributors are required to satisfy the expected demand in their supply area. Currently, Brazilian generation supply can be sold via five types of markets:

1)"Old energy"* auction contracts (long-term): approximately 40% of the 2007 market;
2) "New energy"* auction contracts (long-term): delivery started in 2008;
3) Free-market contracts (long- and short-terms): approximately 25% of 2007 market;
4) Imbalance Market Sales: To balance the actual power without CCEE contracts; and
5) Distributed Generation: to Distribution Company +for small ones with limited price.

*Old energy represents the existing plants that were already contracted in the 1990s, while new energy refers to that energy produced by plants that have not yet been built, or by the existing plants that meet certain criteria.

The electric trade in CCEE was made in the following two classified markets.
i) Trading with Distco with Energy Auctions in **ACR**

The Regulated Market (ACR): In the regulated market, distribution companies will purchase electricity for their captive consumers through public bids regulated by ANEEL and conducted by CCEE.

Every year, ANEEL has some Energy Auctions to supply enough energy for demand to Distribution Companies. In general cases, the contracts are long-term: 30 years for hydro power plants, 15 years for others power plants, for "**New Energy**" (power plants not built before the year of auction); or short-term: 5 years or less for "**Old Energy**" (power plants already built before the year of auction).

ii) Trading with other CCEE participants in **ACL**

The Free Market (ACL): In the free market, electricity is traded between generation concessionaires, IPPs, self-generators, energy traders, importers of energy and free consumers.

In December 2006, ANEEL published Resolution nº 247 that regulates energy trade between renewable power plants and small consumers called "Special Consumers." This retail trade in renewable energy is the only way for the consumers to choose their energy sellers (more than 500 kW).

The energy trader can buy and sell renewable energy with energy portfolios to warrant a flat curve of production due to the fact the renewable power plant production is very instable. The Resolution nº 247/2006 established the wire tariff discount for who trade renewable energy, too.

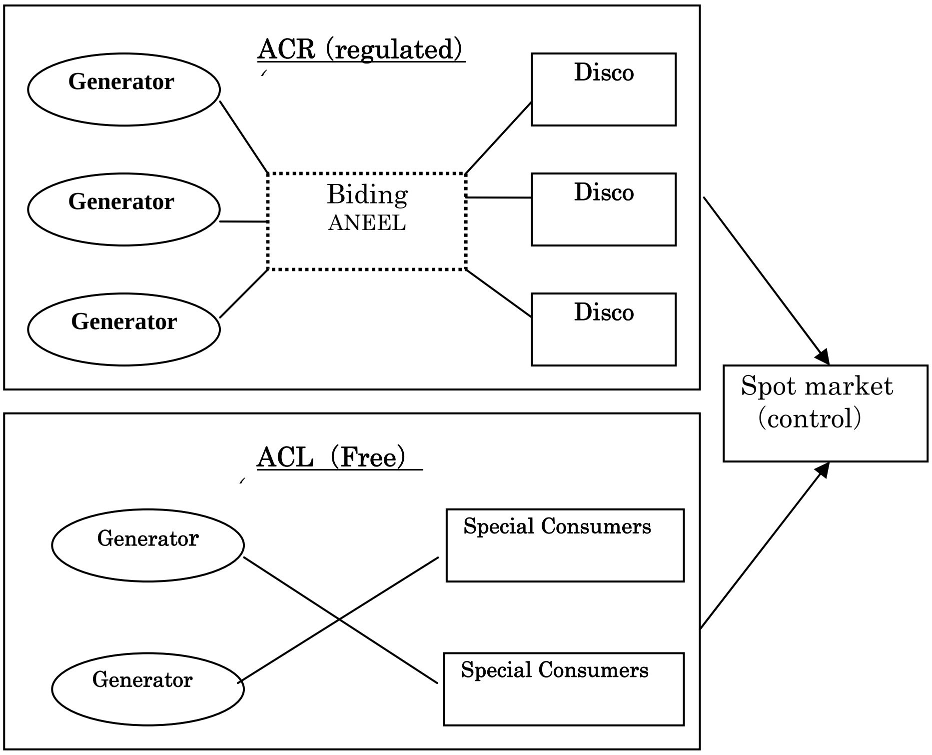


Fig. 2.2.2 Flow of Electric Power Market Trade

2.3 Present Situation and Future Plan of Generation

2.3.1 Present Situation of Generation

The electricity generation in 2010 was 475 TWh, which was 1.9% higher than the previous year generation. It is worth remarking that the Brazilian electricity generation matrix has predominance of renewable sources, especially hydropower which accounts for 89 % of the total domestic supply. The electricity generation growth in the past 20 years is also described below.

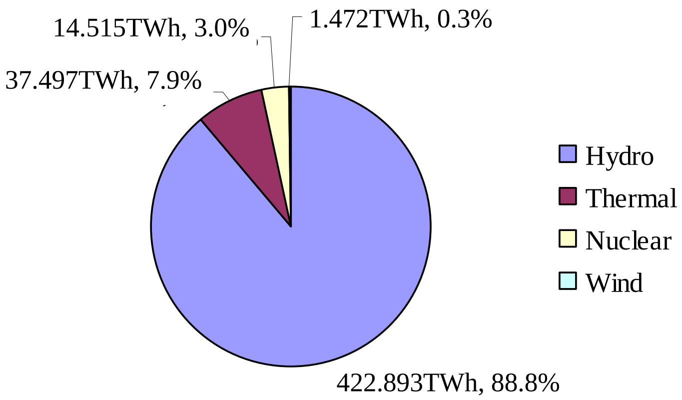


Fig. 2.3.1 Generated electricity in 2010 in Brazil (TWh, %)
(Source: Presentation material of ANEEL)

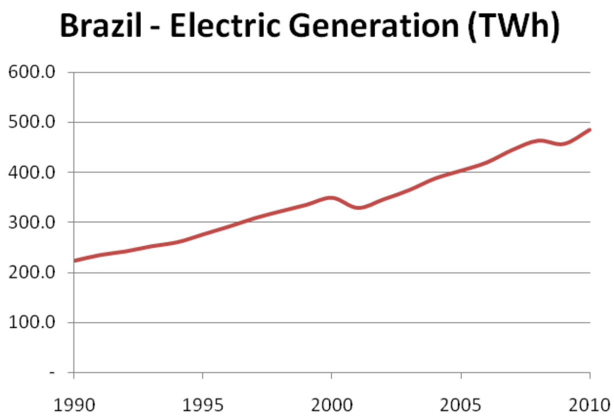


Fig. 2.3.2 Electricity generation growth from 1990 to 2010 in Brazil
(Source: Presentation material of ANEEL)

2.3.2 Future plan

The CNPE and MEE announce 10 years Brazilian Energy Plan (PDE) every year. According to PDE 2020 published by EPE, the domestic electricity supply is expected to reach a total of 867.3 TWh in 2020, with an annual increase rate of 4.8 % over 2010 figures. Considering the Domestic Electricity Supply, the hydropower supremacy will continue in 2020, standing for 73.4 % of the total compared to 80.6 % in 2010 including imports. This relative reduction is offset by the strong expansion of wind and biomass generation. In this context, renewable energies are left with 87.7 % share in 2020, a percentage higher than in 2010, 86.2 %.

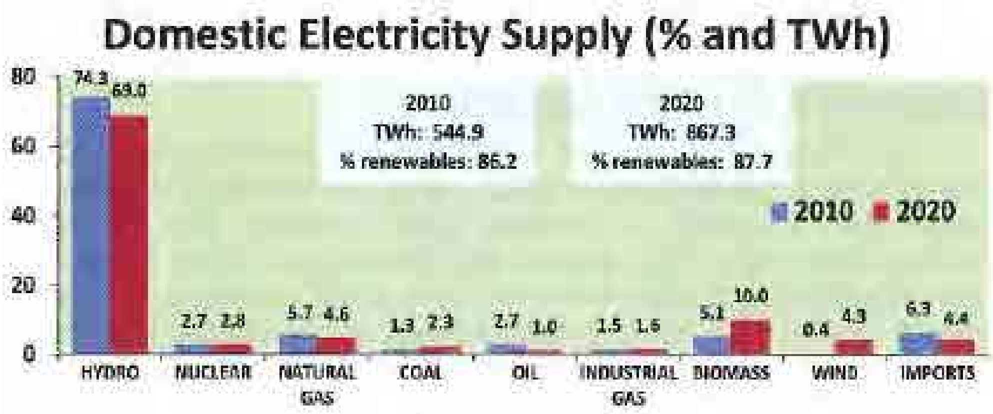


Fig. 2.3.3 Domestic Electricity Supply (% and TWh)

(Source: PDE 2020)

The Brazilian electricity generation installed capacity will reach 181.6 GW in 2020, with increase of around 69.2 GW over 2010. With the electricity imported from Itaipu hydro power plant, a total of supply will achieve 187.4 GW.

Considering only SIN, without captive self-producers, the installed capacity will reach 171.1 GW in 2020, with increment of 61.6 GW. Hydropower accounts for 56 % of the expansion (34.8 GW), while biomass and wind power account for 25 % of the expansion (15.4 GW). Projects already contracted account for 69 % of the expansion (42.2 GW).

Table 2.3.1 Power plant expansion – Total (GW)

Power Plant Expansion - Total (GW)

Sources	2010	2020	Increment	Structure (%)	
			2010-20	2010	2020
HYDRO	76.3	108.5	32.2	64.5	57.9
NUCLEAR	2.0	3.4	1.4	1.7	1.8
NATURAL GAS	11.3	13.4	2.2	9.5	7.2
COAL	1.6	3.4	1.8	1.3	1.8
OIL	6.9	10.9	4.1	5.8	5.8
INDUSTRIAL GAS	1.3	3.1	1.8	1.1	1.7
SMALL HYDRO	4.3	7.1	2.8	3.6	3.8
BIOMASS	7.8	20.1	12.3	6.6	10.7
WIND	0.9	11.5	10.6	0.8	6.2
TOTAL	**112.4**	**181.6**	**69.2**	**95.1**	**96.9**
IMPORTS	5.9	5.9	0.0	4.9	3.1
TOTAL SUPPLY	**118.2**	**187.4**	**69.2**	**100.0**	**100.0**

Note: Include captive self-producers and isolated systems.
Source: ANNEL's Generation Information Databank, 12/31/2010

(Source: PDE 2020)

Table 2.3.2 Power plant expansion – SIN (GW)

Power Plant Expansion – SIN (GW)

Sources	2010	2015	2020	Increment 2010-20	Structure (%) 2010	Structure (%) 2020
HYDRO (*)	82.9	94.1	115.1	32.2	75.7	67.3
NUCLEAR	2.0	2.0	3.4	1.4	1.8	2.0
NATURAL GAS	9.2	11.7	11.7	2.5	8.4	6.8
COAL	1.8	3.2	3.2	1.4	1.6	1.9
OIL	3.9	9.9	9.9	6.0	3.5	5.8
INDUSTRIAL GAS	0.7	0.7	0.7	0.0	0.6	0.4
SMALL HYDRO	3.8	5.0	6.4	2.6	3.5	3.8
BIOMASS	4.5	7.4	9.2	4.7	4.1	5.4
WIND	0.8	7.0	11.5	10.7	0.8	6.7
TOTAL	109.6	140.9	171.1	61.6	100.0	100.0

(*) Include imports (Itaipu-Paraguai)
Note: do not include captive self-producers

(Source: PDE 2020)

By 2020, 42.2 GW are contracted, of which 23.6 GW from hydropower, 1.4 GW from nuclear power, 10 GW from conventional thermal and 7.2 GW from renewable sources. The five major hydro projects are: Belo Monte (11,233 MW), the Xingu River, 2015/16; Jirau (3,300 MW), the Madeira River, 2013; Santo Antonio (3,150 MW), the Madeira River, 2012; Teles Pires (1,820 MW), the Teles Pires River, 2015 and Estreito (1,087 MW), the Tocantins River – 2011.

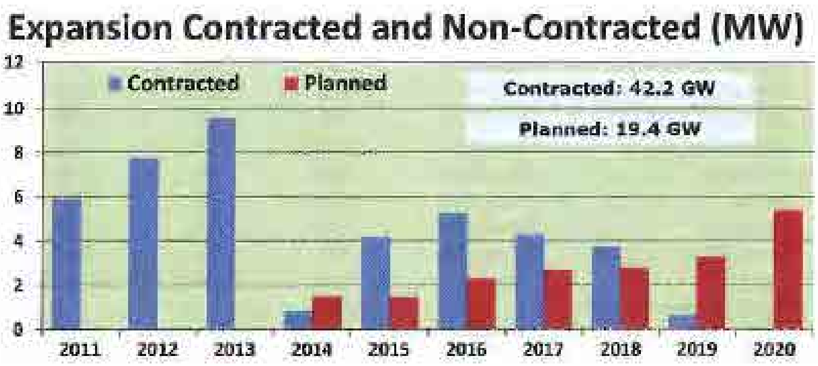


Fig. 2.3.4 Expansion Contracted and Non-Contracted (MW)

(Source: PDE 2020)

Status		River Basin	MW
Approved by ANEEL	1	Tapajós e Jamanxim (7 projects)	14,245
	2	Teles Pires e Apiacas (5 projects)	3,697
	3	Araguaia (reinventário)	3,100
	4	Aripuanã	3,000
	5	Itacaiúnas	200
	6	Jari	1,100
	7	Jatapu	650
	8	Juruena	5,000
	9	Rio Branco	2,000
In process	10	Sucunduri	650
	11	Trombetas (reinventory)	3,000
		Total	36,642

Fig. 2.3.5 Major Hydroelectric Inventory Studies (Map 1)

(Source: PDE 2020)

2.4 Present Situation and Future Plan of Demand

2.4.1 Present Situation of Demand

The highest level of power demand in 2010 in SIN was around 70.5 GW. The electricity demand is growing at a rate of 5-6 % per year. This rate is expected to continue in the medium term. The electricity sector revenue, except free market in 2010 was around 45 billion USD. The revenue of free market is estimated to be 11 billion USD.

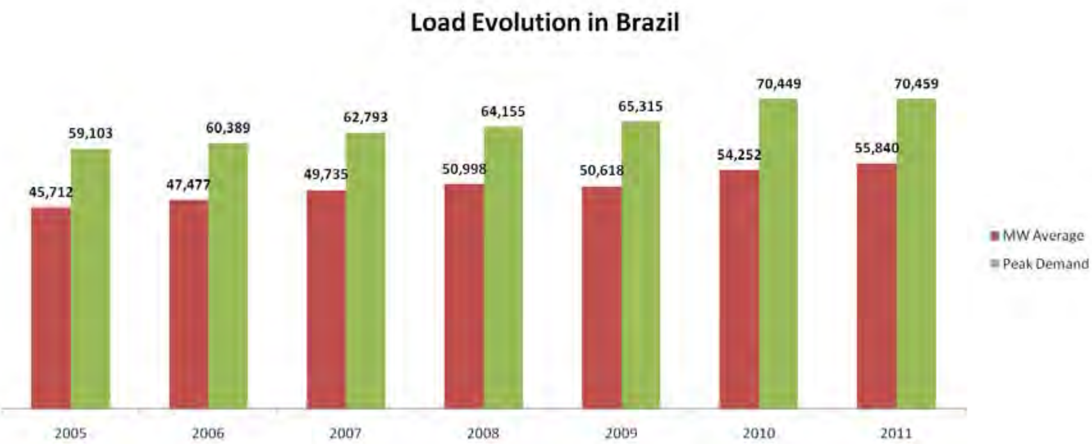


Fig. 2.4.1 Power demand in Brazil (kW)

(Source: Presentation material from ANEEL)

2.4.2 Future Plan of Demand

The final electricity consumption grows at an annual rate of 4.8 % from 2010 to 2020. The residential and industrial sectors are growing at a rate of 4.7 %. In this context, the service sector goes from 23.3 % to 24.3 % in the final electricity consumption.
The Northern region has the highest electricity consumption growth rate, raising its share in the total consumption, from 8.5 % in 2010 to 10.8 % in 2020. The Southern and Southeast/Midwest regions reduce their participation.

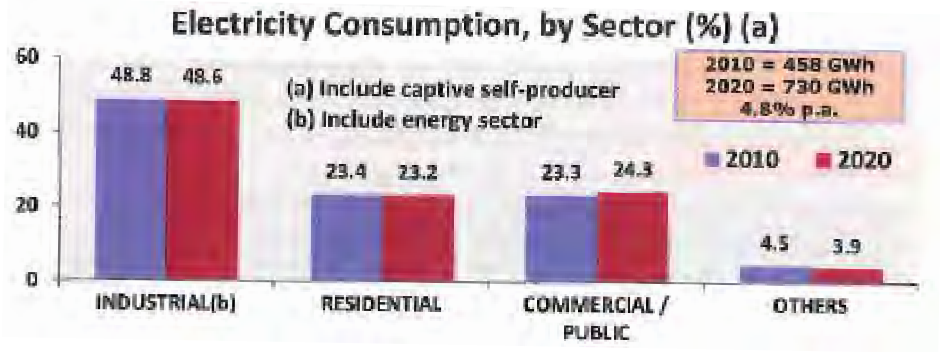


Fig. 2.4.2 Electricity consumption by Sector (%)

(Source: PDE 2020)

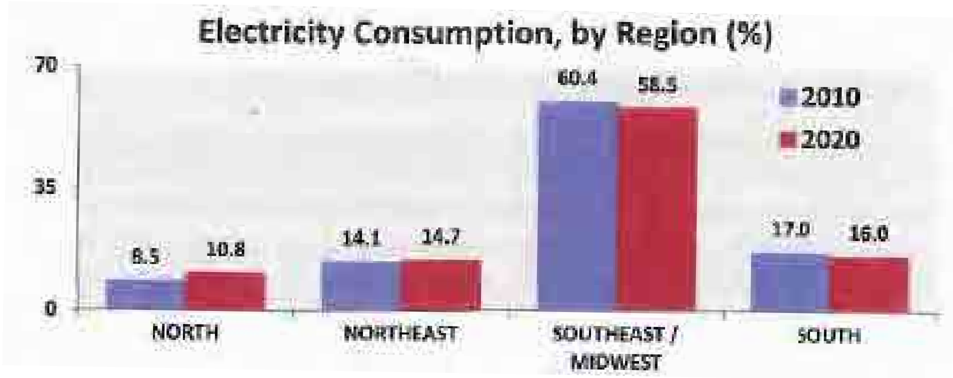


Fig. 2.4.3 Electricity consumption by Region (%)

(Source: PDE 2020)

2.5 Present Situation and Forecast 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 balance of demand and supply was studied in PDE 2020. 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. 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-of-river plants.

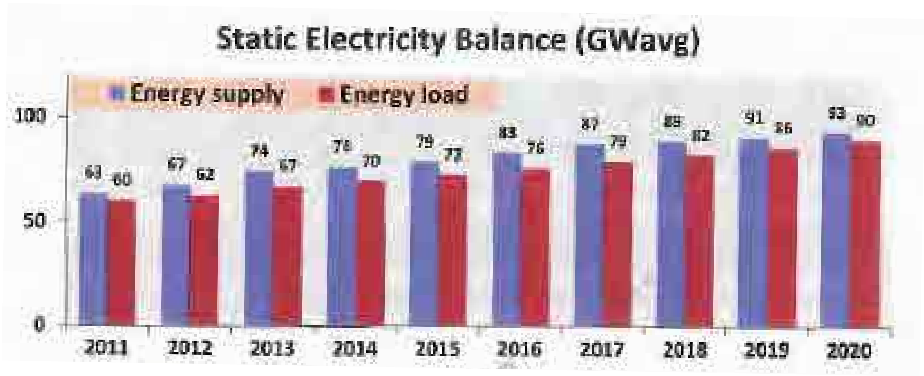


Fig. 2.5.1 Static electricity balance (GW ave rage) (Source: PDE 2020)

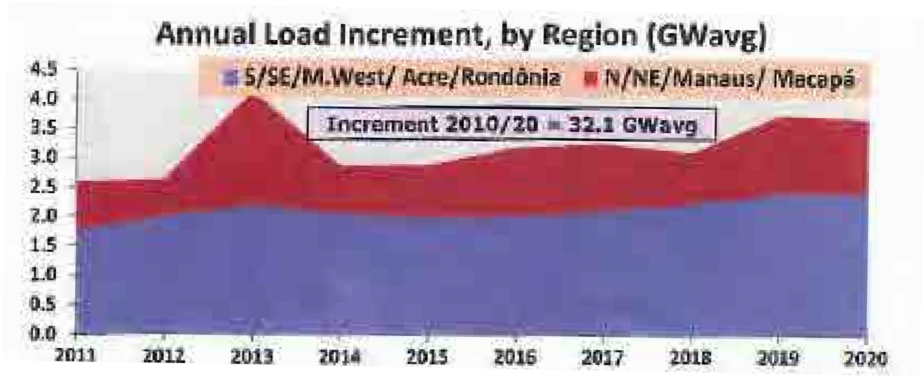


Fig. 2.5.2 Annual load increment by region (GW average) (Source: PDE 2020)

2.6 Power System Overview

SIN in Brazil covers an area of 4,000×4,000 km^2 that consists of four systems; north system, north-east system, south-east and middle-west system, and south system. There are more than 100,000 km of transmission lines (>=230 kV) that have a total of 116 GW generations. The transmission system consists of 138 kV, 230 kV, 345 kV, 440 kV, 500kV, and 750 kV, and the frequency is 60 Hz. All of this system is operated by ONS. Most power stations that have a total of around 110 GW install capacity are located in the east side of Brazil. On the other hand, the west side is expected to have potential capacity of around 120 GW in the future. SIN has international connections with Argentina, Uruguay, and Paraguay through frequency changer substations because those adjacent countries use 50 Hz. The distribution sector is operated by 63 major distribution companies and around 50 smaller and rural ones. There are almost 69 million electricity consumers.

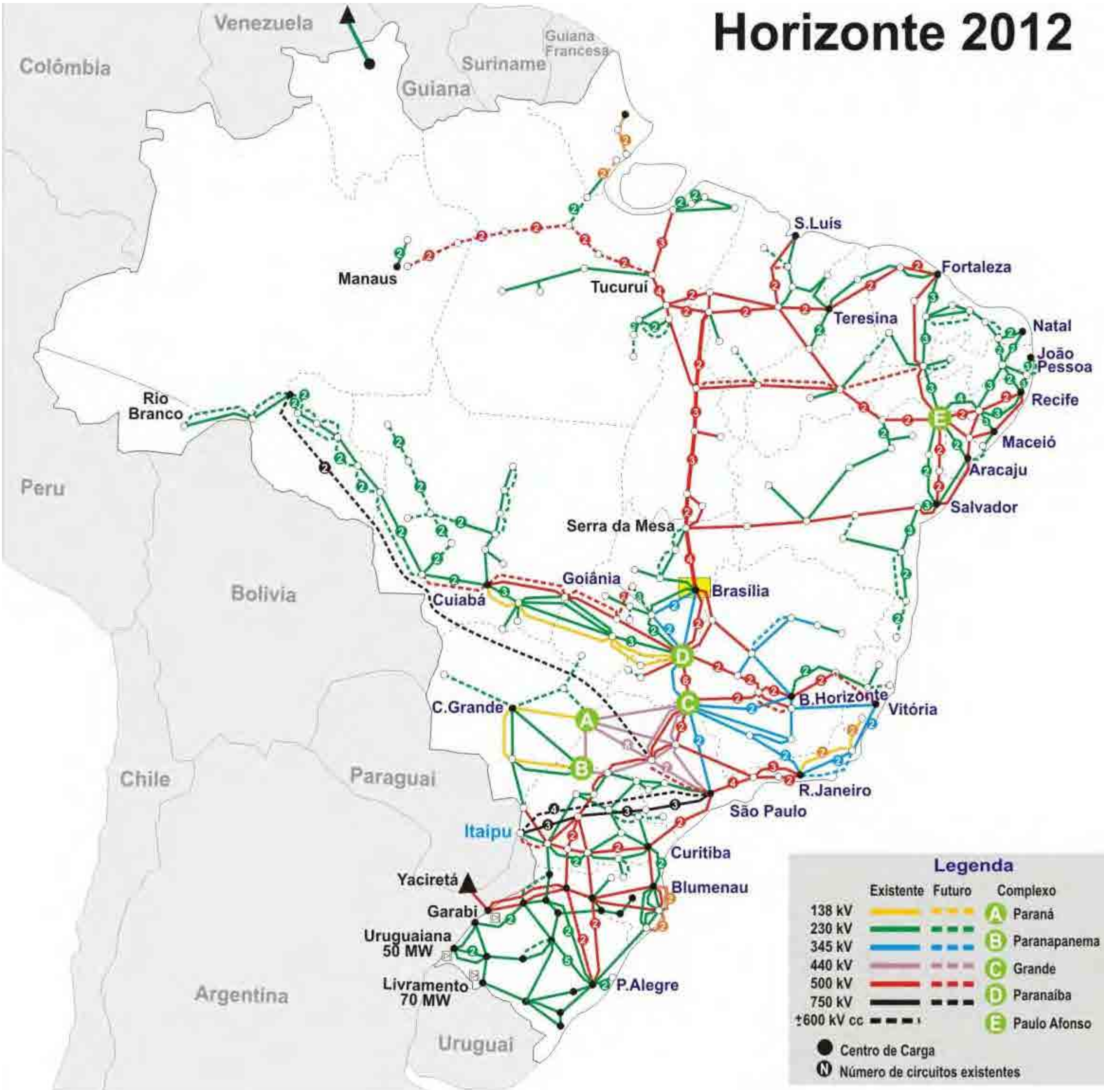


Fig. 2.6.1 Power system diagram in Brazil (Source: Presentation material from ANEEL)

Expansion plans of transmission lines and other energy facilities are shown in Tables below.

Table 2.6.1 Expansion of transmission lines

Expansion of Transmission Lines (Map 2)

	Projects	States	km	Conclusion
1	Interconnection Tapajós - SE	PA, MT, GO e SP	4,400	2017
2	Interconnection N-NE e N-SE	PA, TO, MA, PI, CE, PE e BA	8,350	2016
3	Interconnection Teles Pires - SE	MT, GO e SP	4,500	2015
4	Interconnection Manaus - Boa Vista	AM e RR	750	2014
5	Reinforcement in Southeast Region - 500 kV transmission lines	MG, SP, RJ, MT e GO	5,350	2015

(a) Manaus, (b) Belo Monte, (c) AC/RO, (d) Tapajós, (e) Teles Pires, (f) Itaipú, (g) Boa Vista, (h) Imperatriz, (i) Ivaiporã

(Source: PDE 2020)

Table 2.6.2 Expansion of Energy Facilities

Other Expansion of Energy Facilities

Facilities	Unity	2010	2020	Increment 2010-20	% 2010-20
TRANSMISSION LINES	thous km	100.7	142.2	41.5	41.2
SUBSTATION	GVA	222.1	291.4	69.3	31.2
REFINING CAPACITY	thous bbl/d	2,046	3,505	1,459	71.3
GAS PIPELINES	km	9,295	9,745	450	4.8

(*) Expansion of the present refineries: 4 thous b/d; Abreu and Lima Refinery (RNEST-PE): 230 thous b/d; COMPERJ-RJ: 330 thous b/d; Premium Refineries (600 thous b/d in MA and 300 thous b/d in CE)

(Source: PDE 2020)

2.7 Distribution Losses

Distribution losses in Brazil are about 15.6% in 2010 (Tech: 8.3%, Non-Tech:7.3%), that number is worse than that in Association of Southeast Asian Nations (ASEAN) countries. The most problems in Brazilian distribution companies are especially non-technical loss that is equivalent to 27,000 GWh/year (US$ 1.5 billion/year).

The government set a cap on the percentage of the non-technical losses the utilities can charge through the other customers. There is also a law that mandates that utility companies invest at least one percent of their profits in energy efficiency projects including “Slum electrification program[1]”.

According to the entire Brazilian map below, there are big area differences, that is, in the areas supplied by Eletrobras and Rio de Janeiro, non-technical losses are almost 10-30%.

Thefts stop the disk of the meter, reverse the disk screw of the meter or bypass meter. In this way, the most of the trick is the mechanical meter tampering.

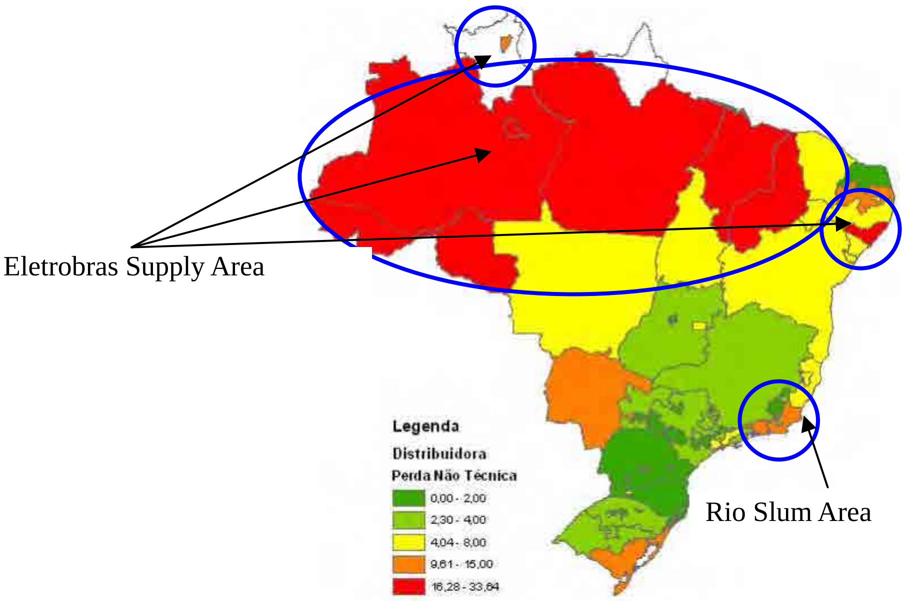


Fig. 2.7.1 Map of Non-technical Losses in Brazil

1 The Slum Electrification and Loss Reduction program (SERL)

In Brazil, the number of people living in slums is estimated to be two million. That is why the International Copper Association (ICA) and USAID launched the Slum Electrification and Loss Reduction Program (SERL) in October 2005. The program was starting in Brazil and India. The idea is to support development projects that aim at improving safety and quality of electrical power for slum residents and that allow utility companies to recuperate at least part of their so-called ‘non-technical losses.’

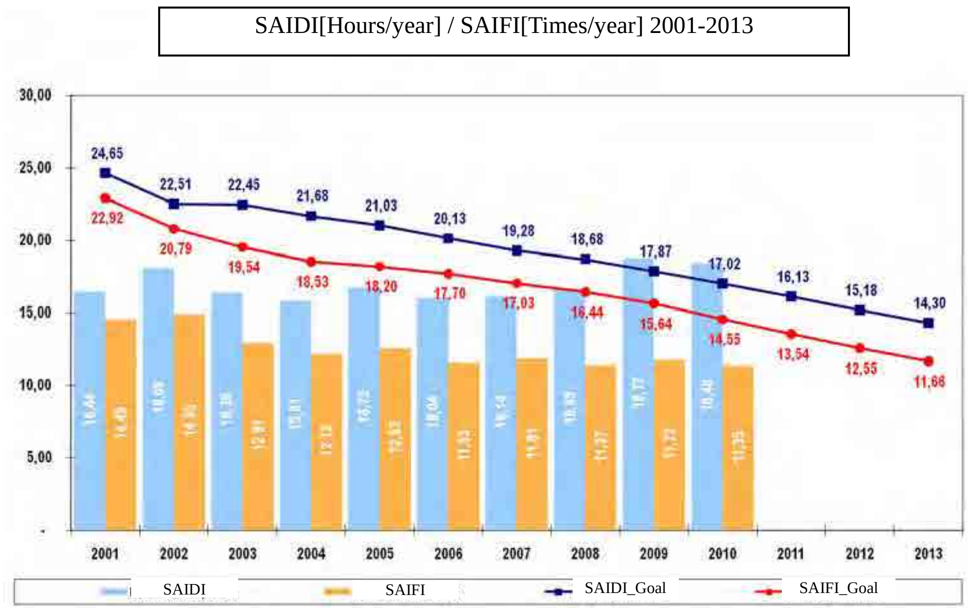
2.8 Outage Situation (SAIDI/SAIFI)

There are two indexes (SAIDI and SAIFI) to indicate the electric power reliabilities. In Brazil DEC (Duration of outages per consumer per year) and FEC (Frequency of outages per consumer per year) are those indexes. ANEEL orders the distribution companies to report their actual indexes and next year's goals every year and if the distribution companies cannot achieve their requirements, the companies shall pay back the penalty to their customers.

According to the chart below, FEC has been decreasing, but DEC has been increasing for the past 10 years. The causes seemed to be two factors. One is that as the supply area is expanded it takes a long time for the technicians to reach the site. The other is that the distribution system becomes very complicated and so it is difficult to detect the fault point in the distribution line.

