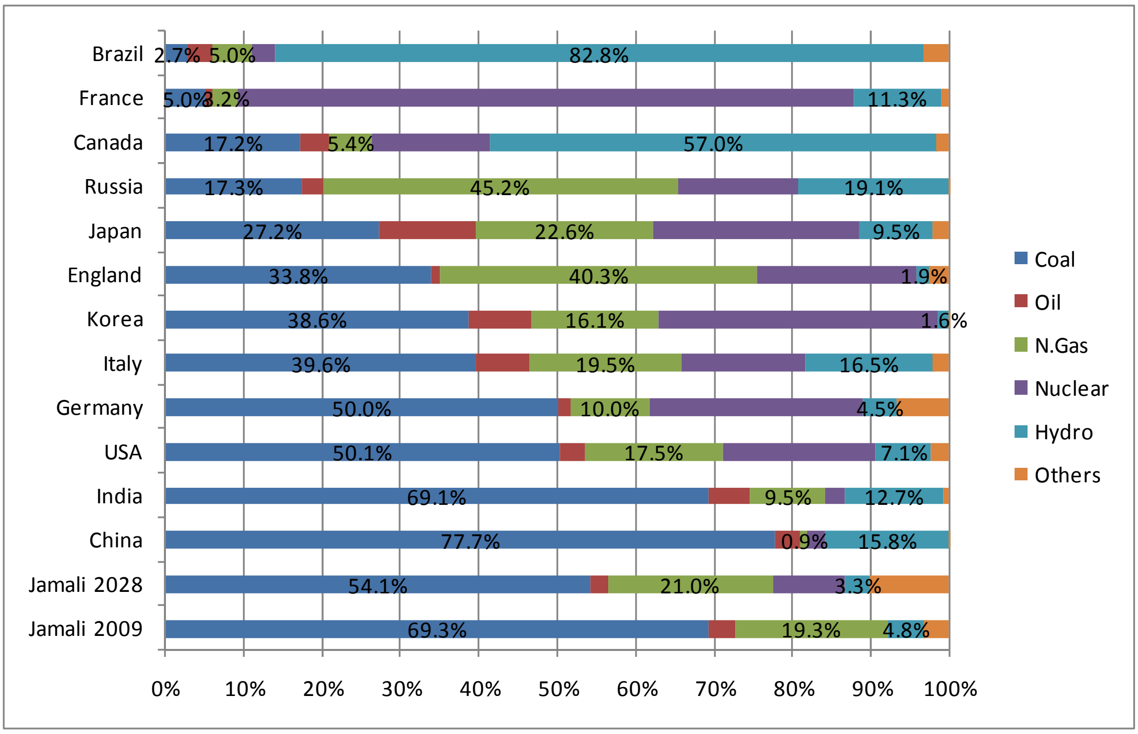
5. OPTIMAL POWER DEVELOPMENT PLAN

5.1 Optimal Power Source Development Plan

5.1.1 Optimal Power Source Development Plan and its Salient Feature

As discussed in Section 4.6.4, Scenario 2, Diversification of Power Sources, is selected as the optimal power development plan for Jamali.

Fig.5.1-1 shows primary energy component of generated energy in major countries in 2004. Fig.5.1-1 also includes Jamali 2009 and 2028 for reference. As shown in Fig.5.1-1, the proportion of coal of 54.1% corresponds to that in USA and Germany, gas 21.0 % to that of Japan, and renewable energy 10.2% to that of Germany approximately.



Source: IEA Electricity Information 2006 Edition

Fig. 5.1-1 Generation Component for Major Countries (2004)

5.1.2 Towards Implementation of the Optimal Power Source Development

(1) Coal-fired Thermal Plants

1) Preparation of candidate sites

Coal-fired thermal plants will play a dominant role in the future power source development in Jamali even in the power sources diversification scenario. The additional capacity excluding the fast track program 6,900 MW will be 29,000 MW. If the unit capacity of new coal-fired thermal plant is assumed 1,000 MW, twenty-nine (29) project sites (or lots) are required. Inventory of candidate sites with the possibility of land acquisition should be prepared as soon as possible.

2) Introduction of Supercritical coal-fired thermal plant

Currently, existing coal-fired thermal plants are operated at base load pattern. However, operation pattern of coal-fired thermal plants in the future are expected to cover not only base load but also middle load due to the introduction of many geothermal plants and nuclear power plants, both of which are to be operated at full base load. The current subcritical coal-fired thermal plant can be operated at middle load pattern. However partial operation of subcritical thermal plants lowers thermal efficiency and offer stable operation within the range of 50 to 100% maximum continuous rating (MCR) approximately. On the other hand, supercritical thermal plants offer stable operation within the range of 35 to 100%[1] MCR approximately and high thermal efficiency of more than 40%[2] in comparison with 30% ~ 37% of the PJB Paiton and IP Suralaya thermal plants. Higher thermal efficiency means less fuel consumption and less air pollution emission. Based on the above reasons, introduction of supercritical coal-fired thermal plants with proven technology is recommended.

3) Introduction of clean coal technology

(a) FGD and low NOx burners
Along with the introduction of supercritical coal-fired thermal plants, introduction of clean coal technology such as FGD (flue gas desulphurization) equipment and low NOx burners should be introduced to avoid the acceleration of air pollution in Jamali.

(b) IGCC (Integrated Gasification Combined Cycle)
IGCC is also one of the latest clean coal technologies, although it cannot be said IGCC is proven technology at the moment. High thermal efficiency of 40 % or more is expected and operational flexibility is also expected because IGCC fires gas converted from coal. In Japan, ten (10) power utility companies jointly established "Clean Coal Power R&D Co., LTD. (CCP)" in 2001 in order to research and develop IGCC by using a demonstration plant of 250 MW class. Operation tests were commenced on September 20, 2007 and the rated capacity of 250 MW was attained on March 7, 2008. Operation tests will be continued until the end of 2009 to verify reliabilities of the plant. If PLN has a strong interest in the development of IGCC, sending PLN staff to CCP as a long term overseas training is recommended. Fig.5.1-2 shows photos of demonstration IGCC plant with 250 MW class in Japan.

[1] Source: "Latest Experience of Coal Fired Supercritical Sliding Pressure Operation Boiler and Application for Overseas Utility", Babcok-Hitachi
[2] Source: Latest Experience of Coal Fired Supercritical Sliding Pressure Operation Boiler and Application for Overseas Utility", Babcok-Hitachi

Fig. 5.1-2 Photos of IGCC Demonstration Plant in Japan

4) Utilization of Low Rank Coal (LRC)

As mentioned in Section 4.1.3, about 80% of the proven reserves are the middle and low rank coal. Utilization of low rank coal seems to be one of the key issues for not only PLN but also the Indonesian Government. If utilization of low rank coal is attainable, the following benefits are anticipated;

(a) High and very high rank coals (> 6,100 kcal/kg) can be allocate to export to a certain extent as has been done so far, and earn the foreign currencies under the soaring coal prices in the world market. Foreign currency earning can support the import oil-based fuel, such as HSD and MFO being imported at the moment.

(b) Utilization of low rank coal will contribute not only to the security of stable energy supply but also to alleviating air pollution problem in Jamali because of its less content of sulfur.

(c) Restriction on coal consumption will be mitigated and more flexible expansion planning of coal-fired thermal plants will be available, if necessary.

In order to utilize low rank coal, the following measures are proposed;

(a) Developing coal-fired thermal plants at mine-mouth in Sumatra (and in Kalimantan in the long-term), and using low rank coal as fuel because LRC is not suitable for storage/transport for long time due to its higher water content and more active oxidizing substances as mentioned in Section 4.1.3.

(b) Using low rank coal in mixture with higher rank fuel coal, as being done in Suralaya thermal plant, and/or using LRC in gasified form by IGCC.

(2) Gas-fired Thermal Power Plant

Study on the introduction of CNG (Compressed Natural Gas) System is recommended as proposed in Chapter 4. CNG System is expected to allow gas-fired thermal power plants more flexible operation (such as peak pattern operation) by storing gas at power station side.

(3) Geothermal Plants

1) PLN Participation

According to the optimal power source development, about 2,600 MW of geothermal plants are to be developed from 2010 to 2028 and most of them are presumably to be developed by IPP scheme. To promote the IPP development, MEMR announced the "Ministerial Regulation No.14/2008" as mentioned before.

At the moment, the relevant provincial government[3] executes PQ/Bid evaluation of the prospective developers. PLN is formally involved in the PPA negotiation stage and onwards. There is a concern that the capability of provincial government to execute technical evaluation of bidders may not be sufficient. In terms of proper development of geothermal plants, the central government, with a help from PLN if necessary, should prepare the evaluation criteria to be adopted by local governments.

2) Risk Reduction

Potential steam producing area is provided by MEMR to developers but the specific drilling locations in the area are to be determined by developers in the current framework. This leaves developers having to burden high risk of developing geothermal plants. The high risk will results in costly development and lessen the interest of developers consequently. A preliminary FS level study for potential sites prior to bidding is desirable to lessen the risk burden of developers.

(4) Java-Sumatra Interconnection

Basic concept of Java-Sumatra Interconnection is to develop IPP coal-fired thermal plants at mine-mouth in South Sumatra and to deliver surplus power of 3,000 MW by HVDC (High Voltage Direct Currency) to the Jamali system which is under tight power balance condition.
Java-Sumatra Interconnection seems to have the following advantages;

(a) No transportation of coal. This means stable power supply will be available because coal transportation by ships is sometimes interrupted by weather condition.

(b) Substitution for plant sites in Jamali. This means less deterioration of air pollution in Jamali where population density is very high.

(c) Development of the area surrounding power plants. This will contribute to the revitalization of local communities and economy through the improvement of infrastructures.

This idea may also be applicable to Java-Kalimantan Interconnection planning because South and Central Kalimantan have the largest coal reserve and production in Indonesia.

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[3] A part (2.5%) of electricity sale is paid to the relevant provincial government as mentioned in Section 2.2.2.

PLN Engineering, a PLN's subsidiary company, has almost completed a feasibility study for Java-Sumatra Interconnection project. In parallel with PLN Engineering's study, JBIC project is on-going, the Terms of Reference (TOR) of which consist of capacity building of PLN staffs and topographical route survey of offshore and onshore cable portions. JBIC has shown the strong interest in offering financial support for the implementation of Java-Sumatra Interconnection.

PPAs between PLN and IPP developers are still under negotiation at the moment. It should be emphasized here that PLN needs to keep the implementation schedule of IPP coal-fired thermal plants so that Java-Sumatra Interconnection starts sending power to the Jamali system in 2014 on schedule.

Fig. 5.1-3 shows the tentative Java-Sumatra interconnection route.

Fig. 5.1-3 Tentative Java-Sumatra Interconnection Route

(5) Renewable Energy (Solar, Wind, etc.)

1) Solar Power (Photovoltaic Power Generation)[4]

Solar power seems to be the most appropriate generation system among renewable energy (solar power, wind power and biomass) considering the preferable weather of Indonesia. In the optimal power source development, about 6,000 MW of solar power systems are to be developed for the next 20 years. Concerning solar power, Germany has managed to become the world's leading solar power generating country as shown in Fig. 5.1-1 even though it has relatively poor solar radiation condition.

Germany's solar power systems in the aggregate generate about 3,000 MW of power in 2007, 1,000 times more than in 1990. The reasons why German has successfully become the world leader are owing to the Government' efforts as mentioned below.

(a) Renewable Energy Law in 2000, which offers economic incentives to people introducing renewable energy sources, was designed to help fight climate change and reduce dependency on fossil fuels.

(b) "Feed-in Tariff" system, which gives anyone who generates power from solar power, wind or hydro a guaranteed payment from the local power company. The power companies are obliged to buy for 20 years at more than triple market prices (49 cents per kWh for solar electricity).

Expanding use of solar power system contributes to not only climate change and fossil fuels saving but also creating new industries and job opportunities. It is expected in Germany that the number of jobs in solar power alone to double to 90,000 over the next five years and hit 200,000 in 2020.

MEMR will need to establish specific measures to promote expanding use of and investment in solar power system because the current energy law stipulates the target primary energy mix which, however, does not accompany any specific measures for realization.

2) Wind Power

Wind power system is economical only in locations where average wind velocity is 6 m/s or more at 30 m above the ground level. Wind power totaling 0.5 MW[5] in capacity has been installed in Indonesia so far. In the optimal power source development, about 3,200 MW of wind powers are assumed to be developed for the next 20 years. A required land for a 600 kW class wind power unit is about 50 m square (equivalent to a rotor diameter). Installation of wind power sometimes accompanies environmental issues as listed below;

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[4] The numbers presented in this item are referred to "Cloudy German unlikely hotspots for solar power", Reuters, July 29, 2007 (www.boston.com/news/science/articles/2007/07/30/cloudy_german_unlikely...)

[5] Source; Presentation material "Promotion of Renewable Energy, Energy Efficiency and Greenhouse Gas Abatement in Indonesia", at Manila 5-8 October 2004 by MEMR

(a) Installation in and around national parks and conservation forest areas posing concerns for landscape
(b) Radio disturbance caused by metal rotors
(c) Threats of rotors hitting birds

MEMR is recommended to develop an Environmental Impact Assessment guidelines or criteria in cooperation with MOE.

Fig. 5.1-4 shows photos of wind farm in Hokkaido, Japan.

Fig. 5.1-4 Photo of Wind Farm in Hokkaido, Japan

(6) Utilization of JICA Reports

JICA has a library and most of JICA reports can be accessed or downloaded from the JICA Library Website.
The JICA Library address in English is “http://lvzopac.jica.go.jp/libary/indexeng.html”. Utilization of the JICA Library and its archives is strongly recommended especially for PLN and MEMR local offices[6] which may have infrequent access to the relevant JICA reports, not only as references for projects but also for capacity building.

The following reports relevant to power development in Indonesia are available at the moment on the JICA Library Website:

(a) Master Plan Study for Geothermal Power Development in the Republic of Indonesia (September 2007)
(b) Study on the Optimal Electric Power Development and Operation in the Republic of Indonesia (August 2002)
(c) Study on the Optimal Electric Power Development in Sumatra (July 2005)

[6] P3B Sumatra responsible for power development planning in Sumatra does not know the existence of “Master Plan Study for Geothermal Power Development in the Republic of Indonesia”

5.1.3 Study on the Leading Power Projects in Indonesia

The validity of the implementation of a nuclear power plant and a pumped storage power plant, which are the leading, first-of-a-kind, power projects in Indonesia, is studied in this section.

(1) Nuclear Power Plant

The first unit of nuclear power plant 1,000 MW is scheduled to be put into the system in 2018 and the total capacity of 5,000 MW by 2028 in the optimal power source development plan. Since the development of nuclear power plants is an unprecedented challenge for Indonesia, the schedule allows for a four year period until 2012 to address key issues, such as safety and environmental assessments, and to develop consensus over the development itself, leaving six years for the construction of the first unit. Considering the current progress[7] toward the implementation, the scheduling of implementation of nuclear power plants is full of uncertainties.

1) Power source development plan without nuclear power plants

Influence of delay or postponement of the nuclear power program on the power source development plan is studied for the following case.

Case without nuclear power plant (W/O Nuclear):

Additional coal-fired thermal plants with unit capacity of 1,000 MW will substitute for nuclear power plants with the same capacity. Reserve margin of 30 % will be kept after 2018.

(a) Net Present Value (NPV) of power source development plan

Table 5.1-1 shows the cumulative cost of power source development plan until 2028 converted to 2009 price with discount rate of 12%. As shown in the table, NPV of the plan will be increased by 1.3% for w/o Nuclear.

Table 5.1-1 Cumulative Cost for With and Without Nuclear

Case	Investment Cost (Million US$)	Salvage Value (Million US$)	Operation Cost (Million US$)	Objective Function (Million US$)	Ratio
With Nuclear	26,429	-9,505	73,001	89,925	1.000
W/O Nuclear	25,091	-8,834	74,857	91,114	1.013

(b) Generation Energy Component

Table 5.1-2 shows the generation energy component in 2028 by fuel type. 9.2% of nuclear- generated energy are substituted by not only coal but also gas, oil and geo.

[7] The national team has not yet established and the establishment are delayed for 1 ~ 2 years against the schedule.

Table 5.1-2 Generation Energy Component in 2028 (%)

Case	Coal	Gas	Oil	Geo	Nuclear	Others	Total
With Nuclear	54.1	21.0	2.2	6.2	9.2	7.3	100.0
W/O Nuclear	61.3	22.3	2.6	6.4	0.0	7.3	99.9

Note: Others include Hydro (3.3 %) and renewable energy (4.0%).

(c) Capacity Factor

Table 5.1-3 shows the capacity factor in 2028 for the main power sources. As shown in the table, the capacity factor except gas and hydro will be increased due to the compensation for energy produced by nuclear power plants. Especially, capacity factor of LNG will increase by 7%.

Table 5.1-3 Capacity Factor in 2028 (%)

Case	Coal	Gas	LNG	HSD	Geo	JS-I	Hydro
With Nuclear	60.2	87.3	59.4	28.6	83.9	30.3	25.6
W/O Nuclear	68.3	87.6	66.2	34.3	85.6	34.7	25.6

(d) Coal, Gas/LNG and Oil Consumption

Table 5.1-4 shows the coal, gas/LNG and oil consumption in 2028. As shown in the table, coal consumption in 2028 will be increased by 13.5 Million ton or 12.5 % for W/O Nuclear case.

Table 5.1-4 Coal, Gas/LNG and Oil Consumption in 2028

Case	Coal	Gas/LNG	Oil
Unit	M. ton	M. mmbtu	M. KL
With Nuclear	107.9	692.1	3.1
W/O Nuclear	121.4	732.8	3.7

(e) CO_2, NOx and SOx Emission

Table 5.1-5 shows CO_2, NOx and SOx emission in 2028. As shown in the table, CO_2 emission will be increased by 30.2 Million ton or by 12.6 % for W/O Nuclear case mainly due to increase of generated energy by coal-fired thermal plants. NOx and SOx emission for W/O Nuclear will keep the almost same emission level as those of “With Nuclear”.

Table 5.1-5 CO_2, NOx and SOx Emission in 2028

(Million ton)

Case	CO_2	NOx	SOx
With Nuclear	239.4	1.4	0.5
W/O Nuclear	269.6	1.5	0.5

(f) Conclusion

Increase of total cost, fuel consumption and CO_2 emission are confirmed by WASP simulation in the case of "Without Nuclear Plants".

(2) Pumped Storage Power Plant

As shown in Figs. 4.6-4 to 4.6-7 "Results of Simulation" for four (4) scenarios, pumped storage power plants present low capacity factor for every scenario. This result is caused by the simulation method described in Section 4.6.1 in reproduction of the operation pattern of each scenario by using coal price as a parameter.

Table 5.1-6 shows the generation energy and capacity factor of pumped storage power plant(s) in the case of original coal price of 80 $/ton. Since the available energy for the installed capacity 3,000 MW is 4,200 GWh, pumped storage power plants will be operated at full capacity for four hours a day on average after 2020 affected by the large scale introduction of coal-fired thermal plants and nuclear power plants which will provide pumping energy for pumped storage at low cost. Therefore, the pumped storage power plants will be very efficient and their development should be promoted.

Table 5.1-6 Generation Energy and Capacity Factor of Pumped Storage Power Plants

Year	2015	2018	2020	2022	2024	2026	2028
Capacity (MW)	500	2,000	3,000	3,000	3,000	3,000	3,000
G.Energy (GWh)	751	2,853	4,200	4,200	4,200	4,200	4,200
C.Factor (%)	17.12	16.27	15.98	15.98	15.98	15.98	15.98

5.2 Optimal Power System Expansion Plan

Final goal of system analysis in this study is to develop the optimal power system expansion plan in consideration of technical reliability and economic aspects on the basis of the optimal power source development plan.

A long term optimal power system expansion plan for the coming twenty-years was developed in accordance with the following procedure shown in Fig. 5.2-1.

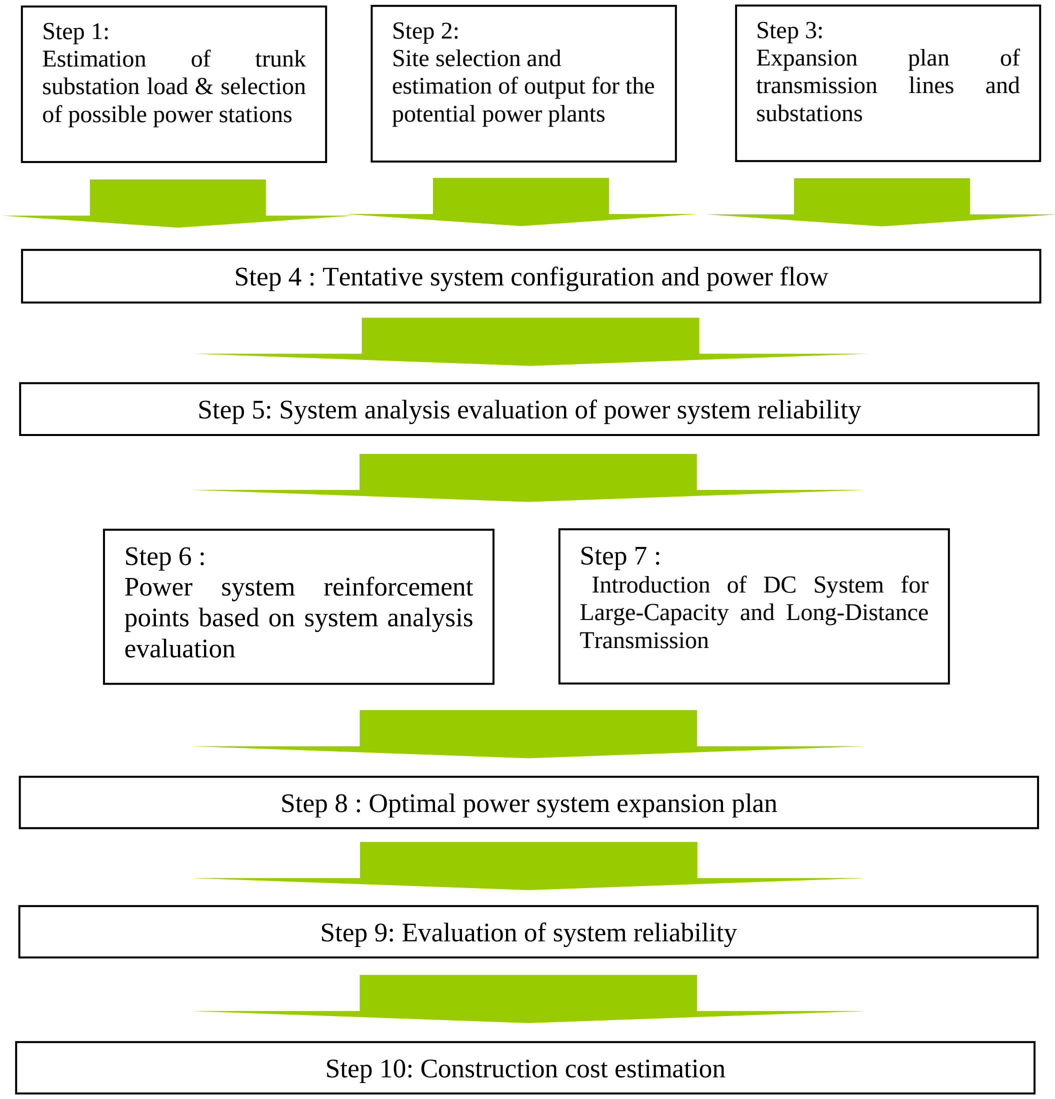


Fig.5.2-1 Workflow to develop the Optimal Power System Expansion Plan

5.2.1 Estimation of Trunk Substation Load and Site Selection of the Potential Power Plants

Estimation of each trunk substation load and proper site selection of the potential power plants shall be a first step to forecast the power flow for each year to be studied.

(1) Estimation of Trunk Substation Load

A trunk substation load was estimated in accordance with the following procedures:

1) Demand forecast at peak load and off-peak lord

As the result of the study in the previous chapter, power demand in the whole of Jamali region was forecasted as shown in Table 5.2-1.

Table 5.2-1 Demand Forecast in Jamali System

(MW)

<table>
<tr><th>------</th><th colspan="2">2010</th><th colspan="2">2015</th><th colspan="2">2020</th><th colspan="2">2025</th><th colspan="2">2028</th></tr>
<tr><th>Demand</th><th>Peak</th><th>Off- Peak</th><th>Peak</th><th>Off- Peak</th><th>Pear</th><th>Off- Perk</th><th>Pear</th><th>Off- Peak</th><th>Perk</th><th>Off-Perk</th></tr>
<tr><td>Region 1</td><td>7,815</td><td>5,882</td><td>9,372</td><td>7,072</td><td>15,209</td><td>8,331</td><td>19,503</td><td>9,746</td><td>21,523</td><td>10,706</td></tr>
<tr><td>Region 2</td><td>3,653</td><td>2,723</td><td>5,029</td><td>3,640</td><td>6,180</td><td>4,830</td><td>8,723</td><td>6,242</td><td>10,019</td><td>7,294</td></tr>
<tr><td>Region 3</td><td>3,587</td><td>2,269</td><td>5,363</td><td>3,443</td><td>6,322</td><td>5,020</td><td>9,333</td><td>6,969</td><td>10,850</td><td>8,398</td></tr>
<tr><td>Region 4 (East Jawa)</td><td>4,835</td><td rowspan="2">5,050</td><td>6,923</td><td rowspan="2">7,410</td><td>8,937</td><td rowspan="2">9,903</td><td>12,413</td><td>13,396</td><td>14,143</td><td rowspan="2">15,964</td></tr>
<tr><td>Region 4 (Bali)</td><td>645</td><td>969</td><td>1,248</td><td>1,867</td><td></td><td>2,177</td></tr>
<tr><td>JAMALI system in total</td><td>20,535</td><td>15,924</td><td>27,657</td><td>21,565</td><td>37,895</td><td>28,084</td><td>51,840</td><td>36,353</td><td>58,712</td><td>42,362</td></tr>
</table>

Souse: Demand Forecast of JICA Study Report ** (Base Case)

2) Generation capacity forecast to be connected with less than 150 kV system

The total generation capacity connected to 150 kV and lower systems was estimated by comparing the trunk substation load of assumed power flow by PLN and the demand forecast in each region. Power source development schedule for 150 kV systems and below after 2016 was derived from the result of this study.

3) Estimation of trunk substation load

Each substation load after 2016 was estimated by applying regression method to the PLN plan for 2007 to 2016 shown in RUPTL.

4) Estimation of each trunk substation load ratio

Each trunk substation load ratio in a region was estimated on the basis of the estimated trunk substation load and the total load in the region.

5) Estimation of each trunk substation load

Each trunk substation load was estimated on the basis of the total load of the trunk substations in each region (“demand forecast in each region” – “generation capacity of the lower voltage system”) multiplied by each trunk substation load ratio calculated in the previous step.