There is no official data of failure causes in Brazil, but according to the interviews with the engineers, the causes are lightning, small animal and tree touching in rural areas. Brazilian distribution power line is mostly overhead and underground cable is very rare.

ANEEL tends to accelerate the power quality improvement, and it is the background of accepting the Smart Grid.



1) DEC-Duration of outages per consumer per year (in hours)
2) FEC-Frequency of outages per consumer per year (number of outages)

Fig. 2.8.1 Outage duration and outage times in Brazil

These SAIDI and SAIFI include the upper grid outage by the transmission failures. But in fact these outage times caused by the transmission are rare case and negligible because the transmission line in Brazil are formed in a loop and double circuits system. Therefore, the values of SAIDI and SAIFI can be considered mainly caused by distribution facilities.

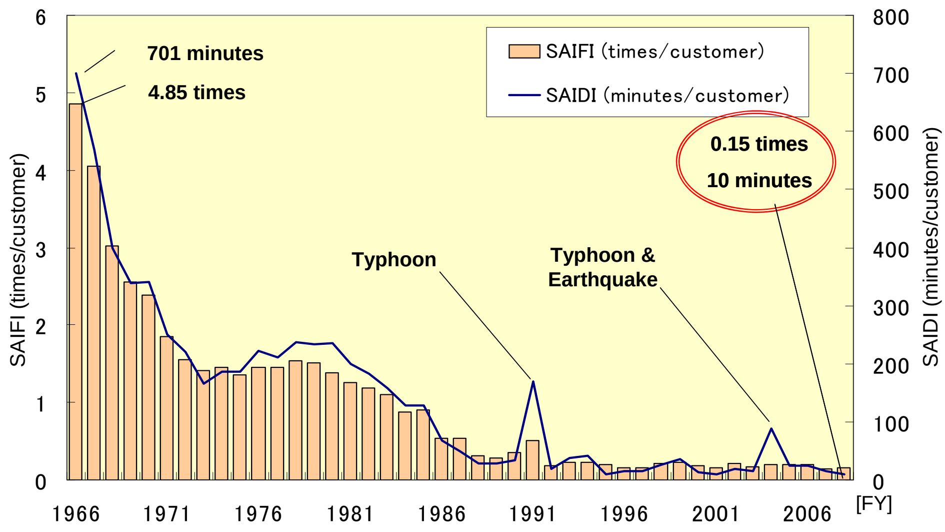


Fig. 2.8.2 Outage duration and outage times in Japan
(Source: The Federation of Electric Power Companies of Japan, etc.)

There is a big difference in the power quality geographically in Brazil. SAIDI is around 10 hours in the urban areas, but more than 20 hours in the north (Amazon) and south.
Natural condition is the major reason, but in rural areas, once a distribution failure occurs, it takes a long tome to restore the problem.
Distribution companies conduct the measurements to increase the maintenance staff and strengthen the workforce such as carriage trucks and boom truck. But it is not expected as drastic measures.

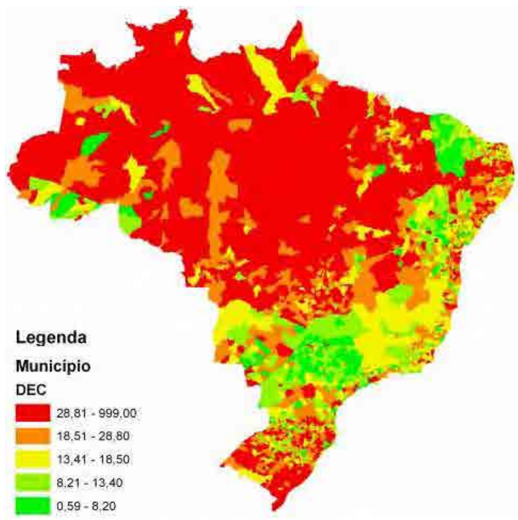


Fig. 2.8.3 DEC (SAIDI) in Brazil

2.9 Electricity Tariff System

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 economy-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.

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 other are included in the costs of generation and transmission. The charges are CCC (Fuel Consumption Bill), RGR (Global Reversal Reserve:electric 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 2.9.1.

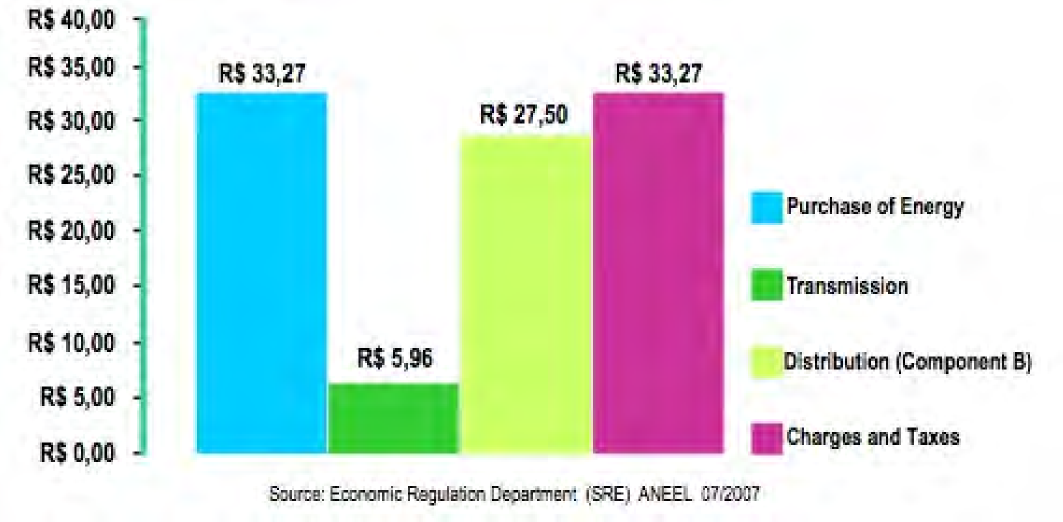


Fig. 2.9.1 Shares of cost components in supposed electric bill R$100 (average in 2006)

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 B1 tariffs by each distribution company in ANEEL's web site are shown in Table 2.9.1.

Table 2.9.1 B1 Tariffs by each distribution company

Sigla	B1 - Residential (R$/kWh)	Sigla	B1 - Residential (R$/kWh)
AES-SUL	0,31497	CPEE	0,40444
AMPLA	0,40188	CPFL- Piratininga	0,31421
BANDEIRANTE	0,32537	CPFL-Paulista	0,32883
Boa Vista	0,27330	CSPE	0,38596
CAIUÁ-D	0,29764	DEMEI	0,39024
CEA	0,19729	DMEPC	0,30642
CEAL	0,33946	EBO	0,29599
CEB-DIS	0,29825	EDEVP	0,33151
CEEE-D	0,34021	EEB	0,36454
CELESC-DIS	0,32974	EFLJC	0,39923
CELG-D	0,29353	EFLUL	0,35300
CELPA	0,36990	ELEKTRO	0,36604
CELPE	0,34427	ELETROACRE	0,41696
CELTINS	0,44766	ELETROCAR	0,38706
CEMAR	0,44364	ELETROPAULO	0,29651
CEMAT	0,41257	ELFSM	0,41142
CEMIG-D	0,38978	EMG	0,45352
CEPISA	0,41986	ENERSUL	0,43062
CERON	0,38895	ENF	0,37582
CERR	0,32900	EPB	0,37554
CFLO	0,31341	ESCELSA	0,33882
CHESP	0,41269	ESE	0,33793
CJE	0,30617	FORCEL	0,39056
CLFM	0,42706	HIDROPAN	0,38745
CLFSC	0,39938	IENERGIA	0,37083
CNEE	0,32818	JARI	0,32911
COCEL	0,34107	LIGHT	0,34304
COELBA	0,38203	MUX-Energia	0,34665
COELCE	0,40199	RGE	0,40849
COOPERALIANÇA	0,37352	SULGIPE	0,41871
COPEL-DIS	0,30926	UHENPAL	0,44479
COSERN	0,34472		

(Source: http://www.aneel.gov.br/area.cfm?idArea=493)

Incidentally, the ANEEL is concerned with the quality of supplied power so that it sets SAIDI and SAIFI goals for each distribution company and if the distribution companies cannot fulfill the goals, the ANEEL orders them to pay 1% of the invoice amounts as a penalty.

2.10 Present Situation and Future Plan of Renewable Energy

Renewable energy in Brazil accounted for 87.2% of the domestically-produced in Brazil, according to preliminary data from the 2010 National Energy Balance, conducted by EPE. There are projects for the development of biomass, solar and wind energy, but these are still on a relatively small scale.

Defines Renewable Power Plant:
- Very small hydro power plant: MCH– Micro/Mini Central Hidroelétrica (< 1 MW)
- Small hydro power plant called PCH –Pequena Central Hidroelétrica (1 MW - 30 MW)
- Biomass power plant under 30 MW
- Wind power plant under 30 MW
- Photovoltaic Power under 30MW

Renewable energy, like hydro, biomass and wind, will account for between 16 and 34 percent of new generation added over the next few years. While this may be viewed as an opportunity, integrating these renewable into the distribution grid will also present challenges, as the grid was designed for one-way power flow from a central generating facility to the consumers. Smarter Grid will be needed to help integrate this renewable power into the grid.

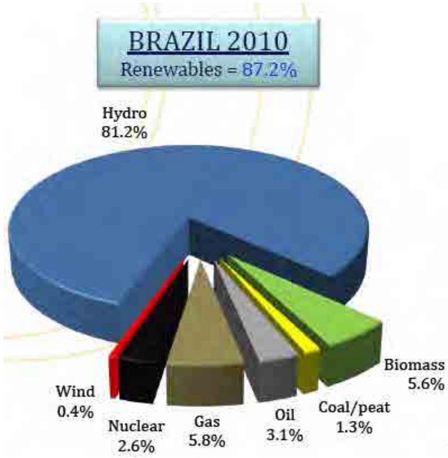


Fig. 2.10.1 Renewal Energy in Brazil

2.10.1 Wind Generation

In this decade, a drought in Brazil cut water of the country's hydroelectric dams. The crisis led to diversify away from water power. The bidding is expected to lead to the construction of two wind farms with an investment of about US$ 6 billion for over the next two years. Wind energy's greatest potential in Brazil is during the dry season and so it is considered a hedge against low rainfall and the geographical spread of the existing hydro resources.

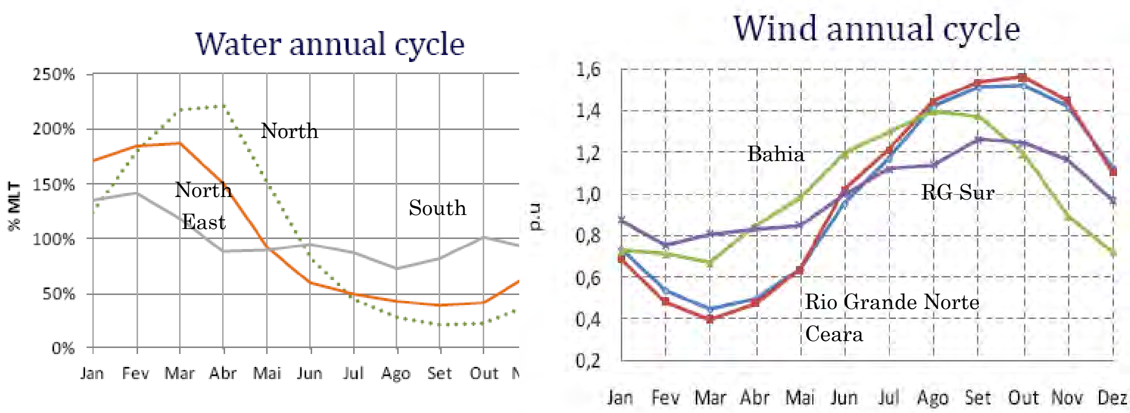
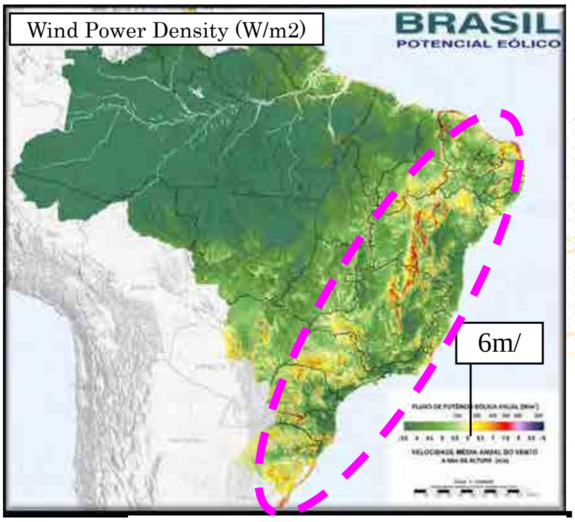


Fig. 2.10.2 Water and Wind Generation in a Year

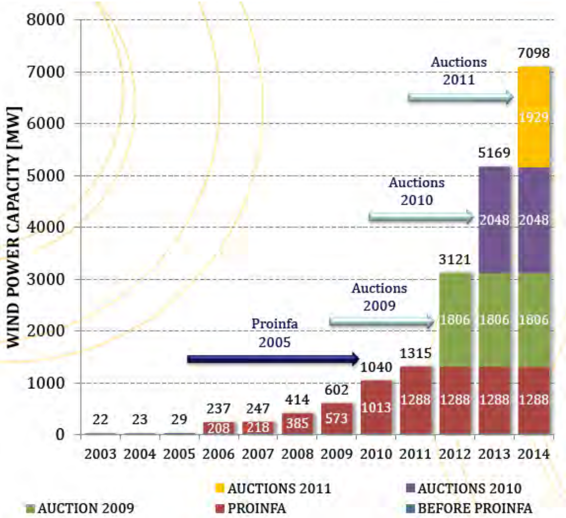
Brazil's technical potential for wind energy is 143 GW, the most projects of which are based in the coast. The Brazilian Wind Energy Association and the government have set a goal to achieve 10 GW of wind energy capacity by 2020 from 605 MW in 2010, and there are another 450 MW under construction. The industry hopes the auction will help kick-start the wind-energy sector.
In 2010, 36 wind parks and wind farms in the country, were located in Northeastern Brazil (5 States),

Southern Brazil (3 States), and Southeastern Brazil (1 State). Potential of wind in Brazil is more intense from June to December, coinciding with the months of lower rainfall intensity. Other 10 projects are under construction with a capacity of 256 MW, and in 2010, 45 projects started the construction to generate 2,139 MW in several States. A U.S. Company, General Electric, has one factory in the city of Campinas, Brazil, and one partnership with the Tecsis in Sorocaba, meeting the demand of the new projects.

ANEEL put up wind-only energy for the country's first auction. Around 1,800 megawatts (MW) were contracted with energy from 71 wind power plants scheduled to be delivered in 2012. While focusing domestically on wind-energy generation, Brazil is part of a larger international movement toward wind power as a primary source of energy. In fact, wind power has the highest expansion rate among all the available renewable energy sources.



Source: Brazilian Energy Balance 2010 by EPE



Source: Brazilian Energy Balance 2010 by EPE

Fig. 2.10.3 Potential and Development Wind Generation

2.10.2 Biomass Generation

Biomass is one form of the clean energy, as it uses organic garbage, agricultural remains, wood shaving or vegetal oil. Refuse cane, with its high energetic value, has been used to produce electricity. The recent interest in converting biomass to electricity comes from not only its potential as a low-cost, indigenous supply of power, but its potential as environmental and developmental benefits. For example, biomass may be a globally important mitigation option to reduce the rate of CO_2 buildup by sequestering carbon and by displacing fossil fuels. Nearly all of the experience with biomass for power generation is based on the use of waste and residue fuels (primarily wood/wood wastes and agricultural residues). The production of electric power from plantation grown wood is an emerging technology with considerable promise. Company CPFL the study team visited also developed biomass power plants aggressively in these days.

Brazil used tax incentives beginning in the mid-1960s to initiate a reforestation program to provide for industrial wood energy and wood product needs. With the discontinuation of the tax incentives in 1988, plantation establishment in Brazil has slowed although the commercial feasibility of using eucalyptus for energy and other products has been clearly demonstrated.
Additionally, sugarcane residue is produced from May to November and this period is the water shortage season in Brazil. These advantages also accelerated biomass generation especially in the southeast and south regions.

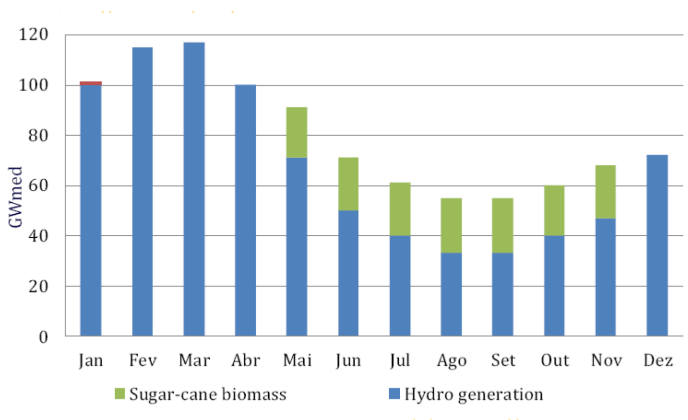


Fig. 2.10.4 Complementarity between Hydro Generation and Bioelectricity

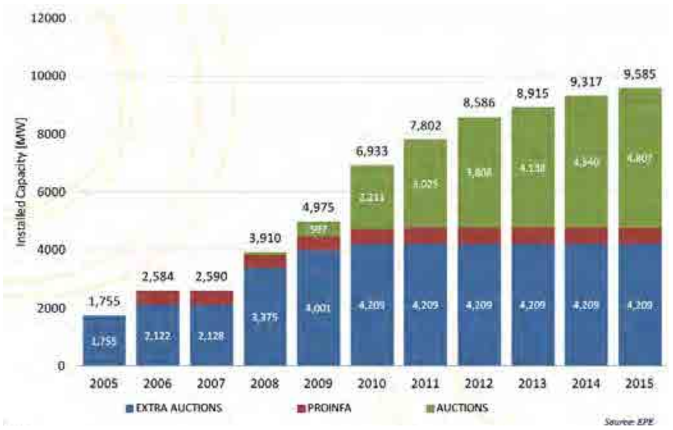


Fig. 2.10.5 Theoretical Potential of Biomass Electric Power Generation in Brazil

2.10.3 Solar Power

The total installed photovoltaic power capacity in Brazil is estimated only 12 - 15 MW in 2010 of which 50% is for telecommunications systems and 50% for rural energy systems.

2 MW were produced by a Brazilian company "Heliodinamica" since it was established in 1983 in São Paulo State. The only other company to manufacture photovoltaic modules in Brazil was Siemens Solar, which operated a factory from 1998 to 2001 in Gravataí, State of Rio Grande do Sul. Other components of photovoltaic systems, such as batteries, inverters, charge controllers and DC appliances can be found with some difficulty. There has not been yet a well-developed market in Brazil until now.

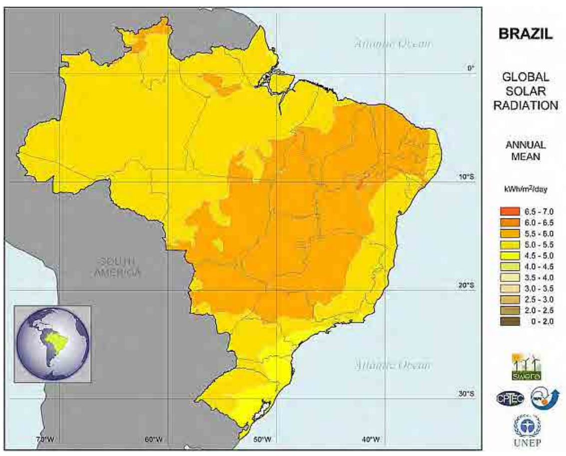


Fig. 2.10.6 Received Solar Energy

Grid-Intertied Systems

The first and largest Brazilian grid-connected photovoltaic system was installed by a utility company (CHESF) in parallel with its electric power grid in Recife, the capital of Pernambuco State located in the northeast of Brazil. Three other systems were installed by university research groups, UFSC: Federal University of Santa Catarina, USP: University of São Paulo, and UFRJ: Federal University of Rio de Janeiro. The research groups responsible for each of the installations regularly follow up the performance of these systems.

Solar arrays will be installed on the roofs of two football stadiums in Brazil.

Estádio de Pituaçu in Salvador will be the first football stadium having solar panels installed for the Soccer World Cup in 2014 in Latin America. The ground-breaking 403kWp rooftop array will be installed by Gehrlicher Ecoluz Solar do Brazil, a joint venture between a German project developer, Gehrlicher Solar, and a Brazilian environmental technology group, Ecoluz Participações. Gehrlicher was awarded the project after winning an international tender offered by the Brazilian utility Coelba, which is providing financial backing alongside the Bahia State Government. There are other tenders for all 12 World Cup venues currently in progress.


Mineirão Stadium in Minas Gerais


Pituaçu Stadium in Bahia

Brazilian solar power development just started in 2010 and there are no serious problems such as frequency fluctuation and unbalance of the surplus energy from small photovoltaics. And the survey team realized that there is no official report related to solar power. Information on the below list is from local newspapers in 2010. According to the list, many projects will start in Brazil soon.

1. Already operated

Location	Organization	Capacity	Reference
Taua, Ceara State	MPX Energia	1MW	The operation started in August 2010. PV panel : Kyocera

2. Already construction started

Location	Organization	Capacity	Reference
Bahia Pituaçu Stadium	Gehrlicher, Ecoluz	400kW	Coelba
Minas Gerais Mineirão Stadium	Cemig	400kW+ 200kW	Cooperation with KfW + GTZ

3. Permits submitted to ANEEL

Location	Organization	Capacity	Reference
Paraiba	UFVs Cajazeiras	30 MW	
Paraiba	Patos	30 MW	
Paraiba	Pombal	30 MW	
Bahia UFV	Ibipeba	20 MW	
Tocantins/Mato Grosso	Equatorial Serviços	30MW	Usina de Colinas
Tocantins/Mato Grosso	Tropical Serviços	30MW	Usina de Araguaína
Tocantins/Mato Grosso	Barcelona Serviços	30MW	Planta de Confresa
Caraúbas	Companhias Veneza	30MW	
Dix-Sept Rosado	Interior	30MW	
Marcelino Vieira	Record	30MW	

4. Being bid

Location	Organization	Capacity	Reference
SP/Votuporanga	Geração de Energia Brazil	30MW	Sky Solar Sunbeam Geração de Energia Votuporanga
Florianopolis	Eletrosul	(1MW+8MW	
Pernambuco Fernando de Noronha	CELPE	400kW	Micro Grid with Desel power

Chapter 3 Present Situation of Smart Grid Introduction into Brazil

3.1 Brazilian Government's Policies and Plans

At present the federal government has not decided the policies about smart grid yet. The MME has created a working group for smart grid within the ministry and studied. However, the MME is planning to create a new working group expanding the members to other related ministries and agencies and decide smart grid policies.
The other related ministries and agencies in addition to ANEEL closely related to the MME are considered as follows.

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

It is considered that incentives such as reduction and exemption of taxes to promote smart grid are to be published as national policies, but the new working group has not been organized actually. The group inauguration may be in and after February 2012 at the latest as a schedule.
In addition, outside of the government, ABRADEE, an association of the distribution companies in Brazil, is working for smart grid actively under the approval of ANEEL. However, the above MME working group is limited to the government and ABRADEE, distribution companies or even national or state distributors cannot be members of the MME Working Group as long as they are operators. The new MME working group is within the government deciding policies as regulators.
This positioning is different from the cooperation between the Ministry of Economy, Trade and Industry and the industry in Japan and can be considered the Western way of thinking that the operation and regulation are divided clearly and the administration leads. Therefore, it seems a little distant from the Japanese way that the administration leads supporting the industry with unity.
In any case, there is no government policy decision about smart grid as of the beginning of 2012. Its background is that the dissociation of the government and the private described above and the government seems to incline to be passive or not so active preparing policies studying the trends in advanced countries such as Europe and the US.

3.2 Present Situation and Plans of Smart Community

Regarding the Smart Community Project, Both MME and ANEEL have just concepts but no specific plan at present and they try to study in the near future.
The reasons are, as follows

- ✓ As there are many stake holders related to “Smart Community” such as different ministries, state governments, and many sectors like transport, water and sewage, and city planning, it is very complicated to coordinate them.
- ✓ As Smart Grid is related to a specific sector, power industry and MME think it should start from Smart Grid and will spread to the idea of Smart Community in the future.

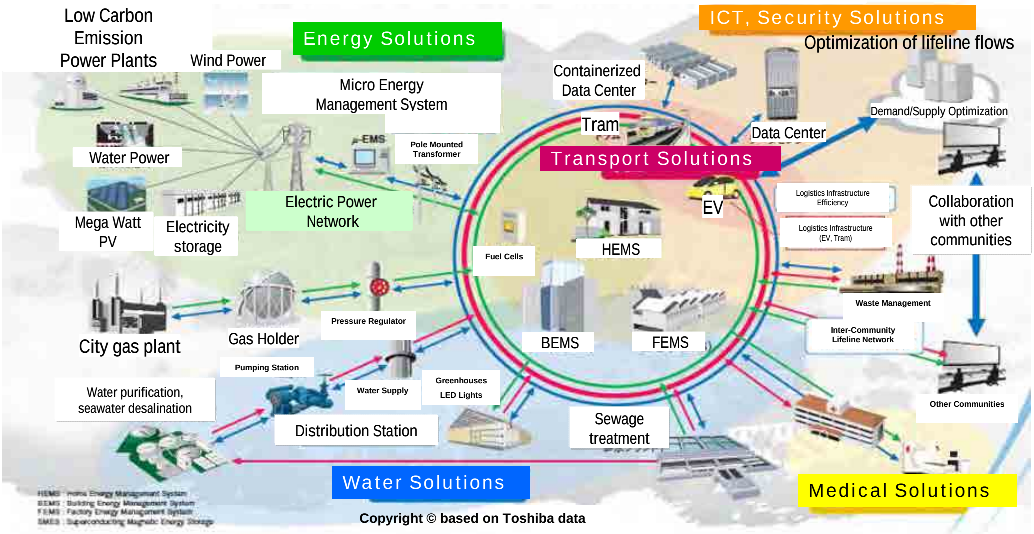


Fig. 3.2.1 Conceptional Overview of Smart Community

But in fact, some cities like Curitiba in Parana State and Belo Horizonte in Minas Gerais are planning and studying the concept of Smart Community. The survey team collected the related information on the occasion of visits at the city offices.

- **Parana State**

They are planning Smart Community Projects in Rio Grande and Morretes excluding Curitiba The main contents are wide from the securities of water sewage, gas to school and hospital. That plan includes Photovoltaic introduction to the stadium of the Soccer World Cup Game. Additionally Electric Vehicles are studied there.

- **Minas Gerais State**

CEMIG is planning the combination of smart grid and BEMS for the condominium. Especially, Mineirão area is the target of intelligent power supply such as Minas Solar 2014 mentioned Chapter 2, 2.10 including the photovoltaic power and electric vehicles.

- **Others**

Japanese companies proposed the idea of the hybrid system with Electric Vehicle and battery in Sao Paulo and AMPLA, respectively (Rio de Janeiro. State).

An Italian electric power utility company, “Enel” that already introduced smart meters to all their customers, conducted a smart home project called “energy@Home” in Brazil in cooperation with Telecom Italia and appliance companies.

This kind of smart home projects such as Home Area Network (HAN) are introduced in Light Company in Brazil and other utilities are watching these effects. But HAN is currently just a future image and it takes several years to be popular in Brazil.

Value-Added Services (VAS) based upon information exchange relates to energy usage, energy consumption and energy tariffs in the Home Area Network (HAN)

Fig. 3.2.2 Concept Overview of Home Area Network

3.3 Present Situation and Plans of Smart Grid Introduction

3.3.1 "What is the Smart Grid in Brazil?"

According to Smart Grid Interoperability Standards Road Map by EPRI (Electric Power Research Institute), the Smart Grid is characterized by a two-way flow of electricity and information to create an automated, widely distributed energy delivery network. It incorporates the benefits of distributed computing and communications into the grid to deliver real-time information and enables the near instantaneous balance of supply and demand at the device level.

Nowadays many investors are already searching the opportunities of smart grid in Brazil. Smart Grid developments in Brazil are at the challenging stage and have significant potential for local and international energy companies there. The utilities have undertaken pilot projects in Smart Grid for the past three years with international smart energy technologies and modernization of the electric power system.
According to the Brazilian National Energy Plan in 2010, almost all Brazilian electric utilities began studying Smart Grid in order to prepare themselves and to strategically direct their investments in new infrastructure and Research and Development (R&D) projects towards the modernization of the Brazilian electric system.

According to ABRADEE, although in Brazil the working group of Smart Grid focuses on the Advanced Distribution Operation and Advanced Metering Infrastructure in the current situation, Smart Grid implementation covers the following areas.

- ✓ Advanced Transmission Operation
- ✓ Advanced Distribution Operation
- ✓ Advanced Metering Infrastructure (AMI)
- ✓ Advanced Asset Management (Including optimization of the assets and resources)
- ✓ HAN: Home Area Network (HAN)

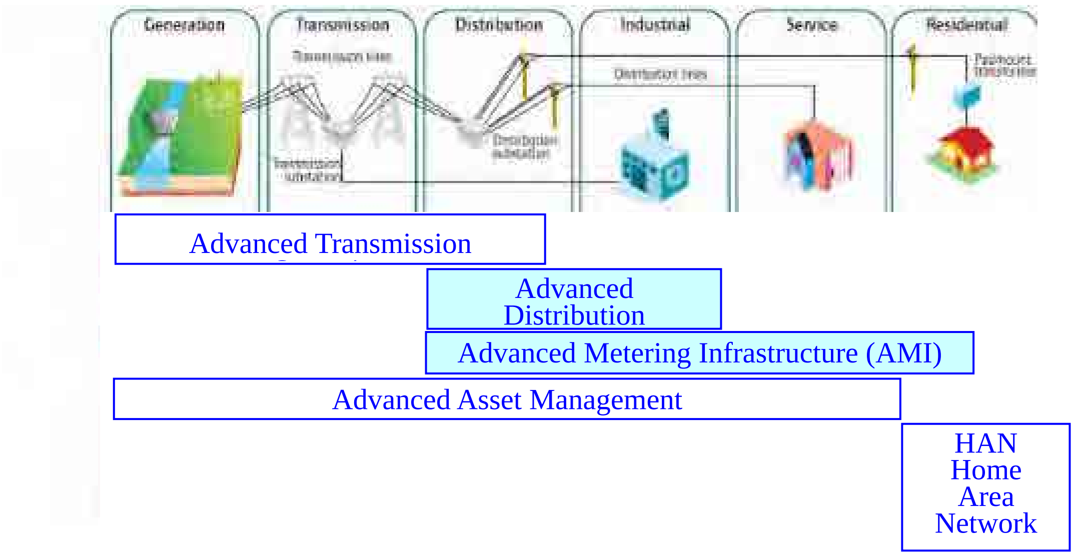


Fig. 3.3.1 Concept of advance transmission/distribution connected to HAN

And the practical goals of Smart Grid implementation by ABRADEE are: as follows,

(1) Improvement of the system reliability and power quality
(2) Reduction of non-technical losses
(3) Increase of the operational efficiency (Peak load efficiency etc)
(4) Encouragement of distributed generation especially small-scale renewable energy

3.3.2 "Why are many players focusing on Smart Grid in Brazil?"

Brazil is showing significant Smart Grid activities. The utilities have undertaken pilot projects of Smart Grid. Since 2008, there has been a growing interest in smart energy technologies in Brazil.

But why now in Brazil? A private institution in the USA, "Northeast Group Consultant," presented its analysis in the conference of "Smart Grid 2001" in December 2011. According to the chart below, Brazil has the largest potential market in Latin America and the regulatory framework is almost deregulated in smart grid market, especially smart meter industry. Brazil is identified as a country that recently has had and continues to have high economic growth and, hence, the need for expansion and modernization of the electric power system in order to cope with the increased energy demand.

And more important reasons are many Brazilian distribution companies are suffering from the non-technical losses so-called "Power thief or meter tampering." As Brazil will hold the Soccer World Cup and the Olympic Games several years later, many distribution companies are struggling to improve their power quality.

These factors lead to accelerate Brazilian industries to install smart grid or smart meters for the past 3 years.

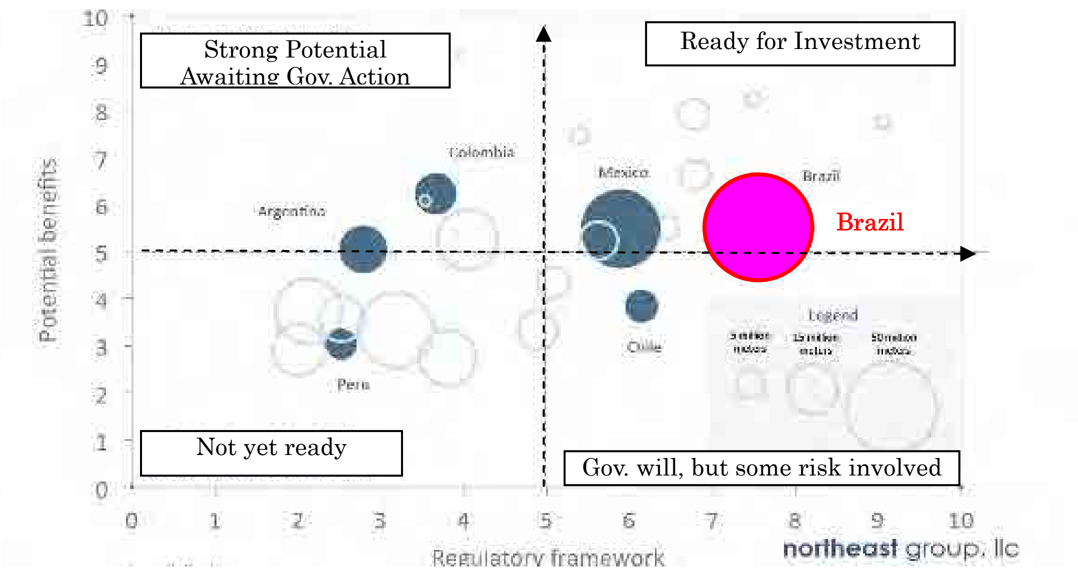


Fig. 3.3.2 Potential of Smart Grid In Brazil
(Source: Northeast Group Consultant Smart Grid 2011)

3.3.3 Expected roadmap to introduce smart grid into Brazil

In 2010, many electric utilities in Brazil began researching Smart Grid in order to prepare themselves and strategically direct their investments in distribution infrastructure and R&D projects towards the modernization of their electric network system.
According to the survey of a research institute, “EPE,” the electric network infrastructure will be expanded 1.43times in the coming 20 years.

Table 3.3.1 Road Map of Smart Grid in Brazil

Tensão	750 kV	±600 kV	500 kV	440 kV	345 kV	230 kV	TOTAL
Existente em 2010*	2.683	1.612	34.190	6.809	9.991	44.349	99.649
Evolução 2011-2020	-	10.800	21.650	9	252	9.842	42.553
Estimativa 2020	2.683	12.412	55.840	6.818	10.243	54.191	142.202
Total instalado em 2010			99.649 km				
Total previsto em 2020			142.202 km				

epe

+ 42.553 km = + 43%

(Source: Empresa de Pesquisa Energetica(PEP) PDE2020)

The Brazilian electric power industry needs more urgently to reduce non-technical loss. Installation of smart meters is the first priority. And the next target is reliability improvement to upgrade distribution automation and introduce modern technologies reducing power outage duration by the World Cup and Olympic Games.

Fig. 3.3.3 Schedule of Smart Grid Development in Brazil
(Source: Northeast Group Consultant Smart Grid 2011)

3.3.4 Current situation of distribution companies

Cemig is exploring a defiant idea to develop a pilot in a city. AES Eletropaulo was the first to implement and integrate the Smart Metering in its systems. COPEL has worked to implement electrical vehicles and contributed to transform Curitiba into a digital city. And CELESC has been investing in new R&D projects that involve demand response.

Therefore, it is understood that there is a great opportunity of R&D and doing business in Brazil that is prominent in the global economic environment with opportunities for investors in both the energy sector and smart grid.

JICA survey team visited these six distribution companies and had interviews with the engineers related to smart grid.

For the collected information of each company, please refer to Table 3.3.2, The Distribution Companies Features, hereafter.

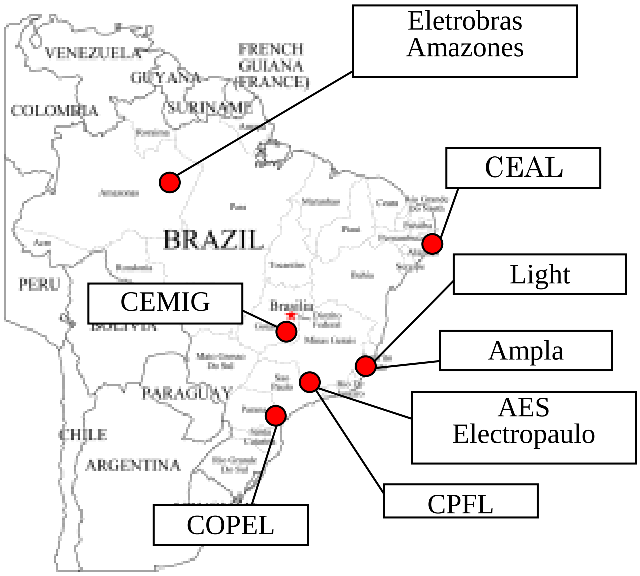


Fig. 3.3.4 Location of distribution companies

Table 3.3.2 The Distribution Companies Features

			CPFL	AES EletroPaulo	Light	AMPLA	COPEL	CEAL (Eletrobras)
Overview	Supply area(name of the city)		8 distribution companies (central part of Sao Paulo State and northern part of Rio Grande do Sul State)	Sao Paulo Metropolitan Area	Rio de Janeiro City	66 cities in Rio de Janeiro State	Parana State	Alagoas State
	No. of customers		6.9 million	6.1 million	4.07 million	2.5 million	4 million	800,000
	Companies ownership		Public: 39.44% Private: 60.56%	Public: 20.04% (Federal Union) Private: 80.0% (AES: 78%, listed 2.2%)	Public: 41.08% (Cemig &BNDES) Private: 58.92%	Private: 100% (Endesa)	Public: 86% (Parana State: 58.6%, BNDES: 26.41%) Private: 13.8% (Stock Excange: 13.5%)	Parent company=Eletrobras: Public:78% (Federal Government: 52%, BNDES: 21%)
	Electric consumption [MWh]		53,981GWh	33,859GWh	22,384GWh	9.367GWh	21,304 GWh	2,246 GWh
	other points		CPFL has subsidiary generation companies and free market services.		Light has affiliated generation and transmission companies.	Endesa has generation, transmission and other distribution (Coelce) companies.	Copel has generation, transmission, telecommunications and gas companies.	Eletrobras is the biggest in generation and transmission. It has affiliated distribution companies in other states.
Their interest of investment as smart grid project (result of interview from them)	Back ground of their challenge		Main objectives to install smart grid are as follows, 1) To reduce NON technical loss using smartmeters. 2)To improve distirbution system operation and labor productivity using Distribution Automation.	AES ElectroPaulo has tow pilot projects for smart grid as follows, 1) Ipiranga pilot: Distribution Automation Not install the facilities. Now under studying of the pilot development items.(1820 customers supplied by 39 TRs.) 2) Slum Morada do Sol project: Smart meter Already start operation for four months, install 560 ERSTER smart meters made in USA.	The most aggressive company for smart meter in Brazil. Introduce "PERSONAS" the segmentation for some kind of customer and install display board in the customer. Introduce this system in Pridencia this year and accelerate smart grid in the future	They focus on a pilot project of Smart City Buzios. The period of the project is scheduled from July 2011 to June 2014. This project includes NON technical loss reduction using AMR system.	They strongly focus on their power quality because they are challenge to be future city in Brasil to have World cup and olympic. They are already operating 200 automation system in distribution and introduce customer service automation but they need more advanced solution in the near future. There are pilot project for 2 Substation(13 feeder) in Fazenda Rio Grande.	Main objectives to install smart grid are as follows, 1) To reduce NON technical loss using smartmeters. 2)To improve distirbution system reliability using Distribution Automation.
	1) Distribution loss reduction (Especially non-technical loss)		○ Main goal is to reduce slam area distribution NON technical loss and switch ON/OFF the meter for demand response in the future.	○ Main goal is to reduce slam area distribution NON technical loss and switch ON/OFF the meter to reduce dispatching cost for lineman.	◎ Main goal is to reduce slam area distribution NON technical loss and switch ON/OFF the meter for demand response in the future.	○ Main goal is to reduce slam area distribution NON technical loss and switch ON/OFF the meter for demand response in the future.	○ Loss rate is lower than that of other utilities (Tech: 6.5%, Non-Tech: 1.5%)	◎ Loss rate is much higher than that of other utilities (Tech: 8.42%, Non-Tech: 23.03%)
	(Their priority measurements)		Not conducted now	Install smart meter and control from office.	1) Already install 2,000 Electra smart meters for the past tow years. And plan to expand them to 60,000.		COPEL want to reduce technical loss by improvement of load balance and power factor Install digital meter (not focus on loss reduction)	Acceralating investment for reduce losses
	2) Streamlining for power supply cost		△ Improve of labor productivity using Distribution Automation in future.	× There are no comments about power cost.	△ In the underground manhole, they install the monitoring system to use smart grid.	× There are no comments about power cost.	△ Improve of labor productivity and high facilities operating rate to reduce power price.	× There are no measurements now.
	(Their priority measurements)		Not conducted now		500kW underground transformers will be automated		1)On going: GIS, Monitoring communication, Call center 2)Charenge: Smart meter to customize electric tariff (TOU) 3)Charenge: Smart meter to ON/OFF the meter switches	
	3) Power Quality Improvement		○ They plan to install Distribution Automation in future. However, there is no specific plan.	○ They planed Distribution Automation in the near future to improve power quality.	○ They planed Distribution Automation in the near future to improve power quality.	○ They plan to install Distribution Automation in future.	◎ Improve of SAIDI(Power outage) (SAIDI: 10 hours Goal: 5 Hours)	◎ Improve of SAIDI(Power outage) (SAIDI: 20hours Goal: 19.36%)
	(Their priority measurements)		They already installed 5,000 reclosers in distirbution lines.	1) They already installed 3,000 reclosers in distribution feeder. 2) Pilot project will research the automation availabilities.	1) They already installed 2,500 reclosers in distribution feeder. 2) Pilot project will research the automation availabilities.	They already installed 240 reclosers in distirbution lines.	1) on going: SS automation, monitoring system 2) Challenge: Distribution Automation and improve distribution operating rate from 50% to 70%.	
	4) Environmental Solutions (Energy Efficiency and Renewable Energy)		× They predict future problem and try to prepare to solve them.	× They predict future problem and try to prepare to solve them.	× They predict future problem and try to prepare to solve them.	× They predict future problem and try to prepare to solve them.	× They predict future problem and try to prepare to solve them.	× They predict future problem and try to prepare to solve them.
	(Their priority measurements)		Not conducted now	Not conducted now	Not conducted now	Not conducted now	R&D for PV, EV and fuel cell battery	
Renewable energy	Current situation		A total of Installed capacity is 4,454MW.	none	2kWSHS×50, electric charging station for 50 Evs		20 small hydro and some biomass power plants	No renewable energy
	Plan, potential		not decided	They are planning to have PV in their own.			Wind: 2MW, PV: 200kW and 1MW	No plan
	problems to introducing renewable energy		There are no problem with renewable energy.	There are no problem with renewable energy.	There are no problem with renewable energy.		There are no problem with renewable energy.	There are no problem with renewable energy.
Power outage	SAIDI including Planned outage (Hour/year)		SAIDI: 4.6 hours in 2010	SAIDI: 10.4 hours in 2010, Goal:9hours	SAIDI: 13.3 hours in 2010	SAIDI: 23.8 hours in 2010	SAIDI:10hrs→ goal 5hrs	SAIDI:20hrs in 2010
	SAIFI (frequency/year)		SAIFI: 4.5 times in 2010	SAIFI: 5.4 times in 2010, Goal: 7times	SAIFI: 5.8 times in 2010	SAIFI: 12.7 times in 2010	SAIFI: 9.5 times in 2010	SAIFI: 14 times in 2010
Distribution system	Distribution line method (loop etc.)		Only radial network	City area : open loop.	City area : open loop.	City area : open loop.	They plan to connect the feeders with open loop.	Only radial network
	No. of section in one feeder			not clear but they already install 3,000 sectionalizers			200 automated sectionalizers among 487 feeders	There are plan to install section switches in the feeder.
	Feature of MV_distribution Line	Overhead [km]					13.8 kV: 96,863km, 34.5 kV: 79,496km	13.8 kV: 38,768km
		Overhead [No of MV feeder]					Total 487 (13.8kV: 431, 34.5kV: 56)	N.A.(69/13.8 Substation : 37)
		Underground[km]	None	None	10%	None	None	None
		Underground[No of MV feeder]	None	None		None	None	None
	Distribution Loss rate (%)[tech / Non-tech]			total: 10%(Tech:6.1%, Non-Tech: 3.9%)	19.4% in 2010, (Tech: 4.5%, Non-Tech: 14.9%)	20.5% in 2010, (Tech: 7.0%, Non-Tech: 13.5%)	11.5% in 2010, (Tech: 6.5%, Non-Tech: 1.5% in 2011)	Total: 31.45% in 2010
	Fault detecting method		5000 Reclosers are installed to isolate the fault. (OC, OCG, in substation is 5/30S (2 shot))	3000 Reclosers are installed to isolate the fault. (OC, OCG,etc)	2050 Recloser is installed to isolate the fault. RMU is installed in undergroud vault.	Recloser is installed to isolate the fault. Fuse are used on the other distribution lines. (OC, OCG, in substation is 5/30S (2 shot))	Recloser is installed to isolate the fault. Fuse are used on the other distribution lines. (OC, OCG, in substation is 5/30S (2 shot))	Recloser is installed to isolate the fault. Fuse are used on the other distribution lines. (OC, OCG, in substation is 5/30S (2 shot))
	DAS		Substation can be controled by SCADA system. DAS is not applied for distribution network. (under planning)	Substation can be controled by SCADA system. DAS is not applied for distribution network. (Only in Ipiranga, recloser can be monitored.)	Substation can be controled by SCADA system. About 70% of reclosers can be monitored in distribution system.	Substation can be controled by SCADA system. DAS is not applied for distribution network. (Under planning)	Substation can be controled by SCADA system. At Substation, reclosr is provided instead of circuit breaker. 200 sets of Gas LBS can be remote controlled.	Substation can be controled by SCADA system. Except separted area such as Parintine. In future, they are planning to provide SCADA system using WAN. DAS is not applied for distribution network.
	DAS (communication method)		(Under planning)	Between Center and Substation: OPGW Between Center and Recloser: Radio (1.5～5GHz) GPRS could not be used due to the bad reliability.	Reclosers can be monitored by GPRS or VHS. In future, WiFi will be applied	Recloser can be monitored by Radio wave. (Protocol: DNP 3.0)	200 sectionalizers can be monitored by Optical Fiber. (Optical fiber cables have beed already installed.)	CEAL has no idea. Parintine in Eletrobras has a plan to apply WiFi between Concentrator and Control Center
	AMI/AMR (Communication method)		Backbone : Optical fiber Last one mile: GPRS/Satelite/RF Mesh (Under planning)	Backbone: GPRS Last one mile: RF Mesh	Backbone: WiFi (under planning) Last one mile: RF Mesh (After testing of PLC / GPRS / RF Mesh)	Backbone: GPRS (Under Planning) Between Concentrators: RF communication (Plan) Last one mile: PLC (Under planning)	Backbone: GPRS (Trial) Last one mile: GPRS (Trial) GPRS is not so good, so GPRS will be chnaged.	CEAL has no idea. Parintine in Eletrobras is planning to appply PLC/RF Mesh/P-MP/ZigBee as trial base.
Meter system	Installation method		Install one meter per one customer	Install one meter per one customer	Install one meter per one customer	Install one meter per one customer	Install one meter per one customer	Install one meter per one customer
	Meter Reading	Period	Once a month	Once a month	Once a month	Once a month	Once a month	Once a month
		Method	Meter reader dispath	Meter reader dispath	Meter reader dispath	Meter reader dispath	Meter reader dispath	Meter reader dispath
	Calibilation	Method	Calibilation method must be adhered to the regulation "INMETORO RTM 431".	Calibilation method must be adhered to the regulation "INMETORO RTM 431".	Calibilation method must be adhered to the regulation "INMETORO RTM 431".	Calibilation method must be adhered to the regulation "INMETORO RTM 431".	Calibilation method must be adhered to the regulation "INMETORO RTM 431".	Calibilation method must be adhered to the regulation "INMETORO RTM 431".
		Period	None	None	None	None	Mechanical type: Once per 25 years Digital type: ANEEL is now considering	Calibilation is not implemented
	Approval process for the qualified meter (Law or regulation / period / method / organization)		INMETORO approves meters according to "INMETORO RTM 431".	INMETORO approves meters according to "INMETORO RTM 431".	INMETORO approves meters according to "INMETORO RTM 431".	INMETORO approves meters according to "INMETORO RTM 431".	INMETORO approves meters according to "INMETORO RTM 431".	INMETORO approves meters according to "INMETORO RTM 431".
	Automatic Meter Reading (AMR)		AMR has not yet beenn installed.	Slum Morada do Sol project phase 1: Smart meter Already start operation for four months, install 560 ERSTER smart meters that have AMR functions.	Already install 2,000 Electra smart meters with AMR functions for the past tow years. These meters and communication equipment are stored in a box ajacent to low voltage lines on a electric pole.	Smartmeters with AMR function are being installed in Buzios smart city project area. These meters and communication equipment are stored in a box ajacent to low voltage lines on a electric pole.	The number of 7,000 AMR meters is installed in Foz de Londrina. These meters and communication equipment are stored in a box ajacent to low voltage lines on a electric pole.	Smartmeters with AMR function are scheduled to be installed in Parintins that has 1,600 customers. (Now in the bidding process)
	Future Plan		AMR will be installed in future. However, there is no specific plan.	Slum Morada do Sol project phase 2 will be implemented. Installation of smart meters will be completed until January 2012.	Plan to expand smart meters to 60,000.	More and more smart meters are scheduled to be installed to reduce non-technical losses.	A pilot project of installing smart meters for large customers is scheduled in Fazenda Rio Grande. Installing smart meters for residencial customers is under consideration.	Smartmeters are scheduled to be installed until December, 2012.

(1) Ceming, “Companhia Energética de Minas Gerais”

Univer CEMIG, a corporate university, is the first Brazilian utility to implement the concept of the smart grid in its totality. CEMIG has been working out an innovative solution to automate the infrastructure of energy distribution. The main projects are distribution automation and “City of the Future” in partnership with CPqD. In 2009, the project, “City of the Future,” was started.

The city chosen was Sete Lagoas, located near Belo Horizonte. Its population is over 200,000 (80,000 customers). (Estimated cost of R$ 32.5 million)

The project, “City of the Future,” includes actions that cover all business processes focusing most notably on the following areas.

(i) Automation of consumers’ measurement
(ii) Automation of substations
(iii) Automation of energy distribution grid
(iv) Telecommunication systems
(v) Operational computer systems
(vi) Management and integration of distributed generation.

In 2010, the R&D projects started and the first step toward the implementation was realized.

(2) COPEL, “Companhia Paranaense de Energia”

COPEL plans to invest more than $ 330 million in projects related to Smart Grid concept by 2014. The main view is to transform Curitiba into “digital city.” The investments are directed towards infrastructure including installation of electrical networks and adaptation of modern systems to energy transfer. Some projects are already being implemented. Smart Grid concept tested in Fazenda do Rio Grande, south of Curitiba Metropolitan Region, is covering 100 million consumers. COPEL’s program is being formulated in coordination with other public services within the Parana State Urban Development. It was intended that the model projects spread the Smart Grid by 2020 to reduce the rates of equivalent duration of interruption per customer (DEC) and equivalent frequency of interruption per customer (FEC).

As shown is Figure3.3.5, COPEL is challenging to improve power reliabilities to conduct the measures as listed below.

- ✓ Strengthening the structure of power failure in the site.
- ✓ Well functioned call center
- ✓ Introducion of GPS system to the maintenance vehicles
- ✓ Information management by PDA (smart phone)

The distribution losses in COPEL are low compared with those of other companies. That is because there are not so many favela in Critiba and an additional factor is that COPEL is trying to reduce them aggressively to manage the facilities and customer information by monitoring them.

In addition, COPEL is challenging further goal to improve technical losses from 6.5% to 4% and the commercial loss decrease from 1.5% to 0.5% within the next few years.

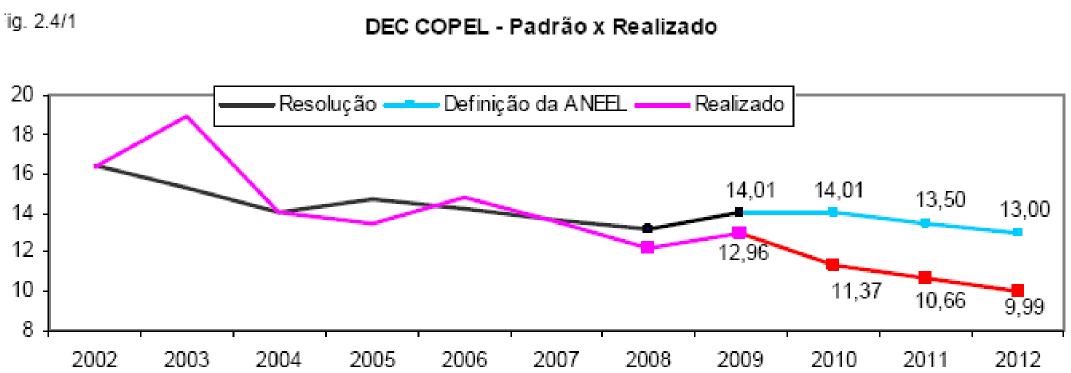


Fig. 3.3.5 SAIDI (DEC) in COPEL

COPEL will automate all operational keys and installed automatic reclosers that supply 650,000 consumers. This action will reduce the number of interruptions and shorten the time needed to restore the services. The company also expects to build 700 km of new compact power grids. The idea of new projects incorporates sensing, monitoring, information technology and telecommunications for the best network performance. At the next step of implementation, the system will be able to identify early failures and reestablish itself and so it can improve the performance. COPEL sees that the system itself, supplied by data and information collected by geometrical processing techniques, will identify the equipment to be repaired, define the process of isolation and restore power within several minutes.

Another initiative related to Smart Grid concepts in 2010 was the launch of the first electric taxi at the Afonso Pena Airport in São José dos Pinhais. COPEL installed the first electric fueling station that recharges the batteries and will also be used within the project site for studies on vehicle performance and the impacts of its use on the electrical system. Today the charging time of this car is 8 hours, but they expect to improve that performance.

The area of R&D will also be focused on, stimulating technological advances in the energy industry once more. Smart grid shall spearhead the development of new technologies in all the segments of COPEL activities.
Telecommunications projects will emphasize broader use of the Company's fiber optic ring, providing increased productivity and efficiency to the operations of its electric system. Important projects can be developed in partnership with the State Government, using technological potential and COPEL's cutting-edge knowledge in digital area better.

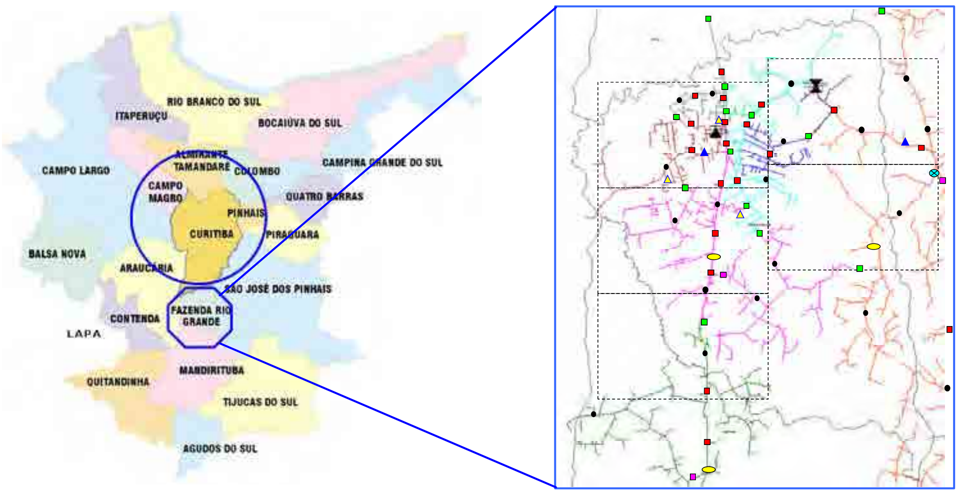


Fig. 3.3.6 Distribution Network in Curitiba

(3) AES Eletropaulo

Since 2007, AES Eletropaulo has been conducting initiatives related to the comprehension and dissemination of Smart Grid concepts. In 2010, the company invested R&D resources in a pilot project to develop a smart distribution system integrating communications solutions, advanced equipment and information systems. At this stage, the project aims to monitor the electrical system and automate the process of power distribution.

The Smart Grid pilot project is being implanted in a circuit that has 4.4 kilometers of overhead and underground cables which make up distribution grid in “Ipiranga,” São Paulo. This region has 2,000 units consumption of low and medium voltage in residential, commercial and industrial segments. In this region, electronic meters were installed to monitor the customers’ energy consumption, monitor the energy balance in 39 secondary circuits and allow the remote execution of various services such as power reading, cutting and reconnection.

AES Eletropaulo started experiments that involve communication between electronic meters, substations, toggle switches and other equipment as well as integration between the company systems. The company intends to analyze the information obtained from the measurement system and integrate it with the automation and operation systems of the concessionaire.

To put the project into practice, various features of the intelligent grids’ concept are being tested and one of them is “self-healing” (a tool that reduces recovery time from a failure in the electrical system). In the case of power failure, a voltage sensor detects the interruption and sends information to the company’s distribution management system which will automatically identify an alternative to restore the power supply. If it is not feasible, the system will send an alert to the specific distributor's operation center, which will trigger a team to meet directly at the site identified.

AES Eletropaulo has continued investing in R&D initiatives and organized a multidisciplinary committee to coordinate and analyze the activities.

(4) CPFL, “Paulista Power and Light Company”

Also in June 2011, CPFL Energia announced its plans to deploy 25,000 smart meters by the end of 2012 to commercial and industrial customers. CPFL is a member of the Global Intelligent Utility Network Coalition (GIUNC), an IBM-led utility consortium which aims to accelerate smart grid development worldwide. CPFL will eventually roll out 6.5 million smart meters. The utility has chosen IBM as its consulting partner.

In other field, CPFL owned 2 wind power plants with 210MW capacity and also have additional 21 Wind Farms under construction.

Fig. 3.3.7 Distribution area and schedule of AMI in CPFL

(5) AMPLA

ENDESA Brazil, a vertical integrated power company, owns two distribution utilities, "AMPLA" and "COELCE." AMPLA started a three-year smart city project in Buzio in July 2011.

In Buzio City following the model of Malaga in Spain, the distribution loss is 17.59% and its non-technical loss is 10%. It is higher than in other areas.

Fig. 3.3.8 Distribution Network of AMPLA

Additionally, the power quality (SAIDI =19.27 hours) is poor so that it is expected to improve the reliability by Smart Grid.

One of the main pilot projects to reduce non-technical loss is introducing digital meters in the box on the pole. These meters can be monitored and manipulated by remote control from the control center.

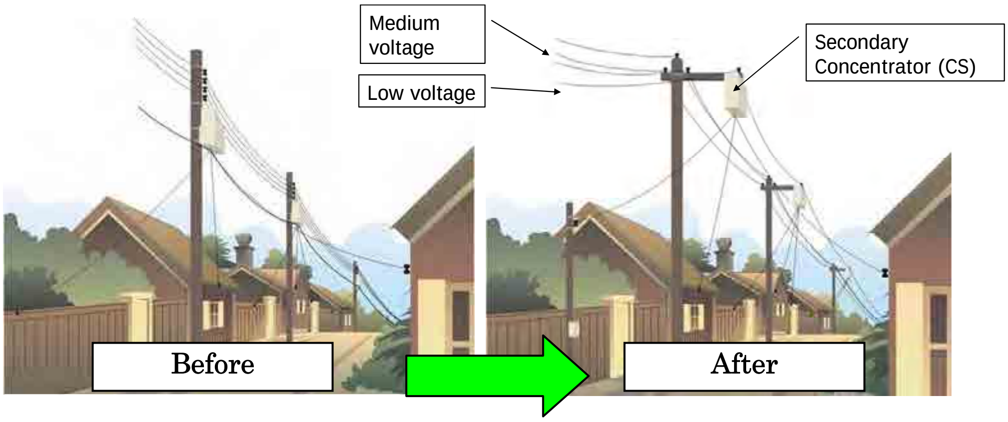


Fig. 3.3.9 Digital meters on the pole

(Source: Landis+Gyr-AMPLA's Solution (Rio de Janeiro) for losses combat)

(6) Light

Light's Smart Grid pilot project in the coming years consists mainly of implementing remote maintenance and customer service. Published in September 2010, the pilot project, which started at the end of 2011, calls for the installation of smart meters in approximately one thousand households in Rio de Janeiro City. These customers will be able to monitor their consumption in real time, establish goals and check expenditure estimates to avoid unpleasant surprises with their electricity bills. Furthermore, Light will select two-hundred participants in this pilot project to test smart outlets that can be programmed to remotely turn appliances off or on using cellphones.

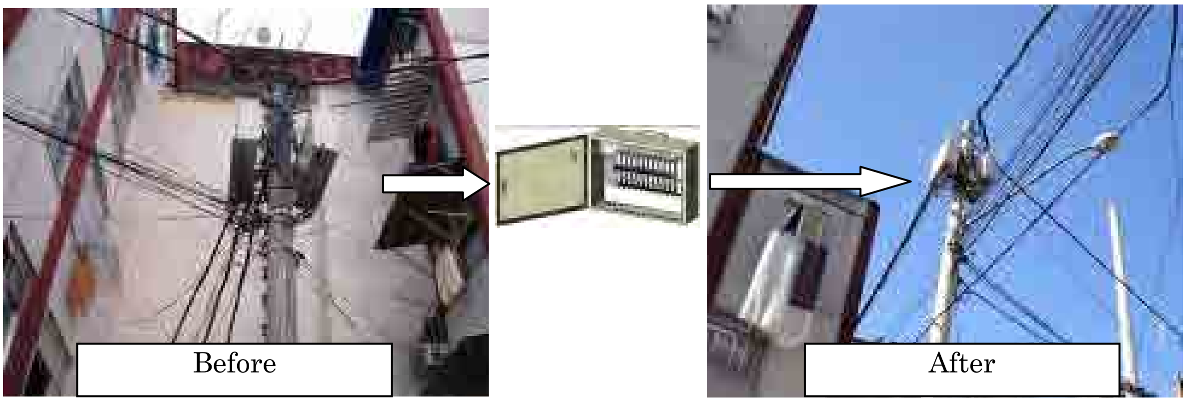
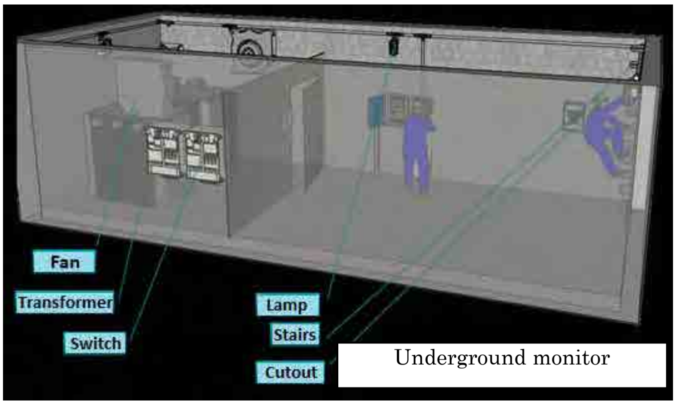


Fig. 3.3.10 Before and after of Distribution Lines to Consumers

The Light Smart Grid Program, which began in September 2010 and will last for three years, is composed of the technologies such as smart energy metering, digital certification, new tariff rates, household automation, distributed energy generation, island mode operation, recharging systems for electric and hybrid vehicles, distribution grid automation, energy efficiency solutions, load-based management, and new customer interaction channels.



3.4 Related Laws and Regulations

3.4.1 The Alternative Energy Sources Incentive Program (PROINFA)

The interest in alternative sources in Brazil began in the early 90s, particularly after the Meeting on Environment Issues held in Rio de Janeiro in 1992 – ECO/1992.
This event allowed the initiation of several pilot projects on alternative sources in Brazil, particularly in solar energy, photovoltaic, and wind power, as well.
Brazil has a huge hydropower potential. Hydro accounted for 89 % of the 475 TWh generated in 2010. As a result, the country is vulnerable to drought.
This was seen during the 2001 electricity crisis when water reserves were abnormally low over a long period of time and the country was on the edge of blackout as no other generation source could make up for the loss of hydro generation. The crisis underscored Brazil's pressing need to diversify away from waterpower and manage electricity demand.
The Alternative Energy Sources Incentive Program -PROINFA, created on April 26th, 2002 by publication of the Federal Law 10,438, being later revised and adjusted through Laws: 10,762 (November 11, 2003), 10,889 (June 25 2004), 11,943 (May 28, 2009) and 12,212 (January 20, 2010) and regulated by decrees: 4,541/2002 and 5,025/2004, is one of the most important programs for the development of alternative energy sources in Brazil with the following objectives:

- 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 term, and the program started from April 2004. The program's main goal is to fund, in financial attractive conditions supported by the Development Bank (BNDES), energy generation projects from wind (wind power), SHP and biomass. 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 quota of initial power to be contracted.