		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Y=aX+b		2,020		2,025		2,028	
		P(MW)	P(MW)	P(MW)	Peak(18)	P(MW)	P(MW)	P(MW)	P(MW)	Peak(18)	P(MW)	a	b	Peak(14)		Peaqrk(14)	Ratio/Region	Peak(14)	
	Cilegon	1	-30	-122	-346	-384	-346	-288	-190	-175	-120	44.7143	-90274	49	0.0067	272	0.02955813	407	0.03921
	Suralaya	245	256	277	292	310	327	343	362	381	400	17.3636	-34607.7	467	0.064	554	0.06007063	606	0.05841
	Balaraja	650	672	538	154	158	168	180	200	210	225	29.8279	-59513.3	739	0.10132	888	0.09636953	978	0.09428
	Lengkong				562	556	576	594	582	750	809	40.5357	-80965	917	0.12572	1,120	0.12149428	1,241	0.11971
	Gandul	896	704	704	704	700	936	976	885	978	1025	45.7333	-91169	1,212	0.16618	1,441	0.15633422	1,578	0.15218
Region1	Kembangan	362	287	328	364	380	418	456	466	498	552	30.8333	-61620	663	0.09092	817	0.08868748	910	0.08775
	Depok	352	404	508	288	300	312	216	220	242	260	15.4	-30788	320	0.04387	397	0.04307258	443	0.04274
	Cibinong	728	770	770	470	506	501	636	636	522	704	31.0357	-61907	785	0.10762	940	0.1020172	1,033	0.09965
	Bekasi	710	818	788	1110	1005	1086	908	804	897	966	81	-162326	1,294	0.17738	1,699	0.1843333	1,942	0.18727
	Cawang	708	744	748	728	700	732	650	562	604	658	48	-96112	848	0.11624	1,088	0.11804275	1,232	0.1188
	SUB-TOTAL	4652	4625	4539	4326	4231	4710	4671	4527	4907	5479			7,295		9,217		10,370	
	Upper Cisokan									130	120			155	0.02362	212	0.02506204	255	0.02638
	Tmbur							466	445	462	490	22.5	-44871	579	0.08845	692	0.08192157	759	0.07855
	Muara Tawar	0	0	0	0	261	262	238	195	200	220	12.5	-24982	268	0.04094	331	0.03915413	368	0.03808
	Cibatu	580	684	641	568	666	734	818	934	1008	1068	85.1429	-170565	1,424	0.21747	1,849	0.21908441	2,105	0.21781
	Cirata	426	478	492	382	436	476	526	574	616	528	32	-63910	730	0.11152	890	0.10543774	986	0.10204
	Lagadar										540			696	0.10631	952	0.11277917	1,147	0.11873
Region2	Bandung Selatan	564	616	642	370	416	470	546	610	526	526	29.5714	-59032	702	0.10729	850	0.10071624	939	0.09716
	Rancaekek				460	490	542	605	660	708	600	34.7857	-69443	824	0.1259	998	0.11823987	1,102	0.11409
	Mandirancan	586	626	544	128	76	118	182	265	302	348	57	-114554	586	0.08952	871	0.10318683	1,042	0.10783
	Tasik	272	358	518	387	452	462	438	458	486	452			582	0.08898	797	0.09440034	960	0.09938
	CIRACAP														0		0		0
	SUB-TOTAL	2428	2762	2837	2295	2797	3064	3819	4141	4438	4892			6,546		8,441		9,663	
	Rawalo		-52	31	72	72	111	216	232	248	396	47.8571	-96140	531	0.08766	771	0.10332598	914	0.10949
	Pemalang		113	135	167	159	187	230	254	254	346	25.5667	-51235	410	0.06758	538	0.0720615	614	0.07356
	Ungaran	556	556	556	556	562	612	662	719	604	651	14.3879	-28337	727	0.11985	798	0.10704612	842	0.10079
	Pedan	560	518	638	612	765	798	862	915	829	852	42.2606	-84272	1,094	0.18054	1,306	0.175055	1,433	0.17156
Region3	Purwodadi				462	490	522	509	540	488	504	5	-9563	537	0.08858	562	0.07534522	577	0.0691
	Ngimbang	236	237	203	272	229	261	278	295	373	388	17.1515	-34223	423	0.06979	509	0.06821665	560	0.0671
	Krian	746	592	578	750	819	870	897	951	954	954	50.9333	-101660	1,225	0.20213	1,480	0.19841711	1,633	0.19554
	Gresik	145	93	81	202	134	146	146	161	182	191	11.6571	-23312	235	0.03884	294	0.03937639	329	0.03936
	Kediri	562	524	570	614	630	636	664	741	670	682			879	0.14498	1,202	0.16118804	1,449	0.17352
	SUB-TOTAL	2805	2581	2792	3707	3860	4143	4464	4808	4602	4964			6,062		7,459		8,350	
	Manisrejo									209	216	7	-13896	244	0.08302	279	0.07504034	300	0.07085
	Bangil						440	492	533	532	532	22.4	-44608	640	0.21776	752	0.20225928	819	0.19348
	Ngoro										243			313	0.10655	428	0.11521948	516	0.12193
Region4	Paiton	532	624	528	436	302	310	396	456	522	383			494	0.16794	675	0.18160108	814	0.19218
	Kapal										236			0	0	0	0	0	0
	Grati	224	195	193	349	183	64	96	117	148	148	22	-44193	247	0.08404	357	0.09601937	423	0.09991
	Surabaya Selatan		554	618	668	588	600	726	762	800	776	45.0286	-89956	1,002	0.34083	1,227	0.32997694	1,362	0.32167
	SUB-TOTAL	756	1373	1339	1453	1073	1414	1710	1868	2211	2534			2,939		3,718		4,234	

6) Estimation of reactive power in each trunk substation

Reactive power in each trunk substation was estimated on the basis of the actual peak and off-peak records of each substation, taking the possible future change into consideration, to obtain realistic figures.

Demand forecast of the trunk substations in each region estimated in accordance with the above mentioned procedures is shown in Table 5.2-2.

Table 5.2-2 Estimation of Trunk Substation Load in Each Region

(Unit : MW)

		2010		2015		2020		2025		2028	
		Peak	Off Peak	Peak	Off Peak	Peak	Off Peak	Peak	Off Peak	Peak	Off Peak
	Cilegon	-361	-100	-176	-100	61	31	356	156	574	232
	Suralaya	280	244	379	339	578	296	724	317	855	345
	Balaraja	148	129	209	187	915	469	1,161	508	1,380	557
	Lengkong	539	469	746	667	1,136	582	1,464	641	1,753	708
	Gandul	675	588	973	870	1,502	769	1,318	577	1,560	630
	Durikabe							565	247	668	270
Region 1	Kembangan	349	304	495	443	822	421	1,068	468	1,285	519
	Parung					292	149	369	161	438	253
	Depok	276	240	241	215	396	203	519	227	626	253
	Cibinong	451	392	519	464	681	349	860	376	1,021	589
	Bekasi	1064	927	892	798	1,603	821	2,220	972	2,742	1,107
	Cawang	698	608	601	537	1,050	538	1,422	622	1,739	702
	SUB-TOTAL	**4118**	**3,586**	**4879**	**4,363**	**9,036**	**4,628**	**12,046**	**5,272**	**14,641**	**5,913**
	Upper Cisokan			129	96	114	95	158	120	209	148
	Tmbur			460	340	428	356	518	393	624	441
	Muara Tawar			199	147	198	165	247	188	302	214
	Ksbru							415	315	519	366
	Cibatu	545	449	1003	743	1,052	876	969	736	1,210	856
	Cirata	366	302	613	454	540	449	666	506	810	573
Region 2	Lagadar		0	0	0	514	428	713	541	942	666
	Bandung Selatan	355	292	523	388	519	432	636	483	771	545
	Rancaekek	441	364	704	522	609	507	747	567	906	640
	Mandirancan	123	101	300	223	433	360	652	495	856	605
	Tasik	371	306	483	358	431	358	596	453	789	558
	CIRACAP				0	0	0	0		0	0
	SUB-TOTAL	**2200**	**1,814**	**4414**	**3,270**	**4,839**	**4,026**	**6,318**	**4,799**	**7,938**	**5,611**
	Rawalo	69	43	247	160	485	399	883	671	1,189	868
	Pemalang	160	101	253	164	374	307	616	468	799	583
	Ungaran	533	335	601	390	663	545	915	695	1,095	799
	Pedan	587	369	825	535	999	821	1,197	910	1,490	1,359
	Butum							299	227	373	340
Region 3	Purwodadi	443	278	485	315	490	403	644	489	750	548
	Ngimbang	261	164	371	241	386	317	583	443	729	532
	Krian	719	452	949	615	1,118	919	1,695	1,289	2,123	1,549
	Gresik	194	122	181	117	215	177	336	256	427	312
	Kediri	589	370	666	432	802	659	1,377	1,047	1,884	1,375
	SUB-TOTAL	**3554**	**2,234**	**4578**	**2,969**	**5,532**	**4,546**	**8,544**	**6,495**	**10,859**	**7,924**
	Manisrejo			208	376	370	537	642	748	831	888
	Kbang							889	1,036	1,194	1,275
	Bangil			529	957	971	1,409	1,038	1,209	1,362	1,455
	Ngoro			0	0	475	689	789	918	1,144	1,222
	Paiton	418	748	519	939	749	1,086	424	617	487	481
Region 4	Kapal			0	0	0	0	854	830	1,317	1,505
	Glnuk							171	207	329	301
	Wtdol							105	154	122	120
	Grati	335	599	147	266	375	544	822	957	1,172	1,252
	Surabaya Selatan	640	1,146	796	1,439	1,520	2,205	2,823	3,287	3,773	4,030
	SUB-TOTAL	**1393**	**2,492**	**2199**	**3,976**	**4,461**	**6,469**	**8,556**	**9,962**	**11,731**	**12,530**

5.2.2 Site Selection and Estimation of Output for the Potential Power Plants

Location and output of the potential power plants to be introduced to Jamali system shall heavily affect the system configuration and trunk line power flow in Jamali system. Therefore the site selection and estimation of power output were assumed on the basis of the optimal power source development plan of this study in consideration of the following issues.

(1) Power Plants and Location to be connected to 500 kV System

New power plants to be installed up to 2016 are derived from RUPTL.

After 2016, new type power plants, such as a nuclear power plant, will also be put into operation. The locations of such power plants have not been officially announced yet, therefore, the locations were tentatively set in consideration of relevant information obtained from PLN as follows:

- Pumped Storage Power Plants (three (3) sites) : Upper Cisokan, Matenggeng, Grindulu
- Geothermal Power Plants : From geothermal potential sites to the center of West Java (to be connected to the 150 kV system)
- Java-Sumatra Interconnection Transmission Line : Transmission capacity of 3,000 MW at receiving end, to be connected to Parung S/S
- Nuclear Power Plant (One site) : North of Central Java with installed capacity of 5,000 MW [1,000 MW × 5 units]
- Coal Thermal Power Plants (six (6) sites) : North of West Java…2 sites including Suralaya P/S)
  North & south of Central Java…2 sites
  North of East Java … 2 sites
- Conventional Hydro Power Plants : Scattered over Java Island from the viewpoint of effective use of national resources, to be connected to the 150 kV or less system.

Also, generated power of additional power plants in the future is assumed on the basis of the optimal power source development plan as mentioned in Table 5.2-3. Demand and supply Balance was assumed to be mostly adjusted by output of thermal power plants.

Table 5.2-3 Additional Power Plants in Optimal Power Source Development Plan

(MW)

Year	2010	2015	2020	2025	2028	Reference
Thermal P/P	----	1,750	12,100	24,700	34,800	Connected in 500 kV system (Keeping demand-supply balance, priority to Gas IPP)
Java-Sumatra Connection	----	3,000	3,000	3,000	3,000	Same as above (Output in full)
Nuclear P/P	----	----	1,000	3,000	5,000	Same as above (Output in full)
Pumped Storage P/P	----	500	3,000	3,000	3,000	Same as above (Output in full)
Geothermal P/P	----	660	1,210	1,760	2,090	Connected in 150 kV system (Output in full)
Hydro P/P	----	----	1,170	2,970	3,270	Same as above (Output in full)

As for the large scale thermal power plants, many preliminary potential sites are being proposed along the coastal areas of Java Island. Power plant locations were determined as above; two sites in West Java, two in Central Java, and two in East Java respectively in consideration of the following points, and the information obtained from PLN.

- for the power flow, sites are to be selected in West Java, where a load center of Jamali region is near, to reduce the burden on the system
- however, for the short circuit capacity, and for the ease of implementation including avoidance of socio-environmental issues such as resettlement, the sites should not be concentrated in West Java
- even out of West Java, locations relatively close to the load center in West Java should be preferred, within 500 km to the west of Central Java and 800 km to the west of East Java
- southern coast of Java Island is not recommended in general, as it is more susceptible to high waves and tides
- for the conservative assessment of the system, assuming locations in East Java which requires longer distance of transmission, would allow for flexibility of siting in the future.

At present, the 500 kV trunk system has heavy flow westward. As the locations of power plants to be installed after 2016 are not specifically set in the optimal power source development plan, there are some uncertainties in future flow conditions. However, there is also a possibility that eastward power flow over Central Java may be increased in the future because of power transmission from Sumatra, development of large scale power plant in Central Java, and demand increase in East Java.

Therefore, locations of new thermal power plants will have flexibility in terms of transmission planning.. Attention was paid to avoid excessive eastward power flow in the optimal power system development plan.

(2) Estimation of Output of Each Power Plant

Output of each power plant at the peak load was adjusted as follows:

* nuclear power plant, power supply from Sumatra, and gas fired thermal plant (Bojanegara P/S) should be operated at a maximum output
* pumped storage hydropower plants should be operated at almost maximum output
* thermal power plants are adjusted to be operated on a severe side in consideration of IPP power sources and system stability

5.2.3 Expansion Plan of Transmission Lines and Substations

Transmission line and substation expansion plan up to 2016 was derived from RUPTL. After 2016, the expansion plan was developed in consideration of the information provided by PLN, on the transmission lines for nuclear power plant, transmission lines for the expansion of Tanjung Jati power plant, and new substation projects in Bali. Power system facilities which require further expansion or reinforcement were examined on the basis of the power flow analysis for each year.

5.2.4 Tentative System Configuration and Power Flow

(1) Tentative System Configuration and Power Flow up to 2025

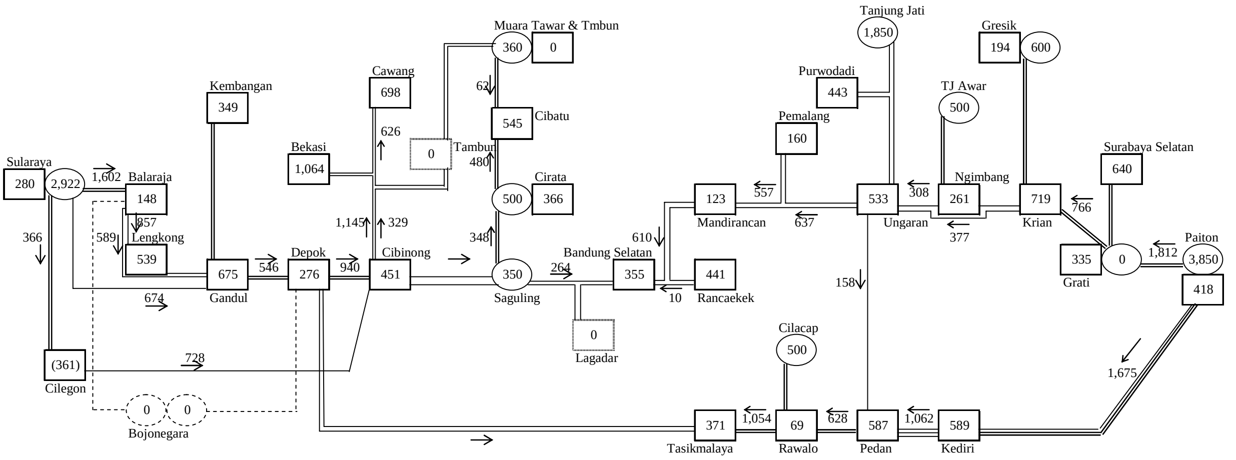
Power system configuration up to year 2016 was derived from RUPTL and demand forecast of 500 kV substations was revised on the basis of the demand forecast of this study.

After 2016, transmission lines connected to the nuclear power plant, Tanjung Jati power plant, Mandiracan-Cibatu power plant, and new thermal & hydro power plants were examined as expansion plans.

This tentative power system configuration was evaluated separately by system analysis and the optimal expansion plan including the existing system shall be studied under the optimal system development plan on the basis of the optimal power source development plan discussed in other section.

Tentative power system configuration and power flow from obtained for each year up to 2025 are shown in Figs. 5.2-2 (1) ~ (4).

(a) Power Flow at Peak Load



(b) Power Flow at Off-peak Load

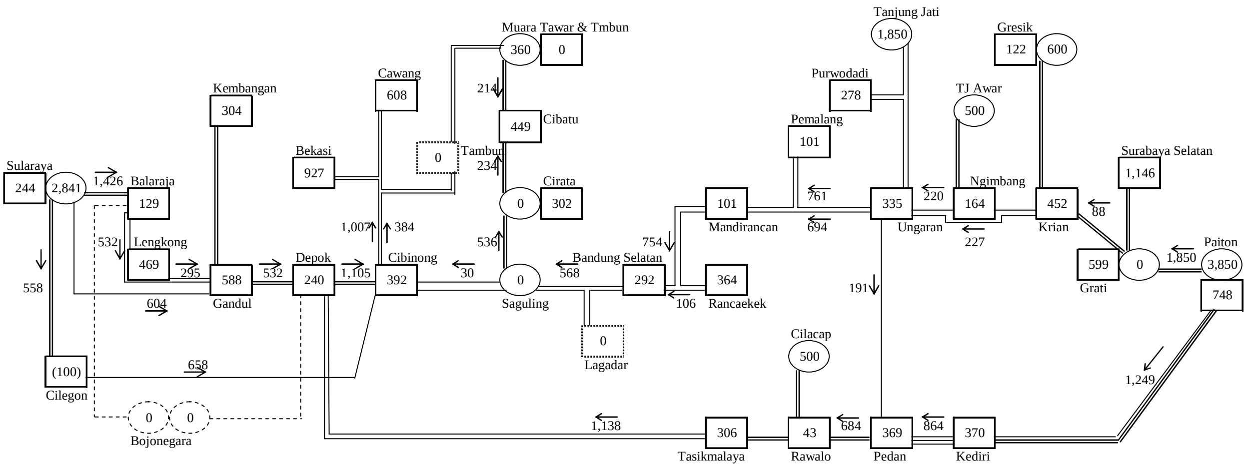
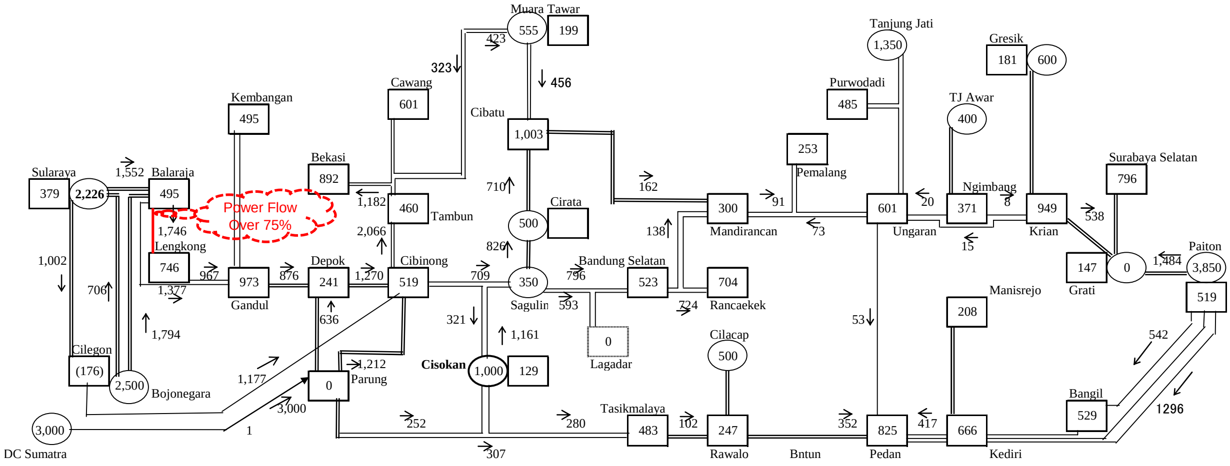


Fig.5.2-2(1) System Configuration and Power Flow in 2010

(a) Power Flow at Peak Load



(b) Power Flow at Off-peak Load

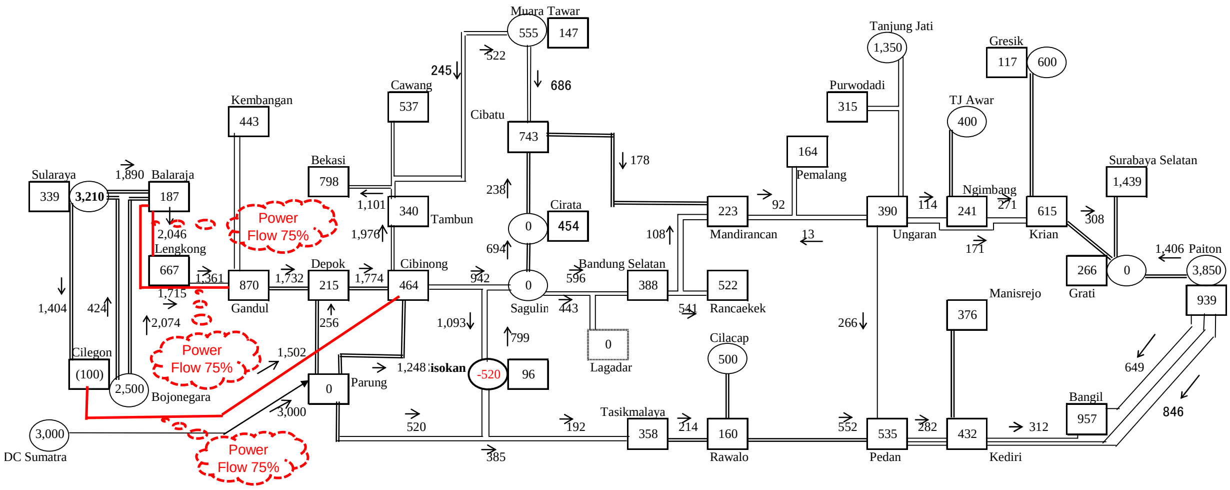
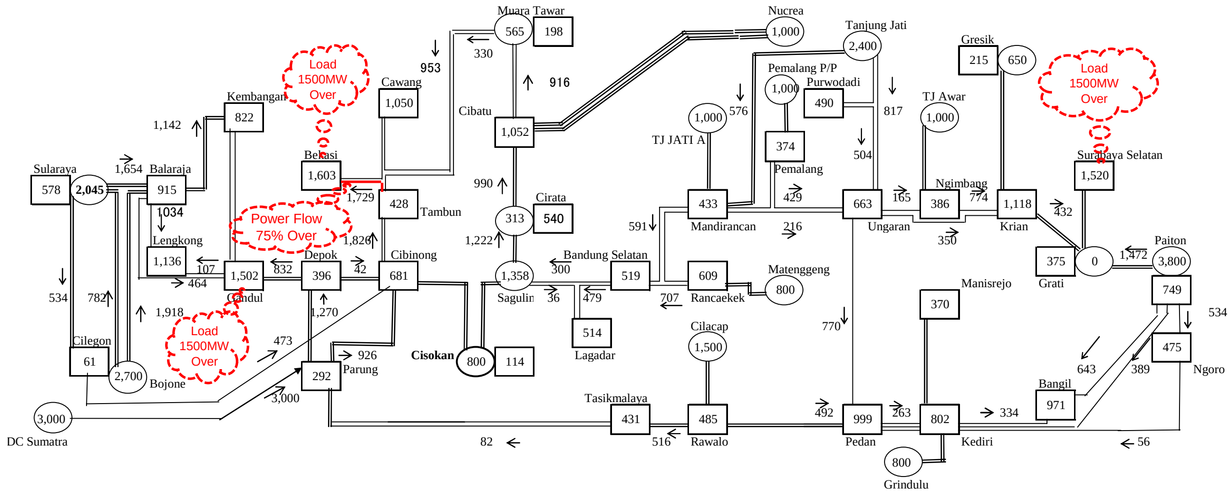


Fig.5.2-2(2) System Configuration and Power Flow in 2015

(a) Power Flow at Peak Load



(b) Power Flow at Off-peak Load

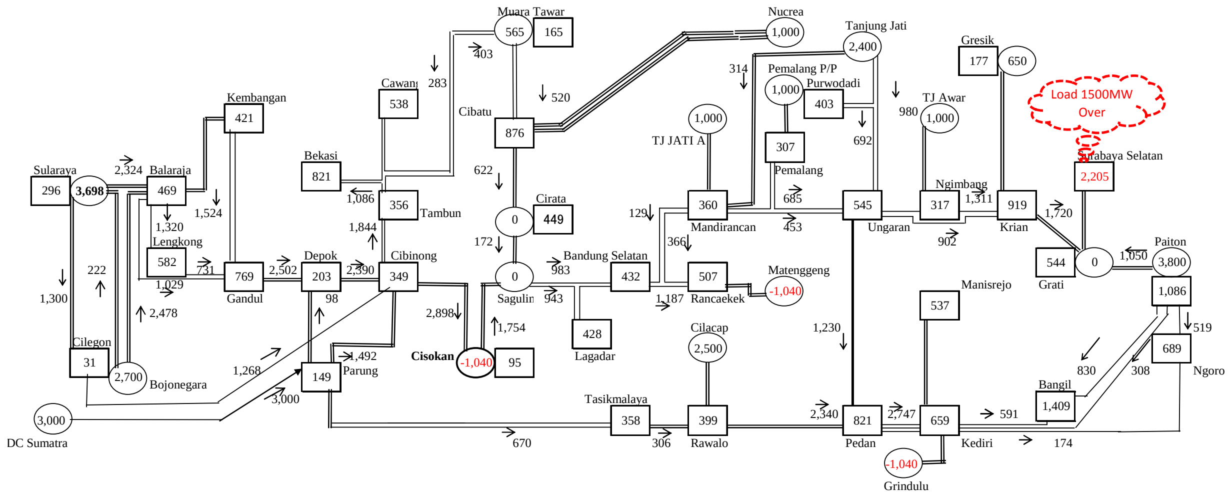
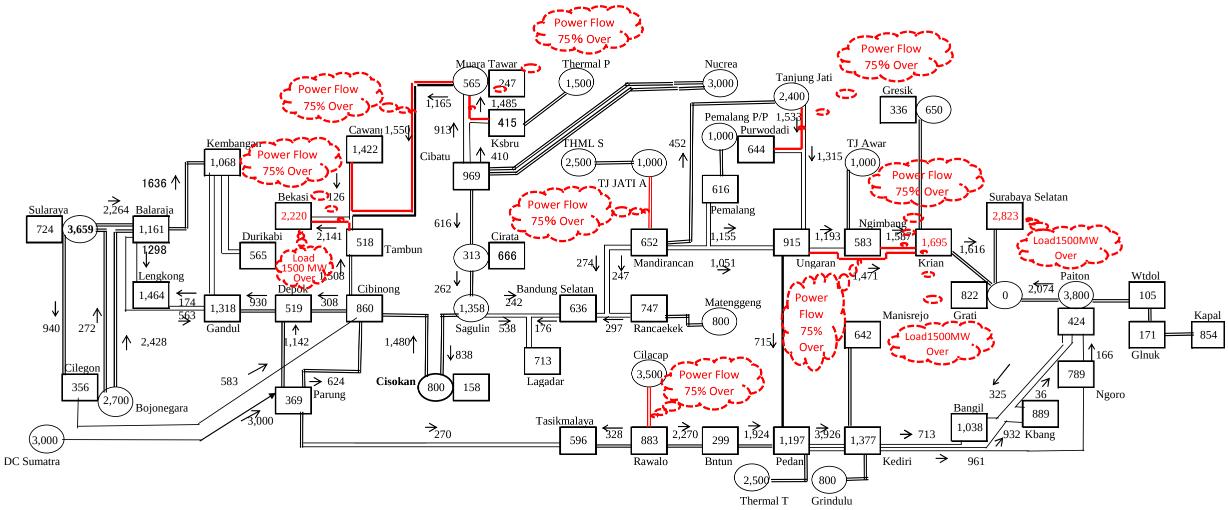


Fig.5.2-2(3) System Configuration and Power Flow in 2020

(a) Power Flow at Peak Load



(b) Power Flow at Off-peak Load

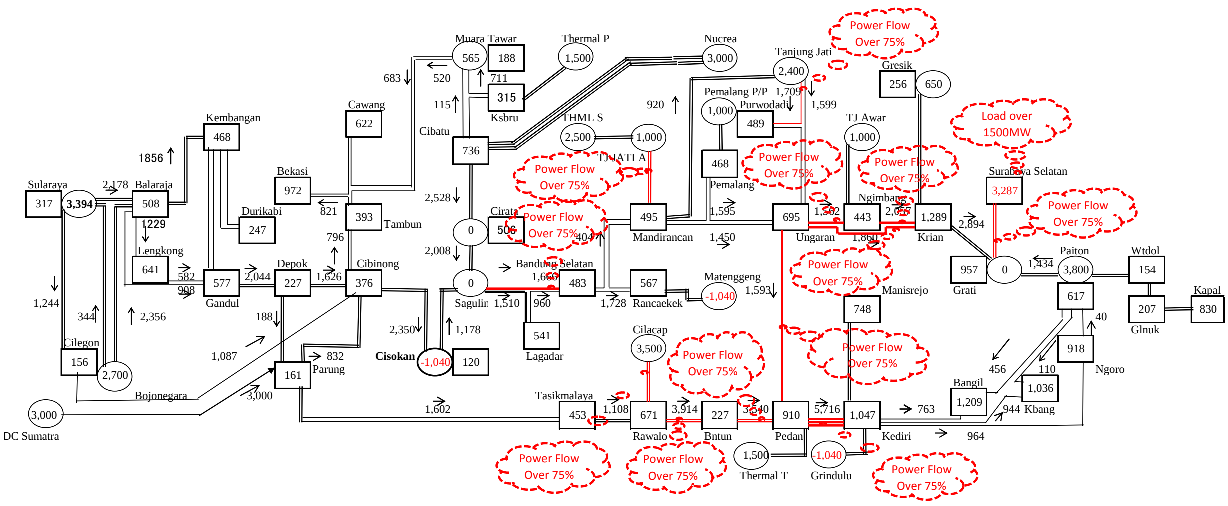


Fig. 5.2-2(4) System Configuration and Power Flow in 2025

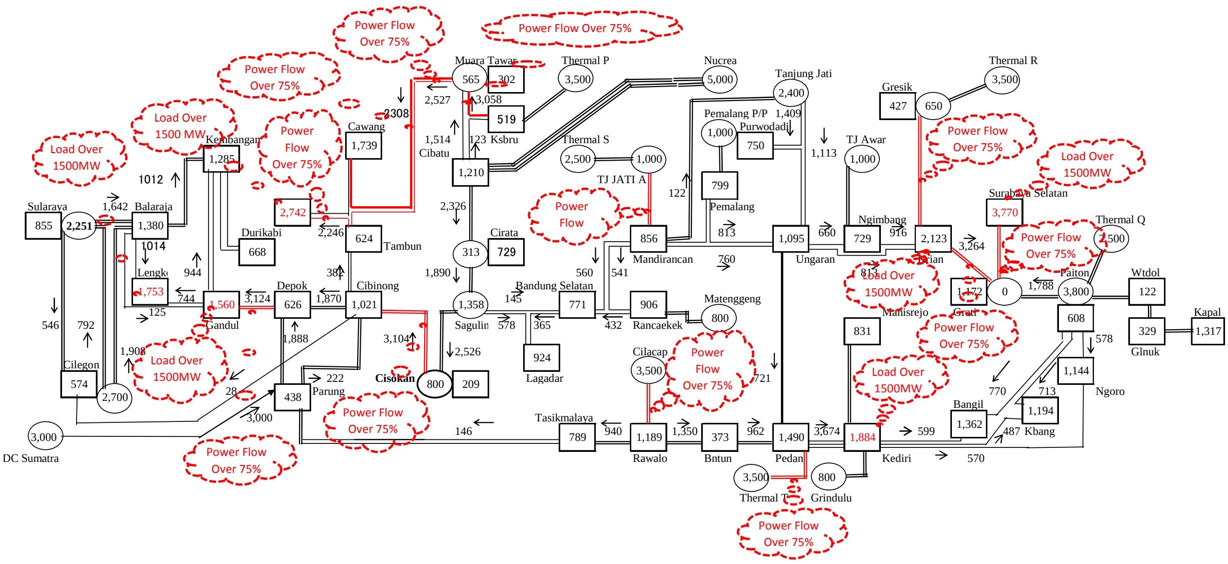
(2) Expansion Plan in 2028

Total system capacity in the final year 2028 was estimated at around 60 GW. Important issue will be the selection of transmission from the nuclear power plant in Central Java. Preliminary plan of system configuration and power flow is shown in Fig.5.2-3.

It is assumed that the trunk power flow runs from Central Java to West Java in the future because of the development of Tanjung Jati power station, nuclear power station, and large-scale thermal power plants in Central and East Java.

It is also assumed that the construction of two circuits of 500 kV transmission lines along the northern part of Java Island, between the nuclear power plant to Mandiracan S/S or Cibatu S/S, shall be a minimum requirement to transmit the generated power by the nuclear power plant in Central Java to the load center in West Java.

(a) Power Flow at Peak Load



(b) Power Flow at Off-peak Load

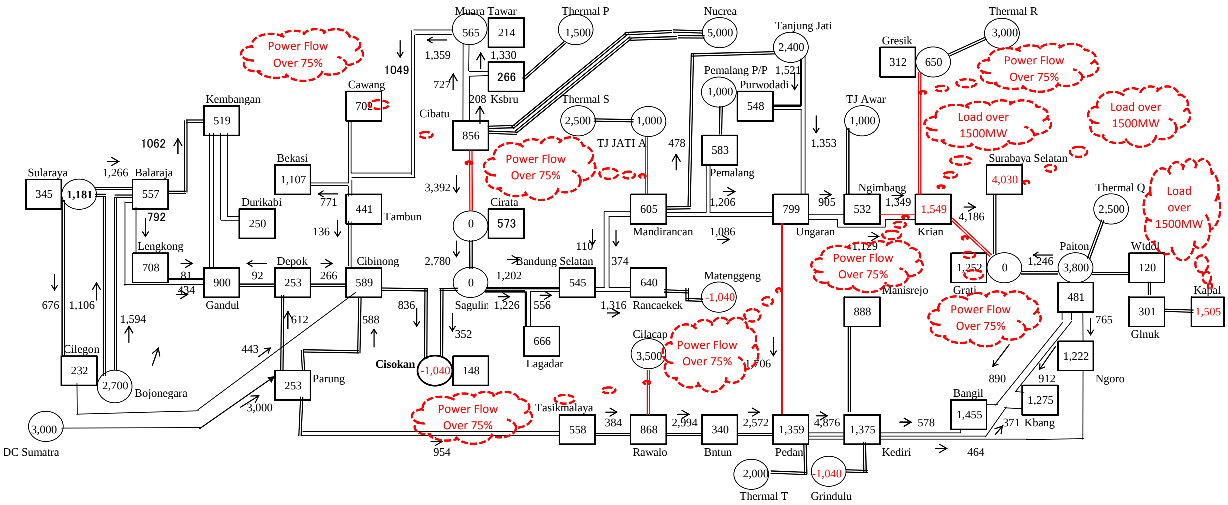


Fig.5.2-3 Java Bali Load Flow Diagram for 500 kV System in 2028

As a result of the system analysis on this power system configuration, of which details will be explained in the latter part of this report, there exist some issues such as short circuit capacity and land acquisition of transmission line route. Necessary countermeasures on such issues shall be examined.

5.2.5 System Analysis Evaluation of Power System Reliability
(quality of power voltage, condition of system power flow, and short circuit capacity etc.)

The results of system analysis on the tentative system configuration and power flow estimation are summarized as follows:

(1) Summary of Power Flow Analysis

Load and system voltage condition of system component equipment obtained by power flow analysis are summarized below:

1) Load condition of main equipments

(i) Load condition of trunk transmission lines

According to the PLN standards, the capacity load ratio is limited to 60% normally and expansion shall be required when it exceeds 80 %.

In this study, conservative evaluation was carried out based on the above criteria because many uncertain factors exist in power resources and substation load in the long term.

In case one of the circuits failed (N-1 rule) under the double circuits operation, time and place were identified when/where the load ratio exceeds 75% of the maximum capacity by limiting the overload ratio within 150%.

In case a single line failed by accident, the overload condition of remaining line should be dissolved within around thirty (30) minutes by system recovering operation.

Results of power flow analysis for each year are summarized as follows:

- Expansion of power system in West Java region is required from the period of around 2015 in relation with a power supply plan to the metropolitan high demand area.
- It is recommended to develop the power supply plan as mentioned above as soon as possible so that actual reinforcement of related power supply system can be started around 2020 based on the expansion plan.
- It is recommended to conduct the study on Ungaran-Pedan transmission line (change the current single circuit to double circuits) as early as possible, so that the project can be completed by 2020 at latest.
- In parallel with expansion of Ungaran-Pedan transmission line, it is expected to develop expansion plan of the 500 kV trunk loop system in the whole of Jamali to be commenced around 2025.
- Regarding the transmission line for large capacity power station, introduction of larger size conductors should be considered at the planning stage, which meet the

capacity of new power plant.

- Large-scale development and expansion is being planned on Tanjung Jati power station. There is a π connection in sending load to the substation on the way to the main grid. Therefore it is suggested to review expansion plan of systems in the vicinity, including better use of Tanjung Jati-Mandiracan transmission line.

Summary of power flow analysis for 500 kV transmission lines for each year is shown in Table 5.2-4.

Table 5.2-4 Summary of Power Flow Condition of Trunk 500 kV Transmission Lines

Transmission line	Year 2010	Year 2015	Year 2020	Year 2025	Year 2028	Countermeasure
Depok-Gandule					flow over 75%	- Expansion of power system in West Java region shall be commenced around 2015 with relation to metropolitan power supply
Balaraja-Lengkong		flow over 75%	flow over 75%	flow over 75%	flow over 75%	
Balaraja-Gandule		flow over 75%	flow over 75%	flow over 75%	flow over 75%	
Cilegon-Cibinong		flow over 75%	flow over 75%	flow over 75%	flow over 75%	
Cibatu-Cirata					flow over 75%	- Expansion of related power supply system shall be commenced around 2020 based on the metropolitan supply plan.
Cirata-Saguling					flow over 75%	
Cibinong-Cisokan					flow over 75%	
Muara Tawar-Tambun					flow over 75%	
Muara Tawar-Cawang				flow over 75%	flow over 75%	
Muara Tawar-Ksbru				flow over 75%	flow over 75%	
Bekasi-Tambun			flow over 75%	flow over 75%	flow over 75%	
Saguling-Lagadar					flow over 75%	- Expansion work shall be commenced around 2025 in parallel with expansion of Ungaran-Pedan transmission line
Krian-Grati					flow over 75%	
Ungaran-Ngimbang					flow over 75%	
Ungaran-Krian				flow over 75%	flow over 75%	
Krian-Ngimbang				flow over 75%	flow over 75%	
Rawalo-Butum				flow over 75%	flow over 75%	
Pedan-Kediri				flow over 75%	flow over 75%	
Saguling-Bandung Selatan				flow over 75%	flow over 75%	
Ungaran-Pedan				flow over 75%	flow over 75%	- expansion of another one circuit shall be commenced in the earliest convenience
TJ Jati A-Mandiracan				flow over 75%	flow over 75%	- Larger-scale conductor shall be examined and introduced in the planning stage
Cilacap-Rawalo				flow over 75%	flow over 75%	
Surabaya Selatan-Grati				flow over 75%	flow over 75%	
Gresik-Krian					flow over 75%	
Thermal T-Pedan					flow over 75%	
Tanjung Jati-Purwodadi				flow over 75%	flow over 75%	- Expansion work shall be commenced in parallel with the expansion of Tanjung Jati P/S

It is very difficult to find out the definite system overload condition in the long term in this study because power flow situation changes by operation of power plants and load condition etc, from time to time and is very much affected by locations of new power stations developed in the future.

Therefore, it is important that this result is incorporated in the system planning of PLN, and will be subject to revision every year.

(ii) Load Condition of Trunk Transformer

For a standard load ratio of transformer, 60% is adapted and next expansion plan is developed when it reaches 80%. Transformer load condition was evaluated at each substation in the following manner for each year.

[Short period overload capacity 150%, continuous overload capacity 110%]

In the case of one transformer → considering the restoration after stoppage, installation of additional transformer should be considered when the load ratio reaches 60%.

In the case of two transformers → considering the restoration in the lower system, installation of additional transformer should be considered when the load ratio reaches 75%.

In the case of three transformers or more → considering restoration in the lower system, installation of additional transformer should be considered when the load ratio reaches 100%.

However there exist some concerns over three or more units of transformers installed at a trunk substation as below.

- Although it is preferable to operate transformers in parallel, there may be a case where transformers could not be operated in parallel and reliability of power supply lowers due to a short circuit problem.
- Load capacity of one trunk substation becomes too large to restore in the case of upper side accident. Impact on users can become very serious because black-out area will be very large.
- Adequate supply area from one trunk substation varies from urban area to rural area in terms of economic power supply configuration. However, in general, distance between trunk substations is within 50 to 100 km even in low demand area. Therefore around 3 units are recommended to be maximum capacity in one trunk substation.
- It should be considered to introduce larger transformer units in large demand area in the future as there is an economy of scale.

Example:

Load concentrated area → max. around 3 units with 750 MVA (500/150 kV Tr) or 1,000 MVA (500/275 kV)

Other area → around 2 units (max. 3 units) with 500 MVA (500/150 kV Tr)

A standard of maximum capacity of one trunk substation should be around 1,500 MVA (500 MVA * 3 units) or 1,000 MVA in the case of restoration by lower power system, although a load concentrated urban area should be evaluated individually.

Followings are the comments derived from the result of the evaluation based on the power flow forecast trunk substations:

- It is suggested to construct a new substation in the vicinity of a existing substation when the load ratio of the substation reaches the capacity as mentioned above considering the load restoration condition from lower system.
- In particular, regarding the large demand area of Jakarta, it is recommended to develop "Power supply method in DKI Jakarta" considering the technical and economical aspects. A direct introduction of 500 kV transmission line into the load center via underground cables should also be studied.
- It is recommended to construct a new substation and additional transformers on the basis of total power supply plan for the southern area in East Java incorporating restoration measures.
- It is recommended to introduce lager size transformer units to have scale merit in consideration of final capacities, durability, necessity of additional substation with a long term perspective.

Summary of load condition for the trunk substations in each year is shown in Table 5.2-5.

Table 5.2-5 Summary for Load Condition of Trunk Substation

Substation name	2010	2015	2020	2025	2028	Countermeasure
Surabaya Selatan	Load over 1000MW			Load over1500MW		- to construct new substation in the vicinity of the existing substation
Krian					1500MW	
Krian			1000MW			
Kediri				1000MW	1500MW	
Lengkong						
New Substation D						- to commence expansion starting from year 2020 based on "DKI Jakarta Power supply method "
Muara Tawar						
Cawang				Load over 1000MW		
Bekasi				Load over 1500MW		
Cibinong					1000MW	
Depok						
Gandul				Load over 1000MW		
Kembangan					Load over 1000MW	
Durikabi						
New Substation M						
New Substation S						- Introduction of 500kV to the load center directly
Bangil				Load over 1000MW		- to commence expansion based one supply plan of southern area in East Java
Kbang					1000MW	
Ngoro					1000MW	
Grati					Load over 1000MW	- Introduction of larger-scale unit of transformer from long term view point.
Ungaran						
Cibatu				Load over 1000MW		
Balaraja						
Pedan					Load over 1000MW	
Rawalo						

2) Condition of system voltage

The voltage range of 500 kV system under normal operation should be kept within 500 kV±5% with no tap changing effects.

The voltage on the power plant side is set higher than the rated voltage by a few percent (%). System voltage analysis was done to predict both overvoltage and under voltage.

The excessive voltage drop would be unavoidable, unless the reactive power of the load demand at each substation is thoroughly compensated by large capacities of shunt capacitor. Finally the system voltage could be kept within a tolerable range on the condition of adequate capacity of shunt equipment. The required amount of shunt equipment was roughly calculated.

The simulation result is shown in Table 5.2-6.

- Reactive power compensation equipment is required to keep the system voltage within a suitable range. Although lagging operation of generator is preferable for stable operation, it will be restricted resulting in the system voltage increase. In case that the demand side voltage increases, output of reactive power from generator is restricted because of high voltage of the sending end.
  The reason of less supply of reactive power from generator (Power factor of a few percent) in Table 5.2-6 is attributable to the total system voltage situation. Efforts should be made to generate lagging reactive power as much as possible by adjusting tap changer for voltage transformer in the practical operation.

Table 5.2-6 Reactive Power Balance

(MVar)

Year		Generator	Power load	Phase modifying system	charger capacity	transmission loss
2015	Peak Load	5319.0 (16530.3 MW)	5946.0 (16070.0 MW)	-2438.5	4194.2	6005.7 (460.3 MW)
	Off-peak Load	3261.2 (15662.6 MW)	4299.0 (15157.0 MW)	-3213.0	4178.4	6353.6 (505.6 MW)
2020	Peak Load	7413.0 (24370.1 MW)	9069.0 (23866.0 MW)	-4423.5	4677.2	7444.7 (504.1 MW)
	Off-peak Load	5759.7 (23013.6 MW)	5376.0 (22246.0 MW)	-4818.3	4611.1	9813.1 (767.6 MW)
2025	Peak Load	12179.3 (36541.7 MW)	13421.0 (35465.0 MW)	-10901.2	5654.1	15313.7 (1076.7 MW)
	Off-peak Load	10487.0 (31209.6 MW)	5612.0 (29647.0 MW)	-8484.5	5616.5	18975.9 (1562.6 MW)
2028	Peak Load	14882.3 (46637.9 MW)	16697.0 (45206.0 MW)	-17361.0	5667.0	21213.4 (1431.9 MW)
	Off-peak Load	10979.8 (37495.7 MW)	2353.0 (35941.0 MW)	-5848.6	5662.5	20137.9 (1554.7 MW)

For reference, an economic evaluation was carried out on the voltage increase by introducing the reactive power compensator equipment in 500 kV power system for the year of 2028. Evaluation result for the case of the system voltage partially increased by 5% by the shunt equipment is shown as below.

* Shunt equipment required for the system voltage increase : 8,999 MVar
* System loss reduction : 59 MW
* Economic benefit of system loss reduction : About Rp. 220 Billion
  [Precondition: *Load factor → 0.61875, Generation cost → Rp. 705.96/kWh*]
* Equivalent economic benefit of shunt equipment: about Rp. 310 Million/MVar
  [Commercial installation cost: about Rp. 240 Million/MVA]

Judging from the above evaluation, it is economic to raise system voltage by installation of shunt equipment at effective point in substations with small short circuit capacity.

The following items should be considered with regard to the actual reactive power planning.

- Reactive power should be planned to keep a balance of not only in the total system, but also in the partial area system.

- The shunt equipment should be installed at the end of the system for the sake of reducing system loss and increasing voltage regulation effect.
- The shunt unit size should be selected within the limit of tolerable voltage Bicker which usually corresponds 2 to 3 percent in consideration of economy.
- Introduction of on-load tap changer to the higher voltage system transformers should be examined.

(2) Condition of Short Circuit Capacity

The 3-phase short circuit capacity of the trunk 500 kV substations as of 2028 is shown in Fig. 5.2-4. The calculated value shows the maximum 3-phase short circuit capacity in the case that all generators are put into the system under severe conditions.

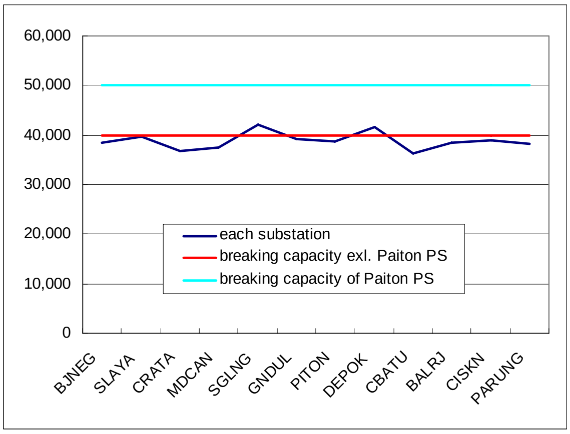


Fig.5.2-4 3-Phase Short Circuit Capacity of Trunk 500 kV Substations

In this study an evaluation of short circuit capacity under 150 kV system was omitted because the 3-phase short circuit current control measurement should be studied on such systems by the construction of new trunk substation or separate operation of transformers.

At present, the designed capacity of all circuit breakers introduced in Indonesia is 40 kV except for the 50 kV of Paiton P/S. The calculated value shows that Cirata and Saguling substations will have relatively high 3-phase short circuit capacity by connecting with the large power plants. If the power plants are constructed or expanded intensively in one area in the future, construction of additional transmission lines might be required to connect to the power system in consideration of 3-phase short circuit capacity.

From the aspect of 3-phase short circuit capacity, as far as system reliability and capacity allows, power plants should be developed uniformly in West, Central, and East Java not centralizing in West Java, a heavy load center. In case that the short circuit capacity is less than 50 kV, circuit breakers with 50 kA or 63 kA will be available under the conditions that there is no severe magnetic field effect to ground wire, tolerance capacity of series connected facilities and communication system etc.

Generally, a 3-phase short-circuit capacity becomes larger as the scale of the system is getting larger. Therefore, by taking a countermeasure of bus separation etc. as shown in Appendix (7) “General Information of System Planning”, 3-phase short circuit capacity is controlled not to exceed the breaking capacity of each circuit breaker.

(3) Result of Transient Stability Analysis

Stability analysis of the 500 kV AC system was carried out tentatively for the major projects under consideration as of 2028. Location of 3-phase short circuit accident was selected in 500 kV transmission line near a power plant under the severe condition and analysis was made by applying accident condition of “3-phase short circuit, clearing time of 100 ms” as mentioned earlier.

The result of analysis is summarized in Table 5.2-7. Swing curve of related bus voltage for each accident case is shown in Fig. 5.2-4. For those cases resulting in “unstable”, countermeasures will be discussed in "Optimal Power System Development Plan”.

1) Stability of 500 kV trunk loop transmission system

Stability analysis on the whole system was carried out assuming the outbreak of accident between Rawalo S/S ~ Butum S/S, having a large loop power flow.
In the case of loop-off by the accident in the vicinity of Rawalo substation, it is anticipated that the whole system shall be in unstable condition, resulting in the serious black-out.

2) Stability of power transmission lines from the nuclear power plant

Stability analysis was carried out assuming the outbreak of 3-phase short circuit accident in the vicinity of the nuclear power plant, then one circuit was opened. In this case, nuclear power plant will become unstable and to be cut off from power system.

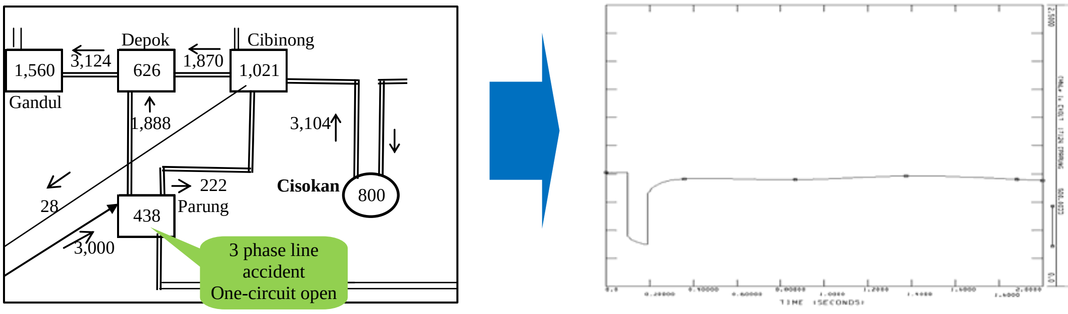
3) System stability in case of stop of Java-Sumatra DC connection

In the case of system voltage drop, the operation of the conventional DC system should be stopped to avoid continuous commuting failure. Therefore impact on the system stability was evaluated assuming that Java-Sumatra DC interconnection stopped and restarted [restarted in 200 ms after the clearance of the accident] due to the system voltage drop caused by the system accident.
It is assumed that the power system is in the stable condition even if the DC system stops in the short time.

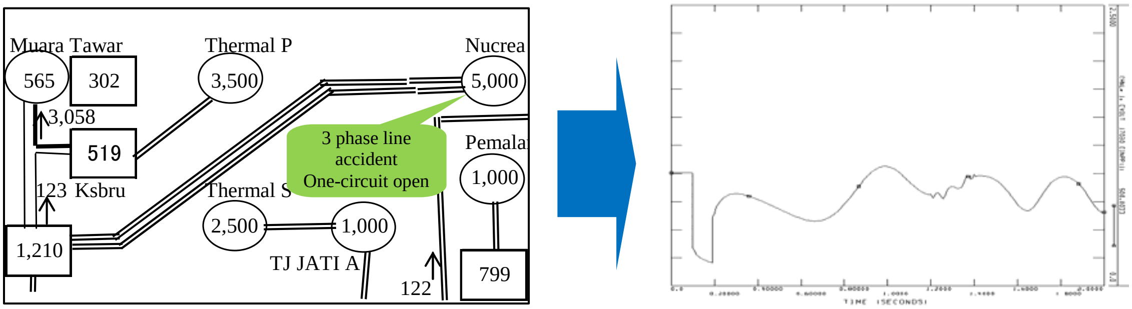
Table 5.2-7 Results of Stability Analysis for Main Projects

Simulation Case	Result of Analysis	Countermeasure
Java-Sumatra DC Interconnector	Stable [Refer Fig.5.2-5(1)]	- Adaption of latest control method (Continuous operation function)
Transmission for Nuclear power plant	Unstable [Refer Fig5.2-5(2)]	Expansion of transmission line(additional one route)or introduction of new transmission system
500 kV Trunk Loop Transmission System	Unstable [Refer Fig.5.2-5(3)]	- Change of site of new power station or connection point of transmission line for reducing loop power flow. - Expansion of southern and northern 500 kV connection (1-2 CCT) [if further countermeasure required] - Adoption of simple shedding system (power & load)

(1) Conventional Control Method [DC system stop and restart (200 ms stop)]



(2) Nuclear Power Plant Project



(3) 500 kV Trunk Loop Transmission System

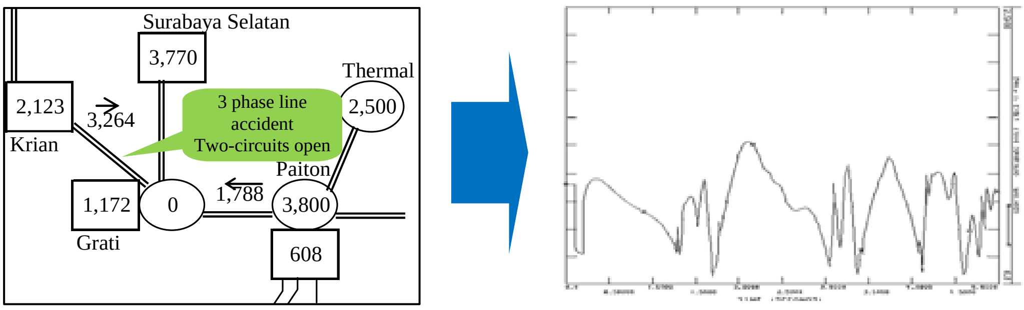


Fig.5.2-5 Swing of Vicinity Bus Voltage in Case of Stop of Java-Sumatra DC Connection

5.2.6 Power System Reinforcement Points based on System Analysis Evaluation

The power system reinforcement points in representative years are derived from the system analysis results under the tentative power system configuration and power flow condition with conventional AC 500 kV transmission as mentioned before.

The summary of reinforcement points is as follows

- Power system configuration in year 2010

  → No urgent issue can be identified. However, it is still recommendable to pay due attention to the load condition of Surabaya Selatan Substation.

- Power system configuration in year 2015

  → There are no urgent issues identfied in Jamali system in particular. However, there seems to be a heavy power flow in the western end area (power system in the vicinity of Balaraja, Lengkong and Gandule) in Java Island depending on power generation and load condition.
  Therefore, it is strongly recommended to consider whether system shall be strengthen for entire region including transmission line of Cilegon-Cibinong in a few years or not since this condition seems only temporary.

  → Regarding Surabaya Selatan substation, it is recommended to introduce larger size transformer (500/150 kV 750 MVA Class) taking into consideration the demand increase in the future.

  → Regarding the new transmission line of Cibatu-Mandiracan, it is desirable to consider this in relation with the introduction of DC transmission mentioned later.
  It is recommended to review the necessity of this new AC transmission line and possibility of 275 kV operation as the first phase for DC transmission line, depending on sending power required.

- Power system configuration in year 2020

  → It is anticipated that some substations in the vicinity of Jakarta area (Bekasi, Gandule substation in particular) will be under heavy load. Therefore, it is recommended to develop new 500 kV trunk substations and reinforcement of related transmission line from the evaluation of optimal power supply to Jakarta Metropolitan area as a whole.

  → It is assumed that load of Surabaya area will increase. Therefore, it is recommended to develop new 500 kV trunk substation in this area in addition to Surabaya Selatan Substation after the consideration on total supply method of this area in the long term

  → It is recommended to introduce DC system for sending large power generated by nuclear power plant located in Central Java to western area.

  → There is a plan to reinforce the transmission line between Tanjung Jati-Mandiracan in accordance with the expansion of Tanjung Jati power station etc. It is strongly suggested to reconsider the necessity of this transmission line on the basis of total power system reliability criteria instead of adaption of partial criteria which include partial stability standard. In particular, installation cost of this transmission line can be very large. Thus, it is recommended to review this reinforcement plan including cost-effectiveness of the plan.

Summary of reinforcement points at year 2020 system is shown in Table 5.2-8.

Table 5.2-8 Summary of Reinforcement Points at Year 2020 System

		Summary of Reinforcement Point
Reinforcement of Transmission Line	500 kV	－**Reinforcement of Load Supply for Metropolitan** • New Transmission Line between Balaraja-Kembangan (Approximate 40 km) and between Kembangan-Muara Tawar (Approximate 100 km) －**New transmission Line correlated with new substation** • New Transmission line between Kembangan-Muara Tawar and Surabaya Selatan (Total length: Approximate 20 km) －**Strength of Power System by establishing of new power point.** • Pemalang Power Supply Line (Approximate 30 km) • Reinforcement of Transmission line nearby Cisokan power plant. (approximate 20 km) • Power supply line by Nuclear Power Plant (Approximate 450 km) : Northern part of Central Java Island near Muria Pen.-Cibatu） • Power supply line of TJ JATI A (Approximate 130 km) • Transmission line correlated with Pumping up power plant :Matenggeng Pumping Up Power Plant (Approximate 50 km), Gurindulu Pumping Up Power Plant (Approximate 50 km) • Reconsider between Tanjung Jati-Mandiracan
New Substation		• New Substation (500 kV) between Kembangan and Muara Tawar where is also nearby Bekasi Substation. • New Main Substation (500 kV) nearby Surabaya Selatan • New Negro Substation of load supply for the South East Java Region. • New Lagadar Substation

- Power system configuration in year 2025

→ It is recommended to develop related transmission lines (new 500 kV transmission line between Muara Tawar- Cibinong and Muara Tawar - Durikabi) on the basis of the Metropolitan heavy load area power supply mentioned before.
It is recommended to build new substation of Durikabi S/S as well.

→ Regarding the transmission of Tanjung Jati-Mandiracan, it is proposed to reevaluate the necessity of this reinforcement in accordance with the timing of expansion of Tanjung-Jati power plant & IPP P/P developed in the vicinity area taking into consideration the total system reliability level.

→ Depending on power development in central Java area in the future、the main power flow of 500 kV trunk line seems to change from current west side direction to east side direction. So, it is recommended to reinforce the transmission system between Saguling-Bandung Selatan and Ungaran - Ngimbang - Krian for increasing sending capacity.

→ Transmission of Ungaran-Pedan which connects southern and northern 500 kV transmission lines seems to be very important pointing terms of power flow and system reliability.
Therefore, it is recommended to reinforcement another one circuit on this part urgently.

→ Regarding the new transmission lines related to new power stations, conductor size of transmission line should be considered and larger size should be adapted to meet final capacity of power station.

→ Judging from increase of demand and difficulty of developing power plants in Bali

Island, it is recommended to reinforce the interconnection with AC 500 kV overhead transmission line because of insufficient capacity of current 50 kV submarine cable (Sending Capacity of 200 MW).

→ It is desirable to reinforce power supply system in the southern area in Java Island (especially south east area) in accordance with increasing power demand of this area.

Summary of reinforcement points at year 2025 system is shown in Table 5.2-9.