The Feed-in system consists of more advantageous tariffs for generating plants that use renewable sources of energy 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[2].

A quota of energy is to be compulsorily acquired by the power distribution companies for each energy source that is meant to encourage transferring the costs of buying more expensive energy for consumers[3]. This system is the same system as Renewable Portfolio Standard (RPS) implemented in Japan

The program currently provides for the operation of 144 plants, totaling 3,300 MW of installed capacity distributed as follows: 1,191.24 MW from small hydro plants, 1,422.92 MW of 54 wind plants and 685.24 MW of 27 power plants based on biomass. The deadline for early operation of the project was December 2006 and subsequently extended (Ordinance 452/2005 from the Ministry of Mines and Energy) to December 2008 and later (Law 11,943) postponed to December 2010. 43 % of the projects contracted by PROINFA were based on wind and located in the northeast region of the country.
An example of auction results is shown below. Wind prices dropped from 16.4 – 14.4 (at PROINFA) to 7.7 USc / kWh in 2010 auction.

2 ANEEL, Technical Note 0043/2010
3 ANEEL, Technical Note 0043/2010

Table 3.4.1 Example of auctions in 2010

	R$/MWh	USc/kWh
Hydro	99.48	4.6 – 5.9
Small hydro	144.00	8.3
Bagasse	144.60	8.5
Wind	148.39	7.7
Fuel oil	144.7*	8.3
Coal	140.00*	8.3
Natural gas	145.00*	8.0

* Not fully included the fuel costs.

(Source: Report by ANEEL)

3.4.2 Resolution N 247, December 21, 2006

Resolution N 247 regulates the right of Renewable Power Plants trade energy with Especial Consumer (retail energy trade) and gives benefits as wheeling fees discounts.

(1) Targets of Renewable Power Plant
- Very small hydro power plant called MCH (under 1 MW);
- Small hydro power plant called 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)

(2) Definition of Especial Consumer
- One consumer unit or group of consumer units that has over 500 kW of demand

(3) Wheeling fees discount

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

3.4.3 Time of Use Tariff

(1) Customers except for low voltage

Time of use tariff has already been used for industrial and commercial customers categorized as A group. Two types of tariffs, Blue and Green tariffs, are used depending on the voltage levels and demand. These tariffs include prices during the peak hours (P) and off-peak hours (FP). Moreover, they also include prices during the dry season (from May to November) and the rainy season (from December to April). The peak hour comprises 3 consecutive hours from 5 pm. to 10 pm. and the off-peak hour comprises the remaining 21 hours of the day. Examples of time of use tariffs are shown below.

Table 3.4.2 Examples of time of use tariff in Brazil (year 2011)

A4		TUSD (R$/KW)		TE (R$/MWH)			
		P	FP	P		FP	
				PS	PU	FPS	FPU
AES Eletropaulo	BLUE time-of-use	44.83	11.06	344.69	313.09	220.24	201.90
	GREEN time-of-use		11.06	1385.55	1353.95	220.24	201.90
CEMIG	BLUE time-of-use	63.64	17.23	315.45	28.,59	201.76	185.02
	GREEN time-of-use		17.23	1793.48	1764.62	201.76	185.02
LIGHT	BLUE time-of-use	68,8	18.66	402.02	365.26	257.21	235.87
	GREEN time-of-use	5	18.66	2000.55	1963.78	257.21	235.87
ESCELSA	BLUE time-of-use	69.92	19.52	385.98	349.67	242.97	221.90
	GREEN time-of-use		19.52	2009.33	1973.03	242.97	221.90
COPEL	BLUE time-of-use	56.08	13.93	351.32	319,64	226,55	208.16
	GREEN time-of-use		13.93	1595.53	1563,84	226,55	208.16
RGE	BLUE time-of-use	56.33	14.29	406.35	368,35	256,74	234,70
	GREEN time-of-use		14.29	1714.18	1676,19	256,74	234,70
CELTINS	BLUE time-of-use	90,6	27.48	390.01	352,25	241,32	219,42
	GREEN time-of-use	7	27.48	2495.39	2457,62	241,32	219,42
CEMAT	BLUE time-of-use	61,4	20.03	46.07	423,42	295,17	269,83
	GREEN time-of-use	3	20.03	1893.71	1850,06	295,17	269,83
CELPA	BLUE time-of-use	76,9	21.66	346.91	310,05	215,31	196,60
	GREEN time-of-use	5	21.66	2129.04	2096,78	215,31	196,60
AMAZONAS EM	BLUE time-of-use	50,4	16.83	407.28	366,59	247,03	223,42
	GREEN time-of-use	7	16.83	1579.08	1538,39	247,03	223,42
COELCE	BLUE time-of-use	63,7	18.09	380.14	343,56	236,05	214,80
	GREEN time-of-use	0	18.09	1859.26	1822,67	236,05	214,80
CEPISA	BLUE time-of-use	67,2	15.62	294.84	265,87	180,80	164,00
	GREEN time-of-use	3	15.62	1856.15	1827,19	180,80	164,00

Source: Federal Ministry for the Environment Nature Conservation and Nuclear Safety

(2) Low voltage customers

Time of use tariff for residential customers has not been used. However, time of use is thought effective because there is a significant difference of demand between peak and off-peak hours. Peak hours are estimated to be caused by usage of hot shower in the evening. Moreover, usage of air-conditioners also affects peak demand. Especially, time of use is needed in the southern area such as Rio de Janeiro and Sao Paulo, and it enables construction of power plants to be extended because of peak shift.

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

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 on the occasion of its rate revision between 2012 and 2014.

For low voltage customers, whether in residential, commercial, industrial or 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 the intermediate will be between those two times. On weekends and holidays, the cheapest rate will be used for all hours of the day. However, the white rate will begin to be valid only when the distributors replace the electromechanical energy meters by electronic ones. This has been studied by ANEEL and was discussed in Public Hearing No.43/2010. The white rate mode will not account for public lighting and low-income customers. Detailed specifications of electric meters for TOU have not been decided yet as of January 2012.

Another change, valid as of January 2014, is the creation of the Green, Yellow, and Red Rate Flags, to act as traffic light, and will be reflected in rate differences to the customers. The green flag means lower costs for fuel. The yellow flag indicates a warning signal because the generating costs are increasing. In turn, the red flag indicates that the former situation is worsening. The target will be all customers of SIN, high and low voltage ones. The image of a display terminal that displays the green, yellow, and red rate information is shown below. ANEEL is now considering inputting the target of energy conservation data into the terminal using number buttons shown in the figure.

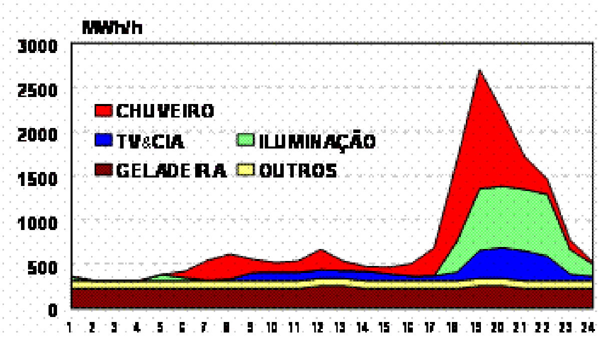


Fig. 3.4.1 Example of daily load curve (residential customers)

(Source: Presentation material from ANEEL)

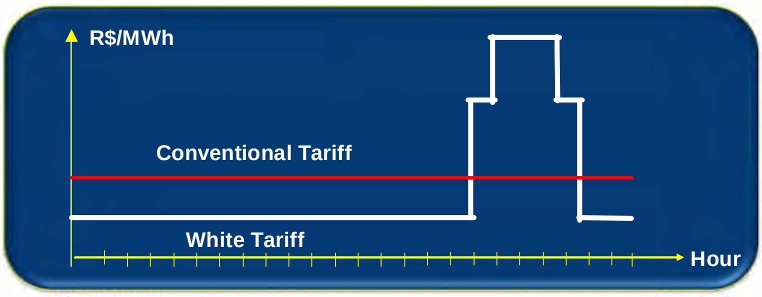


Fig. 3.4.2 Time of use tariff (White tariff)

(Source: Presentation material from ANEEL)

Fig. 3.4.3 Display terminal showing Green, Yellow, and Red Rate

(Source: ANEEL web-site)

3.4.4 Net-metering

ANEEL is now studying net-metering system. One of the main objectives is to reduce obstacles of distributed generation (up to 1 MW) connection to low voltage lines. In the United States, 44 states enforce this policy.

- Net metering allows a two-way flow of electricity between a distribution company and customer with Distributed Generator (DG).
- Should the generation be lower than the load, the customer only pays the difference of prices between the energy used and the energy generated.
- Bidirectional meters measure backward flows when electricity flows into a grid.

Net metering allows electric customers who generate their own electricity using solar energy (or other forms of renewable energy) to bank excess electricity on the grid, usually in the form of kilowatt-hour (kWh) credits. In the U.S.A., most states' net metering policies were established through legislation. Many states have raised the capacity limit for individual systems. Massachusetts allows net metering for certain systems up to 10 MW and New Mexico allows net metering for certain systems up to 80 MW. In several states such as California and North Carolina, time-of-use tariff is available for net metering customers. However, time-of-use requires specialized reversible smart meter that is programmed to determine electricity use any time during the day. It is a future issue for Brazil how to determine the specification of smart meters considering net metering functions.
In Japan, the feed in tariff system is implemented to provide incentive to install renewable energy. Two meters are used to measure buying and selling electricity because the price of selling electricity rate from customers to utilities is higher than one of buying rate. Although net metering system is different from feed in tariff system, Japan has rich experience of connecting PV to distribution grids. It is assumed that Japanese manufacturers has chance to enter this field in Brazil.

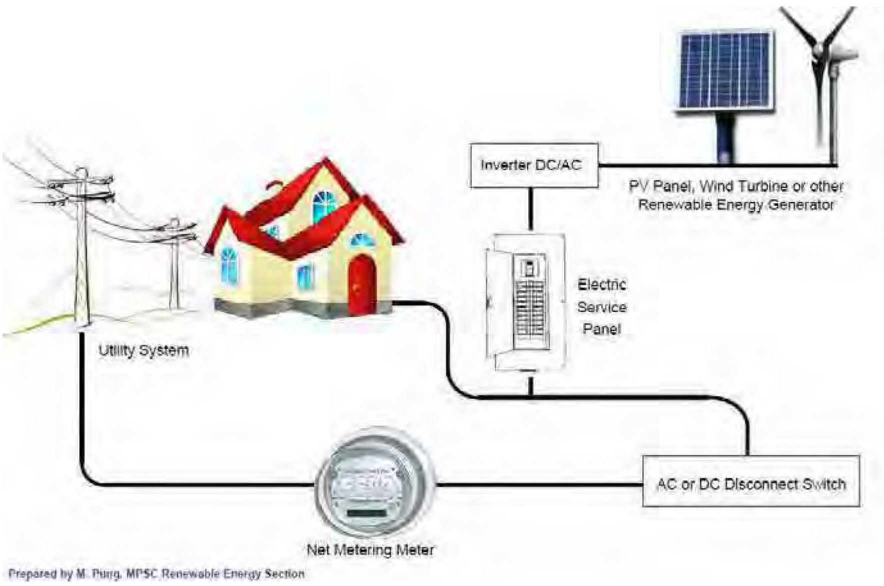


Fig. 3.4.4 Net-metering system
(Source: Presentation material from ANEEL)

Chapter4 Study Results of Distribution Companies

4.1 Overview of Distribution Companies

4.1.1 CPFL Energia (Companhia Paulista de Força e Luz)

CPFL is a listed company and has affiliated companies of distribution, generation and power commercialization as a holding company. In the distribution domain, it has eight subsidiary companies operating in Sao Paulo, Rio Grande do Sul, Parana and Minas Gerais States with 6.7 million customers in 569 municipalities supplying 39,250 GWh (as of the end of December, 2010)

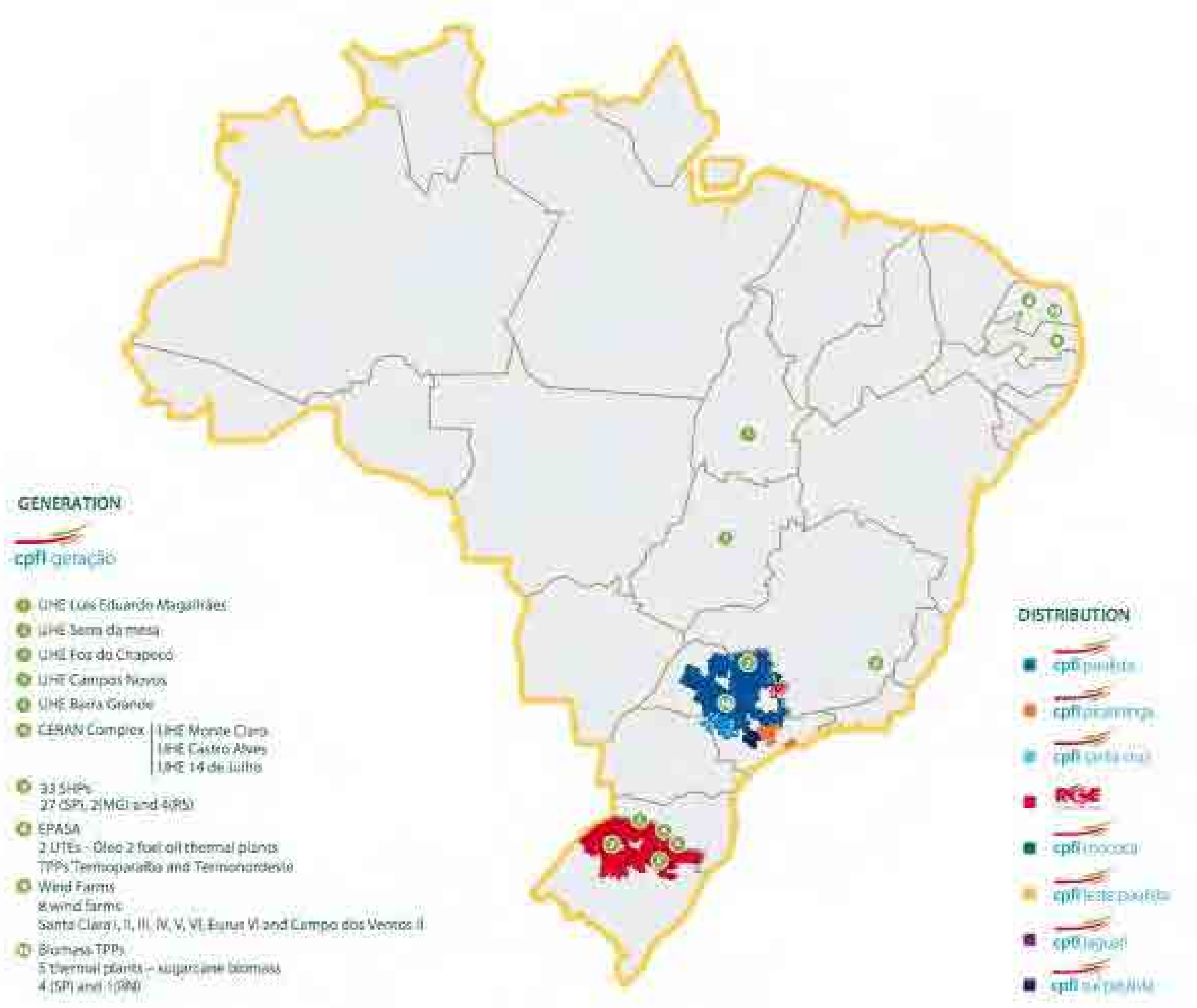


Fig. 4.1.1 Operation area of CPFL

(Source: CPFL Annual Report 2010)

The central subsidiary distribution company, Companhia Paulista de Forca e Luz (CPFL Paulista), covers 234 municipalities in Sao Paulo State with 3.7 million customers.

All of the affiliated distribution companies sold 52,044GWh (65,044GWh if 13,000GWh for free market is included) in 2010 and the operation revenues were R$15,864 million (15,864÷65,044＝0.244R$/kWh). In detail, CPFL Paulista sold 26,988GWh and got R$8,115 million as revenues (8,115÷26,988＝R$ 0.301 /kWh as sale unit).

The majority shareholder of the holding company (CPFL Energia) is BB Carteira Livre I (pension fund of Bank of Brazil whose majority voting rights is owned by the federal government) with 31.02% and the BNDES has 8.42% share so that the public (federal government) share is 39.44% in total and the remaining share is private including listed stocks.

4.1.2 AES Eletropaulo

AES Eletropaulo is the largest distribution company in Latin America. It annually supplied 33,859GWh to 6.1 million customers in 24 municipalities of the Sao Paulo Greater Metropolitan Area. The revenues were R$14,714 million (net R$9,697 million) so that the sale unit was R$0.435/kWh (net R$0.286/kWh). The shareholders are shown in Table 4.1.1 and the majority shareholder is AES (the U.S. company) with 31% and adding the share of its subsidiary, Cia Brasiliana de Energia, 4.4% and AES has 35.4%. On the other hand, the public has only 8.4% adding Federal Union's 8% and the BNDES's 0.4%.

Table 4.1.1 Shareholders of AES Eletropaulo

Shareholder	Common	%	Preferred	%	Total	%
AES ELPA	51,825,798	78%	0		51,825,798	31%
União Federal	13,342,384	20.0%	0		13,342,384	8.0%
Cia Brasiliana de Energia	0	0.0%	7,434,388	7.4%	7,434,388	4.4%
BNDES	1	0.0%	734,576	0.7%	734,577	0.4%
Others (Free Float)	1,436,634	2.2%	92.570.106	91.9%	94,006,740	56.2%
Total	**66,604,817**	**100.0%**	**100,739,070**	**100%**	94,006,740	**100.0%**

As date 12/31/2010

(Source: http://ri.aeseletropaulo.com.br/Show.aspx?id_canal=ZfYTCy99yh0gwa7kaEZR9Q==)

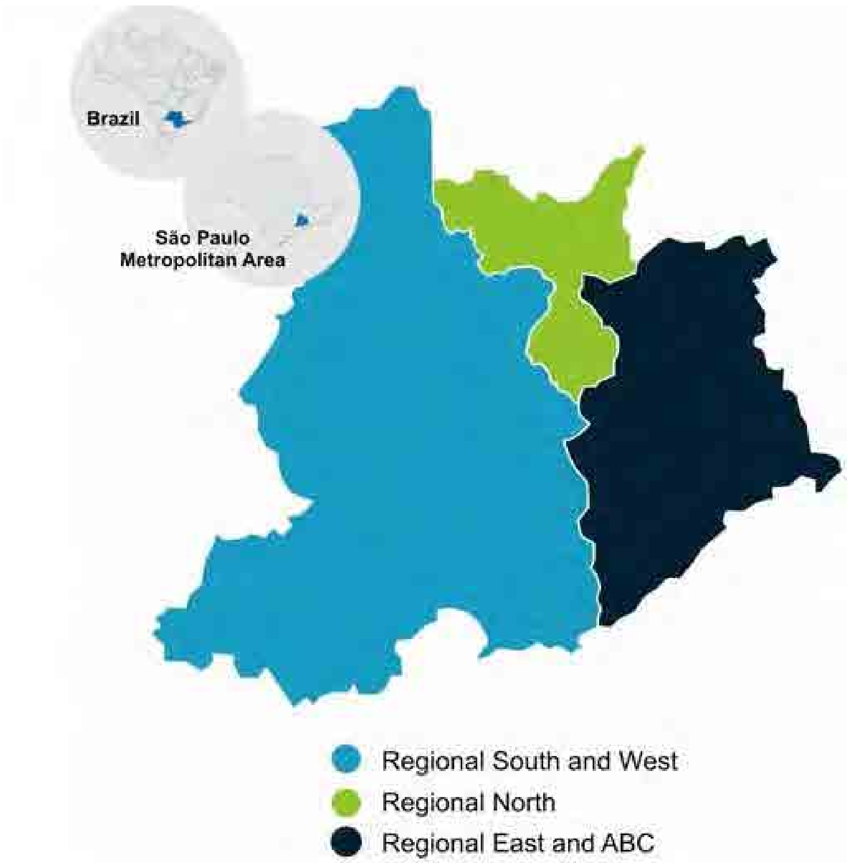


Fig. 4.1.2 Service area of AES Eletropaulo

(Source: http://ri.aeseletropaulo.com.br/Show.aspx?id_canal=ZfYTCy99yh0gwa7kaEZR9Q==)

4.1.3 Light

Group Light (headquartered in Rio de Janeiro) has 31 municipalities in Rio de Janeiro State as concession area, supplying electric power to 4 million customers. The holding company is Light S.A. that has Light SESA as affiliated distribution company, Light Energia as affiliated generation and distribution company and Light Esco and Lightcom as affiliated commercial and service companies.

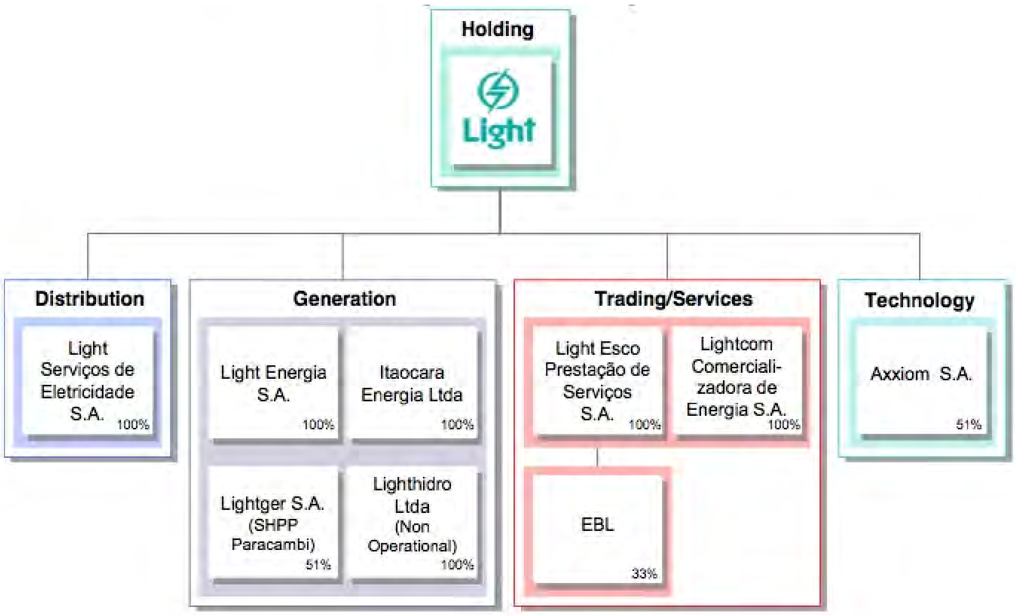


Fig. 4.1.3 Structure of Light

(Source: Light)

The electric power consumption in 2010 was 22,384GWh and the net revenues were R$6,509million and so sale unit was R$0.291/kWh.
The shareholding structure of Light is shown in Figure 4.1.4 and the public shares are 41.08% in total summing 26.06% of Cemig (Minas Gerais State) and 15.02% of the BNDES. The private has remaining 58.92%.

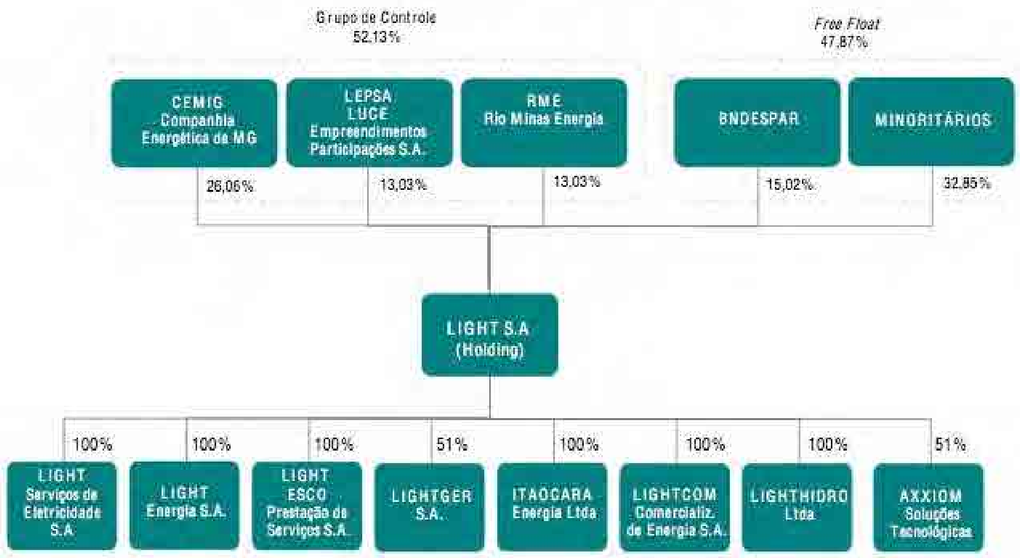


Fig. 4.1.4 Shareholding structure of Light

(Source: Light)

4.1.4 AMPLA

AMPLA is a distribution company that has 66 municipalities in Rio de Janeiro State as service area supplying 9.367 GWh consumption power to 2.5 million customers.
91.94% of AMPLA capitals are owned by Endesa (Spain) which controls AMPLA, but 92.06% of Endesa stocks are owned by Enel (the largiest power company in Italy) which controls Endesa. The most important shareholder of Enel is the Ministry for the Economy and Finance, Italian Government with 31.24% share.
Endesa has two power plants (665MW hydro and 322MW thermal) in Brazil, a 100% affiliated transmission company, CIEN (transmission line between Argentina and Brazil), and AMPLA and Coelce (58.86% shareholder, serving in Ceara State) as affiliated distribution companies.

4.1.5 COPEL

COPEL's distribution company is supplying power to a total of 3.7 million consumers in 392 municipalities among the total 399 municipalities of Parana State and Porto Uniano in Santa Catarina State. The sold electric power was 21,304GWh in 2010. The consumption in Parana State Capital, Curitiba City, was 7,059.426GWh and the revenues were R$1,719.054 million so that the sale unit was R$ 0.244/kWh.

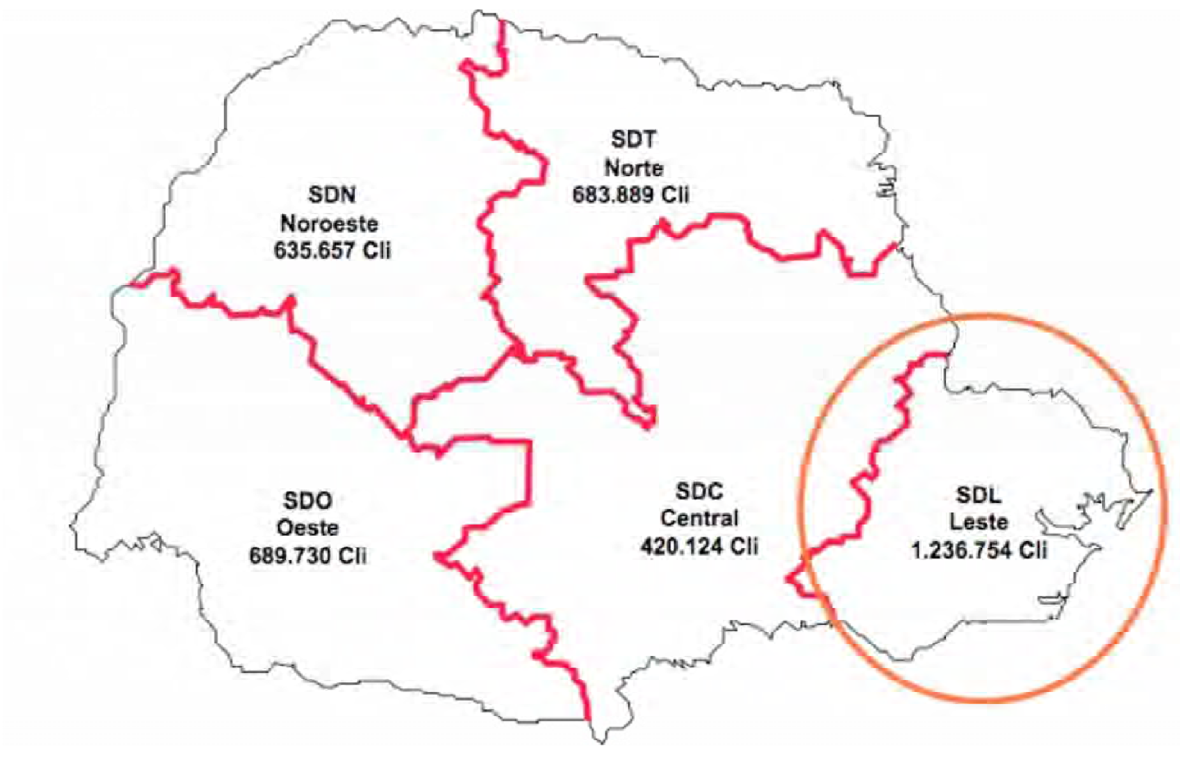


Fig. 4.1.5 Service Area of COPEL

Parana State government has 58.6% of COPEL voting rights and in addition the BNDES has 26.41% so that the public has 86%.
Furthermore, COPEL has affiliated generation, transmission, telecommunication and gas companies. In particular, the telecommunication company has fiber optic network and it is very useful for smart grid.

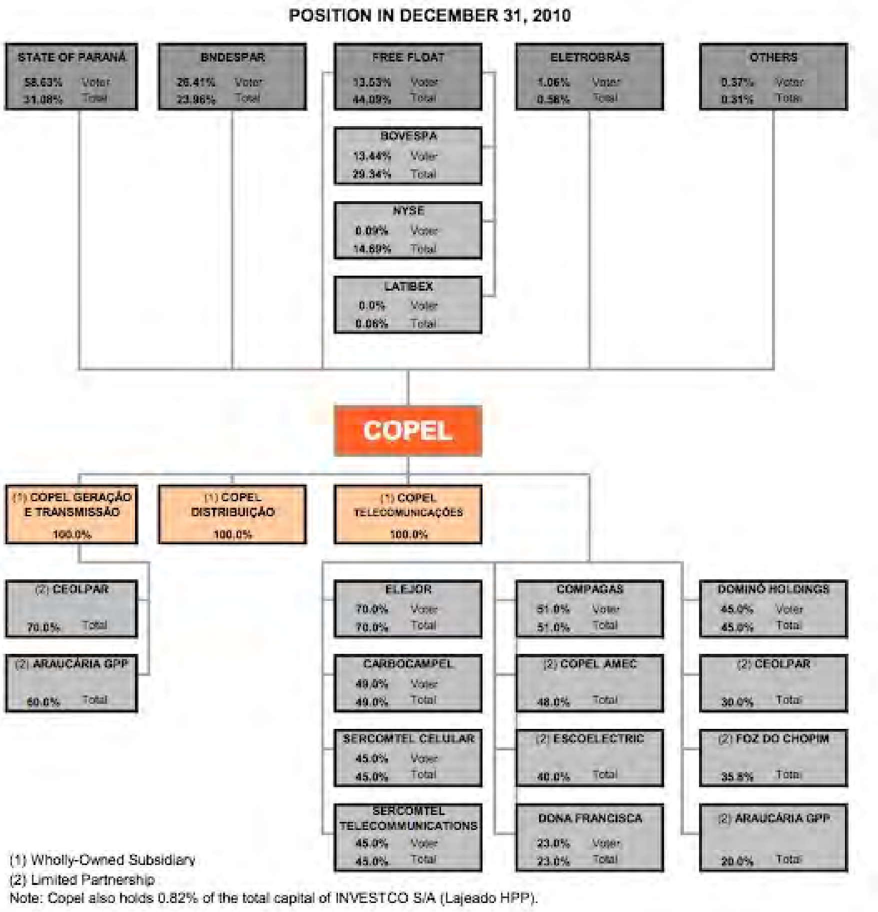


Fig. 4.1.6 Shareholders of Copel

4.1.6 CEAL (Companhia Energética de Alagoas)

CEAL is a distribution company whose serviced area is Alagoas State. It supplied 2,503 GWh in 2010 and the revenues were R$706 million so that the sale unit was R$0.282/kWh.
CEAL is a 100% affiliated company of Eletrobras and based on Alagoas State. 65% of Eletrobras stocks are public (federal government and fund: 46.5%, BNDES: 18.5% and 65% in total) and the remaining 35% shares are private. Eletrobras has six affiliated distribution companies and CEAL is most eastern located among them. Eletrobras itself has affiliated generation and transmission companies.