Table 5.2-9 Summary of Reinforcement Points at Year 2025 System

		Summary of Reinforcement Point
Transmission line	500 kV	－**Reinforcement of continuation Load Supply for Metropolitan** • New Transmission Line construction between Cibinong-Muara Tawar(Approximate 40 km) －**Transmission Line construction correlated with new substation** • Additional line between Kembangan and Muara Tawar. Also additional line near by Surabaya Selatan(Total length 20 km) • Near by Krian（between Krian and Gresik）correlated with substation (approximate 10 km) • New substation at Ksbru, Bntum and Kbang (Total 30 km) • New substation at Durikabi (Approximate 10 km) • Power System (500 kV) between Java and Bali with correlated new substation (Approximate 120 km) －**Reinforcement of Power System by establishing new Power Point** • Transmission Line reinforcement with New Power Plant construction nearby Muara Tawar (Approximate 50 km） • Transmission Line reinforcement with New Power Plant construction nearby TJJATIA (Approximate 40 km) • Transmission Line reinforcement with New Power Plant construction near by Pedan or Kediri (Approximate 100 km) • No sea water pumped storage system is listed since there are many indeterminate factor considering as risk. • No additional power supply from Sumatra Island is considered since there are many indeterminate factor considering as risk. －**System Reinforcement related** • There might have a main power system (500kV) reinforcement between Ungaran and Krian based on increasing current toward east direction However in this report it is omitted since those current could be temporary double current. • Dual Line between Ungaran and Pedan is strongly required for the stabilize of Power system. (Approximate 150 km)
New Substation		• Additional new main substation (500kV) nearby Bekasi (between Kembangan and Muara Tawar) • Additional new main substation (500kV) at nearby Surabaya Selatan • New substation at Kbang as load supply for south east Java Island region • New substation at Butum、Ksbru and Durikabi • New substation at Witdol, Glnuk and Kapel correlated with Bali Island Power system. • New substation near by Krian (Between Krian and Gresik)

- Power system configuration in year 2028

→ Reinforcement of transmission lines related to new power plants

→ It is recommended to develop a new 500 kV trunk substation between Muara Tawar - Durikabi and related transmission lines on the basis of the Metropolitan heavy load area power supply.

→ It is recommended to develop an additional 500 kV trunk substation in the vicinity of Kediri substation in accordance with increasing demand of Kediri area.

→ It is recommended to take some countermeasures for reducing eastward power flow in loop system which seems to increase due to the extension of Cilacap power plant and additional power supply from Sumatra Island etc.

→ It is recommended to take some countermeasure for reducing heavy power flow between Krian-Grati in accordance with more demand increase of Surabaya Selatan area.

Summary of reinforcement points at year 2028 system is shown in Table 5.2-10.

Table 5.2-10 Summary of Reinforcement Points at Year 2028 System

		Summary of Reinforcement Point
Reinforcement of Transmission Line	500 kV	－**Continuation for reinforcement of Load supply in JAKARTA Special Province** • Additional new substation between Kembangan-Muara Tawar (approximate 10 Km) －**Power System Reinforcement by establishing new Power Plant** • Transmission Line reinforcement with New Power Plant (Coal K) near by Gresik (Approximate 50 km) • Transmission Line reinforcement with New Power Plant (Coal P) near by Paiton (Approximate 40 km)) • Transmission line between Kediri and Manisrejo correlated with additional substation (Approximate 10 km)
New Substation		• Additional main substation (500 kV) nearby Bekasi (between Kembangan and Muara Tawar) • Additional substation between Kediri and Manisrejo.

5.2.7 Introduction of DC System for Large-Capacity and Long-Distance Transmission

The largest concern of Java-Bali power system is how to transmit the large power generated by large-scale power plant located in Central Java to load center in West Java for long distance.

Although further study should be made on this issue, the additional two new transmission lines would be required at least, even after the existing AC 500 kV transmission line will have been reinforced as shown in Fig.5.2-6 for reference.

This system has the following main concerns

- Obtaining the right of way for new several additional AC 500 kV transmission roots
- Arrangement of huge installation cost for new AC 500 kV transmission line
- Adjustment for further system expansion and situation change in the future

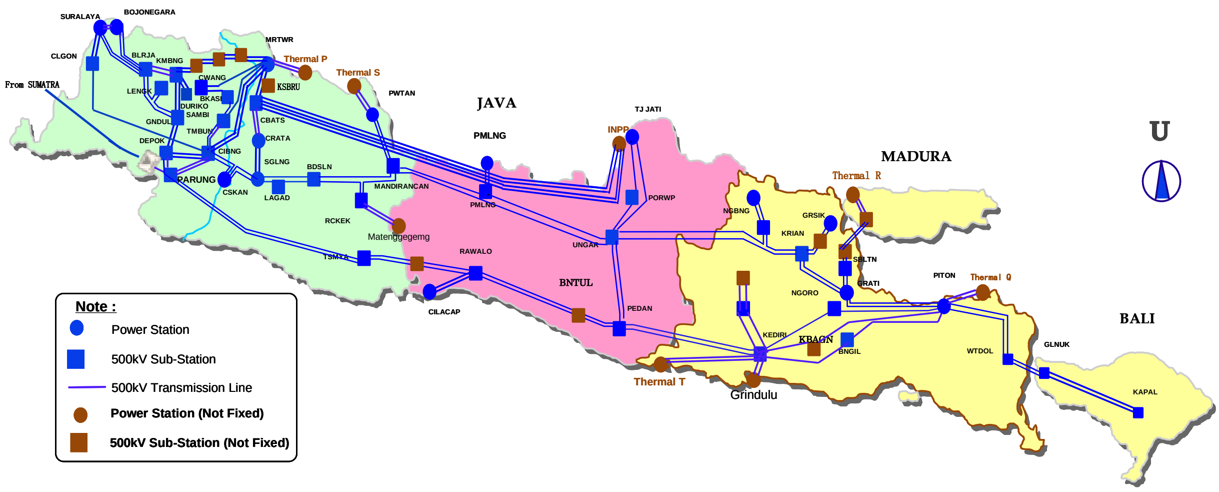


Fig5.2-6 Image of Java-Bali Power System Configuration in the Future (Year 2028)

Therefore, comparison of possible new transmission systems was done as follows:

(1) Comparison with New Transmission System

For the trunk line power system configuration under continuous expansion, it is particularly important that the flexibility of power system is maintained in order to cope with the change of situation in the future in economic and efficient manner.

1) Concept for optimum trunk line system design

As a general concept, the following design policy for trunk line system was considered for developing the trunk line configuration.

- Optimization of system reinforcement keeping pace with power plants developments
- Flexibility of the trunk power system to cope with future expansion and situation change of power system
- Efficient long term reinforcement based on criteria for reliability
- Power supply quality balancing between economic efficiency and social demand
- System composed of widely available equipments for the ease and economy of O & M
- Use of the latest proven technology for the stability of power supply and economy
- Simplicity of the power system with high reliability
- Utilization of the existing equipments
  - Adoption of the minimum protection system against large-scale system breakdown
- Enhancement of supply-demand balance by regional block

2) Evaluation of alternative power reinforcement methods

To resolve these issues in reinforcement of the existing 500 kV transmission line system, several alternative reinforcement methods were compared and evaluated.

As currently available proven technology, two methods, the ultra high AV voltage and DC system, were selected.

Table 5.2-11 shows the comparison of several reinforcement measures in terms of installation cost, flexibility and reliability.

Table 5.2-11 Comparison of Several Reinforcement Measures

Method	Install Cost	Flexibility	Proven Technology	O & M
Direct Current	++	++[BTB]	+	+
Ultra AC High Voltage	-	+	-[Loss]	-
Existing AC 500 kV	+	+	++	++

Legend : ++ : Excellent + : Good - : Fair

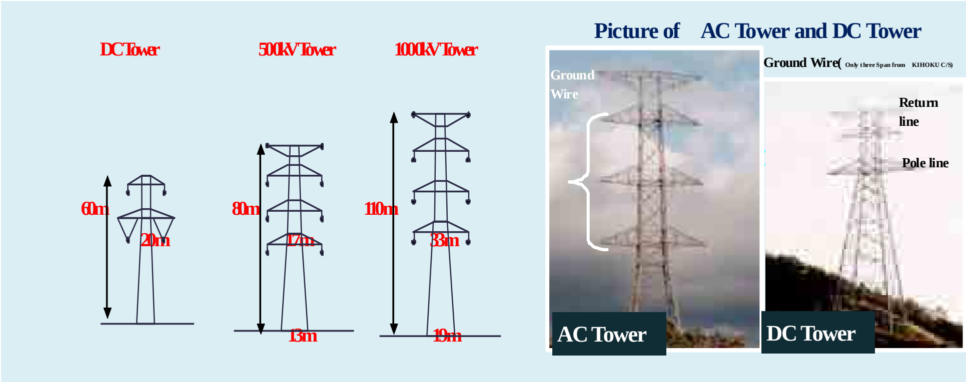


Fig. 5.2-7 Schematic Tower Design of Each Method and Photos

3) Outline of AC/DC installed cost comparison

Regarding the total installation cost, the DC system has a lower transmission line cost than AC system, but requires expensive AC/DC convector stations at both ends.

In general, DC system is suitable for transmitting large power for long distance as shown in Fig.5.2-8.

Brief comparison shows that the economic break-even point is in somewhere between 300 to 400 km in Indonesia. Fig.5.2-8 shows the rough comparison of installation cost of two transmission systems.

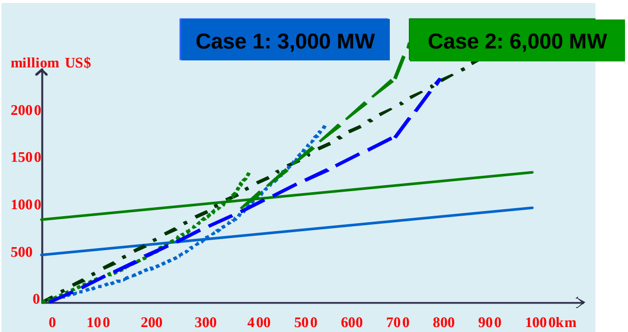


Fig.5.2-8 Comparison of Install Cost for Each Transmission System

4) Outline of AC/DC sending capacity comparison

Fig. 5.2-9 shows the outline of sending capacity comparison of two transmission systems. AC system has a problem of stability and its sending capacity decreases with distance as shown in Fig. 5.2-9.

On the contrary, DC system has no stability problem and its sending capacity is almost constant independent of sending distance.

Consequently, DC system has more suitable technical properties in sending large power for long distance. For sending large power from Central to West Java, the distance is around 500 km. It requires a massive reinforcement to the existing AC 500 kV transmission line, if more power is to be transmitted on this line.

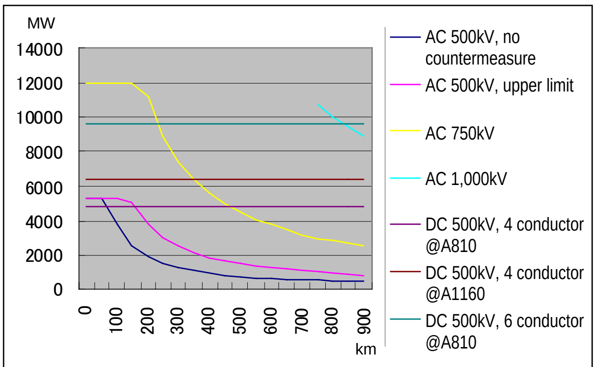


Fig.5.2-9 Illustration of Sending Capacity for Each Transmission System

5) Main DC system projects

DC transmission lines in the world are shown in Figs.5.2-10 to 5.2-13 for reference.

Fig.5.2-10 World's Main DC Facilities

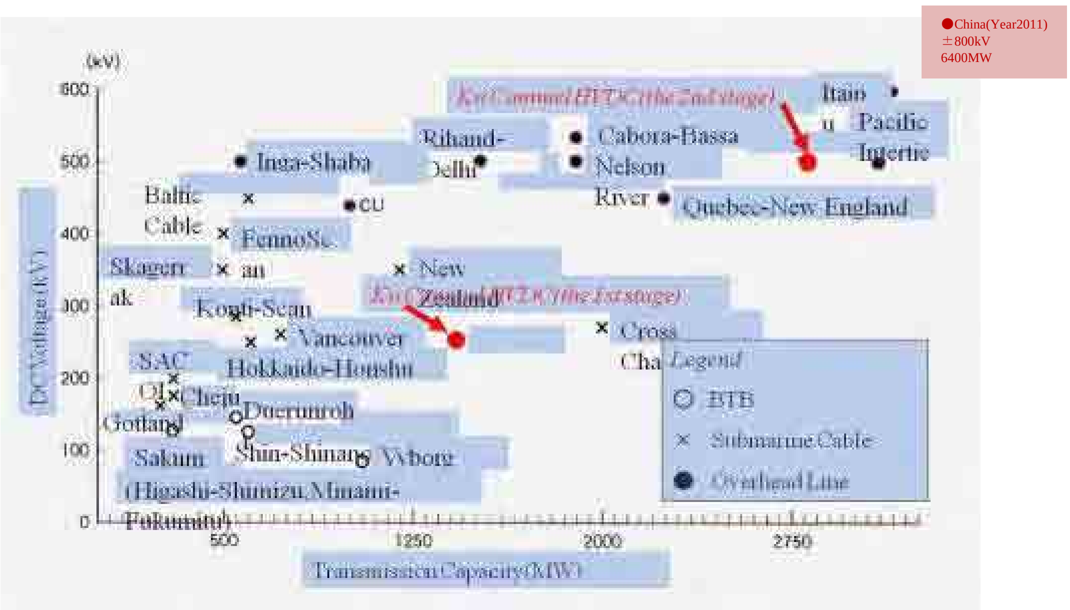


Fig. 5.2-11 Relation between Transmission Capacity and DC Voltage in the World HVDC Project

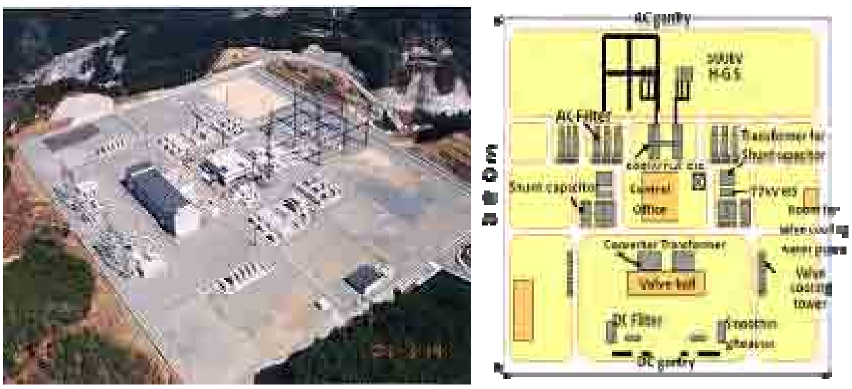


Fig.5.2-12 Instance of Actual AC/DC Convertor Station
(KII Channel HVDC Project in Japan :KIHOKU Convertor Station)

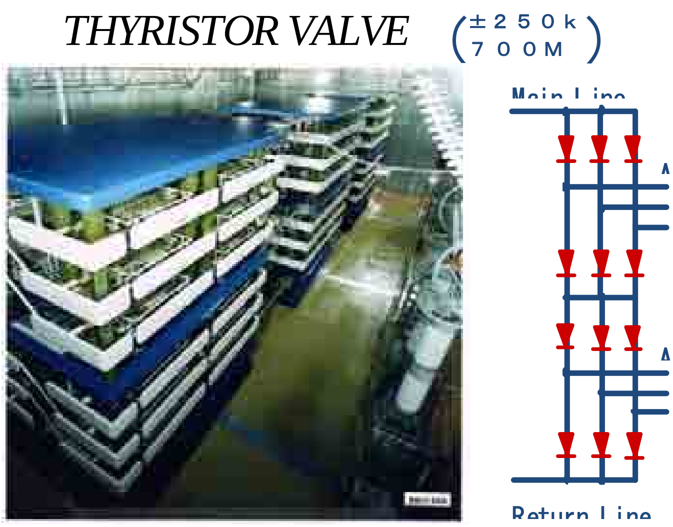
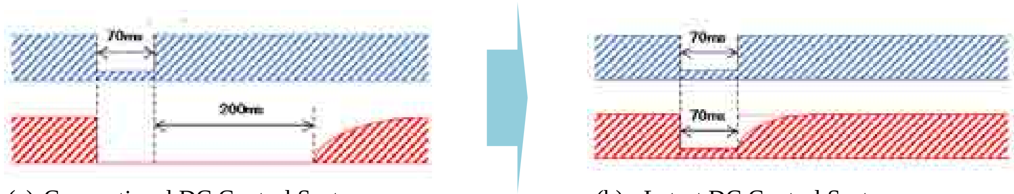


Fig.5.2-13 Compact Thyristor Valve installed in KIHOKU C/C
(Key Equipment in C/C)

6) Latest DC system operation method

Conventional DC system must be once shut down and restarted if system voltage dropped by fault accident etc, to avoid the occurrence of continuous commuting failure. Once the system is shut down it requires around 200 ms before restarting, which has a large impact on the transmission system. This operation used to make DC system unreliable. However, the latest DC control method enables continuous operation even if there is a system voltage drop and is able to restart immediately after restoring the system voltage as shown in Fig. 5.2-14. Therefore, the latest DC system has the same reliability as AC system and is able to be adopted in the important part of power system.



(a) Conventional DC Control System
If AC voltage became lower DC System will stopped
It required 200 ms for restart the system

(b) Latest DC Control System
Even if AC voltage became lower, DC System kept running
No disadvantage compared to AC System

Fig.5.2-14 Continues Operation Control Function of DC System during AC accident

(2) Introduction of Direct Current Power Transmission

As the result of comparative study above, direct current power transmission is recommended to be introduced for sending large power for long distance in future system. Direct current power transmission has many advantages over alternating current transmission as follows

- Less installation cost compared to AC system

- More flexible to meet situation changes in the future, particularly in Jamali context;
  - ⇒ Ease of introducing power transmission from Kalimantan Island.
  - ⇒ Ease of accommodating AC separate operation (BTB Operation), when required
  - ⇒ Capability of sending large electric power for long distance without stability issues.

There will be other issues arising in the future, such as stability for power system and 3-phase short circuit capacity with increasing number large power stations and expansion of the system. The recommended system retains a future flexibility with adaptability to the existing AC system.

5.2.8 Optimal Power System Expansion Plan

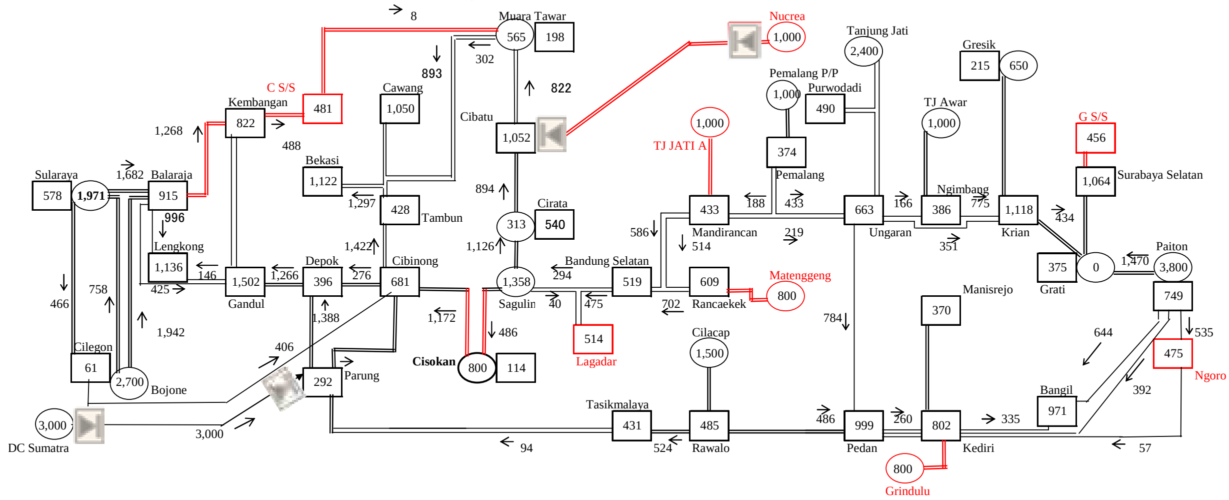
The optimal power system reinforcement plan was developed in conformity with the optimal power source development plan and the results of power system analyses.

The requirements for the optimal power system reinforcement plan are as follows;

- Capability of sending large power for long distance in as the optimal power source developing plan requires.
- Capability to adjust to short circuit issues arising in the future
- Economy with less environment impact and
- Retaining expandability and flexibility in the long term
  －Adjustability to changes in power plant locations
  －Ease of introducing power transmission from Kalimantan Island.
  －Ease of accommodating AC separate operation (BTB Operation) when required for stability and short circuit capacity
- Stability under accidents in 500 kV main power system loop.

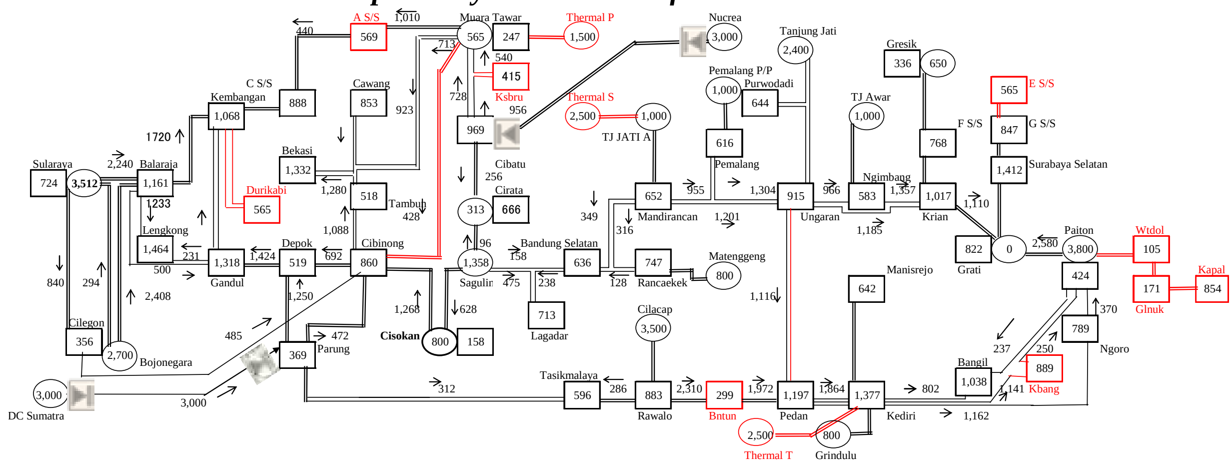
Main system structures of the optimal system reinforcement plan for year 2020. 2025 and 2028 are shown in Fig.5.2-15
It should be noted here that the power system structure will be subject to reevaluation and revision based on actual changes in structure, load condition and progress of power station projects, etc.

Optimal System Structure for 2020



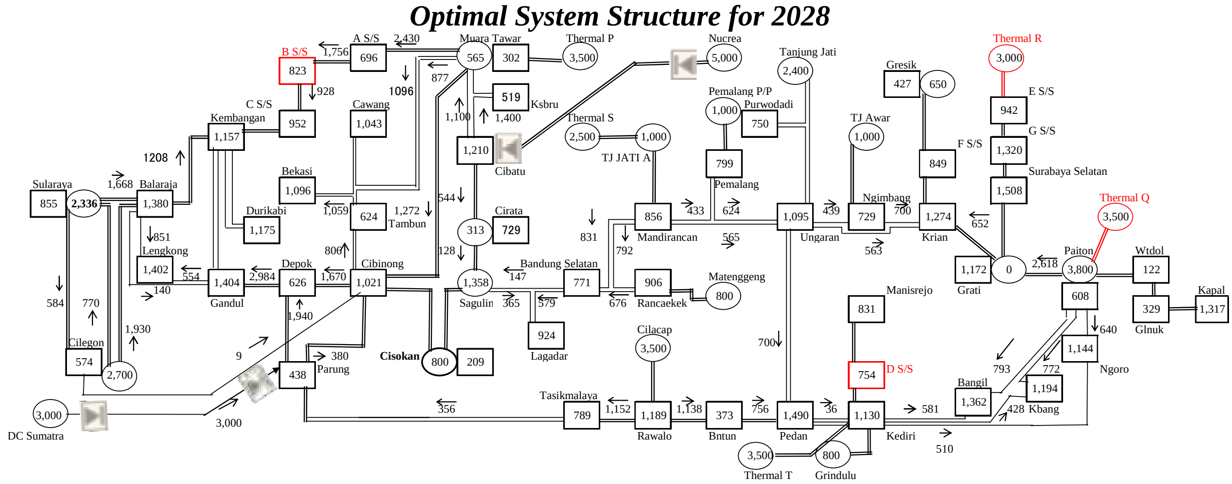
Red is reinforcement point between 2016-2020

Optimal System Structure for 2025



Red is reinforcement point between 2021-2025

Optimal System Structure for 2028



Red is reinforcement point between 2026-2028

Fig. 5.2-15 500kV Main System Structure Step and Current Assumption Chart based on Optimal System Expansion Plan

Table 5.2-12 Summary of Optimal Power System Development Planning for Each Year

		2010	2015	2020	2025	2028
Peak Demand (JICA)		20535	27657	37895	51840	58712
Reinforcement of Transmission Line (km)	500kV	------	-------	890	570	110
New Substation (No.)	500kV	------	--------	4	10	2

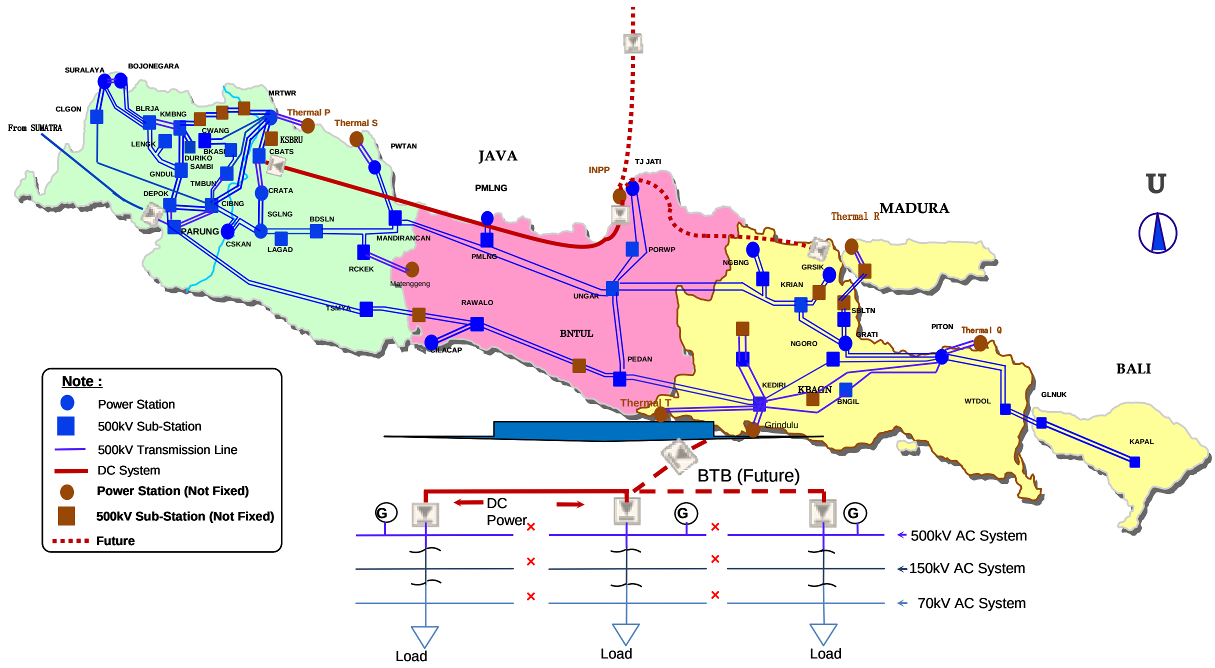


Fig.5.2-16 Image of DC System for Java-Madura-Bali Power System by 2028
(Capacity for Power System: Approximate 60 GW)

5.2.9 Evaluation of System Reliability

System analysis carried out on the tentative system configuration revealed some issues in the stability, etc. These issues were examined for the optimal system development plan for 2028.

(1) Evaluation of System Power Flow

Power system is reinforced on the basis of the analysis results in the optimal system development plan, which eliminates stability issues, etc. The effectiveness of the reinforcement is shown in the power flow figures below, in terms of overloads in the transmission line and main transformers. Further, the simulation revealed that relevant voltage in the system can be maintained within the allowable range.

(2) Evaluation of Short Circuit Capacity

The result of short circuit analysis on the optimal power system development plan for 2028 is shown in Fig.5.2-17. The dotted line in the figure shows the 3-phase short circuit capacity in case that the existing 500 kV transmission lines are reinforced.

The calculation shows that short circuit level is lower compared to the case of existing AC 500 kV transmission system reinforced, and no significant countermeasures should be required other than some 50 kV circuit breakers.

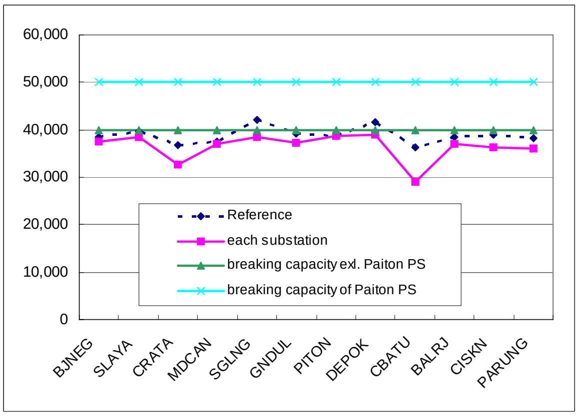


Fig.5.2-17 3-Phase Short Circuit Current at Major Substations of 500 kV

Employment of DC system is expected to reduce 3-phase short circuit capacity and has flexibility to accommodate BTB operation easily when required under further capacity increase.

(3) Result of Transient Stability Analysis

There was partial instability detected in the analysis in the case of system accident in the 500 kV tentative system configuration in year 2028. Transient stability was checked for the optimal power system development plan.

The result of the analysis is shown in Table 5.2-13, and swing of related bus voltage caused by system accident is shown in Fig. 5.2-18 as well.

The optimal power system development plan seems to maintain the stability at important segments, i.e., nuclear power transmission line, Java- Sumatra interconnection line and 500 kV transmission line in the loop system.

Regarding the transmission line for nuclear power, transient stability analysis was omitted because DC transmission system is assumed here.

Table 5.2-13 Stability Analysis Result of Major Projects

System Analyzed	Result	Possible Countermeasure for Tentative System
500 kV loop trunk transmission system	Stable [Ref. Fig. 5.2-18]	Alleviation of loop power flow by changing connection of main power supply line -Change to double circuit line of 500 kV North-South Interconnection Line

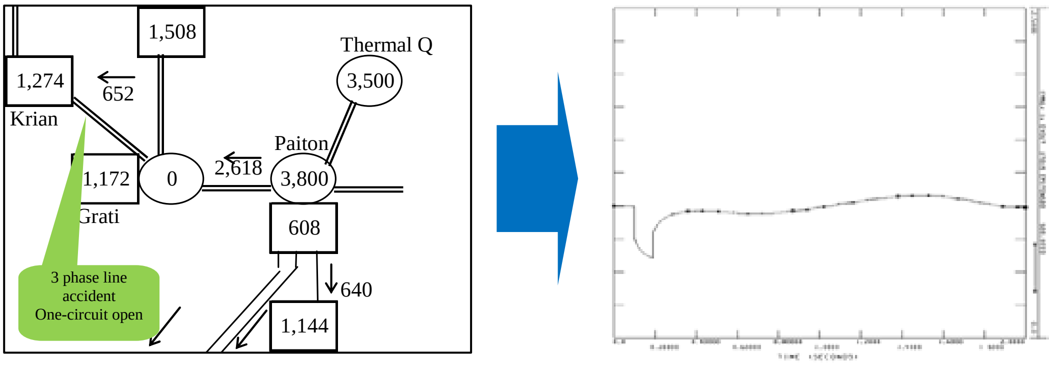


Fig.5.2-18 System of 500 kV Loop Trunk Transmission Line

5.2.10 Construction Cost Estimation

Construction cost for the optimal power system development plan was calculated and shown in Table 5.2-14.

Table 5.2-14 Cost Estimation for Construction of the Optimal Power Development Plan

		Installed Capacity in 2006	2007-2010	2011-2015	2016-2020	2021-2025	2026-2028	Remarks
Demand (MW) [JICA]	Peak	19466	20535 (2010)	27657 (2015)	37895 (2020)	51840 (2-25)	58712 (2028)	
	Expected Increase	-------	1069	7122	10238	13945	6872	
Transmission Line (km)	500kV	3128	1529	1008	890	570	110	
	150kV	11055	6329	1534	1200	3000	600	30 km
	70kV	3985	132	0	-	-	-	
Transformer (MVA)	500/150	15500	10164	9500	13650	18593	9162	0.75 Diversity Factor
	150/70	3579	800	310	-	-	-	
	150/20	24470	15480	11070	21667 +200	29513 +680	14542 +1200	0.63
	70/20	2791	720	560	-	-	-	
Planned New Substation	500kV	--	7	4	4	10	2	
	150kV	--	65	45	40	100	20	10
	70kV	--	1	-	-	-	-	
AC/DC Converter [MVA]		----	-----	-----	5000*2	------	-----	
Capacitor (MVar)		----	-----	----	1666	10406	4668	Power Factor of Generator 0.95
Estimated Construction Cost (Unit : Million US$)								
Trafo Dist & GI 150kV		-	620.42	388.48	590	990	370	New Constriction 4 Transformer 1 (50 MVA)
IBT 500/150 kV & GITET 500 kV			507.46	391.01	450	820	270	New Construction 45 Transformer 10 (500 MVA) → Ref. Data 1.
IBT 150/70kV			17.48	7.50	-	-	-	
Converter			---	---	800	----	---	0.08 Million US$ /MVA
Capacitor			1.72	-	40	230	110	0.9 Million US$ /40Mvar
Transmission Line			2077.19	438.82	460	770	150	0.3 (500 kV)&0.2(150 kV) 0.2 (500 kV) DC ~2015 [Reduction required between Cibatu - Mandiracan]
150/20 kV Tr Replacement			---	----	4	14	24	Rapid increase expected → Ref. Data 2.
Scadatel			51.60	12.45	13.50	13.50	8.10	Assumption using annual average of 270 from 2011 to 2016 after completion of SCADA 2 system

Note : Data by year of 2015 are derived from RUPTL.

< Supplement Data 1 : Construction cost of new 500 kV substation >

Construction costs for new 500 kV substations are estimated in consideration of past similar projects in Indonesia.

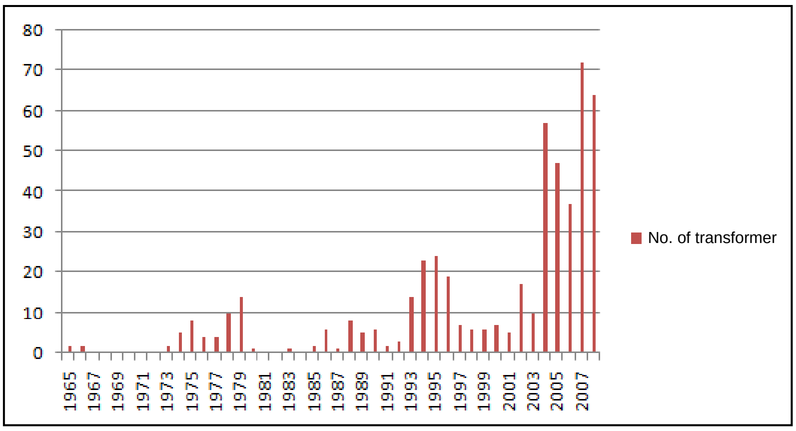
Estimated Construction Costs for Substation of 500kV						
Indonesia						
500kV Substation (500kV AIS 2 Diameters, 500MVA 2 Units, 100MVar ShR 2Units)						
Price in Year 2001	US$	26,913,030				
Year 2001 Index	143.4		Year 2008 Index			190.9
Escalation Factor	1.3312413					
Price in Year 2008	US$	46,576,058	→		US$	46,600,000
500kV 500MVA 1 Unit						
Price in Year 2001	US$	11,771,342				
Year 2001 Index	143.4		Year 2008 Index			190.9
Escalation Factor	1.3312413					
Price in year 2000	US$	15,670,497	→		US$	15,700,000
500kV TR 500MVA 1 Unit						
Price in Year 2001	JPYen	365,144,000		US$		3,319,491
Year 2001 Index	143.4		Year 2008 Index			190.9
Escalation Factor	1.3312413					
Price in year 2008	US$	4,419,043	→		US$	4,500,000

< Supplement Data 2: Summary of aging situation of transformer under 150 kV >

Aging of transformers under 150 kV is shown in the figure below. Replacement of aged transformers has been done increasingly recently and facility problems arising from aging is expected to be reduced. Judging from the actual aging record, aged transformers have been replaced at interval of around 35 years.

Therefore, the replacement cost of transformers for this study period is included in the cost estimation above. After the study period, the replacement cost will increase further because more transformers will be aging thereafter.

Regarding 500 kV transformers, most of them have been operated for not over 20 years because the introduction of 500 kV system was started in 1990's in Indonesia. Therefore, no replacement cost for 500 kV transformers are considered for this study period.



5.2.11 Issues and Recommendations for Optimal Power System Expansion Plan

(1) Countermeasures against Large Power Failure Accident

Electricity serves indispensable role in such various fields as production, information, and social activities. The fundamental function required for the electric power system should be a stable supply of electric energy without interruption at the rated voltage and frequency. Not only the quality but also the reliability of total system should be required to enhance its services since the impact of large power failure accident on social/economic activities is becoming larger along with the power supply and demand increase.

Although the stability criteria have not been applied in Indonesia at the moment, it is recommended to introduce the following simple protection system to part of the system, which is effective in avoiding large-scale black out accident. It is also suggested in the long term to employ stability criteria and to reinforce existing power systems step by step.

1) Protection against extreme frequency drop

To avoid the occurrence of large-scale power failure accident which may spread to extreme frequency drop caused by power shedding of generator, etc., a simple protection method is recommended as a short term countermeasure. Currently, Java-Bali system is protected mainly for power flow in consideration of accidental outages of any equipment. Regarding system protection against frequency drop, load-breaking using frequency drop relay is installed. However, over-load shedding and large system frequency fluctuation may occur and it would take long time for restoration.

More reliable protection system employing relevant protection standards and apparatus should be introduced in the long term for protecting the system from frequency drop. However, considering current situation which requires urgent power supply expansion, an employment of a simple protection system against large-scale power failure accident is recommended for the short term in such a large power transmission system of over 3,000 MW.

The outline of this countermeasure is illustrated below.

Example of Countermeasure: Simple Load-Breaking System by sending trip signal

Approximate 6% of system capacity is used for calculation of stiffness.

⇒Stiffness → Around 2,000 MW

[=Power system Capacity (60GW)* Rate between Day and night Demand (0.6)*6%]

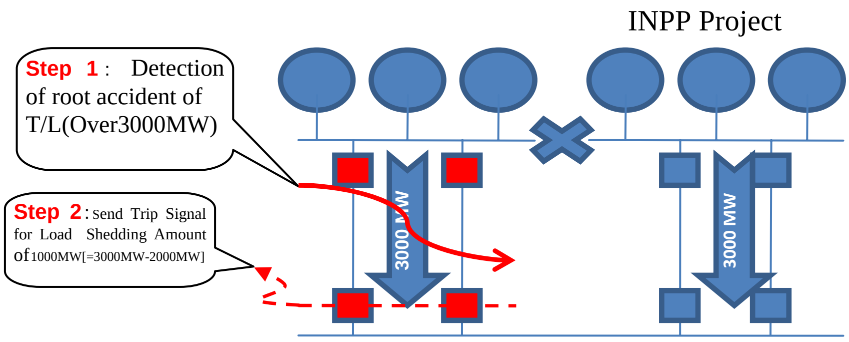


Fig. 5.2-19 Sample of Load-Breaking System

Sending trip signal to break the load amount equal to the balance of allowable power supply shedding out of total power shedding caused by power transmission accident in the nuclear power system frequency for example, is desirable.

2) Protection against whole system collapse caused by system stability problem

Although Jamali system is currently operated in loop, no protection against system stability issues is established. Therefore, should a route accident in loop system occur with certain power overflow level, the synchronizing force between the West/Central Java power plant group including Surabaya and Tanjung Jati P/S and the East Java power plant group including Gresik and Paiton P/S, etc. may be lost and the whole power system failure may happen. To avoid such a large power interruption, a simple protection system in loop lines is recommended to be installed, which would enable separating the Jamali system as illustrated in Fig. 5.2-20

Regarding the load shedding system by sending trip signal, it is required to consider a cooperated operation with existing low frequency load shedding relay (K95).

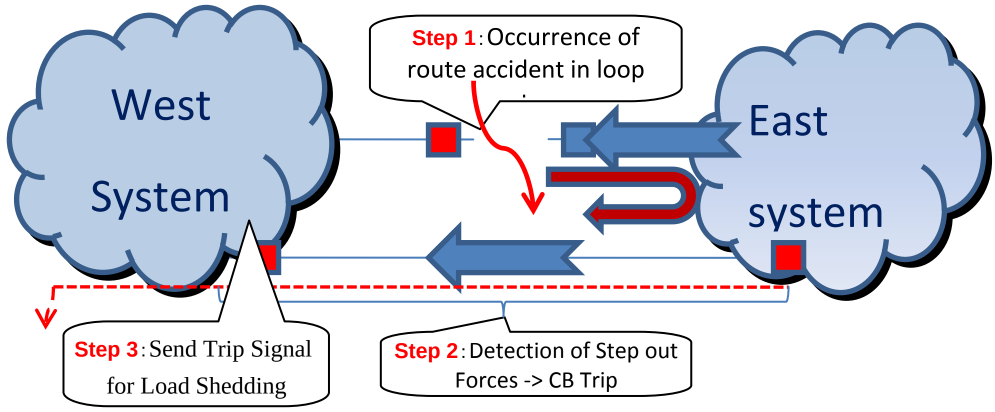


Fig. 5.2-20 Image of Simple Protection System in Loop Transmission Lines

(2) Employment of Middle Power System for Power Transmission and Distribution

Generally, the power transmission is composed of high/middle-voltage transmission lines and low-voltage distribution lines. Examination was done to study whether the higher voltage should be used considering the future demand in the higher demand density area.

1) Current demand density

Table 5.2-15 shows the current demand density as of 2006. Demand density issue can be divided into two; i.e. that of heavy load density of Jakarta City and its vicinity and that of other areas with relatively light load density. Regarding electric demand density, density of heavy load density area exceeds 5 MW/km^2. On the other hand, average density of local or light load areas is under 1 MW/km^2.

Table 5.2-15 Current Demand Density in Java-Madura-Bali Area

Area	Residence (GWh)	Industry (GWh)	Commercial (GWh)	Public etc (GWh)	Total (GWh)	Area (km^2)	kW/km^2 (Lf=0.75)
Bali	951.93	87.38	938.67	147.05	2,125.03	5,449.37	59
Jawa Timur	6,574.85	8,737.33	2,016.17	994.75	18,323.11	46,689.64	60
Jawa Tengah dan Yogyakarta	6,121.55	4,040.69	1,274.14	977.43	12,415.81	35,932.86	53
Jawa Barat dan Banten	9,343.10	17,761.26	2,363.94	830.50	30,298.80	45,943.69	100
Jakarta Raya & Tanggerang	8,655.10	8,029.36	7,450.28	1,746.16	25,880.91	740.29	5,321
JaMali Total	31,646.53	38,656.02	14,043.20	4,695.89	89,043.66	134,755.85	101

However, it is necessary to consider distribution system as well, because demand density of about four times as large as the current density is forecasted within the study period up to 2028.

2) Optimal transformer bank combination at distribution substation

Considering the above mentioned demand density and based on the assumed uniform demand density within a distribution area shown in Fig. 5.2-21, an optimal transformer bank combination at a distribution substation was calculated taking the following factors into consideration.

* Reduction of construction cost including additional distribution substation and dispatching feeders
* Evaluation of related system losses

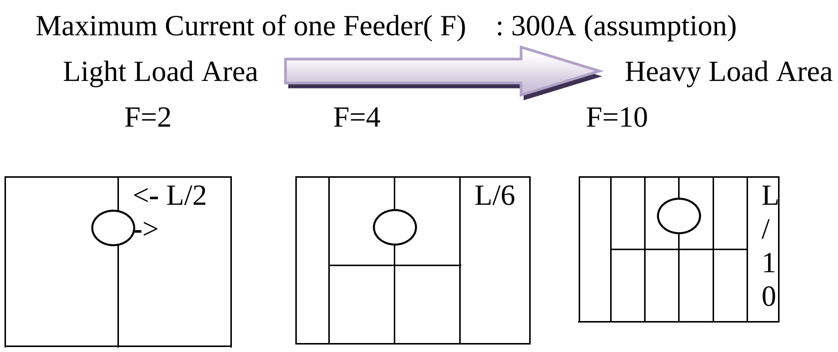


Fig.5.2-21 Example of Dispatching System

Based on the assumption mentioned above, Fig. 5.2-22 shows the optimal bank combination calculated. From this result, a bank combination of 100 MVA at 3 banks should be recommended in a heavy demand density area and a smaller bank combination should be recommended in a light demand density area.

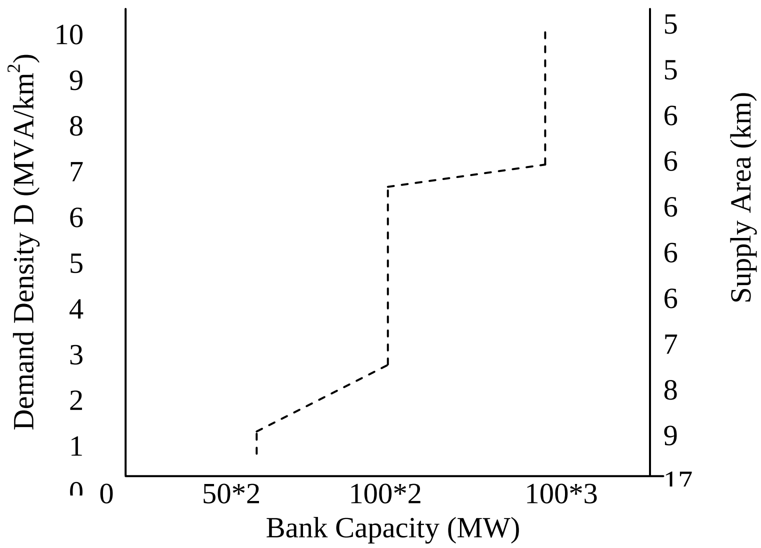


Fig.5.2-22 Optimal Bank Combination

3) Employment of higher voltage into middle dispatching system

An effectiveness of employment of higher middle system voltage in a heavy density area was evaluated with further assumptions as follows.

Pre-Condition

- Summary of dispatching line distance and demand density level of a heavy density area in Indonesia
  [Allowable current of dispatching line -> around 300A]

	Current	Future
Demand Density (Length)	5 MVA/km^2 (6 km)	20 MVA/km^2 (3 km)

- Maximum length of middle dispatching system between trunk substation and dispatching substation.
  → Considering protection relay and tolerable voltage drop, etc. the maximum voltage drop of 5% was assumed with the capacity of 100 MVA, 3 bank, LF:90% for dispatching substation, then the maximum dispatching length was calculated.

The result of rough comparison of medium system voltages is shown in Table 5.2-16.

Table 5.2-16 Rough Comparison of Each Medium System Voltage

Middle System Voltage (kV)	Sending Capacity/ 2cct. 410 mm^2 [Impedance Base 1,000 MVA]	Max Length (km)	Bank Combination of Trunk Substation	Number of Dispatching Substation for Trunk Substation	Rough Line Length [km]	Required Trunk Substation	System Loss
150	760 MVA [0.08 + j0.9]	50	500 MVA*3 Units	5	6-9	Many (Around 25)	Large
220	1,100 MVA [0.05 + j0.6]	70	750 MVA*3 Units	8	9-12	Medium (Over 10)	Medium
275	1,360 MVA [0.04 + j0.5]	90	1000 MVA*3 Units	10	9-15	Little (Under 10)	Small

In addition, sending capacity rate ratios of these medium voltages are as follows:

- Sending Capacity rate ratio of 220 kV system voltage:
  Twice of the capacity of 150 kV's, one fifth of capacity of 500 kV's
  $(220/150)^2 : (500/220)^2 = 2.15:5.17$

- Sending Capacity rate ratio of 275 kV system voltage:
  Three times of the capacity of 150 kV's, one thirds of capacity of 500 kV's
  $(275/150)^2 ; (500/275)^2 = 3.36 : 3.31$

The result shows that in terms of the balance of sending capacity ratio to existing voltage level, 275 kV system is preferable to 220 kV system.

Judging from the comparison between 220 kV and 275 kV for next intermediate system voltage, 275 kV system has following advantages compared to 220 kV system.

- The longer maximum length of sending line is achieved and the more operational dispatching substations are to be provided.
- The number of necessary trunk substations is smaller.
- The transmission loss becomes smaller.

In addition to these advantages, 275 kV system is superior in that sending capacity balance with the existing system voltage, simplicity of system voltages and smaller construction cost will be expected. Therefore, 275 kV should be recommended as the higher middle system voltage in the future.

Further, for the extremely heavy demand density areas, direct transmission at higher voltage as 500 kV should be studied in terms of economy and technical advantages.

(3) Frequency Drop during Pumping up in Pumped Storage Power Generation

In Upper Cisokan Pumped Storage Project, four pumping motors with unit capacity of 275 MW each are designed. The motors will be the biggest single load in Jamali 500 kV power system. Such a large load shall be examined in detail as to the possibility of triggering frequency drop. PLN publication "Evaluasi Operasi System Tenaga Listik Java Bali 2000", which explains the relationship between load loss and drop of frequency in the Jamali power system should provide good insight into the matter.

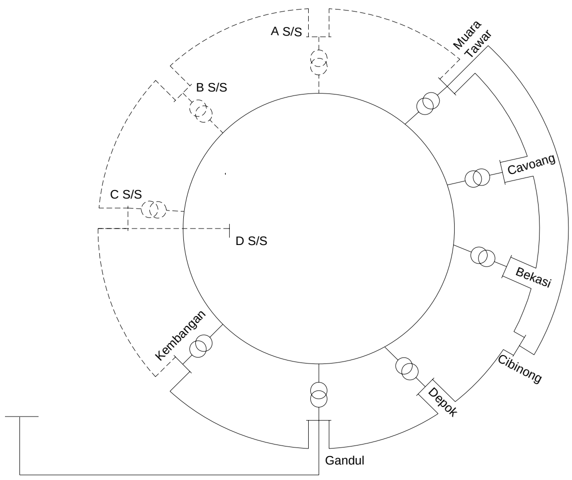
If the motors to be selected for the project are not adjustable speed type, full pumping load is put on the power system at night. In this case, the maximum frequency drop will be around 0.2 Hz. As the allowable range of frequency under normal conditions is 50±0.2 Hz, this drop of 0.2 [Hz] seems acceptable under the larger system capacity at night in the future. However, simultaneous start of more than two units of pumping should be avoided..

(4) Keeping Governor Free of around 3% at Late Night

To meet the quality standard of power supply at night time and to cope with insufficient capacity of Governor Free (3%) through the increase of base energy supply power with nuclear power etc, it is recommended to consider the use of adjustable speed pumped generation and daily start stop thermal power plants (DSS Units) to maintain required capacity of Governor Free.

(5) Study on Power Supply Method to Heavy Demand Density Area (DKI Jakarta area)

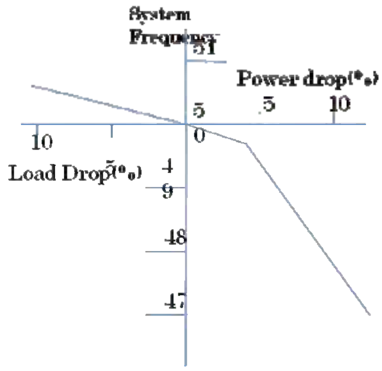
Power demand will continue to be concentrated in Jakarta area in the future. Therefore, it is recommended to study an economic power supply method taking into consideration such matters as the employment of middle high system voltage or 500 kV voltage directly in this area and the spaces required for installation of facilities related to transmission and substation, etc.



A schematic of the power supply method is shown in the figure on the right hand side.

(6) Evaluation of Increasing Frequency in Sumatra System

Generally, a power system has characteristics depending on the amount of "Automatic Frequency Control (AFC)" and "Governor Free Operation (GF)" of power plants in operation.



The figure on the right hand side shows the relationship between power shedding and frequency drop (with the GF capacity of 3%).

In Jamali system, cases of frequency drop are well examined and countermeasures are taken as required. However, in case that a route accident of Java-Sumatra interconnection occurs when sending at full capacity 3,000 MW, frequency rise in Sumatra power system may result.

The frequency rise takes place slower than frequency drop due to the fluctuation of supply and demand. However, it is recommended to study the impact of frequency rise in Sumatra system in case under small system capacity during night time even if power systems in Sumatra are interconnected.

Power control is recommended to restrict the frequency rise under 1 Hz to prevent occurrence of generator or turbine vibration.

(7) Optimum Connection Point in Java-Bali System with Additional Java-Sumatra DC Connection

Additional power supply from Sumatra to Java is being planned. If this plan materializes, new DC transmission system will be required and optimal connection point in Jamali system should be identified.

Judging from the space necessary for AC/DC converter equipment and the availability of the right of way of new DC transmission line, Lengkong or Balaraja substation should be selected. Although connection to Lengkong S/S seems to have less system losses because of its nearness to the load center, it is recommended to study the installation cost including related system reinforcement and the impact to environment etc, along with the evaluation of loss reduction effect by simulation.

(8) Other Issues and Recommendations

1) Enhancement of system reliability and countermeasure against instant fluctuation to cope with higher social and industrial requirement

Enhancement of power supply reliability is surely required in the future in light of the further industrialization and commercialization and improvement of social standard in Indonesia. Instant power fluctuation as well as power interruption will be larger issues, which will bring about considerable losses particularly to such high value-added industries as a semiconductor production. Home medical instruments will be more widely used in the future, for which reliable and stable power system should be required. Further, power supply services with classified electrical charge for improved quality will also be demanded.

2) Phase modifying system

Voltage problem is being managed in Indonesia by using phase modifying system. As employment of this system in large number is anticipated in the future, its balance as well as installation locations must be examined in view of system-wide and local requirements. It is recommended to plan this system with due consideration of tap effect of transformer, reduction of system loss, ensured reactive output of generator, etc.

3) Establishment of automatic voltage controller

Load dispatching facilities of below 150 kV class are being operated at full capacity, and manual load-breaking is occasionally applied to control the capacity. In the event of a voltage collapse exceeding the limit of so-called nose-curve, manual operation cannot control the situation in time. Thus, it is recommended to provide automatic voltage controller in the long term at some particular points where installation of this equipment is more economical than a reinforcement of dispatching transmission line, etc. It is also recommended to consider installing a breaker by means of voltage-down relay instead of manual breaking.

4) System restoration method against whole power interruption

In the case of large-scale power interruption in the whole system, each transmission line shall be recharged step by step using the power from, for example, a pumped storage power station. Extraordinary voltage rise by Ferranti effect has been already anticipated in recharging a long distance transmission line with line shunt equipment. In this case, quick system restoration would be hindered. Therefore, it is recommended to apply the instant analysis by EMTP, etc. in the future system. Also utilization of transformer is recommended instead of line shunt reactor installed currently.

5) Multiple leveling of load breaking system

Ultimate back-up relay that prevents the impact of an accident influence whole system is used in Indonesia. It is recommended to consider the multiple leveling of load breaking for preventing over-loaded shutdown, speed decrease of frequency, mitigation of fluctuation and quick restoration in Bali system in particular. It is also recommended to review the existing layout of load breakers so that some part of the system can operate separately.

5.2.12 Recommendation for Further Study

Following issues are recommended for further study.

- Power supply method to heavy demand density area (Jakarta Metropolitan Area)
- DC connection with Kalimantan
- Installation of DC System to BTB Operation
- System planning criteria such as stability criteria in relation to changes of social situation (requirements for power supply with higher reliability etc.).
- Enhancement of demand-supply balance in each block
  - Sending a large amount of electricity for long distance through trunk line power system should not be continued since imbalance of supply and demand emerges when connection lines are interrupted and part of the system is isolated. It also increases system losses. It is desirable to have supply and demand balanced in each sub region.

Finally, it should be noted that the results and recommendations of this study are subject to revision when there is a change in situation that affects Jamali system.

5.3. Financing Investment and Promotion of IPP

In 2004, New Electricity Law (Law No. 20/2002) which was aiming at liberalization of the sector and introduction of market-based competition was judged unconstitutional on the basis that such direction is an abandonment of the government's responsibility to assure the welfare of the nation. Therefore, as the basis for the discussion below, it is assumed that the current sector structure remains as it is now for the foreseeable future, including that PLN is the sole buyer of the power generated by individual generation companies and is the sole seller to the final consumers of the power.

5.3.1 Financial Requirement of the Optimal Power Development Plan

The Optimal Power Development Plan (Scenario 2) involves investment for power plants only amounts to US$ 112 billion by 2028. The component of the investment by types of generation is as shown in the figure below.

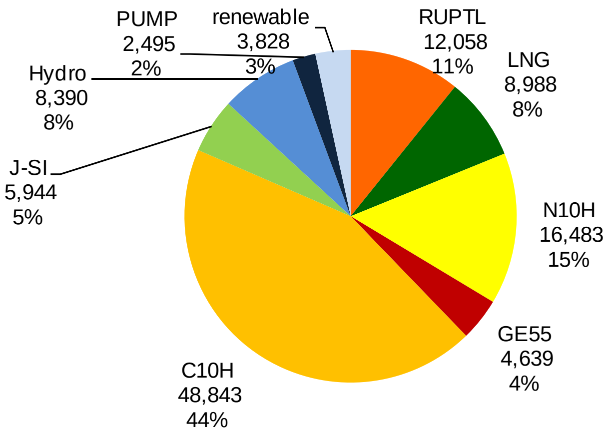


Fig. 5.3-1 Component of Cumulative Investment for Power Plant by 2028

For each type of generation, investment should be scheduled and done as follows.