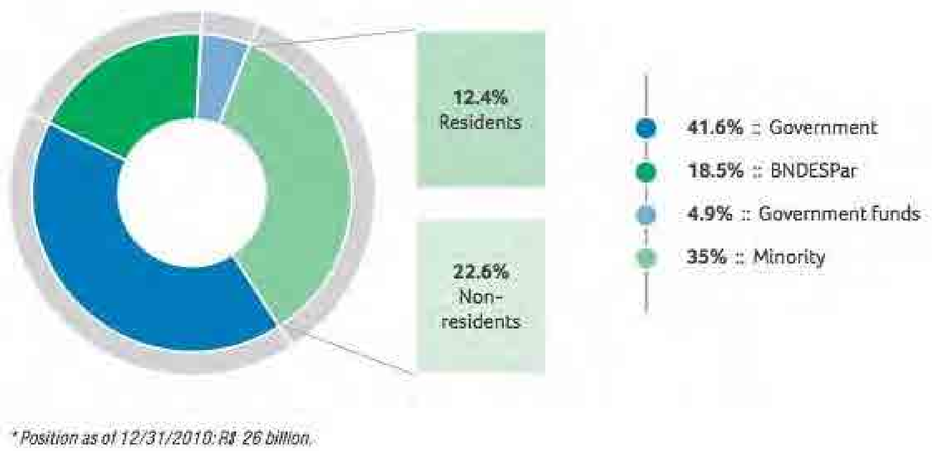


Fig. 4.1.7 Capital structure of Eletrobras (Source: Eletrobras Sustainable Report 10)

Fig. 4.1.8 Service areas of Eletrobras' affiliated distribution companies
(Source: Eletrobras Presentation materials)

4.2 Existing Distribution System

4.2.1 Outline

Although, underground lines of Light company in Rio de Janeiro account for 10 %, almost all of the distribution systems in Brazil consist of overhead lines.Distribution companies purchase electricity based on a long term contract. In distribution substations (138kV/13.8kV), the voltage is transformed into 13.8 kV, and furthermore into 220 V or 110 V to supply customers.

4.2.2 Overhead Distribution Line

Most OH lines consist of radial networks. In urban areas, distribution companies are installing section switches. In some areas, reclosers are installed to separate a section that has an accident point.

Fig. 4.2.1 Example of distribution line

4.2.3 Underground Distribution Cable

As shown below, customers are connected with each other through ring-main-unit (switch), and the end of a distribution line has a section switch adjacent to another line. When a fault occurs, a breaker in a substation is opened, and then power is supplied subsequently by the operating ring-main-unit and section switch.

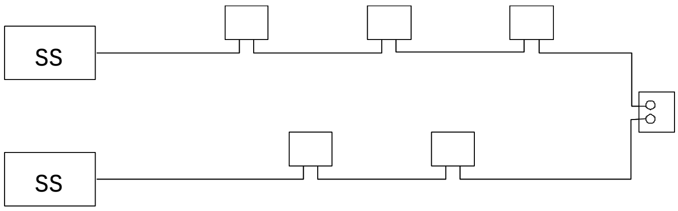


Fig. 4.2.2 Image of underground system

Fig. 4.2.3 Example of underground facilities

4.3Distribution Substation

4.3.1Responsibility of Distribution Company

The voltages used on transmission lines are 500kV, 230kV and 138 (69) kV. They are the work scope of transmission company. The work scope of distribution companies is 13.8 (11.9) kV, which is stepped-down from 138 (69) kV as shown in Figure 4.3.1.

4.3.2 Single Line Diagram of Distribution Substation

Configuration of a typical distribution substation is as shown in Figure 4.3.1.
Two (2) 138 (69) kV transmission lines are connected to 138 (69) kV busbar at the substation. On the 138 (69) kV busbar, one (1) to three(3) power transformers with 20 to 40MVA are connected to step-down the voltage to 13.8(11.9)kV and connected MV switch gear. On the 13.8 (11.9) kV busbar, four to five feeders are connected. When the required load power is larger than the total power of three (3) power transformers, another new substation should be provided at a different location.
When electric power is distributed to consumers near the substation, 13.8 (11.9) kV is used. However, in case of distributed electric power to the consumers located far from the substation, the higher voltage (34.5kV) is used as distribution voltage in order to compensate the voltage drop.

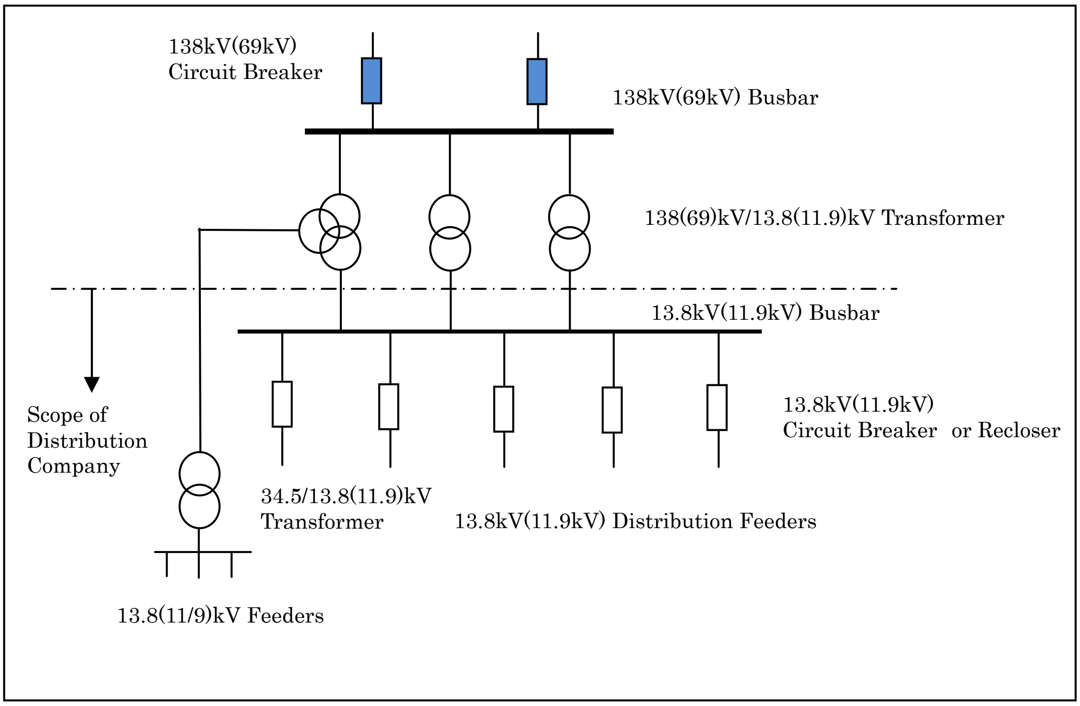


Fig. 4.3.1 Single Line Diagram of Typical Distribution Substation

4.3.3 Insulation Method of Switchgear

The insulation method of HV Switchgear is air insulation as shown in Figure 4.3.2 below. The Gas Insulated Switchgear is not used for HV switchgear because the price of land is not expensive in Brazil. A cubicle type air insulated switchgear is adopted to medium Medium voltage which is less than 15kV as shown in Figure 4.3.3.

Fig. 4.3.2 Typical Distribution Substation (AMPLA)

Fig. 4.3.3 MV Switchgear at Distribution Substation (AMPLA)

4.3.4 Number of Transformers and Capacity at Typical Distribution Substation

The capacity of distribution transformer is 20MVA to 40MVA and number of transformers at one substation is one (1) to three (3). Considering redundancy of transformers, two (2) or three (3) transformers are provided at one substation. Typical load current of a distribution feeder is 630A and four (4) to five (5) feeders are connected to the substation.

4.3.5 Control and Protection Equipment

Control equipment of substation is an integrated type of control equipment and protection relays. The interface with remote control such as Distribution Automation System (DAS) is integrated into the control equipment. Accordingly, the control/protection system is designed in very compact design which is composed of two panels with 1000mm widths. Over-current and earth fault relays (51 +51N) are adopted for protection.

Fig. 4.3.4 Bay unit of 13.8kV Feeder

4.3.6 Reclosing Scheme

The reclosing scheme of MV distribution feeders is a two-shot reclosing scheme. The first reclosing is performed after extinguishing time of arcing on the feeder. The second reclosing is performed after several minutes in order to recover the distribution feeder. The three-shot reclosing scheme, which has been applied in Japanese distribution system, is not used in Brazil. Accordingly, a sectionalizer has not been provided on distribution feeders but ‘recloser’ is used instead of sectionalizer to re-energize the feeder.

4.4 Distribution Facilities

Brazil has a wide diversity in geographic characteristics and there are a variety of facilities in every distribution company.

4.4.1 Urban Distribution Facilities

Main nominal voltage is 138kV / 13.8kV in distribution substations and power is supplied by overhead distribution lines. Most of the feeders from radial systems though there are open loop systems in main areas.
The distribution feeders in only small part of the area are divided into a few parts by sectionalizers. And these sectionalizers which can be monitored by communication lines are introduced in only urban areas. Generally distribution automation in Brazil is not common. Underground cables are laid just in Rio de Janeiro metropolitan areas.
Regarding the pole transformers, as the capacity is around 75-100kVA on average, distribution feeders are not so long with small capacity.
A three-phase four-wire system is applied to low voltage lines and bundling wires are taken place of three wires because of thefts prevention measurements. Capacitors to improve a power 6 factor are not common on the poles.

4.4.2 Rural Distribution Facilities

In rural areas, distribution feeders come out from tertiary winding of the 34.5kV distribution substation. These feeders are mostly radial and not connected with other feeders.
There are many tall trees in tropical areas. Therefore, the main cause of the power failures are tree touches. The rest of the causes are lightning during squalls and small animals.

4.5 Communication System

The communication systems and facilities used in the existing and future Automatic Metering and Smart Grid are summarized hereafter.

4.5.1 Communication Method and Facilities for Smart Grid of Each Company

(1) CPFL

CPFL has planned to use the same communication route for automatic metering as that for remote control of local switchgears. For the last one mile communication from each consumer to secondary concentrator and secondary to primary concentrator, it was planned to apply RF mesh or GPRS. For the communication from primary concentrator to substation, it was planned to apply one of GPRS/Radio/Satellite communications. And from substation to Center, fiber optic communication is planned to apply. In case of an isolated consumer, it will be connected to Center directly by GPRS. Figure 4.5.1 shows the communication system of CPFL.

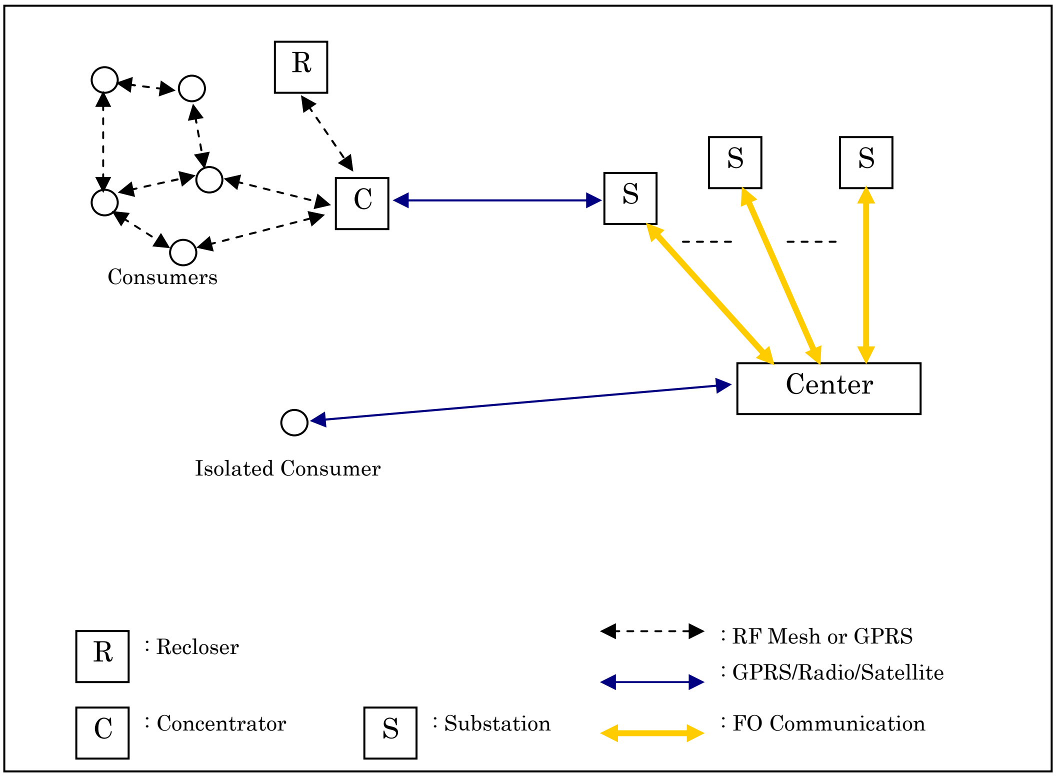


Fig. 4.5.1 Communication for Smart Grid (CPFL)

(2) AES Eletropaulo

AES Eletropaulo has SCADA for transmission and substation control. However, they do not have DAS for 3000 sets of reclosers on their distribution network. For the communication from substations, fiber optic communication (OPGW) is applied. At the beginning, they planned to use GPRS, but GRPS does not give good results in communication. Then the radio communication (1.5 to 5GHz) is applied to reclosers on the distribution network. They are testing the function of radio communication at this moment.

A planned communication method of Smart Grid is RF mesh between consumers and secondary concentrators mounted in a box on distribution poles and a primary concentrator. Then the primary concentrator is connected to Center by GPRS. But the security of communication depends on the system of Communication Company. The reason why they do not use fiber optic communication is the cost to install the optical fiber cable. They should install the dedicated optical fiber cable which they can not rent to a third-party. Accordingly, the fiber optic communication costs a lot.

Figure 4.5.2 shows their planned communication system.

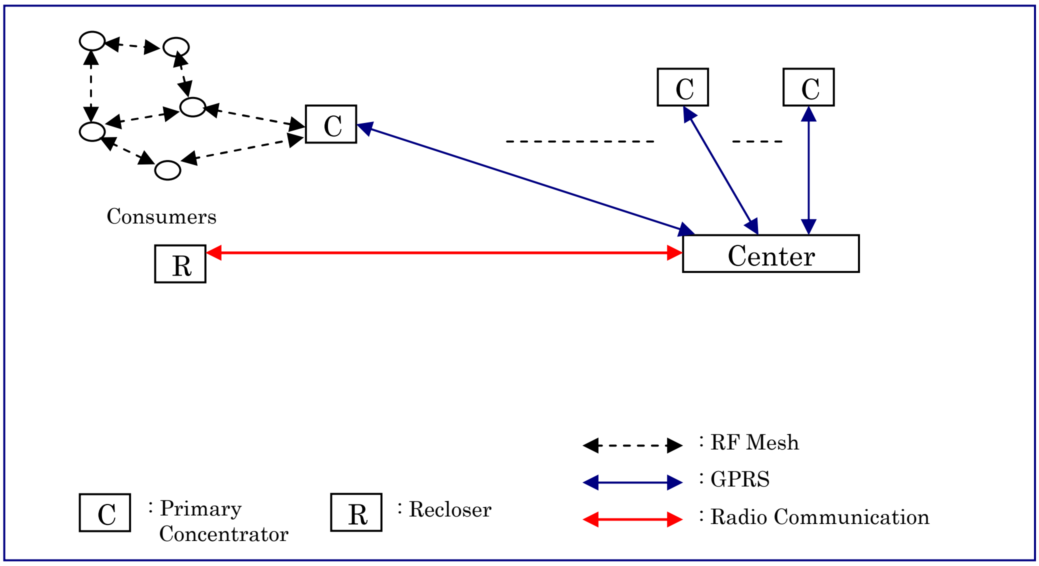


Fig. 4.5.2 Communication for Smart Grid (Eletropaulo)

(3) Light

Light has DAS to control the reclosers. At this moment, they have used GPRS and Radio communication for DAS. In the future, they are planning Wi-Fi for communication. For the last one mile communication, they have examined several communication methods such as Power Line Carrier (PLC), GPRS, RF mesh and they consider that the RF mesh is possible for the last one mile communication. They do not think PLC is suitable for the last one mile communication. For backbone network, they consider Wi-Fi network (900MHz) owned by Light. The reason why they do not use fiber optic communication is the difficulty to install the optical fiber cable. The communication system of light is shown in Figure 4.5.3.

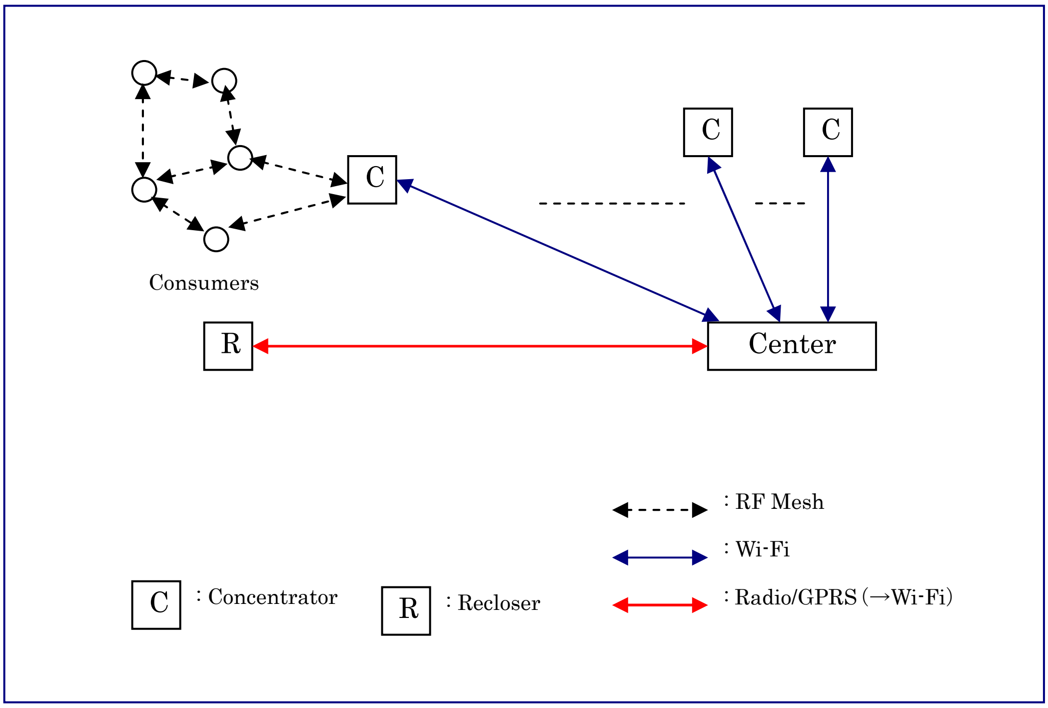


Fig. 4.5.3 Communication for Smart Grid (Light)

(4) AMPLA

For the last one mile, radio communication by L&G or PLC (Narrow band) by COMPLANT will be applied. For the communication between secondary and primary concentrators, RF mesh will be applied. For backbone communication, GPRS will be applied. They have two kinds of reclosers (Normally Open and Normally Close) to be monitored by radio communication (DNP3.0).

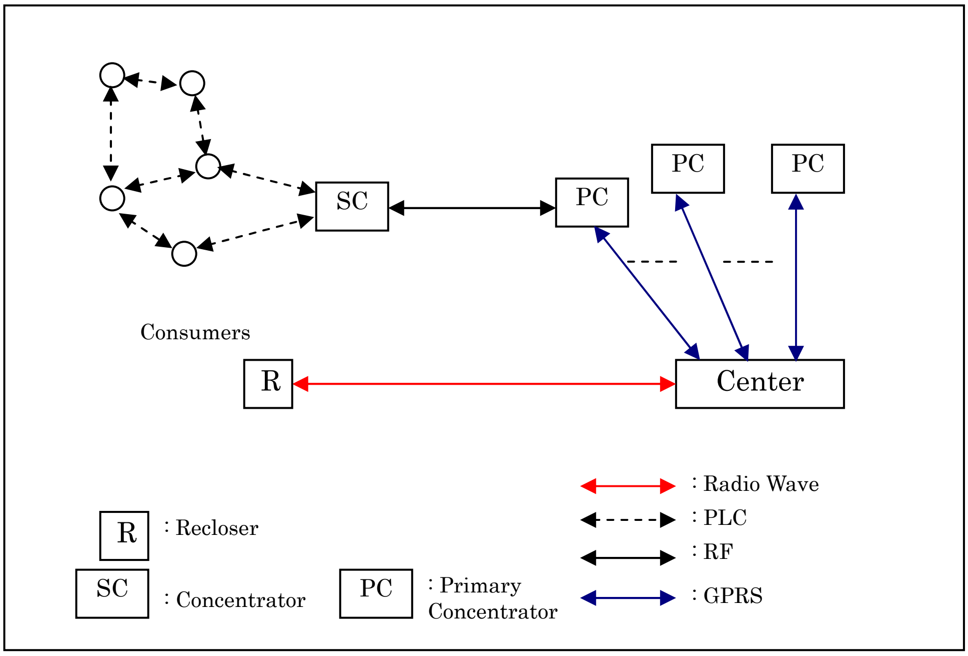


Fig. 4.5.4 Communication for Smart Grid (AMPLA)

(5) COPEL

COPEL does not monitor the local distribution switchgear, but they are planning to test the sectionalizer with fault detection in 2012 and operate DAS from 2013. Now they are evaluating the candidates of possible technique.

They are trying an operation of 7000 sets of Automatic Metering in Foz de Londrina near the Iguazu. The communication method is GPRS for the trial, but the cost of GPRS (8R$/month) is very expensive compared with the manpower cost of meter reading (0.5R$/Month). In order to reduce the cost, they are considering the economical communication media instead of GPRS. At this moment, they use GPRS not only the last one mile but also backbone communication. Actually, they have experienced communication delay of GPRS when weather condition is not good. In Curitiba, COPEL considers to use fiber optic communication as backbone communication in the near future.

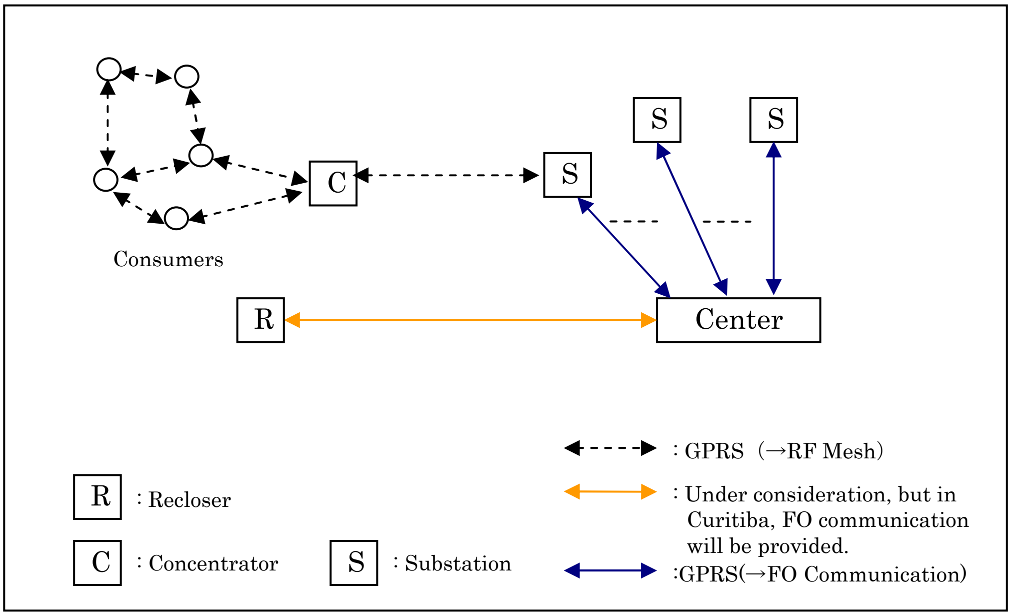


Fig. 4.5.5 Communication for Smart Grid (COPEL)

(6) Amazonas State Energy Distribution Company (Manaus Energia: Eletrobras' subsidiary)

They are planning to divide the Parintins City into four areas. In each area, four kinds of communication media will be applied for trial use. The four kinds of media are RF mesh (900MHz), Point to Multi points (450MHz), Zigbee and PLC (Narrow band) for communication. In the future, one of the best communication methods will be selected from the four kinds of media. They are planning to use Wi-Fi for the backbone communication between the concentrators and Center. They explained they would provide their own Wi-Fi communication. They also considered using WAN for the communication between Manaus and Parintins. Figure 4.5.6 shows the communication system for Parintins.

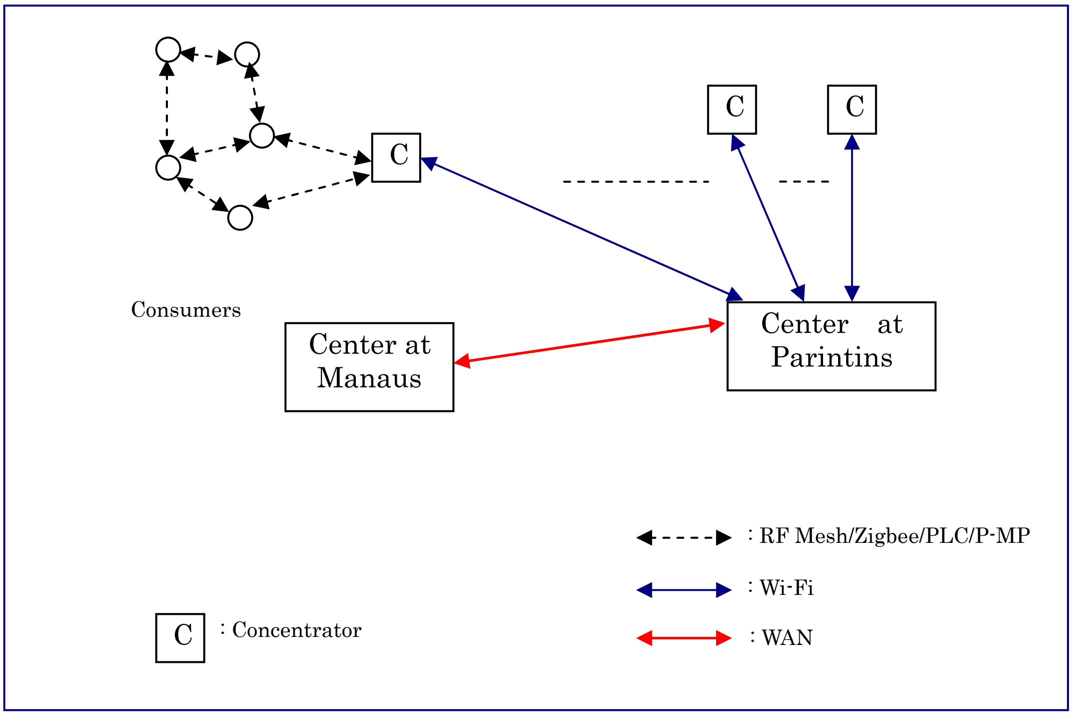


Fig. 4.5.6 Communication for Smart Grid (Manaus Energia)

4.5.2 Problems and Difficulties to Be Solved

(1) Unification of communication system

We have visited and collected information from utilities regarding the communication systems. Then we could acknowledge the differences of communication systems among the utilities. It may be possible to carry out the trial operation in pilot plant, but it will be problems of cost and quality of communication in Brazil. It may increase the cost of equipment. If several kinds of communication equipment are produced, it may cause cost-up because of limited number of products. Also the approval and maintenance, etc. cost. The costs may be born by the manufacturers, but it may reflect the consumers' costs ultimately.

(2) Cost for communication

Some utilities planned to use GPRS or the links of Communication Company. Although it is not a problem in a pilot plant because the number of consumers is not so large. However, it will cause a lot of costs for a big number of consumers in the commercial operation. We consider that utility shall provide their own economical communication media. Or a big change of communication method is expected in the commercial operation.

(3) Speed of communication

In a pilot plant of Smart Grid, the communication media with a lower speed such as PLC and GPRS are used. In the future, if the media are used for HEMS or BEMS, communication media with a high speed will be necessary and then it is better to consider high speed communication in order to maintain the expandability of the Smart Grid to Smart Community. In addition, it should be considered that the speed of GPRS may be delayed by the number of users to access to the GPRS.

4.6 Watt-Hour Meters

4.6.1 Current Situation

(1) Overview

There are several types of meters; meters for residential, commercial and industrial, and grid. Both of mechanical and electrical types are used and basically, one meter is installed per one customer. However, ANEEL plans to exchange 65 million meters for electronic ones. All of the distribution companies that JICA survey team visited implement meter reading every month.

(a) Mechanical type

(b) Electronic type

Fig. 4.6.1 Examples of meters

(2) Meter calibration

Meter calibration is implemented before shipment. However, calibration after installment is not regulated by the Government. Whether or not calibration is conducted depends on each distribution utility. For example, COPEL conducts mechanical meter calibration every 25 years.

(3) Related regulation

All of the meters sold in Brazil need to obtain approval from Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO), and this procedure takes about one year. Detailed calibration and installation methods are explained in the regulation, "RTM431." In the RTM431, the accuracy of meters must be less than 0.2 % ~ 2.0 % depending on the types of meters.

4.6.2 Smart Meter

(1) Overview

One of the objectives to install smart meters is to reduce fraud of electricity. In May 2010, ANEEL agreed to partner with the Ministry of Science, Technology and Innovation to create a standard for the local manufacturing of smart meters. The regulator also announced tentative plans for a nationwide rollout of smart metering, expecting to replace about 65 million meters by 2021. The Brazilian Electronic and Electrical Association (ABINEE), which is a non-profit organization for electrical and electronics industry, is already working to define new standards. Smart metering regulation is now under analysis.

ANEEL is also studying cost and benefit analysis based on several scenarios as shown below.

Table 4.6.1 Scenarios proposed by ANEEL

Scenarios	Costs	Benefits
0 – No intervention	Meter installation	Loss reduction
1 – Basic	Meter installation	Loss reduction
2a – Tariff and quality	Meter installation + Reading const addition	Loss reduction + Peak demand reduction +Quality improvement
2b – Tariff and quality	Meter installation + Reading const addition	Peak demand reduction
3a – Communication	Meter installation + Reading const addition	Increased values: Loss reduction +Peak demand reduction +Quality improvement
3b – Communication	Meter installation + Reading const addition	Increased values: Loss reduction

(2) ANEEL's view on Smart Meter

In the public hearing of AP 043/2010, minimum requirements for the meters for residential and commercial / industrial low voltage customers were studied. Main topics are shown below.

- Communication system with public protocol
- Remote reading and disconnection / connection
- TOU tariffs
- Interruption registers
- Voltage transgressions registers

Due to the subject discussed in the scope of the hearing, the theme is still a proposal of ANEEL and not the final decision.
In regard to the comprehensiveness of the proposal for regulation, the minimum requirements of the metering systems are applied to providing consumer units in Group B. Such comprehension is applied to provision of new connections to consumer units on the occasion of replacing, for any reason, the metering system of the existing consumer units.

Complementary functions shall be verified by short-term interruptions and long-term interruptions for the purpose of calculating DIC indicators – Duration of Interruption per Consumer Unit -, FIC – Frequency of Interruption per Consumer Unit - and DMIC – Maximum Duration of Interruption per Consumer Unit. Another function is the need of capability to apply different tasks, at least, in four time charging rates.
Another theme handled in the regulatory proposal concerns the availability of information to the consumers. In this context, the information regarding consumption of active and reactive electric power, in addition to the data regarding the continuity of supply and the total quantity and total duration of interruptions considered for the purposes of calculating the DIC, FIC and DMIC indicators is proposed to be made available to the consumers. Another item that shall be informed by the metering device is the identification of the current charging rates.
ANEEL also recognizes that it takes time to develop the new meters providing the minimum functions required by ANEEL and used in the market. Therefore, it will take some time for the manufacturers to be able to develop models and subject them to metrological approval prior to marketing to distributors. In parallel, the distributors also need to adjust. Therefore, ANEEL proposed an 18-month term, following the enactment of the Regulatory Directive for beginning the use of the metering with the minimum requirements set forth.

Based on the regulatory proposal coming up for discussion in the Public Hearing AP 043/2010, there shall be a possibility of bidirectional communication between the metering device and the data management center. In regard to the choice of the communication protocol, we propose that it should be at the discretion of the distributor.
In the Technical Note made available in the Public Hearing 043/2010, ANEEL comments that the possibility of remote communication between the metering system and the distributor’s management center must be foreseen, as follows:

- Means of communication for data traffic: at least one means of communication for data traffic between the central data management center and the metering system must be available;
- Remote acting: there must be a capacity for suspension and reconnection of the electricity supply remotely;
- Data Traffic Directing: there must be an available capacity of bidirectional communication between the central data management system and the metering system; and
- Communication protocol: the communication protocols shall be chosen at the discretion of the distributor and they shall necessarily be public.

These requirements for smart meters have not been determined yet as of January 2012. Once standards for smart meters are enacted, more than 20 manufacturers can sell meters after obtaining the approval by Instituto Nacional de Metrologia, Normalização e Qualidade Industrial (INMETRO). However, it will take at least half a year to take INMETRO’s approval.