LNG thermal : almost constantly required in and after 2015, US$ 750 million every year

Nuclear : every three years on and after 2018, US$ 3,300 million

Geothermal : in 2011 and 2014, approximately US$ 500 million, and almost constantly on and after 2015, US$ 250 million every year

Coal thermal : US$ 2,000 million in 2012, and in and after 2017 with fluctuation, on average US$ 3,900 million every year

Java-Sumatra Interconnection and Mine-mouth coal thermal in Sumatra:
US$ 6,000 million in aggregate on 2014 and 2015

Hydro : Intermittently after 2020, US$ 900 million per year on average

Pumped storage : in five years between 2015 and 2019, US$ 2,500 million in aggregate

As for the reinforcement of transmission lines, the future development is planned with a continuity with RUPTL. Therefore, investment for the period before 2015 is a replicate of RUPTL. After 2015, the reinforcement is planned for five year periods as shown in the previous section, investment amount for each period is divided by five, to make a yearly investment value. In addition, investments for distribution system and substations are assumed constant after 2015. As a result, investment schedule is as shown in the figure below.

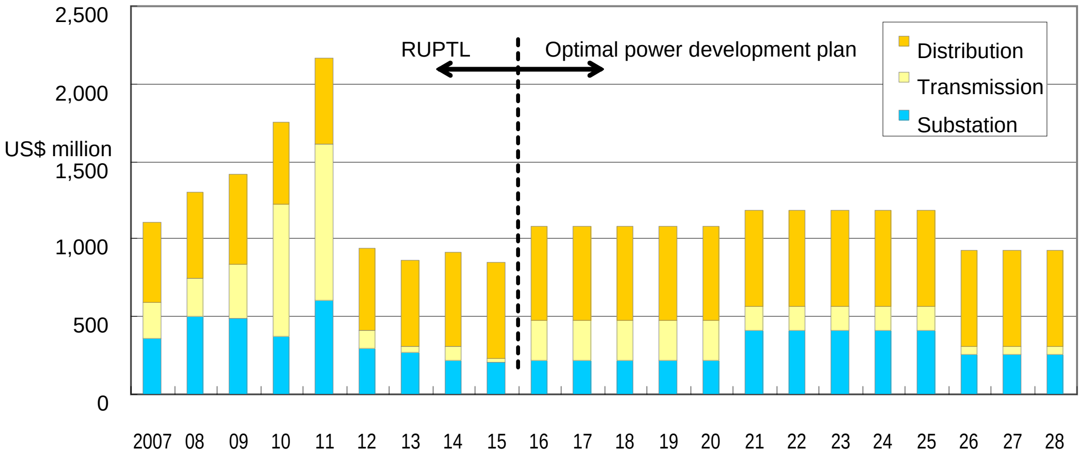


Fig. 5.3-2 Investment Schedule for Augmentation of Transmission System

The above mentioned investment schedule is separated for foreign currency and local currency portions to obtain investment requirement for the optimal power development plan. The separation is done with the ratios shown in the table below.

Table 5.3-1 Foreign/Local Portion of Capital Expenditure

	Foreign	Local
Hydro	55%	45%
Geo	75%	25%
Thermal	85%	15%
Interconnection	90%	10%
Nuclear	90%	10%
Biomass	75%	25%
SS	85%	15%
T/L	85%	15%
D/L	0%	100%

The investment schedule shown in two currencies is summarized in the table in the next page.

Table 5.3-2 Investment Schedule for Optimal Electric Power Development Program

Descripton		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	total
Power Plant																						
RUPTL	F/C	3,115	4,284	1,445	583	0	0	220	0	0	0	0	0	0	0	0	0	0	0	0	0	9,647
	L/C	779	1,071	361	146	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	2,412
	total	3,893	5,355	1,807	729	0	0	275	0	0	0	0	0	0	0	0	0	0	0	0	0	12,058
LNG	F/C	0	0	0	0	0	0	637	637	637	637	0	1,273	0	1,273	0	1,273	0	1,273	0	0	7,640
	L/C	0	0	0	0	0	0	112	112	112	112	0	225	0	225	0	225	0	225	0	0	1,348
	total	0	0	0	0	0	0	749	749	749	749	0	1,498	0	1,498	0	1,498	0	1,498	0	0	8,988
Nuclear	F/C	0	0	0	0	0	0	0	0	0	2,967	0	0	2,967	0	0	2,967	0	2,967	0	2,967	14,835
	L/C	0	0	0	0	0	0	0	0	0	330	0	0	330	0	0	330	0	330	0	330	1,648
	total	0	0	0	0	0	0	0	0	0	3,297	0	0	3,297	0	0	3,297	0	3,297	0	3,297	16,483
Geo	F/C	0	0	549	0	0	366	183	183	183	183	183	183	183	183	183	183	183	183	183	183	3,480
	L/C	0	0	183	0	0	122	61	61	61	61	61	61	61	61	61	61	61	61	61	61	1,160
	total	0	0	733	0	0	488	244	244	244	244	244	244	244	244	244	244	244	244	244	244	4,639
Coal	F/C	0	0	0	1,730	0	0	0	0	6,919	0	3,460	0	3,460	1,730	5,190	0	5,190	1,730	5,190	6,919	41,517
	L/C	0	0	0	305	0	0	0	0	1,221	0	611	0	611	305	916	0	916	305	916	1,221	7,327
	total	0	0	0	2,035	0	0	0	0	8,141	0	4,070	0	4,070	2,035	6,105	0	6,105	2,035	6,105	8,141	48,843
S-J Interconnectio	F/C	0	0	0	0	0	4,280	1,070	0	0	0	0	0	0	0	0	0	0	0	0	0	5,350
	L/C	0	0	0	0	0	476	119	0	0	0	0	0	0	0	0	0	0	0	0	0	594
	total	0	0	0	0	0	4,755	1,189	0	0	0	0	0	0	0	0	0	0	0	0	0	5,944
Hydro	F/C	0	0	0	0	0	0	0	0	0	0	0	1,651	0	1,270	0	1,270	0	0	423	0	4,614
	L/C	0	0	0	0	0	0	0	0	0	0	0	1,351	0	1,039	0	1,039	0	0	346	0	3,775
	total	0	0	0	0	0	0	0	0	0	0	0	3,002	0	2,309	0	2,309	0	0	770	0	8,390
Pump	F/C	0	0	0	0	0	0	229	229	0	457	457	0	0	0	0	0	0	0	0	0	1,372
	L/C	0	0	0	0	0	0	187	187	0	374	374	0	0	0	0	0	0	0	0	0	1,123
	total	0	0	0	0	0	0	416	416	0	832	832	0	0	0	0	0	0	0	0	0	2,495
Renewable	F/C	0	0	0	0	0	0	0	0	0	0	0	0	473	28	565	65	669	111	794	165	2,871
	L/C	0	0	0	0	0	0	0	0	0	0	0	0	158	9	188	22	223	37	265	55	957
	total	0	0	0	0	0	0	0	0	0	0	0	0	630	38	754	87	892	148	1,059	220	3,828
(Solar)		0	0	0	0	0	0	0	0	0	0	0	0	4,970	300	5,935	685	7,030	1,170	8,350	1,740	30,180
Substation	F/C	413	319	519	256	225	186	171	186	186	186	186	186	349	349	349	349	349	215	215	215	5,409
	L/C	73	56	92	45	40	33	30	33	33	33	33	33	62	62	62	62	62	38	38	38	955
	total	486	375	611	301	265	219	202	219	219	219	219	219	411	411	411	411	411	253	253	253	6,364
Transmission Line	F/C	299	719	851	90	39	81	22	215	215	215	215	215	133	133	133	133	133	49	49	49	3,989
	L/C	53	127	150	16	7	14	4	38	38	38	38	38	24	24	24	24	24	9	9	9	704
	total	351	846	1,001	106	45	96	26	253	253	253	253	253	157	157	157	157	157	58	58	58	4,693
Distribution Line	F/C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	L/C	579	529	553	539	559	595	617	617	617	617	617	617	617	617	617	617	617	617	617	617	11,987
	total	579	529	553	539	559	595	617	617	617	617	617	617	617	617	617	617	617	617	617	617	11,987
Total	F/C	3,826	5,322	3,365	2,659	264	4,913	2,532	1,449	8,140	4,645	4,501	3,508	7,565	4,967	6,420	6,241	6,524	6,529	6,854	10,499	100,723
	L/C	1,483	1,783	1,340	1,051	605	1,240	1,186	1,048	2,082	1,565	1,733	2,324	1,861	2,341	1,867	2,378	1,901	1,621	2,251	2,330	33,989
	total	5,309	7,105	4,705	3,710	869	6,153	3,718	2,497	10,222	6,209	6,234	5,832	9,425	7,308	8,287	8,619	8,425	8,150	9,105	12,829	134,712
(Total with Solar)		5,309	7,105	4,705	3,710	869	6,153	3,718	2,497	10,222	6,209	6,234	5,832	14,395	7,608	14,222	9,304	15,455	9,320	17,455	14,569	164,892

Among various power plant types, LNG thermal, nuclear and pumped storage will all be the first implementation in the republic. These projects will surely attract interests and supports from advanced economies. Upper Cisokan, one of pumped storage schemes under planning, is being investigated by the World Bank for financing. Nuclear project is not merely an investment in the power sector. It alone is a national energy policy issue and agencies of Korea and Japan have been offering supports for establishing organization in the country. As for LNG thermal, there are advanced economies depending on the imports of LNG from Indonesia and LNG thermal development will be assisted by those countries which would be willing to keep good relationship with Indonesia. Java-Sumatra interconnection is being investigated by JICA, as well. These projects will all be provided with fund by multi-lateral and/or Bi-lateral financial institutions. Therefore, following discussion for securing finances concentrates on other types of power plants, that is, coal thermal that will take the largest part of the whole system, geothermal, hydro and renewable.

Among these, large part of coal thermal with large investment requirement and geothermal that has been developed mostly by IPPs will have to be financed by IPPs. Other projects will, therefore, have to be financed by PLN’s conventional financing methods as shown below.

- PLN’s own fund
- Loan (Two-step loan from aid agencies, commercial bank loans)
- Bond (and Guaranteed Notes)
- Lease

PLN is mandated to provide public service, called PSO (Public Service Obligation), and this obligation in turn assures compensation of PLN's income when the cost of providing the service is not able to be recovered from the collection of user fees. PLN's surplus profit, if any, is converted to stocks on the balance sheet by the government, which functions as a working capital for PLN in its investment activities. It has been used for local currency portion of transmission/distribution and power development projects. However, considering the size of investment schedule set out in the power development plan, it would not be sufficient to take a significant place in future power plant development. Besides, government subsidy to electricity tariff is calculated for the difference between customer tariffs and indices called BPP, which is a reference provision cost of electricity authorized and published every year by MEMR. Calculation of BPP allows for the cost of capital formation in terms of depreciation of existing assets only, which may not assure PLN's profit sufficient for future investment requirement that is growing at 6 to 7 per cent every year. This issue will be discussed later.

When PLNs investment project is financially supported by multi-lateral and/or bi-lateral aid agencies, it is GOI (Ministry of Finance) that becomes the debtor which in tern provides a two-step loan to PLN. As for the size of such loans, Japan's aid agency JICA (former JBIC), for example, has been providing ODA loans to PLN via GOI in the magnitude of a few thousand million US dollars in a year. But the availability of such loans is variable from time to time, depending on the priority of many projects including those outside of the power sector, and constrained by ODA budgets of donor countries. Therefore, it is very difficult to forecast how much money would be made available from what agencies/financial institutions. But, considering the situation that the power development plan involves nuclear, pumped storage, LNG and large hydro projects which would attract more attentions from donor countries, coal thermal development, which will require large amount of capital every year, is not in a better position in securing loans from donor countries. It seems, therefore, difficult to secure much larger amount of ODA loans for future coal thermal development than available today.

PLN has been issuing bonds in domestic financial market to secure local currency capital for its investment and other activities. Issuance of a bond requires an approval from trustees of PLN, and its value is constrained by some financial ratios such as asset-to-debt ratio, servicing to income ratio, etc. But it is important to raise local currency portion in PLN's investment project as it would be contributing the promotion of domestic industries and to avoiding currency depreciation risks. Therefore, it is desirable to secure more money in local financial market as well as attracting direct investment, and issuing bond is considered to be one way of realizing this with the involvement of various forms of investors in the country.

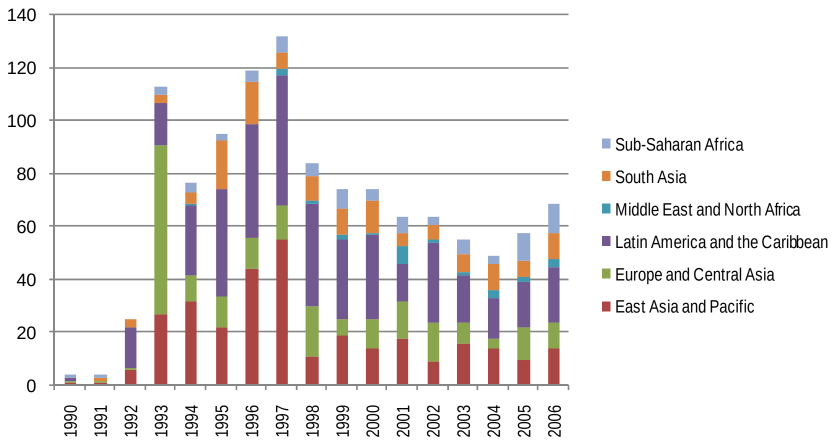
The last channel of securing investment capital is a leasing. There is only one example of PLN taking lease on a power plant from a private lessor, that is Tanjung Jati B power plant. The project initially started as an IPP project in 1990s which was later thrown into a turmoil of Asian financial crisis and suspended for five long years. The project was eventually saved by the introduction of leasing scheme, while PLN is now bearing the additional cost incurred for preservation of the works at project site and factories during suspension. The leasing scheme is, from financial point of view, similar to IPP schemes in that it employs a project finance, escrow accounts, transfer of PLN’s rights based on settlement agreement, interest rates and exchange rates risks allocated to PLN, etc. The only difference is that it is PLN that operates the power plant on the basis of O&M Agreement it signed into with the lessor. As there will be an increasing number of power plants in the Jamali system, it is questionable it there is any more advantage to PLN to secure his own staff to run a power plant than having it run by IPP. Still, it may enable it to have a power plant that is to be operated at very low capacity factor for middle to peak load. Such cases are similar anyway to IPP with respect to financing, and the discussion here handles them together with IPP.

In summary, the four financing channels mentioned above, PLN’s own fund, bank loans, bonds and lease, would not be sufficient to sustain future capital requirement set out in the optimal power development plan, and it will be more important to attract direct investment from private companies/investors in the form of IPPs. Therefore, the following discussion focuses on how to promote IPPs.

5.3.2 Promotion of Private Investment

(1) Record of Private Investment in Power Sector

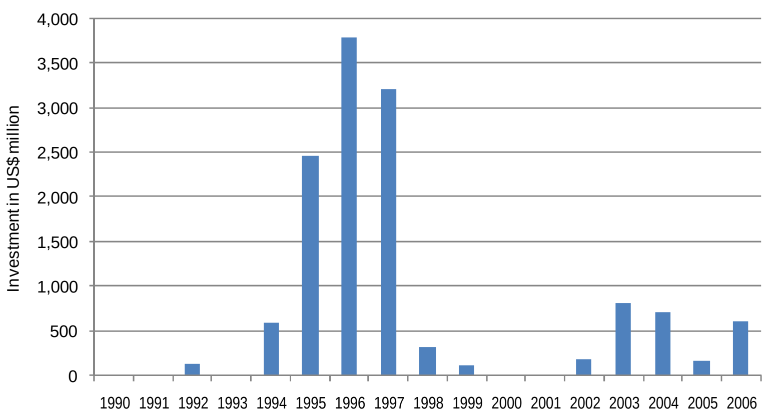
Fig.5.3-3 below shows the number of private investment (greenfield investment, privatization, divestiture, etc) in the power sector worldwide for the period after 1990. The annual number recorded its peak in 1997, followed by sudden drop to two third levels in the year after, and turned upward after the bottom in 2004 at one third level of the peak. In East Asia and Pacific region, there has not been a clear recovery after the slump in 1998.



Source : The World Bank & PPIAF

Fig.5.3-3 Frequency of Private Investment in Power Sector in the World

Fig.5.3-4 shows the value of private investments in the power sector in Indonesia. Again, the peak was recorded in 1996 or 1997, where US$ 3,000 million or so was invested in a year. But after Asian Financial Crisis, no investment was made for a few years and it is only recently that the investment came back but at very low level at around US$ 600-700 million.



Source: The World Bank & PPIAF

Fig.5.3-4 Value of Private Investment in Power Sector in Indonesia

The period that followed Asian financial Crisis was marked by the large drop of production and electricity demand resulted in excess supply, the withdrawal of the World Bank from financial support to IPP projects on the allegation of corruption in IPP consortia nomination, etc., which all culminated in the total suspension of power development in the republic.

Power plant development in cooperation with private entities was, as already discussed in Chapter Two, initiated by the Presidential Decree No. 37/1992, which publicly announced its promotion and led to the boom of IPPs in 1990s. However, necessary regulations to support the decree were very late to come, and the regulatory framework was left incomplete for long time. New Electricity Law enacted in 2002 was later judged unconstitutional and abolished in 2004. By this time, the impending power generation capacity deficiency became apparent, and GOI was under pressure of having to renew the promotion policy of IPPs. GOI held "Indonesia Infrastructure Summit 2005" in January 2005, where President Yudoyono signaled a strong message to private sectors of the government intention to promote private sector involvement in infrastructure development including power generation.

(2) Issues of IPP Promotion and Recent Efforts

In 2003, the World Bank conducted a world-wide survey[8] of investment climate for IPPs which revealed the notions of private sectors as follows. First, respondents to the survey revealed their priorities when investing in a developing country. Those ranked in top ten are as follows.

- Legal framework defining the rights and obligations of private investors
- Consumer payment discipline and enforcement
- Availability of credit enhancement or guarantee from Government and/or multilateral agency
- Independence of regulatory institution and processes from arbitrary government interference
- Administrative efficiency – lead time to get necessary approvals and licenses

Next, respondents answered the factors “what makes for the worst project experiences” as follows.

- Government unresponsive to needs and timeframes of investors
- Retail tariff levels and collection discipline insufficient to meet cash flow needs of sector
- Regulatory commitment expected under long-term contract could not be sustained
- Regulatory process was arbitrary leading to unsatisfactory tariff adjustment and outcomes on disputes
- Laws and contracts were not enforced (e.g., disconnections, payment by counter-parties, etc.)

IPP cases increased rapidly in 1990s got down to nil after Asian financial crisis in 1997-1998, allegation of corruptions, etc. , and came back to life after the completion of re-negotiation of PPA in 2003. During this period and sometime afterwards, those problems of banning of government guarantee, incomplete regulatory framework, etc. were in existence just as was

8 “What International Investors Look For When Investing In Developing Countries, Results from a Survey of International Investors in the Power Sector”, Ranjit Lamech and Kazim Saeed, The Energy and Mining Sector Board Discussion Paper, The World Bank, May 2003.

pointed out in the World Bank survey.

At the Infrastructure Summit held by GOI in January 2005, a list of 91 projects in power, road, port, telecommunication and water service sectors was made public as candidates of private sector involvement and to be developed urgently. Those projects in power sector took up a quarter of the list in terms of investment amount and included a construction of LNG plant located in West Jawa. Also, Central Jawa coal thermal and Pasuruan combined cycle power plants, both within Jamali Region, were among the listed projects. In the summit, a talk between GOI and private companies was held, where private sector expressed their dissatisfaction in the situation surrounding the power sector such as an uncertainty of future direction of the sector after the failure of New Electricity Law and the lack of regulatory framework relevant to IPP development. GOI announced setting up of "Committee on Policy for the Acceleration of Infrastructure Development(KKPPI)", and GOI's renewed attitude towards risk allocation between GOI or state enterprises and private participants, which is a reversal of the policy of not providing any government guarantee to IPP projects including issuance of “Comfort letter”.

As a follow-up to the summit, “2006 Infrastructure Forum” was held in November 2006. Between these two events, a fast track program to build power plants in three years with capacity totaling 10,000 MW, so-called “Crash Program” was announced and initiated.

At “2006 Infrastructure Forum”, GOI also announced new policies related to power plant development as follows.

- Setting up of “Risk Guarantee Fund” that allows the government to take risk allocation
- Setting up of “Infrastructure Investment Fund” to finance government-led projects
- Setting up of a revolving fund to expedite purchasing land for projects, “LAND Acquisition Fund”
- Announcement of Public Service Obligation (PSO) policy that assures financial balances of state enterprises including PLN

In response to these renewed policies, the World Bank and ADB resumed loans and technical assistances to projects, provided financial support to “Risk Guarantee Fund” and sector program loan to “Infrastructure Investment Fund”. Further, on the basis of PSO policy, JBIC made into arrangement with GOI called “umbrella agreement”, which enables provision of loans to power development projects without an issuance of GOI's “Comfort Letter”.

These policies have seen realization with laws and regulations. Fast track program projects initiated in 2006 were given government guarantee of PLN's repayment obligations to loans mostly provided by export-financing facilities by Presidential Decree No.86/2006. Recent hike of oil prices widens the gap between consumer electricity tariff and provision cost of PLN, and inflates the amount of government subsidy to PLN as much as Rp. 37 trillion in 2007, while GOI made sure the payment of the subsidy to PLN. Further, investment environment has been improved. Investment Law No.25/2007 adopted the principle of "no discrimination due to nationality" which assures the same treatment to foreign investors making investment in Indonesia as domestic investors. Meanwhile, one of two model projects announced in Infrastructure Forum, Pasuruan combined cycle has been deleted from the current RUTPL, and the other one, Central Jawa coal thermal, has not been opened to bidding[9].

GOI's determination to promote IPPs accompanied by his actions must have sent clear message to private investors. Some Japanese firms have resumed investment in power sector in the last few years.

Marubeni, a Japanese trading firm, acquired a concession to develop 660 MW coal thermal power plant in Cirebon in West Jawa and concluded PPA with PLN in August 2007. This project had been officially announced in Infrastructure Summit in 2005, opened to international tender in April 2006 by PLN. Estimated project cost is US$ 750 million. A newly setup company, PT. Cirebon Electric Power, will start commercial operation by August 2011. Financing will be provided by JIBC, Korean Exim Bank and consortium of international commercial banks.

Mitsui Co., another Japanese trading firm, together with Tokyo Electric Power Company set up a consortium PT. Paiton Energy to start 1,230 MW coal thermal power plant located in Paiton Complex in 1999. PT Paiton Energy made into PPA with PLN in August 2008 to build Paiton III power plant with 815 MW capacity and supercritical boiler, and to operate the plant for 30 years from 2012. Estimated project cost is US$ 1,400 million. The power plant will be equipped with de-sulfur zing facility to control SOX emission, share common facilities such as coal stock yard, coal feeder, cooling water, etc., with the existing power plants. Financial closing is expected to be early 2009.

Sumitomo Corporation is reported to reach agreement with PLN to develop an extension of the existing Tanjung Jati B power plant, a 1,320 MW coal thermal power plant, and to start commercial operation in 2011. The existing Tanjung Jati B, with the same capacity as the extension and equipped with a low-NOX burner and de-sulfurization, is owned by Sumitomo and leased to PLN who operates the power plant according to the agreement with the lessor. The extension is to be developed as an IPP. The project cost is reportedly estimated at US$ 1.2 billion to $1.5 billion.

These new movements are clearly a reaction to GOI's intention and facilitations made public in Infrastructure Summit in 2005 and Infrastructure Forum in 2006, supported by JBIC via “umbrella agreement”. It is expected that these factors will push forward the private investment in the power sector in Indonesia.

[9] According to BAPPENAS news on its internet web site, as of September 2008, a feasibility study on gas supply to Pasuruan project has been finished and PLN is verifying the study results. As for Central Jawa coal thermal, IFC has been providing a support to draw up a model contract document and the project may be put to open bidding sometime soon.

(3) Private Investment Promotion Strategy

On the basis of the history of IPP evolution in the past and recent policy development of GOI, strategies to promote private investment in the power sector are discussed below.

1) Strategy common to all power plant types

Electricity Tariff

As discussed in Section 2.4.7, current tariff is basically what was established in 2003. Due to the recent hike in oil prices, the gap between the tariff and electricity provision cost has widened: the government subsidy to PLN was Rp. 3 trillion in 2003, and is estimated to be Rp. 60 trillion in 2008 on the assumption of crude oil price at US$ 95/bbl. Supreme Court decision in 2004 that New Electricity Law 2002 was unconstitutional confirmed that the electricity tariff shall be determined by the government with the welfare of the nation in mind. The tariff is, as is the case in petroleum product prices, a very sensitive issue in the country and its upward amendment is not an easy decision for the parliament to take. Meanwhile, as the income of PLN is secured by the subsidy for its PSO position, there is an argument that the level of the tariff and the revenue do not pose any financial issue to PLN. However, the fact that the revenue does not match the cost suggests the underdevelopment of the power sector and may well be a hazard for the private sector to make investment decision. Further, assurance of subsidy may seem to be an uncertainty in the long run, particularly in the view of foreign investors. GOI has to set aside a large part of its budget for the provision of subsidies to petroleum products and electricity. In 2008, such subsidies amount to Rp. 268.7 trillion in the aggregate on the basis of crude oil price at $127 per barrel, which is more than 20% of the government budget. GOI in 2008 is said to have resorted to cut education expenses by 9.5%, health expenses by 7.4%, and other investments by 17% in order to secure the subsidies. The budgetary deficit is planned to be financed by foreign assistance and bond issues. Meanwhile the country risk is reviewed upward, which may lead to the rise in the expected bond yields and eventually financial downward spiral[10]. Cutback in energy subsidies would ease the fiscal pressure of the government and allow for more spending in priority policies.

On the other hand, PLN is in the period of urgent large-scale expansion of generation, transmission/distribution capacities. Loans, bonds and other liabilities including PPAs will be growing in order to secure necessary capital for investment and it is the revenue from electricity sales that supports such fiscal expansion.

Table 5.3-3 is a financial statement of PLN for the period 2001-2007, and Fig.5.3-5 shows the fluctuation of rate of returns (ROR) on net average fixed assets for the last fifteen years.

[10] Asian Development Outlook 2008 Update – Indonesia, Asian Development Bank

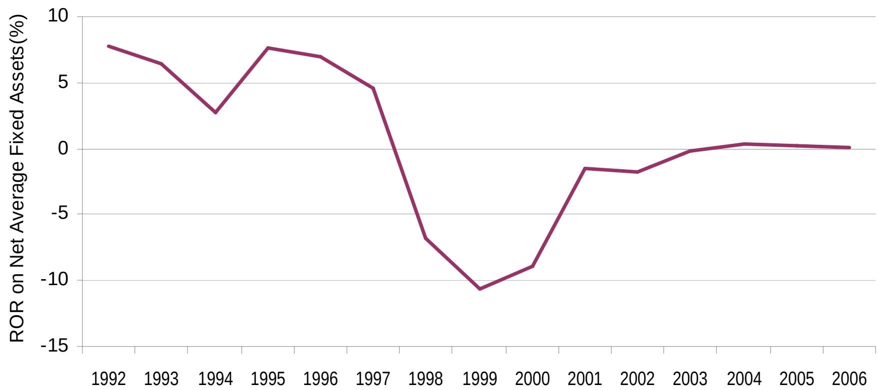


Fig.5.3-5 PLN's ROR on Net Average Fixed Assets

Table 5.3-3 PLN's Financial Statement [2001-2007]

DESCRIPTION	2001	2002	2003	2004	2005	2006	2007
BALANSHEET							(In Million of IDR)
Net Fixed Assets	53,048,330	185,617,938	179,070,368	179,783,781	177,391,351	200,383,256	198,901,833
Construction in Progress	12,340,035	9,587,301	12,028,719	13,603,539	19,674,782	11,286,322	23,430,262
Fixed Assets	65,388,365	195,205,239	191,099,087	193,387,320	197,066,133	211,669,578	222,332,095
Stock Investment	32,774	259,559	312,562	521,148	362,212	591,457	694,660
other Assets	3,267,331	7,463,876	5,182,927	5,205,722	5,749,202	5,835,510	7,240,194
Current Assets	11,521,634	13,091,366	12,530,345	12,679,407	17,665,188	28,821,273	43,212,986
Cash on Hand & in Bank	6,142,461	7,218,517	6,759,657	6,073,057	5,361,749	12,968,420	16,290,782
Inventories	1,394,162	2,104,459	2,253,061	2,187,131	3,765,980	4,183,361	6,774,205
Trade Receivables	2,893,599	2,053,296	1,848,813	1,824,695	1,873,836	2,362,125	2,166,974
other Current Assets	1,091,412	1,715,094	1,668,814	2,594,524	6,663,623	9,307,367	248,247,974
Total Assets	80,210,104	216,020,040	209,124,921	211,793,597	220,842,735	247,917,818	273,479,935
Equities	15,068,792	147,401,894	142,703,581	142,348,843	139,753,679	139,837,946	136,412,740
Deferred Revenues	3,502,134	3,998,868	4,521,360	5,144,568	5,858,062	6,252,377	6,916,376
Long Term Liabilities	37,131,980	49,258,482	45,158,740	47,108,563	49,274,802	74,129,090	89,874,565
Short Term Liabilities	24,507,198	15,360,796	16,741,240	17,191,623	25,956,192	27,698,405	40,276,254
Total Equities and Liabilities	80,210,104	216,020,040	209,124,921	211,793,597	220,842,735	247,917,818	273,479,935
INCOME							(In Million of IDR)
Electricity Sales	28,275,983	39,018,462	49,809,637	58,232,002	63,246,221	70,735,151	76,286,195
Other Trade Revenues	7,083,975	5,164,892	4,621,141	4,041,060	13,297,103	33,991,385	37,756,492
Total Trade Revenues	35,359,958	44,183,354	54,430,778	62,273,062	76,543,324	104,726,536	114,042,687
Electricity Purchase	8,717,141	11,168,843	10,837,796	11,970,811	13,598,166	14,845,421	16,946,723
Cost of Power Plant	18,006,083	29,445,272	31,384,807	33,796,203	44,718,176	73,750,747	N/A
Utilization of Maintenance Material	1,789,559	2,391,061	3,463,610	3,508,272	3,973,066	3,570,416	N/A
Other Operating Expenses	4,197,595	10,144,799	12,900,285	10,435,481	13,734,193	13,061,566	N/A
Total Operating Expenses	32,710,378	53,149,975	58,586,498	59,710,767	76,023,601	105,228,150	111,505,955
Operating (Loss)/Profit	2,649,580	-8,966,621	-4,155,720	2,562,295	519,723	-501,614	2,536,732
Net Income (Expenses outside Operating)	-2,793,808	1,627,069	-2,040,885	-1,117,607	-2,694,282	-583,721	-5,634,798
Profit /(Loss) before Deferred Tax	-144,228	-7,339,552	-6,196,605	1,444,688	-2,174,559	-1,085,335	-3,098,066
Deferred Tax Expenses	-356,261	-1,300,858	-1,388,881	-3,164,503	-2,746,035	-2,972,508	-2,547,041
Loss before Profit from Extraordinary Item	-500,489	-8,640,410	-7,585,486	-1,739,815	-4,920,594	-4,057,843	-5,645,107
Extraordinary Item Profit	183,394	2,326,638	1,685,404	-281,551	0	2,129,987	0
Net Profit /(Loss)	-317,095	-6,313,772	-5,900,082	-2,021,366	-4,920,594	-1,927,856	-5,645,107
FINANCIAL RATIO							
Liquidities	47.01	85.23	74.85	73.75	68.06	104.05	0
Cash Ratio	30.75	60.69	53.04	48.05	35.17	61.92	0
Solvabilities	76.85	29.91	29.6	30.36	34.07	41.07	0
Debt Equity Ratio	75:25	38 : 62	43:57	45:55	45:55	73:27	0
Rentability	-0.23	-5.58	-3.18	0.75	-1.12	-0.51	0
Operating Ratio	92.51	120.29	107,63	95.89	99.32	100.48	0
ROR on Net Average Fixed Assets	-1.88	1.25	-0.57	0.36	0.07	0.37	0
Self Financing Ratio	101.66	86.17	71.05	74.81	52.82	-60.89	0
Equity and Assets Ratio	18.79	68 24	68.24	67.21	63.28	56.4	0
Equity and AT Ratio (Nett)	28.41	79.41	79.69	79.18	78.78	69.79	

The fluctuation in the figure appears to be similar to that of private investment amount in the power sector in Indonesia shown before. Or, the latter even seems follow the former one or two years behind. There is an apparent relationship between private sectors' investment decisions and PLN's financial situations.