(3) Activities of distribution companies

Several distribution companies that the survey team visited have installed smart meters to reduce non-technical losses. Those companies mainly use smart meters made by manufacturers such as GE, Landis+Gyr and ERSTER. For example, AES Eletropaulo uses three phases smart meters made by GE for its pilot project, and their prices are R$400 ~ 500. However, the price is expected to be around US$ 100 in the future. Activities regarding smart meters are shown below.

Table 4.6.2 Activities regarding smart meters

Company	Activities regarding smart meters
CPFL	AMR will be installed in the future. However, there is no specific plan.
AES Eletropaulo	Slum Morada do Sol project phase 1: Smart meter The operation started already installing 560 Elester smart meters with AMR functions. Phase 2 will be implemented. Installation of smart meters will be completed by January 2012.
Light	2,000 Electra smart meters with AMR functions were already installed in the past two years. Several meters and communication equipment are stored in a box adjacent to the low voltage lines on an electric pole. It is planned to expand smart meters to 60,000.
AMPLA	Smart meters with AMR function are being installed in Buzios Smart City project area. Several meters and communication equipment are stored in a box adjacent to the low voltage lines on an electric pole. AMPLA is considering using Landis + Gyr smart meters.
Copel	7,000 AMR meters are installed in Foz de Londrina. Several meters and communication equipment are stored in a box adjacent to the low voltage lines on an electric pole. A pilot project of installing smart meters in large customers is scheduled in Fazenda Rio Grande. Installing smart meters in residential customers is under consideration. AMPLA is considering using Elester smart meters.
CEAL (Eletrobras' subsidiary)	Smart meters with AMR functions are scheduled to be installed in Parintins that has 1,600 customers by December 2012. (Now in the bidding process)

(4) Smart Meter Manufacturers in Brazil

Activities of smart meter manufacturers in Brazil are described below.

・EDP

EDP and Ecil Informatica collaborate to develop smart meters and plan to install 15,300 meters in Aparecida located 170 km from Sao Paulo as a pilot project. The meters satisfy specifications provided by the public hearing in 2010. The price of the meters is three or four times as high as the existing ones. However, the price is expected to be lowered due to mass production in the future.

Fig. 4.6.2 An example of smart meter by EDP (MD-1400 single phase)

・Elester

Elester is a meter manufacturer that has a head office in Germany and 38 branches in the world. Since 1967, Elester has manufactured meters of electric power, water, and gas. It sells smart meters for pilot projects to Light in Rio de Janeiro and AES Eletropaulo in Sao Paulo. According to Mr. Simon Beresford-Wylie, CEO of Elester, Brazil is regarded as the most important market. Thus, Elester Integrated Solutions was founded in Sao Paulo to provide new solutions in collaboration with other bases in South America.

・Landis + Gyr

Landis + Gyr has a plant in Curitiba to provide meters for residential, industrial and power sectors. It focuses on the smart meter system named SGP+M. In this SGP+M system, several smart meters are stored in a box. This system is sold in Colombia, Jamaica, and Mexico as well as Brazil. In Brazil, 440 sets and 110 sets of SGP+M systems are sold to Ampla and Light, respectively.

Fig. 4.6.3 An example of smart meter by Landis + Gyr (SGP+M)

4.7 Distribution Loss and Outage of Each Distribution Company

4.7.1 Current situation of non-technical losses

Distribution losses in Brazil are about 15.6% in 2010 (Tech: 8.3%, Non-Tech: 7.3%). As the level of the non-technical losses is higher than that in other countries, most of the companies are struggling to reduce their levels.

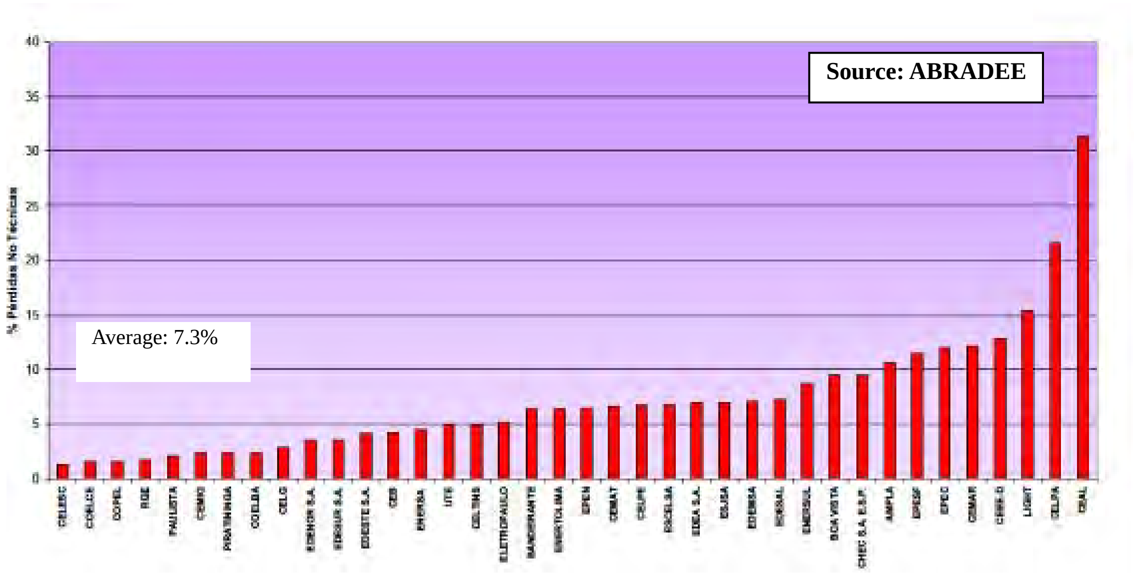


Fig. 4.7.1 Non-technical Losses in each Distribution Companies

(1) Case of Eletrobras

In general, all of Eletrobras' six distribution companies are suffering from the high non-technical losses in 2010. But because of the lack of project fund and its wide service area it is very difficult to improve them dramatically.

Especially in Amazon area non-technical losses are more than 40% in 2010.

Table 4.7.1 Technical and Non-technical Losses in Eletrobras

Companies	Technical Losses	Non-technical Losses	Total Losses
A) ELB Amazonas	2.10%	40.30%	42.40%
B) ELB Acre	11.87%	12.22%	24.09%
C) ELB Alagoas	8.42%	23.03%	31.45%
D) ELB Piauí	12.60%	20.91%	33.51%
E) ELB Rondônia	10.00%	23.99%	33.99%
F) ELB Roraima	8.10%	8.03%	16.13%

Source: Eletrobras annual report 2010

Fig. 4.7.2 Distribution Companies of Eletrobras

(2) Success case to reduce the non-technical losses in Brazil

Rio de Janeiro is the area where the highest electric thefts occurred among any other cities. One of the effective measurements is digital meter installed in high places.

The definition of the smart meter includes the followings.

- Introduction of the digital meter (Prevent tampering)
- Heightening the installing places
- Comparison between mother meter and customer consumptions

The following is a success model project.

Electric theft was easy when the meter was installed in the customer building. The meter boxes are introduced on the pole at medium voltage and their KWHs are monitored.

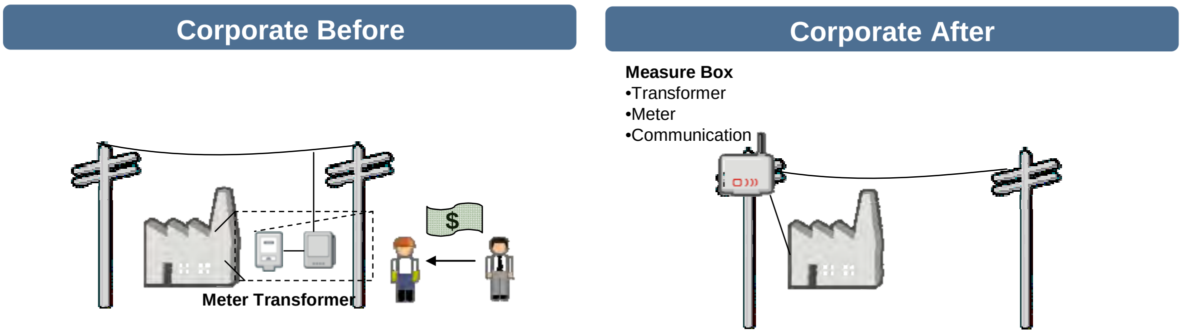


Fig. 4.7.3 Prevention of energy theft (1)

Bundled low voltage wires instead of four wires were introduced at the same height of the middle voltage line. And the second concentrators are installed on the pole and consumption displays are installed inside customer's house.

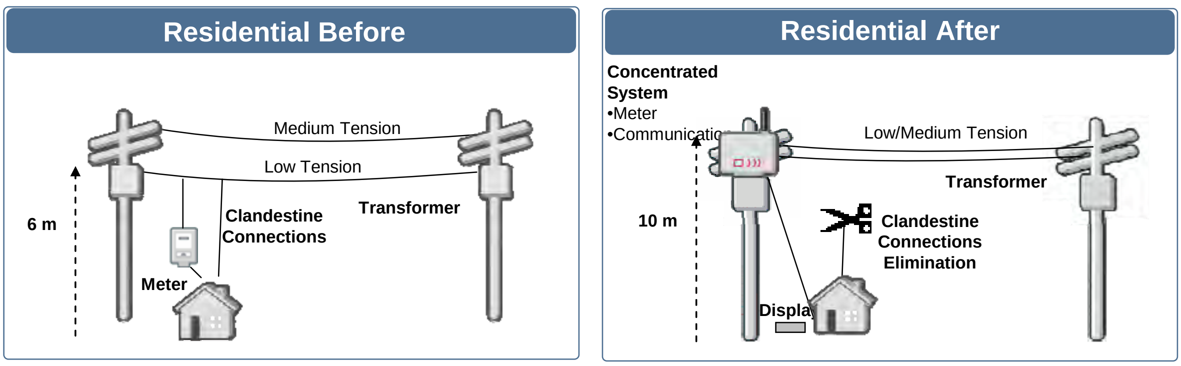


Fig. 4.7.4 Prevention of energy theft (2)

4.7.2 Power qualities in each distribution company

The quality of energy supply is measured by means of two indicators: SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index), which are monitored by the company and by ANEEL. Roughly 50% of the interruptions in 2010 originated in causes that were external to the system (natural phenomena and the environment), 34% were of internal origin (equipment failures, human error, handling errors, etc.) and 16% were scheduled interruptions. Among the main external causes, lightning was responsible for 27%, contact between birds and animals and the network represented 10% and tree-related interruptions accounted for 8%.

Here is the current SAIDI and SAIFI of each distribution company. The average of SAIDI is 18.4 hours and the average of SAIFI is 11.35 times in 2010.

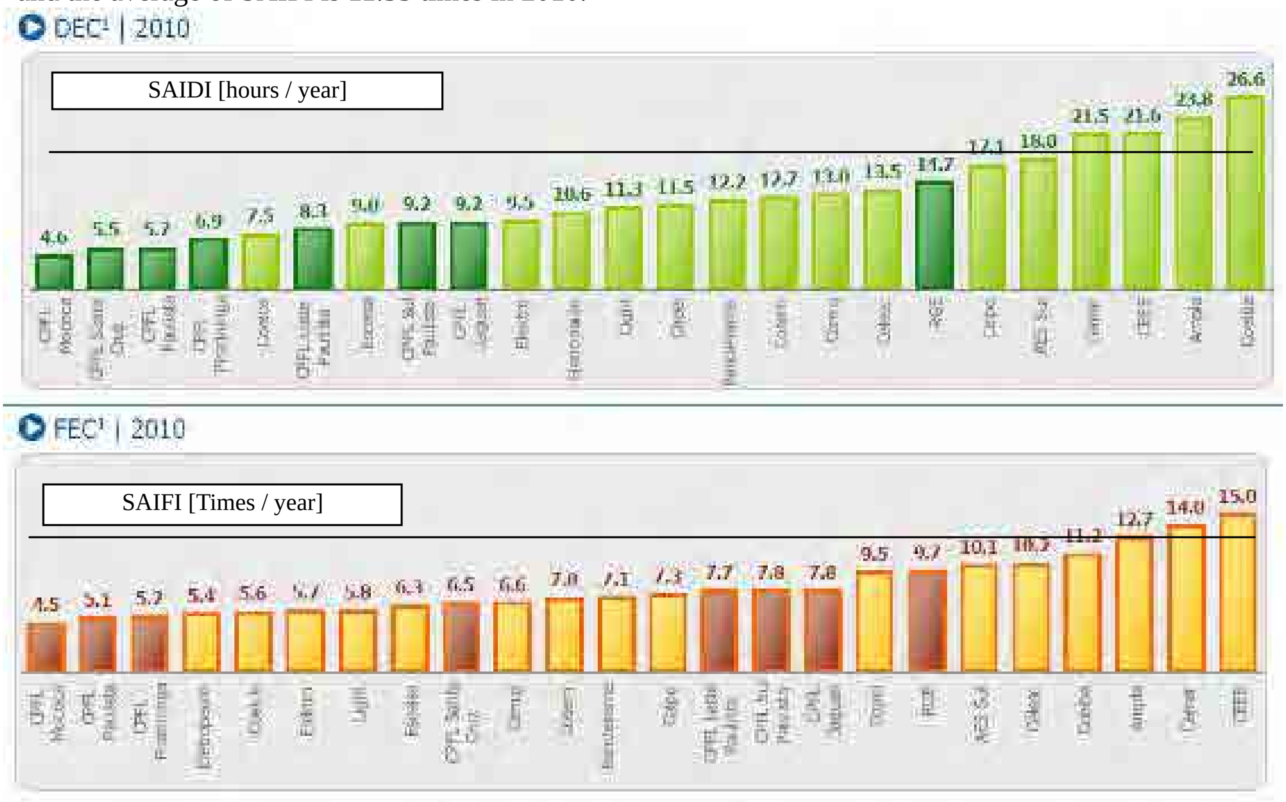


Fig. 4.7.5 SAIDI and SAIFI of Brazilian Distribution Company

Case of Eletrobras
The power reliabilities of Eletrobras supplying power to six rural areas are as follows,
For the past couple of years, there is an improvement in power reliabilities.

Table 4.7.2 SAIFI and SAIDI of Eletrobras

SAIDI	**ED Acre**	**ED Alagoas**	**ED Amazonas (Manaus)**	**ED Piauí**	**ED Rondônia**	**ED Roraima**
2009	47	21	104 (52)	44	34	9
2010	45	20	41 (72)	32	17	17

SAIFI	**ED Acre**	**ED Alagoas**	**ED Amazonas (Manaus)**	**ED Piauí**	**ED Rondônia**	**ED Roraima**
2009	42	16	107 (31)	33	42	21
2010	44	14	32 (60)	32	30	22

4.8 Technical and Managerial Capabilities of Each Distribution Company

The JICA team visited seven distribution utilities and assumed that technical and management levels of the companies are relatively high and they have enough capabilities to maintain smart grid facilities.
The main reasons to decide their high capabilities are as follows.

- ✓ Good management of facilities data because the distribution facilities such as distribution lines, poles and transformers are well maintained by GIS and the team did not see any facilities in bad conditions
- ✓ According to the interviews at the site, the team found that the technicians can understand their facility information well.
- ✓ Among distribution losses, most of the losses are by non-technical losses and technical losses are not so high considering the geographic characteristics and bad conditions of the consumers.
- ✓ They already installed and planned new methods and new facilities.

There are some problems in Brazil according to the interviews with JETRO. The wages of the engineers are skyrocketed because of the lack of engineers and the companies are suffering from the recruit of the good quality employees and need to pay high salaries to keep them.

According to the report of ANEEL, it requires to provide the investment of the capacity building for the engineers who engaged in the research and development of smart metering devices and Information Technologies. The industry estimates an investment in training of employees amounts to R$ 2,800,000.00. This amount includes the cost of training itself, travel, accommodation and meals.

Power utilities also cooperate with some universities below to develop the human resources and co-invest R&D such as renewable energy and power systems.

- ✓ Energia Escola Politecnica Universidade Sao Paulo
- ✓ Rio Cathoric University (IEPUC)
- ✓ Manaus Amazon University(UEA)
- ✓ CPqD Campinas Institution
- ✓ Univer Cemig

Chapter 5 Elemental Technology for Smart Grid Introduction into Brazil

5.1 Elemental Smart Grid Technology

5.1.1 Issue of Communication System

The communication network of this smart grid consists of two networks – backbone network and last one mile network.
The analysis of the communication method adopted in the two networks is as follows.

(1) Backbone network

The data between the control center and M-RTU of a substation and between the M-RTU and feeder (MV) RTU are transmitted and received through the backbone network.

The back-bone network shall be high speed with large data transmission capacity.

There are several options for the backbone network, which are compared in Table 5.1.1.

Table 5.1.1 Comparison of Backbone Communication (X < △ < ○ < ◎ Good)

	Wireless (Wi-Fi)	Fiber Optics	Wireless (GPRS)	PLC
Latency	△	◎	X	X
Reliability	X	◎	X	X
Congestion	◎	◎	X	◎
Resiliency	△	◎	○	X
Maturity	○	◎	◎	◎
Security	○	◎	△	◎
System Expansion	○	◎	△	X
Maintenance Cost	△	○	△	◎
Running Cost	◎	◎	X	◎
Initial Cost (Construction)	X	△	◎	○
Evaluation	**25**	**37**	**21**	**27**

Wi-Fi system is not suitable for the backbone network not only for their low reliability, speed and short transmission distance but also for resiliency during communication problem.

PLC is not a reliable communication method and very unstable in attenuation by reflection and transformer and frequent change of distribution network. Also the transmission speed is not suitable for the future AMR/DR/HEMS which requires high speed data transmission. Then it is very hard to apply for backbone network.

GPRS is not suitable because of its security problem in the public network. The cost can be higher to extend the DAS system and connect the network to a new system, HEMS. In addition, it is difficult for GPRS to upgrade the links to be suitable to high speed data transmission for DAS and HEMS.

The fiber optics communication is the most suitable among the four options but the initial construction cost is higher.
The installation cost of fiber optic cable on over head distribution lines is lower than that of underground cable system. Then it is possible to reduce the installation cost because the overhead distribution line is major in Brazil. Expected cost of fiber optic cable (24 cores) is about US$6,000/ km according to the information from COPEL.

Therefore, the fiber optics communication, which allows high speed and large capacity transmission as well as stable communication, is the best for the backbone network in Brazil.

(2) Last one mile network mainly for Automatic Meter Reading (AMR)

The data between the smart meter and RTU or Concentrator are transmitted and received through the last one mile communication network. Transmission data are as follows.

● Down stream: 50 bytes per each 30mintes

● Up stream: 100bytes per 30minutes

Then required data capacity is (50+100) x 24hurs x 2twise x 31days = 223.2kbytes/month per one customer

The last one mile communication network requires transmission reliability and must be built at low cost.

It is very important that the cost for communication must be low because a large number of smart meters shall be installed for customers.

There are several options for the last one mile communication network, which are compared in Table 5.1.2.

Table 5.1.2 Comparison of Last One Mile Communication

	Fiber Optics	PLC*	Wireless (ZigBee)	Wireless (GPRS)	Wireless (RF Mesh)	Wireless (Wi-Fi)
Latency	◎	X	△	X	△	△
Reliability	◎	X	○	○	○	X
Resiliency	◎	X	◎	△	◎	△
Congestion	◎	○	○	X	○	○
Maturity	◎	○	X	X	X	X
Security	◎	◎	○	○	○	○
System Expansion	◎	X	○	X	○	○
Running Cost	◎	◎	◎	X	◎	◎
Maintenance Cost	○	◎	△	△	△	△
Initial Cost (Construction)	X	○	△	◎	○	○
Evaluation	**30**	**25**	**27**	**19**	**28**	**24**

The low speed and low transmission reliability of PLC is not suitable for the last one mile communication because it often generates transmission errors. The retry method is also not suitable since the major overhead line troubles caused by the retry process to recover from the transmission error state results in increasing of transmission time.

On the other hand, transmitted distance of Wi-Fi is short and reliability is not enough so that it does not provide an ad hoc function when one terminal is in failure. Therefore, Wi-Fi is not suitable for the last one mile communication.

It is easy for GPRS to expand to the last one mile communication because it utilizes the public phone network. However, there are three barriers for GPRS to overcome.

a. It is a public network and security must be ensured.

b. Telephone companies manage the networks and we need to consult with them to expand the networks into new business.

c. The running cost for the entire GPRS connection would be tremendous as shown below:

<Calculation of GPRS running cost>

R$ 8/month for 1Mb/unit

223.2kbytes ＜ 1Mbyte

R$ 8 x 12 months x 700,000 customers = R$ 67.2

For 20years, it may takes R$ 1344M (R$ 67.2M x 20years).

In case of a pilot plant with smaller number of customers, it may not cause a problem in the cost, but in case of actual operation, it may cause a big problem in the cost. Accordingly, it is not suitable to apply GPRS for the last one mile communication considering the running cost.

Fiber optics communication is the best in terms of performance but the problem is that it costs a lot for installation.
Use of fiber optics is recommended since large capacity data transmission is required in the future for customers to provide new functions and services such as remote access, remote medical diagnosis, and HEMS.

Data transmission speed of ZigBee is 20kbps to 250kbps which is suitable for handling the information transmission volume of the smart grid at the initial stage. The power consumption is very low and the transmission distance is short (10m to 70m), but the ad hoc function which can connect to 65,536 terminals may help to extend the communication distance and compensate the signal shedding by obstructions such as big buildings.
RF mesh will low cost and low power consumption which are the same as those of ZigBee provides a multi-hop mesh function with redundancies.

However, it is difficult to apply them to the future applications, which need large capacities of data transmission. The future applications are under development and it is important that the current system shall be operated at moderate cost.

Therefore, ZigBee or RF mesh should be applied to the last one mile communication for the next ten year and it is desirable to replace it with fiber optic communication in the future.

5.1.2 Distribution Fault Detection and Isolation System

The survey team proposes DAS (Distribution Automation System) which consists of server / communication network and has a function to automatically supply power to sound sections after detecting a fault section. Distribution systems in Brazil mainly consist of radial networks, and are assumed to be suitable for fault section detection method that is used in Japan. In this method, Load Break Switches (LBS) are closed successively to detect a fault section, and related equipment can identify the fault section without a computer.
The summary of the system is shown as follows:

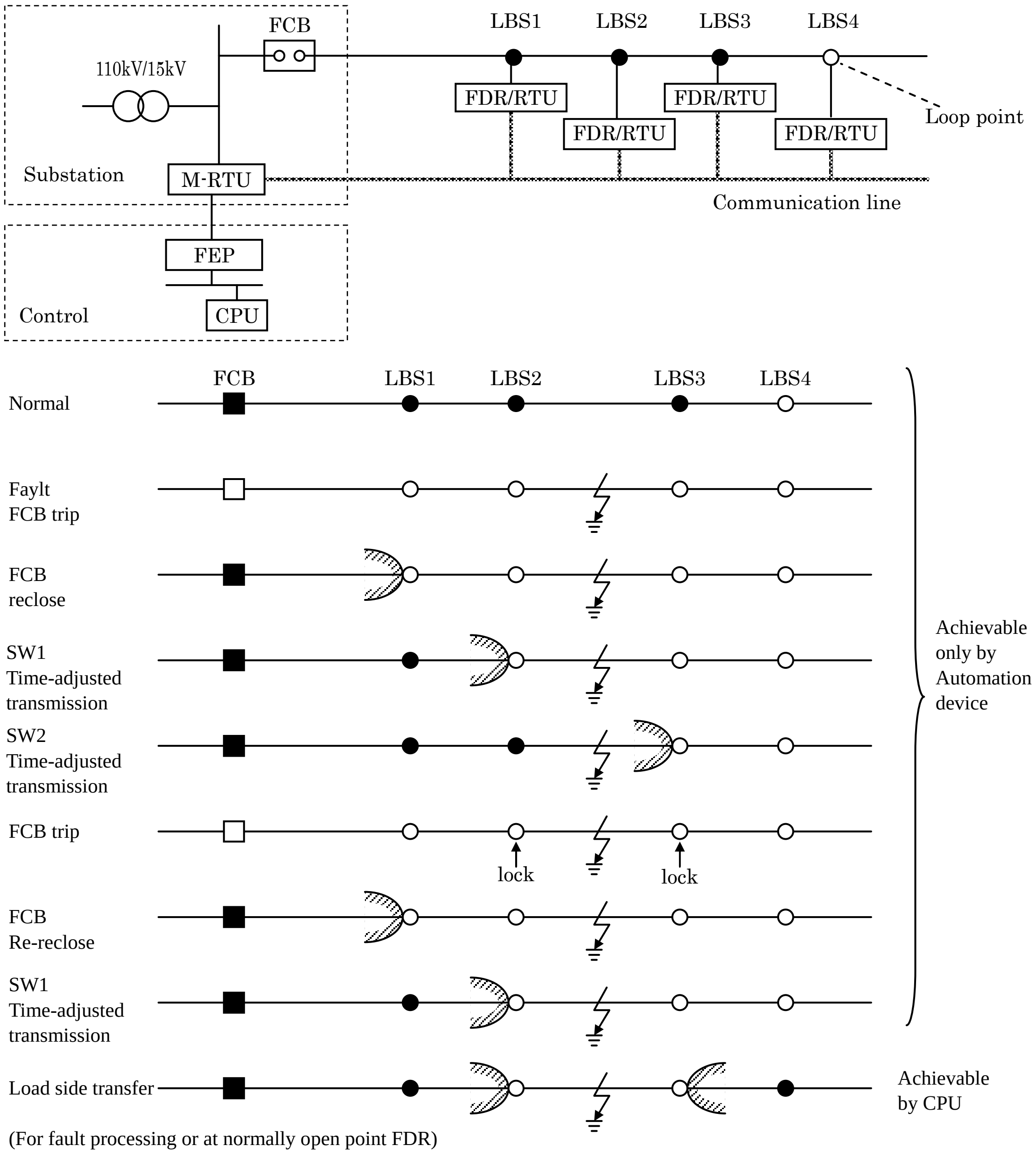


Fig. 5.1.1 Method of fault location detection: Voltage system
(Source: JICA Study Survey Team)

The fault detection system using a computer 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 computer. 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 computer, and a recovery procedure is provided to the operator. Once the operator confirmed the procedure, the computer is directed to operate switches by the operator. It is noted that the switches can be operated automatically without operator's decision.
Reclosers are installed in the existing distribution systems in Brazil. Recovery procedure provided by Distribution Automation System can be applied if the reclosers are installed on branch circuits. In this case, the existing facilities can be used effectively.
Placing reclosers on a main line in a series is not appropriate because protection coordination between

reclosers of a Circuit Breaker in a substation and Circuit Breakers of customers is difficult (due to a margin of error and deterioration with age), and recovery process is complicated if electricity is supplied to reclosers from interconnected point and if reclosers belong to another line due to a change of distribution system.

5.1.3 Installment and Exchange of Smart Meters

The Government of Brazil plans to change 65 millions of meters with smart meters by 2021. In this Section, functions of smart meters are studied based on the current situation.

(1) Needs for Smart Meters

Needs for smart meters and necessary functions in Brazil are summarized in the list shown below.

Table 5.1.3 Need for smart meters in Brazil

Issues	Expected effects of smart meters
Non technical loss reduction	・Introduction of Auto Meter Reading (AMR) to reduce non-technical loss
Peak load reduction	・Peak shift using Time of Use rate ・Peak cut using Demand Response
Streamlining for power supply cost	・Saving of meter reading work using Auto Meter Reading (AMR)
Facilitating renewable energy	・Introduction of net metering

(2) Regulation on Smart Meter

Although several distribution companies have already implemented pilot projects using smart meters, official regulations on smart meters have not yet been decided yet, as of January 2011. Technical note “0044/2010” provided by ANEEL describes the details of their studies and minimum requirements for smart meters as shown below. However, detailed functions and specifications have not yet been decided yet.

- Function to record power outage information
  - ✓ Duration of interruption per customer year（DIC）
  - ✓ Number of interruption per customer year（FIC）
  - ✓ Maximum duration of interruption per customer（DMIC）
- Function to measure in four time charging rates
- Information to customers
  - ✓ Real time rates
  - ✓ Active and reactive power energy
- Open and close function by remote control

ANEEL

Nota Técnica n° 0044/2010-SRD/ANEEL

Em 17 de setembro de 2010.

Processo: 48500.005714/2009-46

Assunto: Instauração de Audiência Pública no intuito de coletar subsídios para Resolução Normativa acerca da implantação de medidores eletrônicos em unidades consumidoras do Grupo B.

Fig. 5.1.2 Technical note “0044/2010”

(3) Basic requirements for smart meters

Basic requirements for smart meters are shown below. Communication between customers and a control center is needed to develop comprehensive systems.

- Function : Auto meter reading, remote control of switches
- Target information : Power consumption, adverse current, time information
- Transmitted to : Customers and electric power companies

(4) Elemental Technology for Smart Meter

Based on the abovementioned discussion from (1) to (3), the elemental core technology for smart meter in Brazil is studied.

- Function needed for reducing non-technical losses

  Functions of smart meters to reduce non-technical losses are listed below.

Table 5.1.4 Functions of smart meters to reduce non technical losses

Issues	Functions
Non performing WHM	・ Checking the performance by AMR
Mistake of meter reader	・ AMR sends accurate digital data to the control center
Pilferage by manipulation of meters	・ An alarm is raised when the cover is opened
Energy theft by direct tapping	・ Ditto
Direct connection to the source side of a meter	・ Function to raise an alarm when a voltage drop occurs ・ Function to detect difference of energy consumption between a distribution transformer and related customers.

- Function needed for reducing peak load

  In Brazil, time of use (TOU) rate is scheduled for low voltage customers. However, specifications of meters needed for TOU have not been decided yet. Examples of functions to reduce peak load are shown below. It is noted that calculation for each time zone can be implemented in a host computer.

Table 5.1.5 Functions of smart meters to reduce peak load

Issues	Functions
Time of Use rate	Measurement and saving of energy consumption (Ex. Data collection interval is 30 minutes)
	Calculation (Ex.: calculation for each time zone can be implemented in a host computer.)
Peak cut by Demand Response (DR)	Opening and closing electricity by remote control
	Providing information to customers ✓ Real time pricing ✓ Active and reactive power consumption

・ Other functions

Several distribution companies that survey team visited plan to install smart meters to streamline their works. Moreover, providing information such as power outage can lead to the improvement of customer satisfaction. The function to change contracts by smart meters is assumed to be effective if workers are frequently dispatched to the site, although this function is not referred in technical notes written by ANEEL.

Table 5.1.6 Other functions of smart meters

Issues	Functions
Streamlining works	Switching function ✓ Open and close electricity by remote control
	Changing contracts by remote control
Improvement of services	Providing information to customers ✓ Active and reactive power consumption ✓ Power outage information

5.1.4 Renewable Energy (PV)

The smart grid technologies are discussed mainly in Brazilian electric distribution power fields and in this study, the scope covers especially Photovoltaic power connected with the distribution system. In contrast the wind turbines which are now developing in Brasil are connected with transmission lines. This study should focus on Photovoltaic Power.

In 2011 only one mega solar power project in Brazil that is already operating in Ceara State is Taua solar power project. Brazilian photovoltaic power developments have just started now. According to the interview mentioned Chapter 2.10.3 about photovoltaic power development, there are many mega solar projects planned in Brazil now and many mega solar projects will be operated within the several years.

Here are the concerned problems in power system when many photovoltaic power plants are connected with distribution lines.

Table 5.1.7 Concerned Problems

Items	Concerned Problems	Measurements
1. Voltage Deviation	Distribution voltage near end rises by photovoltaic power during the light load condition.	Battery SVR
2. D & S Balance (Frequency)	Photovoltaic power fluctuates time to time and needs to control and store energy properly to keep the constant frequency.	Battery Control of photovoltaic power
3. Safety Islanding Operation	Photovoltaic power has risks to supply power unexpectedly to distribution feeder even if during the outage for net work maintenance.	Control of SW for Photovoltaic Protection relay monitoring
4. Protection Coordination	Photovoltaic power is isolated by malfunction of the protection relay when voltage fluctuations/ Instantaneous faults, etc. occur.	Monitor and Control of SW for Photovoltaic

These problems can be solved basically by monitoring the electric data in its feeder SWs and photovoltaic power which are not monitored now. Smart Grid Technology enables customers to monitor these data in the feeders by introducing distribution automation and smart meters.
Additionally, in remote areas such as Amazon and isolated islands in Brazil, it is expected to introduce photovoltaic power to reduce high price generating fuel supplied to micro grid system using diesel generation.
Model projects are studied in Parintins, Amazonas, and Fernando de Noronha Island, Pernambuco. In these micro grid projects, it is vital to coordinate diesel and 100kW class photovoltaic power in order to operate properly as hybrid system. If they are developed without technical study, solar intermittent output may lead the entire power system to collapse or unexpected generating interruption.