These observations lead to the recognition that the tariff needs to be raised to the level that matches the electricity provision cost. Indeed, there is already a move towards this direction within the framework of the existing TDL structure with the approval from the parliament. There has been an adjustment to the rates for industrial users for a few years already within the PLN's discretion, mostly intended to shift the peak demand. In March 2008, MEMR issued an instruction (Siaran Pers) that the customers in the categories of residences (R), business (B), government (P) with the power from and above 6,600 VA are charged at non-subsidized rate (Rp. 1,380/kWh) for their use of electricity above 80% of the category averages. This is a reaction to the rapidly inflating electricity subsidy under the recent hike of oil prices. Customers in other categories are charged at TDL rates but advised to exercise "thriftiness" in the user of electricity. This adoption of non-subsidized rates is reportedly being considered to be expanded to users with smaller VA contracts. These movements reveal that the assurance to financial balance of PLN on the basis of PSO position may not be sustainable when there is an external shock that affects the economy.

Even if the government took the position to react spontaneously to revise the tariff according to the change in economic conditions, the current rule that the revision must be approved by the parliament may induce a significant delay in realizing the revision, or even leave an uncertainty of its realization. Therefore, an introduction of a mechanism to adjust the tariff flexibly to changing economic conditions is desired, along with the upward revision to the current tariff level in the short run.

The rationale of subsidy to the use of electricity by low income population group is an issue outside of the power sector policies. Also, the subsidy is reportedly to be handed over to local governments in the future. In any case, electricity subsidy will have to be limited to applicable to only R-1, 450 VA customer category. There may be a scope of considering a cross-subsidy, with the widening gap of the rich and the poor in the country.

This tariff reform can also be valuable in energy policy in that the prices send the signal of market values of resources to consumers and motivate them to use less of such resources, by reflecting the change in generation cost to the tariff. The realization of cutback in subsidy and introduction of adjustment mechanism of tariff according to the change in input prices will send the power market that the government intends to manage and leave the market more openly and freely.

To secure the sales revenue comparable to production cost and stabilize the financial balance of PLN, an introduction of "Cost-pass-through System" which automatically adjusts the tariff according to the change in input prices. This kind of tariff reform must be unpopular in the country, but it is important that the necessity of tariff reform is not argued from the point mixed up with criticisms to PLN's performance and/or IPPs. It is also important to place more stringent control over SOEs including PLN, mandating them to improve operational efficiency and to pass over the gain to their customers, but such a standpoint should be discussed separately.

Along with the aforementioned tariff reform, it is also desirable to revise the method of calculating PLN's reference production cost, BPP. BPP and the subsidy in 2007 are shown in the table below.

Table 5.3-4 Sales Revenue and Subsidy by Customer Category in 2007

Tariff Category / Sub-Category		Energy Sales		Revenue	Costs	Subsidy		
		TWh	As %	RpB	RpB	RpB	As %	Rp/kWh
Social	**All (S.1 - S.3)**	**2.909**	**2.4%**	**1664**	**2796**	**1,132**	**2.9%**	**389.1**
Residential	**R.1 / s/d 450 VA**	**16.776**	**13.9%**	**6811**	**17041**	**10,230**	**28.7%**	**609.8**
	R.1 / 900 VA	14.701	12.2%	8828	14933	6,105	16.0%	415.3
	R.1 / 1.300 VA	6.589	5.5%	4424	6693	2,269	5.7%	344.4
	R.1 / 2.200 VA	4.341	3.6%	2906	4409	1,503	3.8%	346.2
	R.1 (All)	**42.407**	**35.2%**	**22969**	**43076**	**20,108**	**54.2%**	**474.2**
	R.2 + R.3 (>2.200VA)	4.740	3.9%	3805	4815	1,010	2.4%	213.1
	R.1- R.3 (All)	**47.147**	**39.1%**	**26774**	**47892**	**21,118**	**56.6%**	**447.9**
Business	B.1 (s/d 2.200VA)	2.319	1.9%	1489	2356	867	2.1%	373.9
	B.2 + B.3 (>2.200VA)	16.857	14.0%	12885	15547	2,662	6.8%	157.9
	B.1 - B.3 (All)	**19.176**	**15.9%**	**14374**	**17903**	**3,529**	**8.9%**	**184.0**
Industry	I.1 / s/d 14kVA	0.126	0.1%	103	128	26	0.1%	204.1
	I.2 / s/d 200kVA	3.284	2.7%	2594	3336	742	1.9%	226.0
	I.3 + I.4 (> 200kVA)	**42.209**	**35.0%**	**25523**	**35029**	**9,506**	**25.9%**	**225.2**
	I.1 - I.4 (All)	**45.620**	**37.9%**	**28220**	**38493**	**10,274**	**27.9%**	**225.2**
Government	**P.1 - P.3 (All)**	**4.605**	**3.8%**	**3127**	**4511**	**1,384**	**3.6%**	**300.5**
Other	**T/C/M**	**1.071**	**0.9%**	**1045**	**904**	**38**	**0.1%**	**35.6**
Total		**120.529**	**100.0%**	**75,204**	**112,499**	**37,474**	**100.0%**	**310.9**

Source : Subsidi Listrik / PSO Tahun 2007 Perkembangan Kebijakan Subsidi Listrik

In the calculation of BPP, as in the ordinary accounting rules, depreciation of existing assets only is accounted for as an expenditure item representing investment cost. Under the current situation where a rapid expansion in the large scale is needed, and particularly for PLN who had been away from new investment until the start of the fast track program, depreciation would not allow for increasing requirement of capital for upcoming investment. Realizing the situation, a revision to BPP calculation method to inflate the capital expenditure, or such an arrangement as an accelerated depreciation, may have to be considered.

Openness of Bidding and Competition among Bidders

It is a prerequisite for a selection process of IPPs and/or other construction project contractors to be open and competitive, this is not a given condition even in an advanced country like Japan. Particularly in Indonesia, selection process of IPPs in 1990s were said to have problems, some researches show that the control of malpractices in the country has not been improved very much since[11]. It is not only the control of corruption and injustice, but that the process of bidding is open, that is, that any private companies which are reasonably qualified to participate are able to compete, is important.

As it is assumed in this discussion that PLN is to continue to be a single wholesale buyer of electricity from private generation companies based on PPA, it is a proper bidding process that ensures the competition among private companies to provide electricity more efficiently. If the number of bidders is small, efficiency improvement may not be expected through the competition. Fairness of the selection may be compromised as well. In the current regulation, there must be at least two participants to bidding. If there is only one bidder in re-tender, that bidder is chosen in direct appointment[12]. When the technical requirements to bidders are reasonable and there are only very few bidders, there must be some hidden factors that inhibit private companies from entering. Bidding process should be, therefore, monitored continuously and improved, if any problems are detected.

Since Infrastructure Summit in 2005, bidding process and contractual issues are supervised by KKPPI. KKPPI is established with an intention to have bidding process in public-private partnership projects to be organized by international standards, with respect to their transparency and fairness[13]. Since then, however, those two power sector projects presented at the Summit as model projects have not been implemented, and those projects under the fast track program, which are outside of KKPPI's control, are under progress.

Once KKPPI starts functioning as it is designed to be, bidding and selection processes of public-private partnership projects in the power sector under KKPPI control will be properly regulated and monitored and openness and fairness thereof will be assured. Meanwhile, geothermal projects administered by local governments could be left out, and investors, particularly from outside the country, may find the difference in the proceeding.

There is one more issue about bidding process, that is, situation where only a few companies are taking the market. Recent three cases of geothermal bidding in West Java, all of the three were taken by a consortium of PT Indonesia Power and other one company. Indonesia Power was established in 1990s when the generation division was separated from PLN, taking large shares of generation assets previously owned by PLN together with PT PJB, became a large generation company. It is a desirable thing that these PLN's affiliated companies to become a more market oriented, competitive companies. But the various advantages these two companies have, as incumbents, over those companies who are considering making it into the market, could be very large. If these two companies keep on dominating future bidding of IPP projects, it could pose a problem of preventing a healthy competition among private sector. Some research revealed that new comer companies tend to bid lower than incumbents, and in bidding process where limited,

[11] Governance Matters VII: Aggregate and Individual Governance Indicators 1996-2007, Policy Research Working Paper 4654, The World Bank, 2008
[12] Permen ESDM Nomor 004 Tahun 2007
[13] "INDONESIA INFRASTRUCTURE FORUM November 1-3, 2006", US Embassy Jakarta Official Website..

existing companies only participate, the result of bidding tends to be high[14]. This kind of competition structure should be a subject of monitoring as well.

As mentioned earlier, PLN has to increase its income by raising tariff. In order to have users understand the situation, and earn their support to tariff revisions, the importance of bidding process being fair and transparent cannot be emphasized too much.

Adherence to Project Schedule

The World Banks world-wide survey of investment climate for IPPs mentioned earlier in this section pointed out the government unresponsive to needs and timeframes of investors can be a factor that may lead to an unsatisfactory IPP projects for investors. There was also news of Minister of Energy's comment that "among 150 cases of IPP projects, there are only ten projects that have materialized. All the others have failed in financial closing."[15] Indeed, among ten coal thermal projects started in 2006 under the Fast Track Program in Jamali region, there are only a few projects that are considered to be able to start commercial operation by the end of 2009, and there is one project which has not yet seen a signing with EPC contractor, as of September 2008. Judging from the results of conversation with various entities, the delay is mostly due to the unfamiliarity and lack of specific knowledge and experiences concerning the procedures of financing in the country, on both sides, authorities of Indonesian side and financial institutions of EPC contractor side. When main financing to a certain project is delayed, PLN has to provide capital to the contractor to continue the work by obtaining finances from domestic commercial banks. This kind of bridge financing will increase the cost of PLN's operation and will have to be borne by electricity users, and/or the economy as a whole in the form of subsidy paid by the government. The delay in commercial operation of projects would, particularly under the current situation, affect users in shortage of capacity, and disrupt future program of power development. Financial institutions expecting to provide finances to the project are affected as well, which further upsets financing to upcoming projects and capital securing schedules. Further, in the situation where prices of capital goods are rising as they are now, EPC contractors and IPP operators, by taking so much time after they made into contract and agreements, may become unable to provide goods and services for the costs and prices prescribed in the agreements.

Fast Track Program is, under the acute shortage of power generating capacity, to provide a set of arrangements among relevant authorities and private sector parties to realize the capacity expansion as soon as practically and technically possible. If there are delays under such arrangements, there is no room left for private sector and electricity users to count on the electricity planning. At the moment, it is unofficially acknowledged that the second phase of Fast Track Program is under planning. But before formulating this second

[14] Bidder Asymmetry in Infrastructure Procurement: Are There Any Fringe Bidders?, Antonio Estache, Atsushi Iimi, Policy Research Working Paper 4660, The World Bank, July 2008.
[15] MEMR Internet Web Site News, 12th July 2008

phase, the causes of delay in the first phase should be examined, and countermeasures should be taken to streamlining the process leading to financial closing.

Acquisition of Land for Power Plant and Transmission Line

The responsibility of land acquisition for power plants and transmission lines is allocated to IPP concessionaire. For the financing of land acquisition, a support system using a revolving fund is being provided as mentioned earlier in this section. However, it should also be understood that the difficulty in land acquisition and the risks thereof are significant enough to intimidate particularly foreign private investors to take a project.

As is shown in the power development plan, there are many power plants to be constructed and many of which are coal thermal. On the other hand, finding a suitable location for power plant has been getting increasingly difficult in Jamali region. In the near future, some sites with foreseeable problems will have to be chosen. Therefore, for land acquisition of projects, it is PLN and local governments with more connections with the local communities that have to be play main role, not just assisting IPPs. Besides, construction of transmission lines can be more efficiently and more economically carried out by PLN, than private companies.

Long-term Perspective and Flexible Implementation of Projects

In short-term view, it is advantageous to offer more attractive conditions to IPP project bidders to attract interest of private investors. However, it should be cautioned that some arrangements preferable to private investors could undermine a long-term sustainability of IPP schemes.

In the long run, there are factors such as uncertainties of demand forecast and change in the efficiency of system management, which may affect supply-demand balance of the power system. For the next few years, this will not be a problem because current shortage of capacity consumes all the new additional capacity. After this catching-up period, to consider the balance between the additional capacity and demand growth will be a more sensitive issue, to avoid the excess capacity which results in the unnecessary increase of generation cost. In addition, IPP power plants implemented so far have been basically intended for providing base-load power. From the system operation perspective, there is a shortage in the system of the capacity for frequency stability. There will have to be more power plants that are able to cope with middle- to peak-load operation. To realize this with many IPP power plants to be online, as discussed in 5.5.2, technical specifications and PPA price structure will have to be revised. Specifically, the following measures should be considered.

- Bidding for designated operation pattern
- PPA pricing for middle- to peak-load operation power plant
- Introduction of capacity fee

- Technical specification on power plant ramp rate

Peak-load plant pricing and capacity fee can be accommodated by minor adjustments or additional conditions to PPA prices, i.e., Component A, B, C, and D. There will be, however, large differences in the proportion or comparative levels of these component prices in relation to those of base-load plant cases, and generally speaking, prices will be higher for middle- to peak-load plants than for base-load plant cases. Therefore, standardized upper limit unit purchase prices stipulated in the current regulation, such as in PERMEN ESDM No. 44/2006, will not be relevant. JICA Team has been under the impression that the fact that a unit generation cost of peak-load plant can be much higher than that of base-load plant is not very well understood by concerned parties in the authorities. It is crucial to have this understood and to make adjustments to current rules to allow for middle- to peak-load PPA with lower expected capacity factor and higher unit prices.

Use of Domestic Products and Larger Local Currency Portion

The payment based on PPA is done in foreign currency, i.e., US dollar. Therefore, foreign exchange risk is allocated to PLN. PLN will be exposed more to macro economic shocks if the proportion of IPPs in the generation system grows larger. It is prudent to have a smaller foreign currency portion in its own loan-financed project to better manage the foreign exchange risk. In the current regulations, there are some provisions, such as " the use of domestically produced goods, services, engineering design capacity is preferred (Article 29, UU Nomor 27, Tahun 2003, Tentang Panas Bumi)". It is also desirable to have a mechanism in bidding procedure that values higher the bid that includes more local currency portion. This measure is also compatible with financing projects with bond issues in local financial market.

Higher own-finance proportion in project financing is better strategy for controlling financial risks. It cannot be emphasized enough for PLN to have adequate income to secure financial resources for future investment.

Verification of Restriction on Capital Ownership

Although Investment Law No.25/2007 adopted a principle of "the equal treatment without discriminating the country of origin", an ownership of power plant by foreign capital is limited to 95% maximum. There is no doubt that promotion of domestic capital is important. But in a situation where the expansion of generation capacity is urgent and much of capital needed must be secured by private investment (IPP), it is not given that this kind of limitation is beneficial. Whether this limitation is discouraging foreign capital to make investment decision, and whether minimum 5% participation of domestic capital is contributing to the promotion of domestic investors and companies, should be examined on the basis of actual cases, and if necessary, adequate revision to the regulation should be considered.

2) Strategy by Power Plant Type

Coal Thermal

IPP project implementation method has been adopted mostly in coal thermal and geothermal power plant projects in Indonesia. As coal thermal takes up the largest portion in capital requirement for the optimal power development plan, it should be implemented by IPPs as many as possible.

The risk allocation in coal thermal IPP is as shown in the table below.

Table 5.3-5 Risk Allocation in PLN's Model PPA

Risk	Description / Comment	Shared	PLN	IPP
Land Acquisition	IPP bears the land cost. PLN will assist in the land acquisition.			✔
Plant Site Unsuitability	Risk of unsuitable ground conditions.			✔
Environmental	Risk of major adverse environmental impacts requiring significant mitigation cost.			✔
Fuel Supply	Coal supply agreement will be entered into by the IPP to ensure supply.			✔
Construction and Completion	Risk of delays and cost over-runs. This risk is shifted to the contractor through an EPC contract. The IPP is responsible for engaging the EPC contractor.			✔
Operational Performance (Including Maintenance)	Risk of the power plant not fully functioning in accordance with the PPA.			✔
Exchange Rate	Except for ECR, the five types of payments[1] from PLN to the IPP are fully adjusted for fluctuation in the US$/Rp exchange rate.		✔	
Inflation	Of the five types of payments, those related to operation and maintenance (FOMR and VOMR) are adjusted for inflation in Indonesia relative to that in the US.		✔	
Interest Rate	Risk of a higher debt service cost because of interest rate rise.			✔
Demand	There is no demand risk under the PPA for the IPP, as the PPA is of the take-or-pay nature.		✔	
Regulatory Risk	Risk of the terms and conditions in the PPP agreement not being fulfilled.		✔	
Force Majeure	Risk of acts of God and certain man-made events occurring.	✔		

Source :Information Memorandum, Central Jawa Coal-Fired Power Project, KKPPI

Risk allocation in the table suggests that major risks in coal thermal IPP projects are; land acquisition, fuel coal procurement and environmental protection.

As for land acquisition, as mentioned earlier, PLN should be playing more central role. For the time being, it should be focused on prospective site identification in preparation for upcoming construction of many power plants.

As for coal fuel procurement, it should be noted that the LRC, that is assumed to be chief source of coal thermal fuel in the power development plan, is not a product that is distributed in large quantity in the market, and has not been produced in regular business basis. IPP coal thermal plants in operation now are using imported coal and/or high rank coal, and the procurement is a responsibility of IPPs. The only exception is Cilacap coal thermal plant which has experienced a halt of operation due to the interruption of transportation under the foul weather. Government supports to the production and provision of transport infrastructure are of possible option. The costs for such supports should be within the difference between total costs of high rank coal and LRC provisions, and also be recovered from the LRC sales revenue. Meanwhile, a development of mine-mouth power plant eliminates the cost and the risk of transportation. This, however, demands a large investment cost for under-sea transmission line because most of coal reserve is located in Sumatra and Kalimantan. This investment is justified not only by financial advantages, but also by multiple socio-economic advantages of the unavailability of suitable power plant sites in Java, interconnection of power grids, regional development, and so on.

It should be emphasized that there are many power plants under construction without proper environmental protection like de-sulfurization, de-NOX facilities under the fast track program. All of these projects clear the AMDAL process and they are officially acceptable environmentally. However, in the site survey of Suralaya complex conducted by JICA team, notable impact on surrounding atmosphere was observed. If a similar environmental degradation occurs with an IPP project, especially under circumstances of site finding, IPP coal thermal may become unacceptable to regional communities. A thermal power plant with poor environmental protection capability will not be sustainable. Environmental risk can be allocated to IPPs, but the specifications better than those of fast track program projects should be prepared and demanded to IPP bidders.

Geothermal

Bidding for geothermal development license is conducted by local governments. This rule has been introduced in Geothermal Law in 2003, while it was August 2008 that the bidding was opened for the first time under this rule. Therefore, we have to wait for some time to evaluate the efficacy of this rule. Meanwhile, government/ministry regulations to support the new law have not been implemented yet. For the time being, geothermal projects will have to proceed with legal/institutional uncertainties. There is a criticism that the information provided to bidders based on the pilot surveys conducted by local governments is not sufficient so as for bidders to assess the possibility of exploitation within the reasonable margin or risks[16]. There should be more preliminary site exploration works carried out, and their results provided as information to tenderers. Otherwise, the risks are too large for private companies to make the investment decision on the project. Including this, the processes and standards of bidding for mining license should be provided as soon as possible. As for the preliminary site exploration works, there may be a

[16] From interviews with IPP operating companies.

shortage of funds for a local government. A setting up of a revolving fund to provide a loan can be a solution. The loan can be reimbursed through PPA once the project realized.

The rationale for IPPs having to take the risks of geothermal development is that IPPs are more able to manage physical risks in development and construction of geothermal power plant. Suppose this is correct, one way to take the most out of it is to offer candidate sites in number larger than to be actually developed and to have bidders choose ones they would like to develop. This is a method actually used in small-scale hydro development[17] and is applicable to geothermal development by utilizing the know-how of developers in selecting less costly, lower risk sites. Those candidates that were not chosen by bidders can be later put on bidding again after further exploration data are obtained and provided to bidders or when the average development costs have gone up, or eventually, be discarded.

A geothermal power plant is in many cases planned in a forest and sometimes falls within the boundary of protected forest. Any development activities in protected forests are, in principle, not allowed, but subject to the approval of Minister of Forestry they can be possible. There are cases that a project located in protected forest is advanced with the approval issue unsolved, and put to bidding. Indeed, Kamojang extension project had been signed for PPA and waiting for an approval for some time when it turned out that the Minister approval was not given and the project was cancelled. Bedugul geothermal project has been signed and originally intended to start operation in 2010, but is still waiting for the approval. (See section 4.4.4) This is a tremendous risk to any bidders and must be resolved by institutional improvement, such as setting up a inter-ministry coordinating board where possibility of projects is discussed prior to their advancement to bidding.

PPA unit price of geothermal IPP is regulated by MEMR Permen No.14/2008. The price ceiling is set against the BPP, the standard electricity provision cost, of the region in which the project is located. Jamali region has one of the lowest BPP which may significantly limits the viability of possible geothermal projects. The efficacy of this regulation should be monitored so that it would not impede the private capital investment in geothermal projects.

Being the country endowed with the world-largest geothermal potential, with a plan to heavily invest in geothermal development in next few decades, Indonesia may aim to have the most advanced technology in geothermal resource utilization, and It would be PLN, the sole power utility company of the country, that develops, accumulates, owns and advances the technology. Technical and financial support should be desirable if PLN is to be tasked with such a mission.

[17] The World Bank, Energy Issues, Energy Note No.9, April 1996

Renewable Energy (Solar, Wind, Biomass, etc.)

In the optimal power development plan, substantial investment in renewable sources starts around 2020. Jamali power system is expected to experience a shift of daily peak demand from evening to daytime around this period, and solar power that generates power in daytime will effectively meet the peak demand. At present, as the generation capacity is in serious deficit, an expansion of renewable energy is not a good policy. When power plants taking base load, such as coal thermal and nuclear, will have installed in sufficient capacity with some proportion of power plants with flexible output, such as pumped hydro, renewable energy becomes effectively employed in the system.

Research & development of PV cell is advancing at a fast rate and its production cost falling. In the generation cost estimation earlier in this section, unit investment cost of PV unit is assumed to be US$ 5,000 per kWh, which is the lowest level unit cost at the moment. In ten years, it will be much lower. Suppose it falls down to US$ 2,000 per kWh, unit generation cost is, not as low as other types of generation, at a level which can be absorbed in the whole generation system. Total investment cost of solar generation equipment until 2028 estimated at US$ 30 billion in the optimal power development plan would become US$ 10 billion. Divided by 10 (years), annual investment amount would be US$ 1 billion, which may seem not unrealistic compared to Rp. 60 trillion (US$ 6 billion) spent on electricity subsidy this year.

Investment in solar systems can be done by large number of small-scale individual installations whose generated energy purchased by PLN, or by PLN as in large-scale installations, or a combination of these. However, unless the generation cost falls as other types of generation or as low as electricity users in the aggregate can pay, there must be some kind of promotion devices to attain the total capacity in the optimal power development plan. In some countries, electricity utilities are mandated to purchase the energy generated by solar power at a certain price. Suppose the similar system is introduced in Indonesia, and the price is as low as not to significantly raise the retail price (tariff), there must be some economic measures to lower the investment cost. In Japan, setting up a special account (a fund) from part of income of import tax on crude oil and petroleum products, from which subsidy is paid to those who invest in renewable energy. Outline of this subsidy system is shown below.

It should be reminded that, for the investment in renewable energy, CDM is a useful device that is available.

Japan's Experience in Renewable Promotion

Geothermal

Understanding that the country is not endowed with sufficient energy resources to meet energy demand, as a measure to secure stable supply of energy and also to a response to global warming, promotion of geothermal energy is of primal importance as a resource produced domestically and effective in suppressing CO_2 emission. On the other hand, development of geothermal has problems like a long lead time, large capital requirement and high risks, and is difficult to promote by private investors. Therefore, the objective of this subsidy is to reduce the risks of geothermal resource exploration and to promote investment in development by local governments and/or private developers.
For those candidate sites that have not been well explored due to exploration risks, three types of survey programs (Type A: large area exploration, Type B: preliminary exploration, Type C: in-detail exploration) are assumed, and pilot investigation is carried out in order to encourage private sector development and eventually promote the development.

Step 1 organizations (local government, private company) that have a geothermal development program are invited to submit a geothermal power development plan (site) and a resource exploration plan, among which the candidate is selected.

Step 2 The selected candidate sites are surveyed by the proponents to which survey works are commissioned.

Step 3 Time for the survey is two years at maximum, and the survey work includes the surface investigation, pilot boring (medium diameter, 1,000m depth, and three bore holes), environmental impact assessment.

Step 4 Based on the result obtained in the first year, development plan is revised and continuation of the survey judged.

Table Subsidy amount to geothermal development in Japan

Year	2002	2003	2004	2005	2006	2007
budget	2,434	1,702	1,781	1,653	1,297	1,562

In JPY million

Middle- to small-scale hydro power

Hydro power is a pure domestic energy resource and required to be developed to meet electricity demand. However, remaining hydro power potential sites have become smaller in scale and are located more and more in remote areas, which leads to the higher construction cost and unit generation cost. Therefore, potential with physical and economic viability is limited. Nevertheless, as a pure domestic energy resource with smaller environmental impacts, middle- to small-scale hydro is desired to be developed for energy security purpose and as a countermeasure to global warming.

Middle- to small-scale hydro is less economically advantageous because it bears higher unit construction cost and higher unit generation cost particularly in the initial period of life time. The objective of this subsidy is to lower the initial generation cost by supporting part of construction cost, and to promote its development.

The scope of the subsidy provided to the developer of middle- to small-scale hydro development is as follows.

- A hydro power plant project with output over 1,000 kW and lower than 30,000 kW
- A hydro power renovation project with output lower than 30,000 kW (increase in output due to the renovation should be more than 20%)
- A hydro restoration project with output lower than 30,000 kW (the cause of breakdown is not attributable, such as natural disaster, increase in output due to restoration should be more than 100kW)
- A hydro construction project that employs new technologies.

Table Subsidy amount to Middle- to small-scale hydro power in Japan

Year	2002	2003	2004	2005	2006	2007
Budget	891	790	646	1,000	943	607

In JPY million

Solar power

Effective during 1994 to 2005

To promote the sustained development of solar power investment, financial support is provided for a certain period, to realize installation in a large scale, helping lower the production cost by mass production, and eventually expedite maturing of the market.