As shown image figure below, the total system outage may occur when the photovoltaic power output suddenly decreases. A series of diesel generators may force to stop according to the demand of micro grid. Because the diesel generators cannot follow the steep fluctuation of the power output from photovoltaic system and finally the demand and supply balance might be collapsed.
A general countermeasure against these problems is introducing batteries, but smart grid that can monitor and control each facility can also solve these problems so that these new measures can decrease the expensive batteries and photovoltaic generators can produce energy efficiently with their maximum capacities.

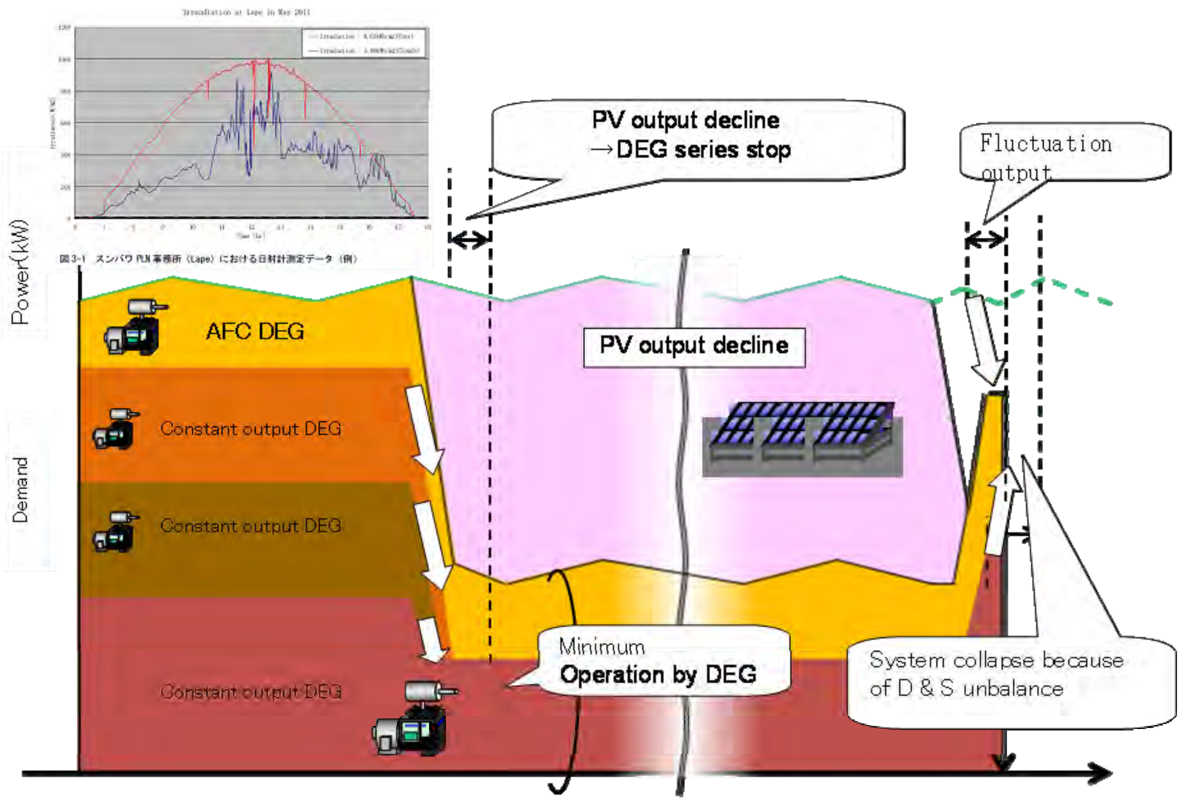


Fig. 5.1.3 Image of Photovoltaic Output Fluctuation and System Collapse

In this way, smart grid and smart meters can monitor and control the related data delicately so that these technologies can solve the voltage problems when many photovoltaic generators are connected to the grid in the near future.

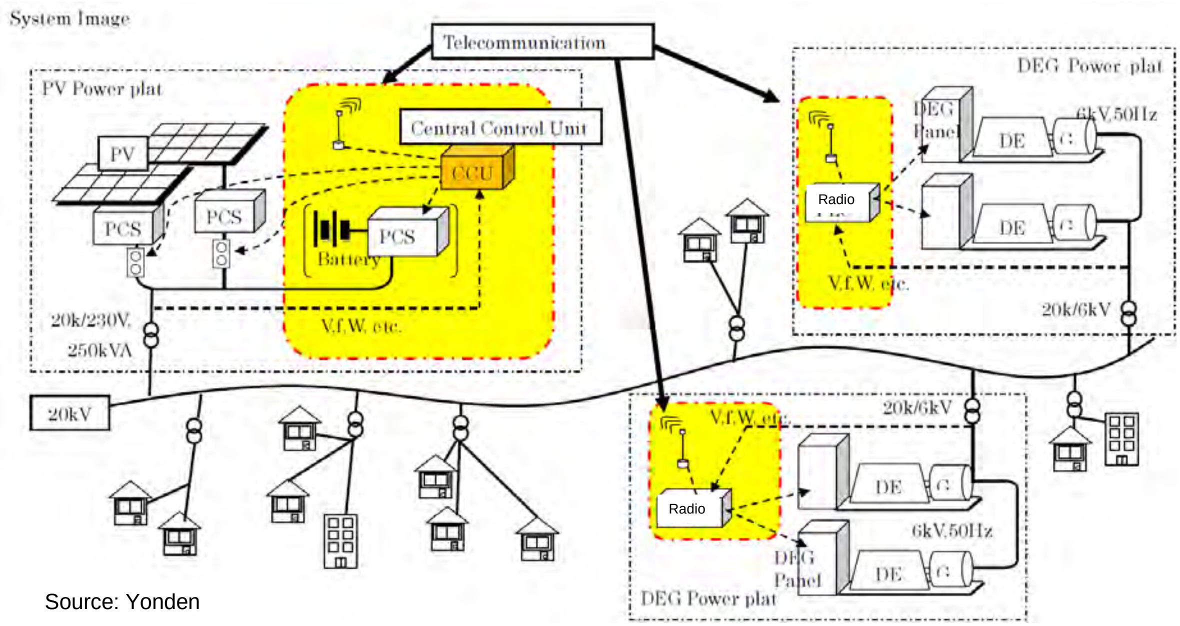


Fig. 5.1.4 An example of the photovoltaic control system using smart grid technology

5.1.5 Control Center

A schematic diagram of control center is shown below.

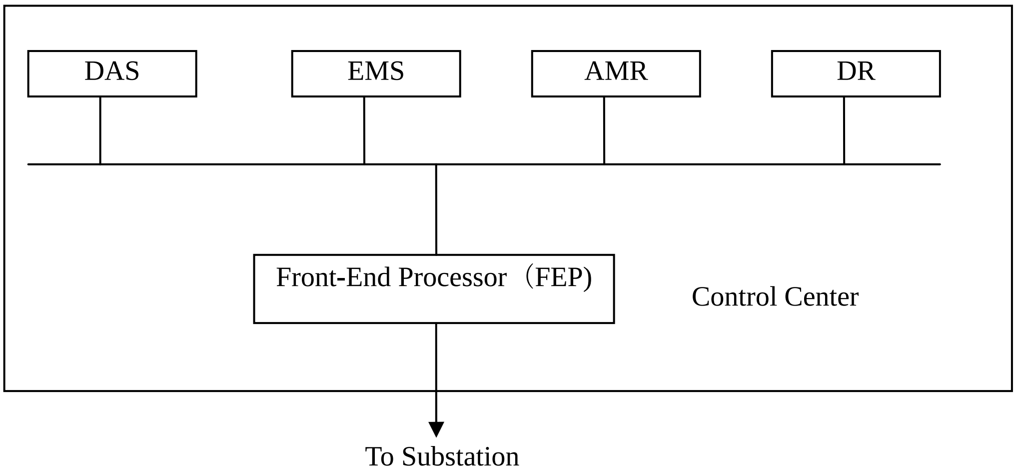


Fig. 5.1.5 Schematic diagram of control center

(1) DAS Server

Functions of DAS are shown below.

- Detecting and isolating the fault section and supplying power to sound sections
- Real time monitoring and control of substations and distribution systems
- Monitoring overload and demand side management
- Operating capacitors to improve power factor
- Data link to SCADA system, etc.

(2) DR server

When power supply is predicted to be short to meet increasing demand based on the SCADA data, planned blackout is implemented one after another for each designated area. Specifically, the demand response function provides command from the AMR server to smart meters located in an area beyond the threshold load level based on the results of monitoring.

Operation of embedded switch “off” as demand response will be carried out by the AMR server.

As well, operation of embedded switch “on” will be carried out by it, when load control can be released.

Demand response is different between houses such as ordinary customers and factories as large demand one.

a. House

When load control is carried out, in case of house as ordinary customer, it will be outage. However, when the recovery switch applied in smart meter is pushed, power supply will be recovered.

b. Factory (Large demand customers)

Considering a trouble when outage for all electricity in a factory happens, part of power for equipment such as air conditioners will go out in the factory using smart meters. A recovery switch of the smart meter enables power supply to be recovered, which is the same as smart meters for houses.

Starting timing of the demand response is considered as follows.

In the beginning of this project, the demand response should be started when power consumption value continues beyond specific time and power set for the initial condition through load monitoring of distribution network area.

In the future, the demand response will be upgraded so that it will be started through two-way communication with customers when power supply is expected to exceed the limit of power supply plan.

(3) Energy Management System (EMS) server

The function of controlling PV output fluctuations can be achieved by implementing rapid charging and discharging for storage battery repeatedly through monitoring power output condition from PV system connected to the distribution systems.

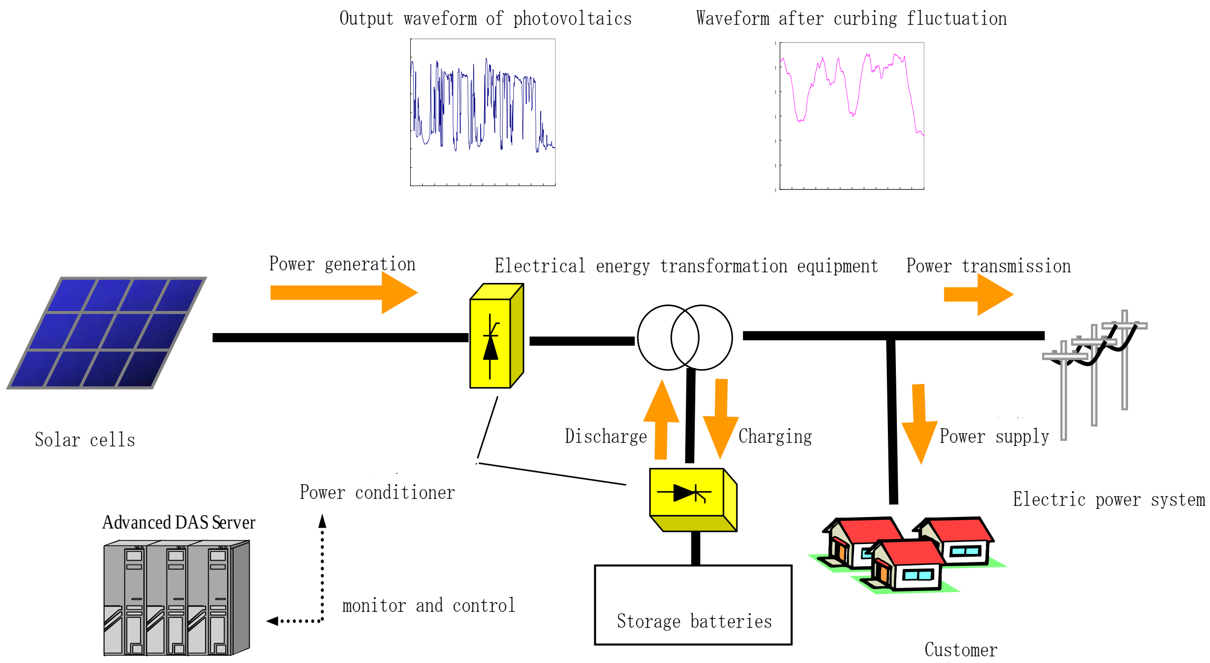


Fig. 5.1.6 Concept of controlling fluctuations from the PV output

(Source: made by Study Team)

By charging in midnight or morning time when energy consumption is low and discharging electricity when electricity consumption is high, leveling of incoming electric power (peak cut) can be carried out in the future.

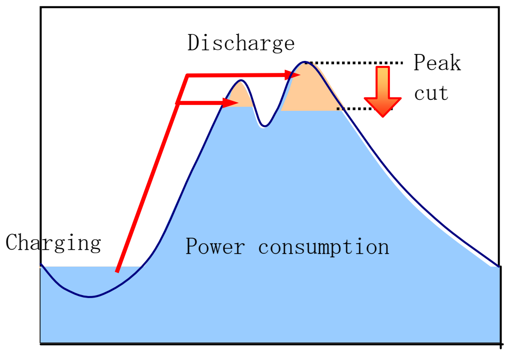


Fig. 5.1.7 Concept of leveling of incoming electric power

(Source: JICA Study Survey Team)

(4) AMR server

A remote automatic meter reading function enables meter reading work to be carried out from far places to measure power consumption value of houses or factories as large demand customer by the watt-meter function of smart meter.

Measured power consumption data are stored temporarily in a smart meter, and AMR server retrieves them periodically. The AMR server calculates the difference of power consumption between previous and present months and transfers the data to the billing system to complete the reading work.

Automatic data connection to the billing system will be introduced in the future.

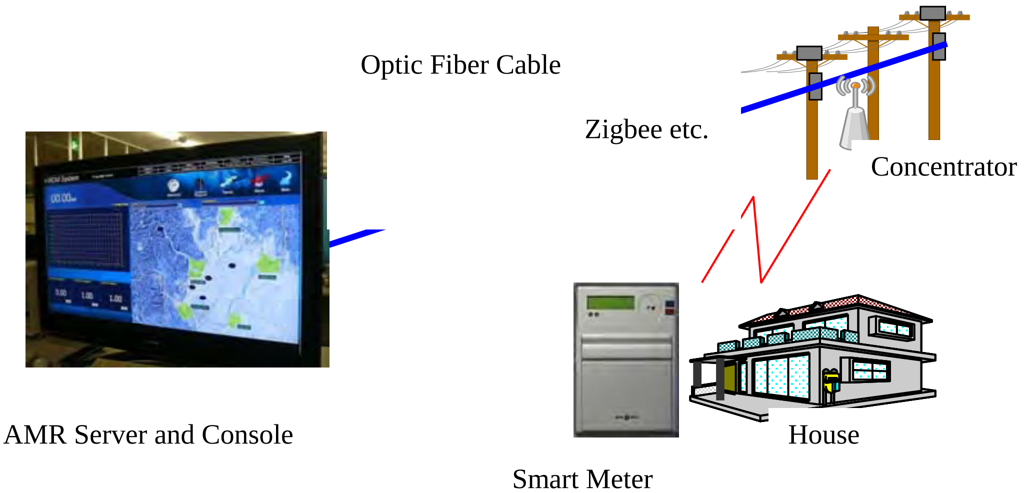


Fig. 5.1.8 Concept of AMR

(Source: JICA Study Survey Team)

(5) Front End Processor (FEP)

FEP functions as interface between DAS server and AMR server such as assistant processor to implement preliminary treatment of data so that the load of main computers is reduced. Communication control equipment is also included in FEP.

5.1.6 Demand Response and Peak Cut program

Demand response (DR) is a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability becomes out of minimum requirements.

DR program using smart meters is one of the smart grid concepts. DR is a tool for Power companies to reduce their peak time demand and there are two classified methods: Direct Load Control and Voluntary Load Control. The former is the system to control electric appliances such as air-conditioners by the power company to reduce their demand. And the latter is the system the customers control voluntarily their electric appliances in response to the information (price signal) from the power company. But both of them need smart meters with power switches to control the devices of the customers.

In Brazil, this DR program has just started now as the expected measure to improve the steep load curve and expected to improve the productivity and the power system operation rate.

This concept is introducing not only with TOU that is time based rates but also with critical peak pricing (CPP) that can reduce emergency peak demand when the demand and supply balance becomes critical in the power market.

This system uses the various tools such as monitoring the meter, Short Message Service (SMS), the Internet and telephone depending on the customers to give them the price information. The customers can have the incentives to get the rebate to participate in this program called incentive-based DR program.

- **The model project in CELESC (Centrais Elétricas de Santa Catarina)**

CELESC, the sixth distribution company in Santa Catarina, study studied three programs as follows;

(i) Demand Response in Florianópolis,

To be approved by ANEEL, the project Demand Response in Florianópolis, Santa Catarina, has the objective to improve load factor of distribution systems through the technology using demand response. The project will install load control devices in 10,000 consumers and smart meters in 3,500 consumers. The company hopes to avoid the occurrence of blackouts and shutdowns, especially in critical times during the summer. The demand management and the most efficient use of the power system will reduce the costs.

(ii) Measurement system in Blumenau

CELESC launched the Project Measurement system in Blumenau that aims to serve 3,670 consumers in the municipality. The project uses PLC (Power Line Communications) technology to send and receive information through the power energy distribution grid. The project implementation consists of three steps: 1) replace the mechanical meters for electronic meters, 2) install a new communication system between each meter and the Blumenau´s substation and 3) install a control center at the headquarters in Florianopolis.

The automated measurement system introduces many benefits such as automatic metering reading remote connection and disconnection modules in meters and automatic restart after the cut-off load curve of consumption automatic record of power failure with date and time of occurrence and monitoring the voltage on the grid.

(iii) Planning District Distribution Network and Generation of Sustainable Energy.

A project will be started in 2011 Planning District Distribution Network and Generation of Sustainable Energy aims to achieve integration planning for alternative sources of generation energy (renewable, waste and sewage) in a distribution district. This project will be applied in Sapiens Park in Florianopolis with the purpose to be sustainable in generation and consumption. Sustainable Energy district networks are defined as local electrical systems (consisting of generators, loads, storage and distribution). This project must justify the deployment of district networks in different environments of interest, promoting, for example:

- ✓ Energy efficiency and quality, supported by local management and operation
- ✓ Opportunity in the market for Smart Grids and offering new services
- ✓ Convergence of energy and environmental solutions.

The results can be applied in different environments/districts that seek quality and energy and environmental sustainability. Moreover, it is noteworthy that the solutions studied in the project can be implemented to modernize the electrical system.

- **The model project by Itaipu EV R&D division in Parana**

Itaipu is the binational company operating Itaipu power station and they are developing battery of EV as a part of smart grid program and conduct the verification research to cut peak demand using the battery of EV. Peak hours in Brazil are just 20 minutes around 6 pm and as shown in below figures, EV battery enables to cut the demand to discharge their power to the grid. They calculated the KW-value of this effect that is equal to the avoided cost to reduce the demand in these hours.

Considering EV battery discharge their power 400MW during 20 minutes peak time, the equivalent cost to develop hydropower is 600 million USD. It is necessary to prepare 200,000 EVs that have 2kW battery capacity in each. That means the value calculation of each EV is 3,000USD (600 million USD/200,000 EVs). These results can be considered KW-Value is 1,500USD per KW is valuable as social benefit in Brazil.

In the same way, peak power shift is effective to reduce generating cost by not only this EV battery but also switch off of residential power appliances such as air-conditioning and water shower heater and it is expecting the beneficial measures as the peak cut program.

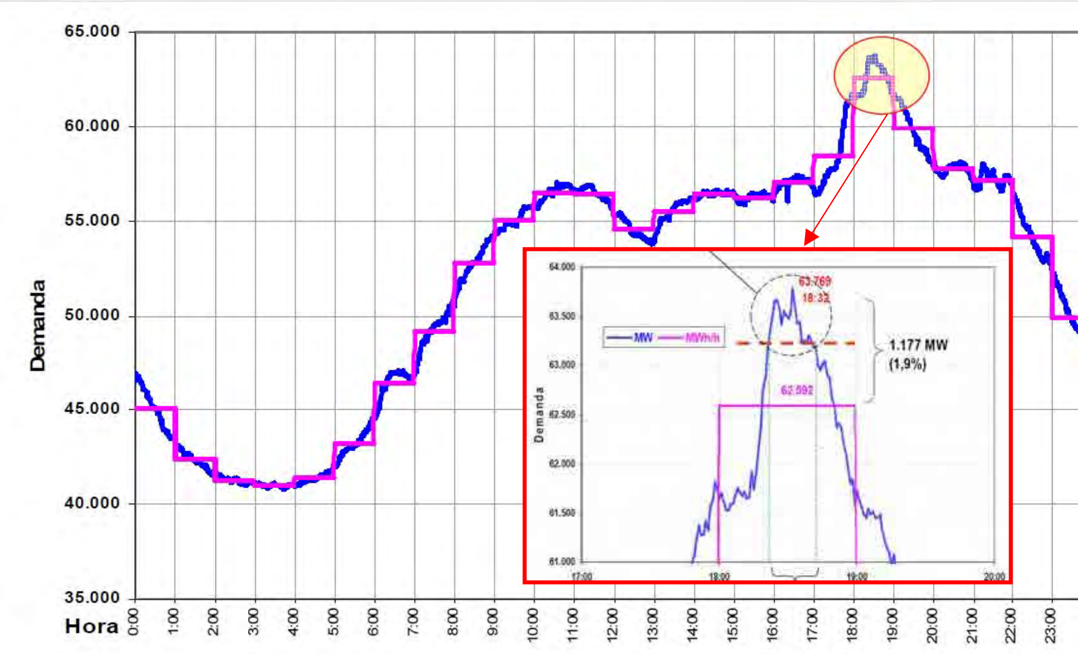


Fig. 5.1.9 Peak cut verification using EV battery

The water storage heaters which are expected to shift the peak load in Japan are not yet introduced in Brazil. The reason is that the TOU rules have just started to be considered now and there are no evidences to confirm its cost merit. In the near future after introducing TOU tariff, the water storage heaters will be expected to implement the demand shift.

5.2 Proposed System and Equipment Based on Investigation

1) Outline of the system and equipment

The core of smart grid is DAS and AMR as described in Clause 5.1. The system configuration is shown in Figure 5.2.1. After AMR is provided to be network, it is easy to provide the function of DR in smart grid. The explanation of each component is described in Table 5.2.1 and 5.2.2

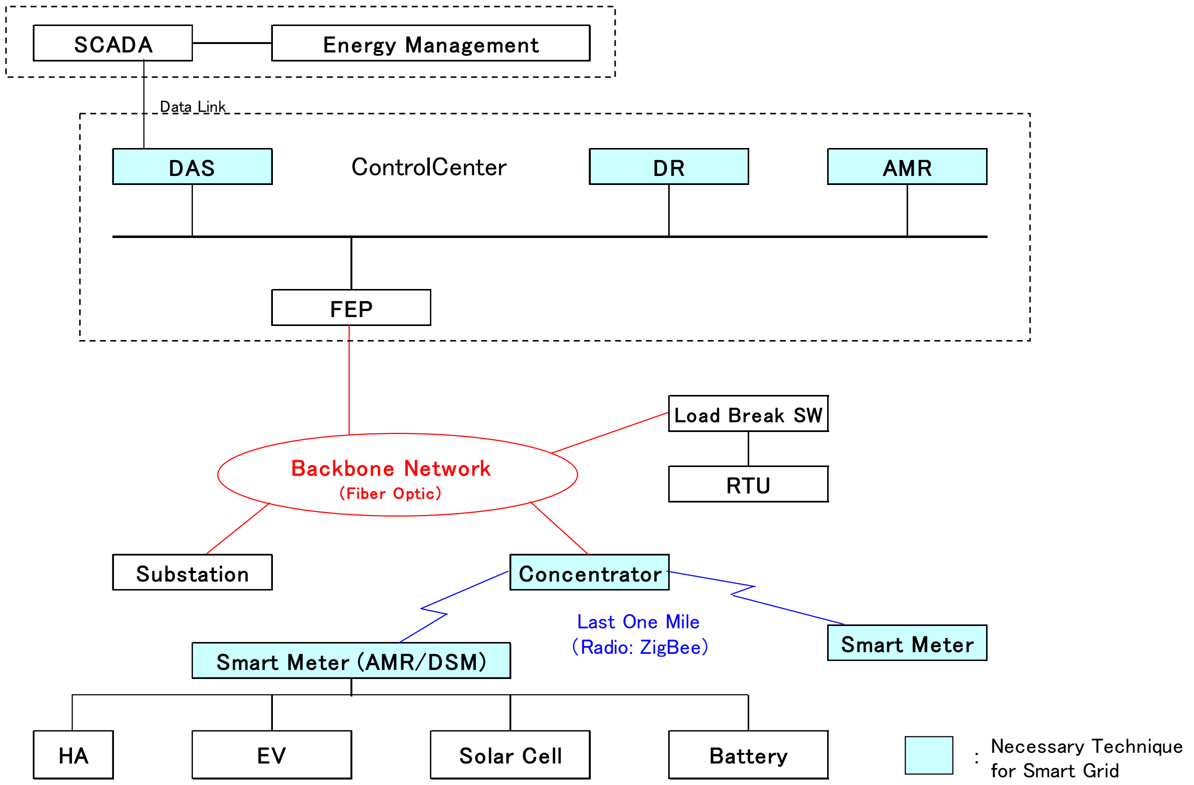


Fig. 5.2.1 System Configuration

(1) Control Center

Control Center is composed of DAS/AMR server. DAS can not only monitor the distribution substation and distribution equipment but also provide DR system.

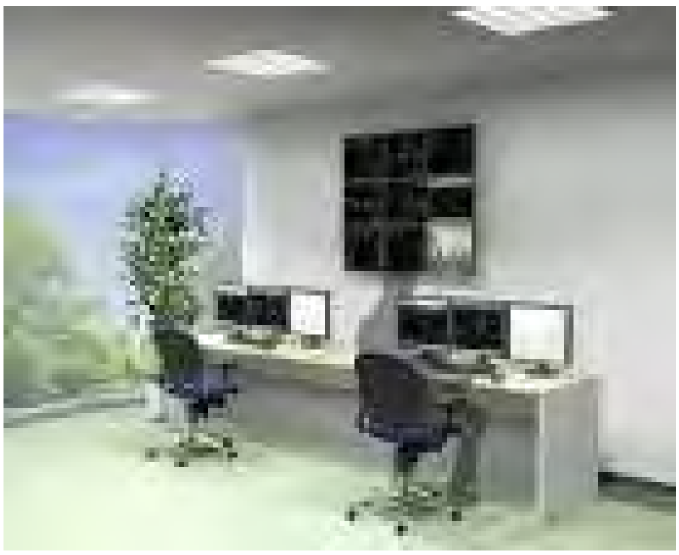


Fig. 5.2.2 View of Operator Room in Control Center

(2) Distribution Substation Facilities

In Distribution Substation, there are master Remote Terminal Units (RTU) to control distribution RTUs, protection relay and communication equipment for backbone network.

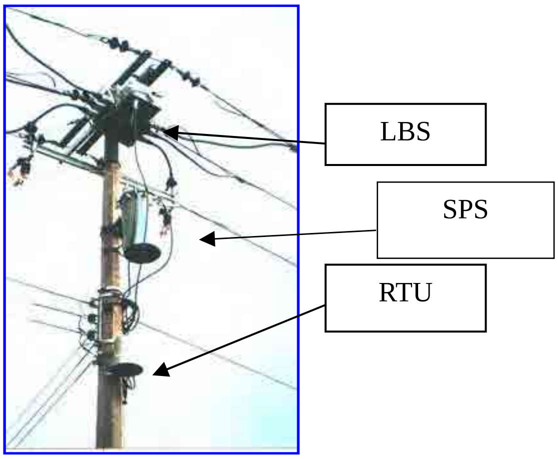
Table 5.2.1 Distribution Substation Facilities

Component	Explanation
M-RTU	M-RTU is installed in each substation to control all RTUs linking to the feeders of the substation and monitor the substation devices. (Sample) 
Automatic Reclosing Relay for FCB of OH Lines	Automatic Reclosing Relay is installed in the existing FCB board at substations. (Sample) 
TRD Board	TRD board is installed in each substation to measure the voltage and current for the banks and feeders.

(3) Distribution Equipment

Distribution facility is composed of 13.8kV Automatic load break switches, RTUs, Power transformers and arresters. In addition, smart meter is provided at each house and smart meters are connected to a concentrator on last one mile network.

Table 5.2.2 Distribution facilities

Component	Explanation
LBS	LBS is automatically switching equipment of OH line controlled through RTU. (Sample) 
Switch Power Supply (SPS)	SPS is to supply the power and detect the voltage.
RTU	RTU is to control LBS by receiving command from Control Center through M-RTU and sending status data to Control Center.
Arrester (for protection against lightning surge)	As the field equipment for OH is installed in outside, the protection equipment against lightning is necessary. Therefore, Arrester should be installed near DAS field equipment. (Sample) 
Smart Meter	Smart meter is an electronic watt-hour meter providing communication interface to transmit the data to center and load break switch interrupting the load. (Sample) 

2) Important points to advance the project

(1) Addition of Interconnection to Other Distribution Feeders
In overhead distribution system, there is no interconnection point or only one interconnection to other distribution feeder. Then it is not possible to feed the power beyond fault point. It is important to make interconnection extending the distribution line slightly. It is easy to extend the distribution feeder and it offers the benefit to feed new consumer from extended line. As providing new interconnection points, it is possible to shorten the outage time effectively.

(2) Provision of Automatic Load Breaks Switch
On trunk distribution line and at interconnection points, necessary automatic load break switch (ALBS) will be installed. If necessary, ALBS will be provided at the load side of recloser. In the existing distribution system, reclosers have been installed. It is recommended to replace the reclosers to the branch.

(3) Distribution Substation
Adaptation work is necessary to make interface to the existing facilities such as current/voltage transducers, protection relays and control switches, etc.

(4) Control Center
Each Control Center shall be provided in one management area in order to accelerate the treatment for multi faults case and daily amendment of network.
Distribution network is shown on the map and real time indication is available on the map. Further important point is that it is very easy to re-construct the database in DAS.
Also it is possible to indicate the information of consumer data by one crick on the display.
DAS can interconnect not only AMR server but also DR, EMS and SCADA system.

(5) Communication Network
The communication between Control Center and Substation will be fiber optic communication as backbone network. Fiber optic cables can be easily installed on the existing distribution line The communication between RTU/concentrator and smart meters will be ZigBee or RF Mesh. When all data cannot be transmitted by DAS RTU, additional concentrator will be provided to transmit the data from smart meters All data of concentrator will be transmitted to AMR server through backbone network.

5.3 Effect

5.3.1 Effect of Outage Duration Reduction

1) Shortening of outage duration
As shown in Fig. 5.3.1, if a fault occurs in Section 4 of the distribution line, the interruption will continue on all of the sections until the fault will be recovered. If DAS 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 5.3.1, whereas Table 5.3.2 shows fault detecting procedure after installation of DAS.

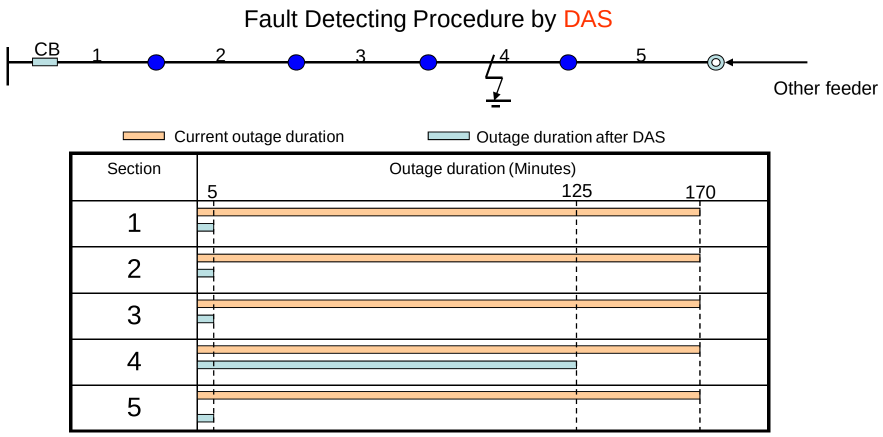


Fig. 5.3.1 Effect of shortening interruption time by DAS

Table 5.3.1 Current fault detecting procedure

（Source: Created by survey team based on PLN survey result）

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

Table 5.3.2 Fault detecting procedure after DAS installation

(Source: Created by survey team based on PLN survey result)

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

After DAS installation, the fault section (Section 4 in Fig.3.5.1) 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

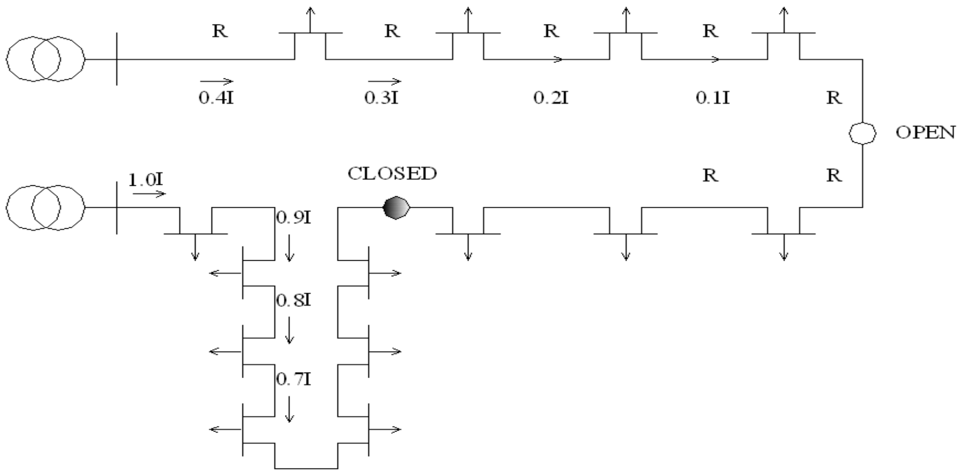
Meanwhile, based on the current system, interruption duration will be 170 min/section, which means the reduction rate is 80% as shown in the calculation below.

(29 min. / 170 min.) x 100% = 17% (≒ 20%)

5.3.2 Effect of Technical Loss Reduction

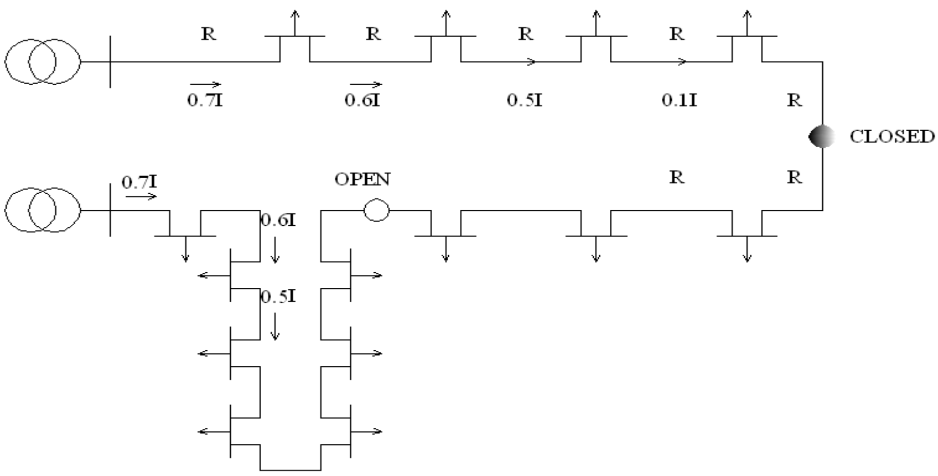
The load condition can be monitored on a real time basis by DAS, and if overload is detected, the load can be split to the neighboring distribution feeders by DAS to improve the unbalance. Based on the calculation, the technical losses can be improved by about 32.5% on medium voltage line.

<Before application of DAS>



Total losses $= (0.4I)^2 .R+(0.3I)^2.R+(0.2I)^2.R+(0.1I)^2.R+$
$(1.0I)^2.R+(0.9I)^2.R+(0.8\ I)^2.R+\ldots\ldots+(0.1I)^2.R$
$= 4.15\ I^2.R$

<After installation of DAS>



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 $= (4.15-2.80) *(100)/(4.15\ )$
$= 32.5\%$

5.3.3 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 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 comparing the data of RTU and Smart Meter.

Table 5.3.3 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.
*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 Study Team)

5.3.4 Improvement of Peak Demand 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 and make efficient operation of power stations.
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 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, consumers want to use power during the interruption and it is possible to use the power with higher tariff to make peak cut/ shift effective.

It is expected that the peak load of small consumers is 2kW (twice of AC consumption of 1kW) considering the future extension of demand.
Also it is expected that the interruptible load for large consumers is 30kW in three divided zones, then it is calculated the controlled load is 840MW in Curitiba City.

2kW x 640,000 + 30kW x 40,000 x 1/3 = 840MW

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.

Chapter 6 Model Projects

6.1 Model Project Site Candidates

6.1.1 Criteria for Model Site Selection

The criteria for smart grid model project site selection are set as follows.

- Areas with representative characteristics taking diverse regional characteristics in Brazil into consideration
- Public distribution company feasible for the future JICA support desirably
- Even planned pilot, but neither implemented immediately nor decided business participants
- Full of cooperation with JICA support project promotion
- Situation and areas as pilot model with show-window impacts on other distribution companies in Brazil

As results of the field survey considering the criteria above, the following two sites were selected as candidates.

(1) Curitiba City (Distribution company is COPEL, which is Parana State company)

(2) Maceio City (Distribution company is CEAL, which is an affiliated company of Eletrobras, national electric power company, serving Alagoas State)

The distribution companies covering these two candidate sites are public and the projects have not been implemented yet nor have been decided the participant companies and the planning is in the future. In addition, (1) Curitiba City represents relatively rich southern cities with low non-technical losses, but a top priority of power supply credibility. On the other hand, (2) Maceio City belongs to the relatively low-income northern region and has characteristics of high non-technical losses. Furthermore, (1) Curitiba City is famous for its environmental policies and public (bus) transportation systems and (2) Maceio City is a coastal resort city so that the model projects in both cities may have strong show window effects. Besides, on the occasion of the field survey, the distribution companies were very active and cooperative with JICA support model projects. In particular, not only COPEL but also Parana State Government showed their supporting attitudes in Curitiba City and seemed to long for the model project. Although CEAL in Maceio City said that the project decision was made by the parent company, Eletrobras, their desire and enthusiasm seemed very strong.

6.1.2 Overview of Model Site Candidates

(1) Curitiba City

Curitiba City is the capital of Parana State and the population is approximately 720,000. The distribution company is COPEL, which is managed by Parana State covering almost all the state area shown in Figure 6.1.1 (the west part is served by a private company). Curitiba City is located almost in the center of the state. It has industrial parks and Japanese companies such as Toshiba and Furukawa are located.

Focusing on the Curitiba City branch office of COPEL, its sold power in four districts including Curitiba City is seven million MWh, the revenues are R$ 1.72 billion and so the sold power unit price is R$ 0.245/kWh on average. Surely, the unit price in Curitiba City is the highest among the four districts shown in Figure 6.1.2.

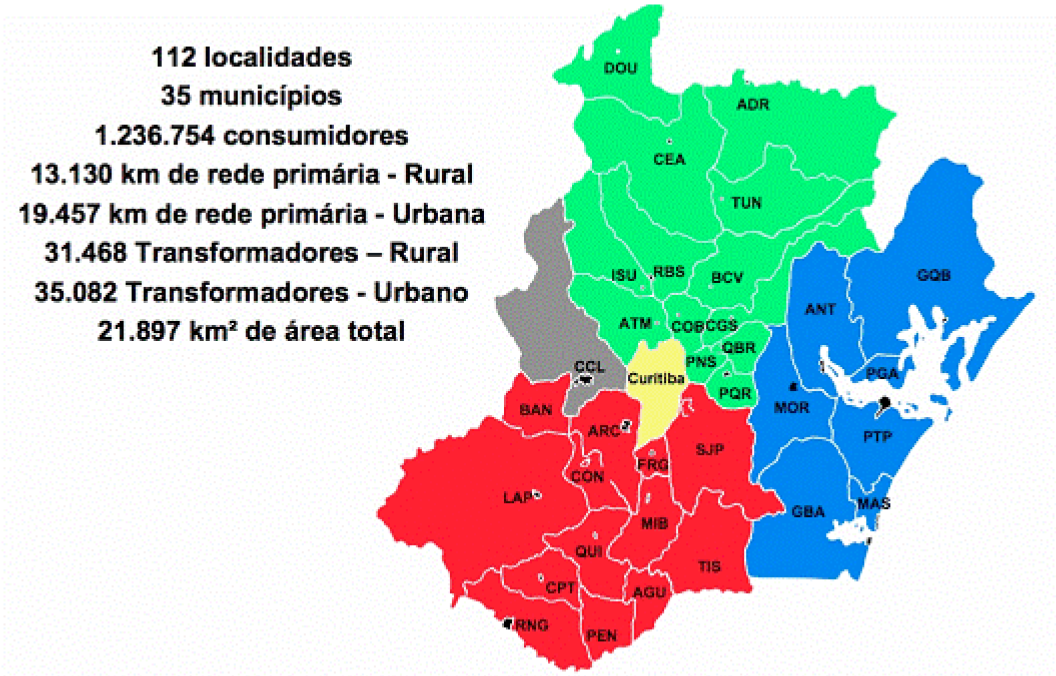


Fig. 6.1.1 Location of Curitiba City

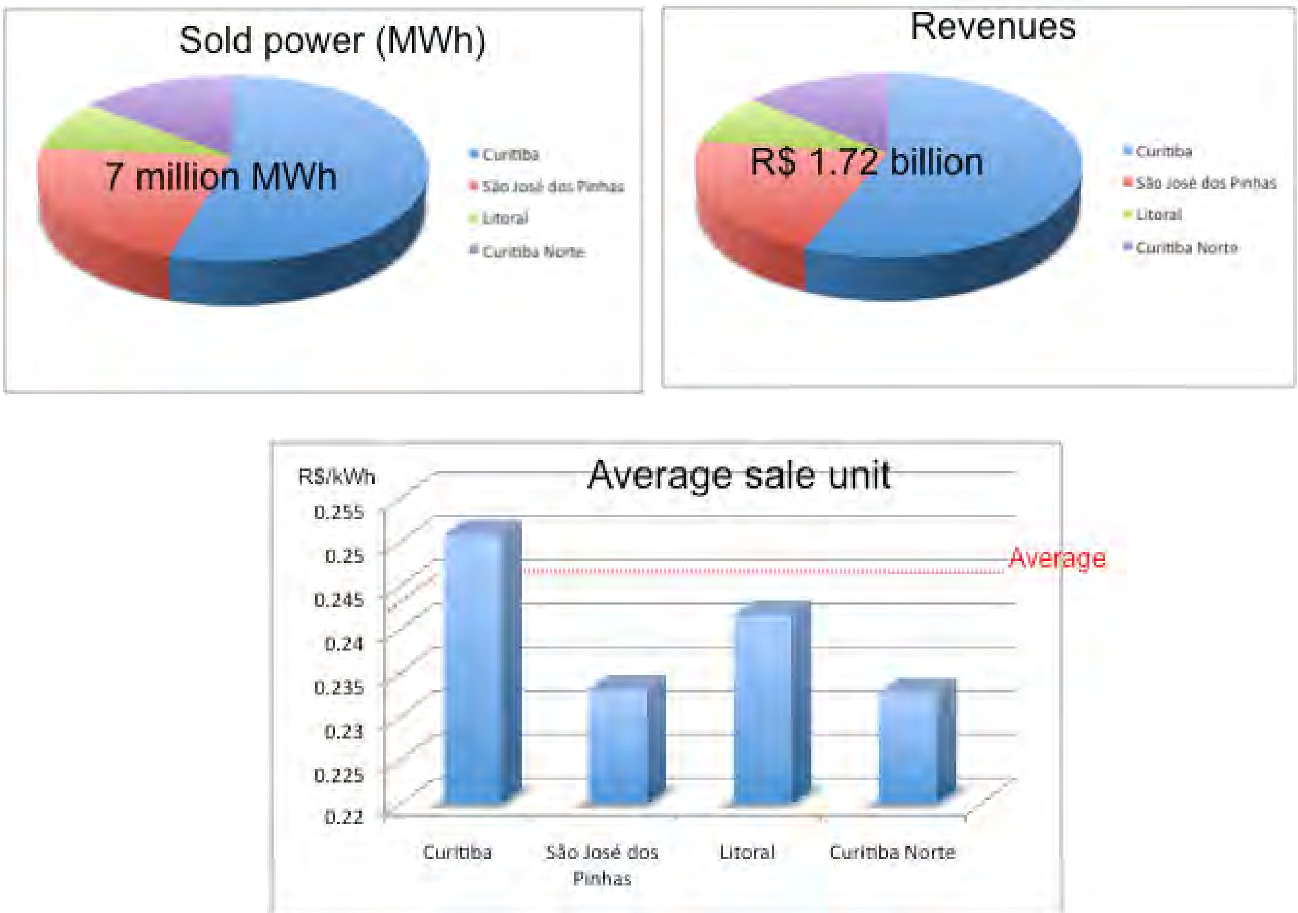


Fig. 6.1.2 Sold Power Situation in Curitiba City Branch Office Area

(2) Maceio City

Maceio City is the capital of Alagoas State located in north-east of Brazil. The population is approximately 950,000. The distribution company, Companhia Energética de Alagoas (CEAL), is one of the affiliated distribution companies of Eletrobras and covering Alagoas State. The candidate site is a coastal district representing the famous coastal resort city of Maceio.

Fig. 6.1.3 Location of Eletrobras' Subsidiary Distribution Companies

(Source: http://www.lonelyplanet.com/brazil)

6.1.3 Distribution Characteristics of Model Candidate Sites

The situations of distribution in both model candidate sites are summarized in Table 6.1.1.

Table 6.1.1 Distribution Situations of Model Candidate Sites

	No. of S.S	No. of feeders	No. of customers	Revenue	Consumption (MWh/year)
Curitiba City	24	197	718,000	MR$ 968	3,859,217
Maceio City	2	15	104,200	MR$ 188	-

	SAIDI 2010 (hours/year)	SAIFI 2010 (times/year)	Technical loss	Non-technical loss	Total loss
Curitiba City	10	9.5	6.5 %	1.5 %	8.0 %
Maceio City	16	(14)	8.42 %	23.03 %	31.45 %

SAIDI of both the districts are more than 10 hours and that of Maceio is 16 hours, more than that of Curitiba. Curitibiba's non-technical loss is low as 1.5%, but Maceio's is high as 23%. The scale of Curitiba is larger than Maceio's as nine times in the revenues and seven times in the customer number. The numbers of substations are 24 in Curitiba, but 2 in Maceio. The numbers of feeder lines are 197 in Curitiba but 15 in Maceio. However, COPEL's response to the model candidate site scale was that it was not too large.

6.2 Scope of Model Project

Project Scope of 2 model candidates is shown in Table 6.2.1 and Table 6.2.2.

Table 6.2.1 Scope of Curitiba branch office in COPEL

Scope(Equipment)	Scope (Quantity)	Explanation of configuration device
Control Center (DAS/AMR)	1 system in branch office	It comprises DAS/AMR server. DAS monitors and controls transformer stations and power distribution equipment. (DR can be also handled easily)
Field device (Transformer station & Power distribution device)	24 Substation in Curitiba branch office There are 220 feeder lines in Curitiba. 4 sections and 3 looped points are recommendable and so 3 ALBS for 4 sections and 1.5 ALBS for 3 looped points are installed in one feeder line. 220 x 4.5 = 990 => 1000 units	Substation equipment comprises Master RTU, Relay and other existing application devices and telecommunication devices that integrate the RTU for power distribution in the transformer stations. Power distribution equipment, comprises 13.8kV Automatic Load Break Switch (ALBS), RTU, power source transformer, arrestor, etc.
Smart Meter	There are 700,000 customers in Curitiba. The existing meters will be exchanged to smart meters for 10 years. => 70,000 smart meters per year	Smart Meter can be single-phase or 3-phase, and consists of electric power meter, switch and telecommunication device.
Capacitor for improvement of power factor	One capacitor will be installed on one feeder line. => 220 units	The capacitor is installed on the feeder line at 2/3 distance from the substation. The capacitor consists of RTU and ALBS, etc.
Fiber optic cable	0 km (Fiber optic cable already has been installed in Curitiba.)	Existing optic fiber (24-core/SM) is used for the communication.
Others	-	Engineering, Contingency, tax, etc.

Table 6.2.2 Scope of Coastal Resort City (CRC) in Eletrobras Alagoas

Scope (Equipment)	Scope (Quantity)	Explanation of configuration device
Control Center (DAS/AMR)	1 system in branch office	It comprises DAS/AMR server. DAS monitors and controls transformer stations and power distribution equipment. (DR can be handled easily, too.)
Field device (Transformer station & power distribution device)	2 Substations in Maceio branch office There are 220 feeder lines in Maceio. 4 sections and 3 looped points are recommendable and so 3 ALBS for 4 sections and 1.5 ALBS for 3 looped points are installed on one feeder line. 15 x 4.5 = 67.5 => 70 units	Substation equipment comprises Master RTU, relay and other existing application devices and telecommunication devices that integrate the RTU for power distribution in the transformer station. Power distribution equipment comprises 13.8kV Automatic Load Break Switch (ALBS), RTU, power source transformer, arrestor, etc.
Smart Meter	There are 104,200 customers in Maceio. Existing meters will be exchanged to smart meters for 10 years. => 10,000 smart meters per year	Smart meter can be single-phase or 3-phase, and consists of electric power meter, switch and telecommunication device.
Fiber Optic Cable	15 feeders x 20 km = 300 km 2 substations x 50 km = 100 km Spare: 300 km Total: 700 km	Optic fiber device (24-core/SM) will be installed along with the overheard distribution feeder.
Others	-	Engineering, Contingency, tax, etc.

6.3 Model Project Costs

Project costs of each model are shown in Table 6.3.1 and Table 6.3.2.

Table 6.3.1 Rough project cost of Curitiba branch office (CTA) in COPEL

Scope	Quantity	Unit Price	Cost (Million US$) (Quantity x Unit Price)
Control center	1	-	7
Substation Facilities Distribution Equipment	24 Substation (SS) 1,000 units	0.2 Million US$ / SS 15,000 US$ / unit	4.8 15.0
Smart Meter	70,000 (700,000)	100 US$	7.0 (70)*
Capacitor	220	45,000 US$	9.9
Fiber Optic	0	6,000 US$/km	0
Others (TAX, Engineering, Contingency etc)	50 %	-	21.9 (53.4)*
TOTAL	-		65.5 (160.1)*

Table 6.3.2 Rough project cost of Coastal Resort City (CRC) in Eletrobras Alagoas

Scope	Quantity	Unit Price	Cost (Million US$) (Quantity x Unit Price)
Control center	1	-	7
Substation Facilities Distribution Equipment	2 SS 70 units	0.2 Million US$ / SS 15,000 US$ / unit	0.4 1.1
Smart Meter	10,000 (104,200)	100 US$	1.0 (10)*
Fiber Optic	700km	6,000 US$/km	4.2
Others (TAX, Engineering, Contingency etc)	50 %	-	6.9 (11.4)*
TOTAL	-		20.6 (34.1)*

*: Cost in case that all of existing meter will be exchanged to smart meter in the first year.

6.4 Financial Effects of Model Project

(1) Reduction of outage duration

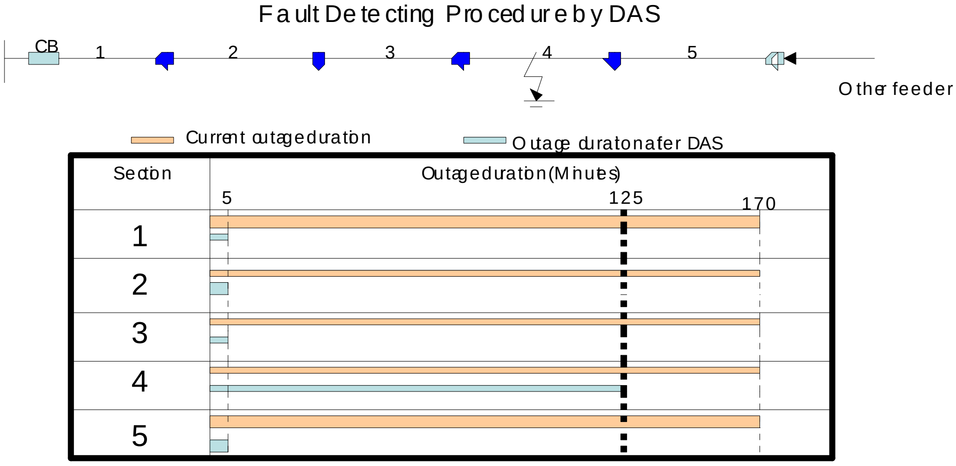


Fig. 6.4.1 Reduction effect of Outage Duration by DAS

As shown in Fig. 6.4.1, if a fault occurs in Section 4 of the distribution line, the outage will continue in all of the sections until the fault will be recovered.
After DAS installation, the faulty section (Section 4 in Fig.6.4.1) will be automatically isolated, and the other good sections (Area 1, 2, 3 & 5) will be supplied automatically within 5 minutes (about 1-2 minutes) and so the average interruption duration in all of the sections will be reduced. The effect of reduction is around 80% as introduced in Chapter 5.
SAIDIs in CTA of COPEL and CRC of Eletrobras are as follows and the economical benefits are also calculated as follows.

<Current outage duration: SAIDI>
- COPEL (CTA): 600 minutes/ customer year (2010)
- Eletrobras Alagoas (CRC): 960 minutes/ customer year

<Reduction of Outage duration by DAS>
DAS can reduce the outage duration to around 80% as explained above and the reduction duration for each distribution company is as follows.
- COPEL (CTA): 600 x 0.8 = 480 minutes (8H) reduction
- Eletrobras Alagoas (CRC): 960 x 0.8 = 768 minutes (12.8H)

<Economical effect>
- COPEL (CTA): Sales in 2010 is around 908 MR$ => 2,000 MR$ (Average for 20 years)
  Increment of sales: 2,000 MR$ x 20 years x 8H/(365 x 24) = 36.5 MR$ (22 Million US$)
- Eletrobras Alagoas (CRC): Sales in 2010 is around 188 MR$ => 350 MR$ (Average for 20 years)
  Increment of sales: 350 MR$ x 20 years x 12.8H/(365 x 24) = 10.2 MR$ (6.4 Million US$)

(2) Reduction of Distribution Loss

The load condition can be monitored on a real-time basis by DAS and if overload is detected, the load can be split to the neighboring distribution feeders by DAS to improve the unbalance. Based on the calculation, the technical losses can be improved by about 32.5% on medium voltage line.
In addition, DAS can improve the power factor by control of capacitor installed on the feeder so that the technical loss can be reduced.
In case the power factor can be improved from 0.85 to 0.95, 10% of the technical loss can be reduced as shown in the following calculation.
Improvement power = $(P^2/E^2) \times [1/(0.85)^2 - 1/(0.95)^2] = 0.276 (P^2/E^2) \times R$ => 30% improvement
The control of power factor will be carried out during daytime so that the effect can be assumed as 8 hours. 30% x 8H/24H = 10%

Non-technical loss can be further reduced by AMR and a 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 as mentioned in Chapter 5.

Based on the effect of the loss reduction, the economical benefits are analyzed as follows.

<COPEL (CTA)>
Distribution loss in COPEL is 8% in 2010 which consists of 6.5% of technical loss and 1.5% of non-technical loss.
If the medium voltage loss in the 6.5% technical loss is 4%, 0.0168 (1.68%) of technical loss can be reduced by DAS as follows.
32.5% (Improvement of load unbalance) + 10% (Improvement of power factor) = about 42%
0.04 (Medium voltage loss) x 0.42 (42% Improvement) = 0.0168 (1.68%)%

The sale in CTA of COPEL is 908 MR$ in 2010 and the average for 20 years is assumed around 2,000 MR$ so that the economical benefit of 33.6 MR$ (= 2,000 x 0.0168) can be expected as improvement of the technical loss. The economical benefit accumulated for 20 years is around 672 MR$ (=33.6 x 20 years).

As non-technical loss can be reduced around 70% by AMR, the non-technical loss of 21MR$ (= 2,000MR$ x 0.015 x 0.7) can be improved. The economical benefits accumulated for 20 years are around 420 MR$ (= 21MR$ x 20 years)(260 Million US$).

<Eletrobras Alagoas (CRC)>
Distribution loss in Eletrobras Alagoas is 31.45% in 2010 which consists of 8.42% of technical loss and 23.03% of non-technical loss.
If the medium voltage loss in the 8.42% technical loss is 5%, 0.016 (1.6%) of the technical loss can be reduced by DAS as follows.
32.5% (Improvement of load unbalance)
0.05 (Medium voltage loss) x 0.32 (32% Improvement) = 0.016 (1.6%)

The sale in CTA of COPEL is 188 MR$ in 2010 and the average for 20 years is assumed around 350 MR$ so that the economical benefit of 5.6 MR$ (= 350 x 0.016) can be expected as improvement of technical loss. The economical benefits accumulated for 20 years are around 112 MR$ (=5.6 x 20 years).

As non-technical loss can be reduced around 70% by AMR, the non-technical loss of 56.4MR$ (= 350MR$ x 0.2303 x 0.7) can be improved. The economical benefits accumulated for 20 years are around 1,128 MR$ (= 56.4MR$ x 20 years)(705 Million US$).

(3) Saving of power purchase and generation construction

The following peak load of customers will be remotely stopped by DR function of smart grid.
- All loads in residential customers are stopped with rotation.
- As for large demand customers, lights and/or air conditioners are stopped with rotation but the important loads such as production facilities can be supplied without stoppage.

The assumption for calculation and the calculated results are as follows.
Load of residential customer in peak time: 2kW
Un-necessary load of large customer in peak time: 30kW
Rotation of stoppage: 3
- COPEL (CTA): (2kW x 660,000 + 30kW x 40,000) x 1/3 rotation = 840 MW
- Eletrobras Alagoas (CRC): (2kW x 100,000 + 30kW x 4,200) x 1/3 = 110 MW

The economical benefits are as follows.

<COPEL (CTA: Curitiba branch office)>
The difference between purchase tariff from the transmission company in peak time and normal purchase tariff is assumed as 0.2 R$/kWh.
Peak-cut is assumed as 2H per day and 40 days so that the economical benefit for 20 years is expected to get around 269 MR$ (168 Million US$) as follows.
0.2 R$/kWh x 840 MW x 2H x 40 days x 20 years = 269 MR$ (168 Million US$)

<Eletrobras Alagoas (CRC: Coast Resort City)>
The difference between purchase tariff from the transmission company in peak time and normal purchase tariff is assumed as 0.2 R$/kWh.
Peak-cut is assumed as 2H per day and 40 days so that the economical benefit for 20 years is expected to get around 35.2 MR$ (22 Million US$) as follows.
0.2 R$/kWh x 110 MW x 2H x 40 days x 20 years = 35.2 MR$ (22 Million US$)

The construction of power generation can be saved by peak-cut, but the effect means to contribute to the power sector and not to the distribution company. Therefore, the effect is not analyzed.

6.5 Financial Analysis（FIRR/EIRR)

6.5.1 Assumption for Financial Analysis

The following assumptions are made for the financial analysis.

- It is assumed that the demand increases at an annual growth rate of 6.28% (approximately 1.8 times in ten years).
- The facilities and equipment excluding smart meters are invested in the beginning.
- 10% of smart meters are invested (replaced) annually in turn, and all the smart meters are installed after ten years described in Note 1 of Table 6.2.3. The initial investment amount is one tenth of the total. The same amount costs annually after one year to nine years later, but it is calculated as maintenance costs.
- Since 10% of smart meters are replaced annually, it is assumed that the benefits, which are non-technical loss reduction and power purchase amount decrease of peak cut, start from one tenth after one year and the total effects appear after nine years (including demand increase). Therefore, the benefits described in 6.3 are estimated based on the assumption that all the smart meters are invested in the beginning and so a little different precisely from the estimates in this financial analysis based on the assumption that the effects increase gradually (a little less for twenty years).

- The old smart meters after ten years are replaced with new meters by 2% annually because of breakdown.
- The annual maintenance costs of the facilities and equipment are supposed 1% of the investment amounts.
- Control Center is reinvested after 15 years of depreciation.
- The tariff is fixed for 20 years because the calculation is in net value (constant price)

6.5.2 Financial Analysis Results

Based on the assumptions above, the financial analysis results are summarized in Table 6.5.1 including investment and effects.

Table 6.5.1 Financial Analysis Results of Smart Grid Investment in Model Sites

Effects	Curitiba	Maceio
Total cost reduction & income increase	US$ 809 million	US$701 milliom
Investment	US$ 66 million	US$20.6 million
Maintenance costs	US$ 134 million	US$23.7 million
FIRR	21.2%	44.4%

FIRRs are 21.2% in Curitiba and 44.4% in Maceio, financially feasible enough. IRR in Maceio is higher because its non-technical loss reduction effects are larger. In either case, IRR is sufficiently high and it indicates that investment in DAS and AMR can be covered without raising tariffs. Or if the investment is funded by loan and the distribution company does not want profits, the tariffs can be lowered by the difference of surplus between the IRR and loan interest rate.

In fact, the distribution company and ANEEL negotiate the tariffs and if the profits can be obtained ostensibly by the smart grid investment, ANEEL will demand to loser the tariffs. However, the profits increase because of the smart grid investment so that it is necessary at least to recover the investment fund, that is, if the fund is loan, the tariffs need high enough to secure the loan repayment and interest payment. The distribution company and ANEEL must recognize this sufficiently.

Chapter 7 Next Direction

7.1 Issues to Promote Smart Grid and Recommendations to Solve Them

7.1.1 Establishment of Laws

Although the laws to promote smart grid have been prepared in Brazil already, as described in 3.4, Chapter 3, they do not seem necessarily sufficient compared with the policies implemented in the advanced countries such as the US and Europe. The laws with the following contents, in particular, are expected.

(1) Promotion to save energy: promotion of TOU to make peak cut/ shift effective
TOU has been implemented excluding for low voltage customers as described in 3.4 and TOU for low voltage customers is examined at present. However, it is necessary to replace mechanical meters with electronic meters in order to implement the TOU. It seems to take time to replace all the meters. In addition, it is more efficient to install smart meters instead of simple electronic meters in order to implement peak cut/ shift effectively as smart grid. Therefore, TOU should be decided as soon as possible and it is desirable to replace meters with smart meters for customers wanting new smart meters and TOU or districts in turn quickly. The policies and regulations to implement them are necessary.

(2) Promotion of renewable energy introduction: promotion of FIT (Feed-in Tariff: fixed purchase price of renewable energy) and preparation of system coordination guideline

PROINFA described in 3.4 is a fixed purchase price system for generation companies or RPS system which obliges generation companies to purchase a certain amount of renewable energy and seems different from the FIT which promotes purchase of distributed power generated by general consumers. While sloar power is expected to increase from now on, ANEEL seems to adopt net-metering, that is, purchase price is the same as sale price, described in 3.4.4. However, it can be considered to set higher purchase prices in the beginning and lower the prices later as the distributed generation such as solar panels becomes popular in order to promote the distributed generation. Therefore, isn’t it necessary to decide FIT after studying FIT widely with policies for distributed generation of renewable energy promotion in parallel? In addition, as distributed generation increases, system coordination becomes difficult so that it is necessary to prepare the operation guidelines.

7.1.2 Technical Issues and Verification

Although there are smart grid systems with achievements or being verified in various countries, they need to be matched to the situation in Brazil. Therefore, it is important to plan and design Brazilian smart grid systems based on the various countries’ achievements and implement and verify the pilot projects. In particular, the items necessary to verify are as follows.

- Telecommunication methods
- Coordination with the existing facilities (particularly, accident detection and exclusion)
- Set-up environment (particularly, conditions such as high temperature and humidity in the northern region)

7.1.3 Smooth Replacement of Old Meters to Smart Meters

It is impossible to replace the existing WHMs at the same time and so it is desirable to start the replacement from the old WHMs. While in Japan, it is possible to replace by the calibration period (ten years for electronic meters and seven years for mechanical meters), it is recommended to replace every seven or ten years, which seem necessary for the calibration in Brazil, too. It is necessary to examine the replacement period in the future.

7.1.4 Human Capacity Training

Smart grid consists of new technologies such as ICT so that training of engineers and maintenance people is essential. Training plans such as classroom type education and practical machine use training through pilot projects need to be prepared.

7.1.5 Maintenance

It is necessary to make machines and equipment constituting the projects maintenance-free as much as possible. It is important to consider from the beginning that the distribution company’s own engineers and maintenance people can respond to the facilities necessary to maintain as much as possible. In particular, the following functions are important.

(1) Display of distribution systems (Since the distribution systems change daily according to the increase and decrease of demand, the display system should enable the distribution company’s own engineers and operator to respond to the change of distribution system softwares easily.)

(2) Preparation of distribution system charts and input of facility data (The software should enable the distribution company’s own engneers and operators to prepare and input easily.)

7.2 Recommendation of Action Plan towards Future Introduction

In Brazil, it is planned to examine the results of smart grid/ smart meter pilot projects verification by 2016 and after that the full-scale introduction will be started so that the plan implementation will be completed by 2030 (according to ABRADEE’s overview).

In order to achieve the verification of pilot projects by 2016, considering that it takes approximately two years to construct the pilot facilities, it is necessary to conduct cooperation preparation studies corresponding to SAPROF in 2012 and conclude the L/A between the Brazilian and Japanese Governments.

It is recommended to decide the functions and specifications of smart grid putting together the achievements of these Japanese support yen loan projects and other pilots and adopt full-scale smart grid in the whole nation of Brazil from 2017. In addition, it is important to establish the laws to promote smart grid and it is expected to achieve it by fiscal year 2016 in parallel.