Type 1: for residences (general, retro-fit)
a person or organization investing in home solar system (the unit suitable for installation on the roof of residence, connected to low-voltage power grid with reverse flow, and with output less than 10 kW), who makes into contract with utility a company.

Type 2: for residences (pre-fit)
a person or organization purchasing a residence equipped with home solar system.

Type 3: for local government
For a local government which provides support for those who purchase or build residence equipped with home solar system

The amount of subsidy is around JPY 20 thousand to 45 thousand per kW (Rp.2 million to 4.5 million).

(4) Recommendations for Realization of Optimal Power Development Plan

For promotion of IPPs, a key to achieve the optimal power development plan, recommendations are made as follows.

<u>**General Recommendations**</u>

1) Retail Tariff

To prepare for rapid expansion of generation capacity, substation and transmission/ distribution lines, financial conditions of PLN, as PKUK, should be strengthened, and the government's subsidy decreased at the same time.

- PLN's profit margin should be increased to allow for future investment. Such measures as a revision to the calculation method of BPP shall be considered.
- In relation to the increase of PLN's profit margin, limiting electricity subsidy to customer category R-1, 450VA is recommended, in order to reduce the government subsidy payment.
- Further, a possibility of introducing cost-pass-through system to the electricity tariff should be studied.

2) Process of Private Partner Selection

To attract more investment from private sectors, the process of selecting private partners (IPPs, EPC contractors, etc.) should be open and fair.

- Bidding process should be monitored by independent body.
- Continuous evaluation and improvement of the process is necessary. Particularly, attentions must be paid to biddings administered by local governments, and relationship between incumbents and new entrants.

3) Project Schedule

Delay in projects would discourage private companies from investing in the sector, add unnecessary costs, negatively affect projects in-waiting.

- To study cases of delayed projects and to find causes and their solutions are necessary.
- In particular, streamlining the process of financial closing of foreign loans is desired.

4) Land Acquisition

Land acquisition for power plant, transmission line is very difficult task for investors particularly for those from abroad.

- Initiative in land acquisition for power plants and transmission lines should be taken by local government or PLN.

5) Long term Perspective and Flexibility in Project Realization

Projects and their implementation details are designed with long term perspective.

- Consideration on sustainability in setting bidding and contractual conditions is important.
- To devise technical requirements in bidding in consideration of the system operation, such as;
  bidding for different power plant operation patterns,
  PPA pricing for middle- to peak-operation power plant,
  introduction of capacity fee in PPA
  setting power plant ramp rate.
- Standardized PPA pricing should be evaluated and revised, if necessary, for different power plant operations.

6) Use of domestic inputs and increase of local currency portion

Increase of foreign currency loans and PPA liability would expose PLN more to foreign exchange risks. Increase of local currency portion in contracts, and also self finance ratio, are desired.

- A method to evaluate highly the bid with higher local currency portion should be studied.

7) Limitation of Foreign Capital Ownership

The current regulation on the limitation of foreign capital ownership of power plant, 95% maximum, can be one of factors that impede foreign investment.

- The efficacy of the regulation in the promotion of domestic industries and private investment in the power sector should be studied and verified.

<u>Recommendations By Power Generation Type</u>

Coal thermal

1) Securing Fuel

LRC will be the main primary energy source for coal thermal power plants. The development and exploitation of LRC should be given support. When mine-mouth coal thermal is to be constructed, investment in submarine cables will be required.

- The support to the development of LRC should be done within the price difference between high rank coal and LRC, and should be recovered from LRC sales revenue.
- Investment on submarine cables should be evaluated not only from coal procurement issues but also from comprehensive views including difficulties of power plant site finding in Java, advantage of interconnection of grids, regional development in remote areas, etc.

2) Environmental Protection

If IPPs construct power plants with low environmental protection capabilities, it would undermine the long term sustainability due to damaging social acceptance.

- Higher environmental standard should be demanded in coal thermal projects even if it leads to higher cost.

Geothermal

1) Institutional Arrangement

Regulations/standards relevant to the development of geothermal have not been provided, which brings in many uncertainties to investment in geothermal.

- Regulations/standards for geothermal development should be provided as soon as possible.

2) Pre-bid Site Survey

More site survey should be carried out before bidding and its result provided to bidders, in order to lower the risks of developers.

- In case that local government lacks the finance necessary for such a pre-bid survey, setting up a revolving fund to supply necessary resources may be effective.

3) Utilizing Developer's Knowledge in Site Selection

To develop geothermal resources more efficiently, the knowledge of private developers should be exploited more.

- To offer more candidate sites than to be developed and to have bidders select their preferred sites in their bid can be an effective bidding method.

4) Geothermal Development in Protected Forest

Geothermal potential sites are often located in and around the designated areas for protected forest

- A provision for confirming the possibility of geothermal development prior to license bidding must be established; for example an establishment of inter-ministry coordination board.

5) Limitation of Standardized PPA prices

As geothermal development cost varies in one project to another, setting PPA price capping on geothermal IPP may preclude investors/developers from participating in bidding.

- The regulation and its effect should be monitored and, if necessary, revised.

6) PLN's Technical Knowledge of Geothermal Development and Support

PLN has in-depth technical and operational know-how in geothermal business and it should keep its advantage as the sole electric utility in the country.

- Such technical supports as an introduction of the latest technologies and financial supports should be considered and provided to PLN, when necessary.

Renewables

1) Promotion of Expensive Renewable Energy

Specific measures to encourage use of and investment for solar power and wind power should be considered and implemented.

- Special fund can be set up to provide subsidy to those who invest in renewable energy generating equipment. Revenue from export tax on fossil fuel can be a source of such fund.
- Mandating PLN to purchase energy generated by renewable sources at fixed prices can be an assurance to investors.
- Tax exemption and/or loan with favorable conditions can also be effective measures.

5.4. Environmental and Social Considerations

[Air Pollution]

Power Source Diversification Scenario has been identified as the optimal power development plan. Even in this scenario, coal-fired power generation is a major power source, and there is a concern over potential impacts on air quality. As mentioned in “4.4.4 Potential Environmental Concerns of Various Power Generation Options and Transmissions (including the “Zero Option”), and Possible Measures against Them”, environmental regulations such as air quality standards and emission standards are not respected adequately in Indonesia, and they do not contribute sufficiently to the protection of air quality. Siting of coal-fired power stations should be determined after the present levels of air pollution at proposed sites are identified and whether additional air pollution loads are acceptable or not is considered.

Electricity from Sumatra to Jamali area through underwater transmission lines will be produced also by coal-fired power stations in Sumatra, so it should be noted that total amounts of air pollutants to be emitted by coal-fired power stations in association with the power supply to Jamali area will be more than emissions only from those in Jamali area.

Monitoring networks of air quality are yet to be established in Indonesia, but power stations are required to conduct quarterly environmental monitoring after they come into operation. In the case of extension of an existing power station, monitoring data of this power station can be referred to predict and evaluate potential impacts of its extension on air quality.

If a new power station is constructed or an existing power station is extended in an area already with heavy air pollution, measures against air pollution, such as installation of desulfurization/denitrification facility, low-NOx burner, efficient electrostatic precipitator and bag filter should be considered. This is also the case for oil-fired and gas-fired power generation. Draft EIS of Onahama Thermal Power Station, one of the latest coal-fired power stations proposed in Japan, reports that efficiencies of the desulfurization facility (FGD), denitrification facility and electrostatic precipitator proposed for this power station are 97.0%, 88.0% and 99.8%, respectively.

[Water Pollution]

Coal-fired power generation, if leachate from its coal storages/ash disposals is not properly managed, may create water pollution. Measures to prevent direct discharge of leachate to the sea need to be taken, and periodical monitoring of water quality should be conducted at wastewater discharge to confirm that there occurs no water contamination.

On the other hand, hydroelectric power station may also cause degradation of water quality, if its reservoir is not appropriately managed for water quality. In Jamali area, substantial amounts of nitrogen and phosphorus have already flown into a reservoir of Saguling

Hydroelectric Power Station, due to the population growth and increase of agricultural lands in its surroundings, to lead to algal blooms there (see "4.4.4 Potential Environmental Concerns of Various Power Generation Options and Transmissions (including the "Zero Option"), and Possible Measures against Them"). Large-scale reservoir type hydroelectric power stations will be introduced in Power Source Diversification Scenario, and proper management of water quality in their reservoirs is required.

[Thermal Effluents]

Majority of power sources in Power Source Diversification Scenario are those with substantial amounts of thermal effluents, such as thermal and nuclear power generation. Whether their operation is acceptable or not should be determined after potential impacts of their thermal effluents on marine organisms and local fishery are appropriately predicted and evaluated. In Jamali area, especially off West Java, East Java and Bali, there are often coral reefs (see Fig.5.4-1), so special attentions need to be taken for their protection. In the case of extension of an existing power station, monitoring data on survival of corals around it can be referred to determine whether its extension is acceptable or not (see "4.4.4 Potential Environmental Concerns of Various Power Generation Options and Transmissions (including the "Zero Option) and Possible Measures against Them". If construction of a power station is required at a site where significant impacts by thermal effluents are expected on marine organisms/local fishery, cooling towers need to be introduced to reduce thermal effluents, or location of the water discharge has to be adjusted to lower their impacts.

Source : GCRMN Report on East Asian Water 2005
(http://www.coremoc.go.jp/report/ease2004/02_02indonesia_j.pdf)

Fig.5.4-1 Distributions of Coral Reefs in Indonesia

[Resettlement]

Reservoir type hydroelectric power generation, large-scale thermal power generation and nuclear power generation require a vast land for their power station, and they are likely to require large-scale involuntary resettlement or lead to losses of habitats for endangered/ precious/rare species. Reservoir type hydroelectric power stations and nuclear power stations will be constructed in Power Source Diversification Scenario, so field surveys should be conducted in advance on residents, land uses and occurrences of endangered/precious/rare species within their construction sites, to confirm that there will be no significant impact on them. When large-scale involuntary resettlement is required, consent from local residents on resettlement needs be obtained and appropriate compensation has to be conducted, in accordance with the Land Appropriation Law (Presidential Decree No.36/2005).

[Geothermal Power Generation]

In Power Source Diversification Scenario, geothermal power generation also plays an important role. Geothermal power generation emits H_2S into the atmosphere and discharges arsenic and mercury in its effluents. In Indonesia, there are emission standards and effluent standards for these substances with potential significant impacts on surrounding environment (see “4.4.4 Potential Environmental Concerns of Various Power Generation Options and Transmissions (including the “Zero Option”) and Possible Measures against Them”, and it is required to comply with these standards.

[Global Warming]

Indonesia has ratified Kyoto Protocol, but it is not subject to the greenhouse gas emission reduction target since it is a non-Annex I country. Thermal power generation to emit substantial amounts of CO_2 provides a major power source in Power Source Diversification Scenario. If legally binding greenhouse gas emission reduction target is established to Indonesia in future, it will be required to improve generation efficiencies of thermal power generation to suppress CO_2 production or to conduct afforestation to sequester CO_2 in the atmosphere. If Kyoto Mechanisms exist in future, these measures may be able to be financed by Clean Develop Mechanism.

It used to be said that hydroelectric power generation does not emit CO_2 and that it is friendly to global environment, but now it is known that it will release methane when water quality in a reservoir goes down. As shown in Table 5.4-1, methane has 21 times more greenhouse effect than CO_2. It is required to take efforts to prevent its eutrophication and subsequent degradation of water quality due to uncontrolled discharges of sewage from around a reservoir.

Table 5.4-1 Global Warming Coefficient[18]

	Greenhouse Gas	Global Warming Coefficient
1	Carbon Dioxide	1
2	Methane	21
3	Dinitrogen Monoxide (Nitrous Oxide)	310
4	Trifluoromethane	11,700
5	Difluoromethane	650
6	Fluoromethane	150

Source: Enforcement Order of the Law to Promote Actions against Global Warming (Goverment Ordinance No.143, April 7, 1999)

[Environmental Performances of Various Types of Power Generation]

For implementation of power development, it is required to identify sites for power stations and to construct and operate them, with due considerations on different environmental performances between various types of power generations.

Re-presented below is "Table 4.4-14 Environmental Performances of Major Types of Power Generation". Environmental impacts completely subject to the location of power stations are not included in this table.

Table 4.4-14 Environmental Performances of Major Types of Power Generation

	Coal-Fired	Oil-Fired	Gas-Fired	Geothermal	Hydro	Nuclear
Air Pollution	SO_2, NOx, SPM	SO_2, NOx, SPM	NOx	H_2S	–	–
Water Pollution	From Coal Storage/ Ash Disposal	–	–	As, Hg	Water Quality Degradation in Reservoir	–
Greenhouse Gas Emission	CO_2	CO_2	CO_2	–	CH_4 from Reservoir	–
Thermal Effluent	Substantial Amount	Substantial Amount	Substantial Amount	Limited Amount	–	Substantial Amount
Involuntary Resettlement	Possible	Possible	Possible	–	May be Large-Scale	May be Large-Scale
River Water Use	–	–	–	–	Impacts Likely	–
Radiation Risk	–	–	–	–	–	Potential

[18] Relative greenhouse effect of a particular gas for a unit concentration in the atmosphere for 100 years compared to the effect of carbon dioxides.

5.5. Measures for the Improvement of System Operation

Against the current situation and causes of problems on system operation, which is mentioned in Section 2.4.6, the suggestions on measures for the improvement of system operation in terms of voltage, frequency and outages are described below.

5.5.1 Voltage

The reasons for system voltage drop in Jamali are that reactive power source to maintain proper voltage is fundamentally lacked and existing reactive source is not fully utilized. Against these reasons, the following countermeasures can be suggested.

[Short Term Measures]

1) Raise of system standard voltage
2) Introduction of incentives and penalties for reactive power supply

[Long Term Measures]

3) Planning of reactive power equipment
4) Installation of on-load tap changer to step-up transformer
5) Installation of PSVR (Power System Voltage Regulator)

Details of each measure are described below.

(1) Raise of System Standard Voltage

By raising standard voltage of higher voltage class, such as 500 kV, it is possible to make voltage of whole system higher and mitigate voltage drop at lower voltage class. Raise of system standard voltage can be accomplished by raising generator terminal voltage.

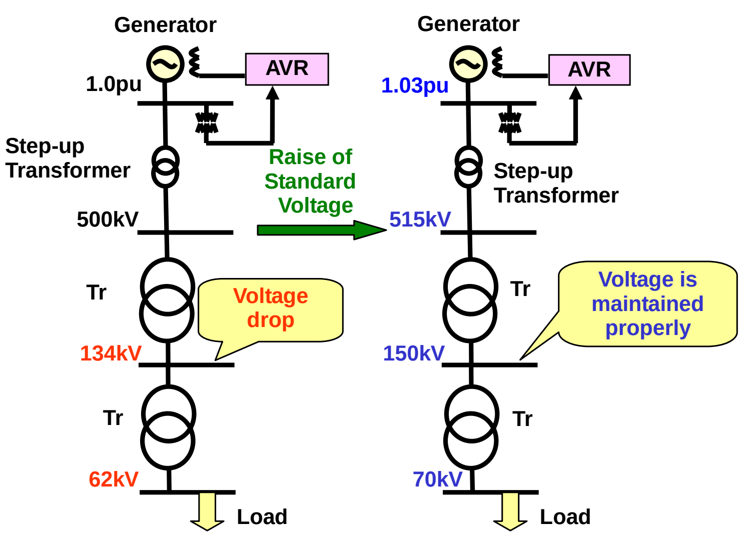


Fig. 5.5-1 Outline of Raising Standard Voltage

The effect of raising standard voltage is not only the solution of low voltage problem but also the reduction of system loss. The result of trial calculation on raising standard voltage, which is conducted through PSS/E using the system data in Jamali, is shown in the table below. It is obvious that, with existing facilities, as terminal voltage is set higher, system loss become smaller. In case voltage is set to 1.03 p.u., losses are expected to be reduced by around 10% compared to the case where voltage is set to 1.01 p.u.

Table 5.5-1 Result of Trial Calculation on the Effect of Raising Standard Voltage

Generator terminal voltage (p.u.)	V = 1.01	V = 1.03	V = 1.05
System Loss (MW)	621.9	552.2	510.9

Although there is large benefit of raising system voltage, excessive voltage rise may cause insulation breakdown of equipment or increase of noise. Generally, maximum allowable voltage of the system is set below the voltage limit of equipment, and there is no problem if maximum allowable voltage is observed. For setting upper limit of voltage operation, it shall be set below the maximum allowable voltage of the system with some margin considering error of metering device. In addition, for each generator, available reactive power output as well as active power output shall be studied.

Raise of system voltage can be executed speedily without any additional installation cost by the operation order so as to raise terminal voltage of generator. There are many IPP generators in Jamali system. In order to make operation order to those generators so as to raise terminal voltage, it is recommended to introduce incentives and penalties for reactive supply as mentioned below.

(2) Introduction of Incentives and Penalties for Reactive Power Supply

Generally, IPPs are reluctant to supply reactive power because supply of reactive power does not produce profit for IPP. Against this problem, application of the system where reward is given for reactive power supply to keep system voltage properly can be suggested. In addition, application of penalties for violation of operation order such as to raise terminal voltage can be suggested. In both cases, it is necessary to prescribe in the rules such as grid code.

(3) Planning of Reactive Power Equipment

It is necessary to install reactive power equipment such as static capacitors and shunt reactors as fundamental solutions to voltage problem. Long term plan is required considering reactive supply and demand balance from long term perspective, and installation of reactive power equipment in accordance with lack and surplus of reactive supply.

Example of the study process of installation of reactive power equipment is described below.

a) Study of planning phase

Generally, in heavy load condition, system voltage drops due to lack of reactive power, because both reactive power consumption by load and reactive losses of the system are large. On the other hand, in light load condition, rise of system voltage is concerned, because both reactive power consumption by load and reactive losses of the system are small.

Therefore, the following section can be considered for the study of installation of capacitors and reactors;

Shunt reactor (ShR) : Lightest load condition in the year

Shunt capacitor (SC) : Heaviest load condition in the year

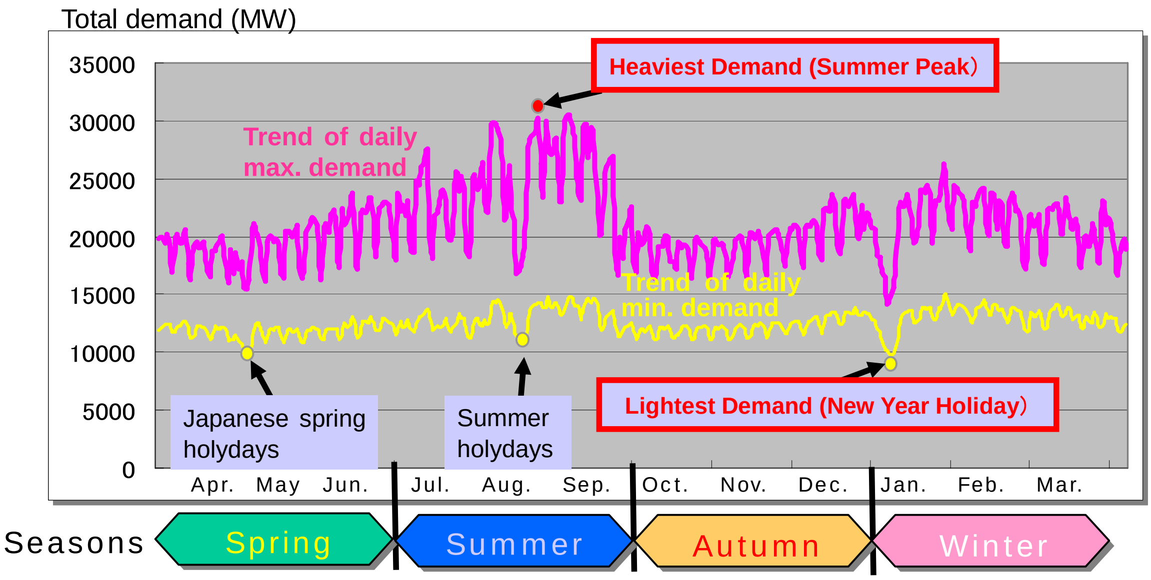


Fig 5.5-2 Example of Study of Planning Phase for Reactive Power Equipment

b) Reactive demand forecast

In consideration with active demand forecast and the relationship between active power and reactive power in the past, reactive demand in the future is forecasted.

c) Checking of supply and demand balance in each block

Reactive power equipment shall be properly distributed in required area, because reactive power cannot be transmitted so far. Therefore, power system is divided into several blocks, and supply and demand balance is checked in each block.

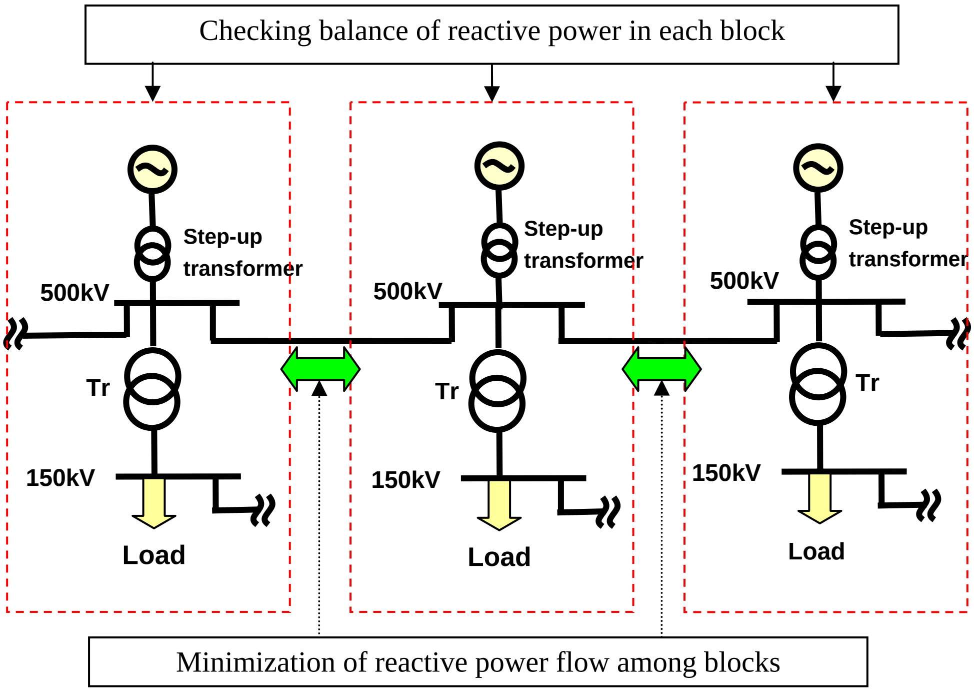


Fig.5.5-3 Outline of Checking Supply and Demand Balance in Each Block

d) Calculation of the required amount of reactive power equipment

Based on reactive supply and demand balance, in order to supplement surplus and shortage of reactive power, required amount of reactive power equipment is studied for each block. Supply and demand balance is checked and reactive power flow among the blocks is minimized.

e) Selection of the capacity of single unit

The capacity of single unit is selected so that voltage shock due to switching of the equipment is within standard range. To make equipment universal, it is better to standardize the capacity of single unit for each system voltage.

f) Power flow analysis

Through the power flow analysis on condition that reactive power equipment is installed, whether the voltage is within acceptable range is checked. In case there is voltage violation, procedure from c) to f) is repeated.

(4) Installation of On-load Tap Changer to step-up Transformer

It is possible to control reactive output of generator by changing tap of step-up transformer at generation plant. The outline is indicated in Fig.5.5-4. When transformation ratio is fixed, with constant voltage control by AVR, it would be difficult to fully utilize reactive power from generators due to restriction of generator terminal voltage in many cases. On the other hand, when transformer is equipped with tap structure, it is possible to enhance ability on reactive power output by changing tap without restriction of terminal voltage.

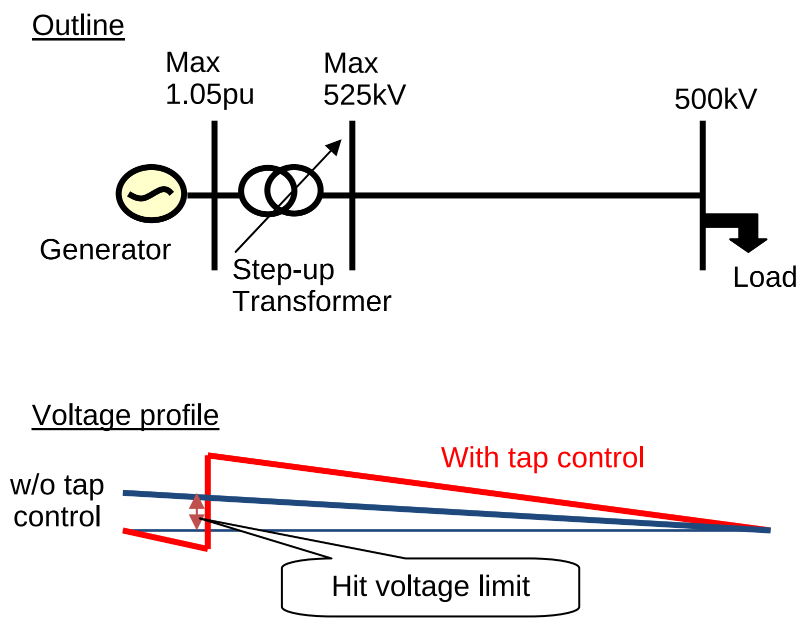


Fig. 5.5-4 Concept of the Utilization of Reactive Power by Tap Change

PLN has already tried to raise voltage by using off-load tap changer at some generators. However, in case of off-load tap changer, it is difficult to change tap properly against voltage fluctuation, because planned outage is required to change tap. Therefore, in order to change tap properly in accordance with the condition of system voltage and reactive power, and utilize reserve of reactive power from generator, changing tap without outage by on-load tap changer is required.

For the application of transformers with on-load tap changer, the place to be installed shall be studied and selected, because it is a little expensive compared to transformers with off-load tap changer. It is better to install on-load tap changer to generators with large capacity such as more than 300 MW and large reactive margin, because on-load tap changer utilizes reactive output margin of generator. In addition, it is necessary to describe in the rules such as grid code so as to force generators including IPPs to install on-load tap changer, which raises installation cost.

When step-up transformer with on-load tap changer is installed at some plant, in order to fully utilize reactive power output, the study on the range of tap and the number of tap is desired. As an example of the study on maximum tap, the tap range which satisfies the following condition would be calculated;

1) Output where reactive power of generator is limit (Ex: Rated output, p.f. = 0.9)
2) Terminal voltage of generator (Vt) doesn’t exceed the default value (Ex: 1.03 pu)
3) Bus Voltage at higher side of step-up transformer doesn’t exceed the maximum allowable system voltage (Ex: 1.05pu)

Namely, the tap which satisfies the condition such as limit of reactive output of generator (P_G+jQ_{Gmax}), generator terminal voltage (V_t=1.03) and bus voltage at higher side (V_s=1.05), will be maximum tap. On the other hand, the number of tap can be selected from the standard value which is larger than [(V_{max} – V_{min})/V_a +1], where the highest and the lowest voltage of the tap is defined as V_{max} and V_{min} respectively, and allowable value of voltage change by tap operation is defined as V_a.

(5) Installation of PSVR (Power System Voltage Regulator)

AVR, which is generally used, detects generator terminal voltage and controls reactive supply from generator so as to keep the voltage constant. With this system, even if system voltage drops, reactive power supply does not reach limit in many cases.

On the other hand, as shown in Fig.5.5-5, PSVR controls high side of step-up transformer which is closer to grid and try to keep it constant. Therefore, it is possible to utilize margin of reactive power supply from generator speedily and try to keep system voltage against fast change of load. PSVR is installed in some utilities in Japan, and contributes to improve system voltage stability.

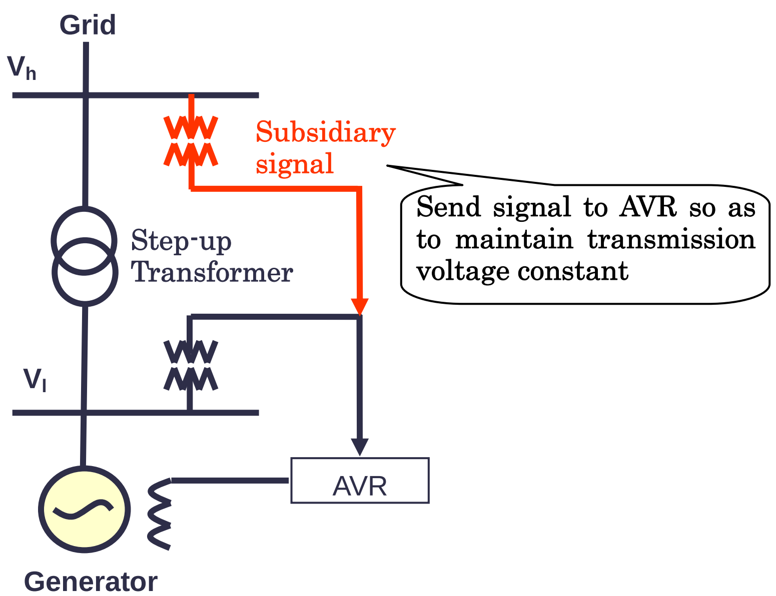


Fig. 5.5-5 Outline of PSVR

The result of trial calculation on the effect of PSVR, which is conducted through PSS/E using system data in Jamali, is shown in Tables 5.5-2, 5.5-3 and 5.5-4. Table 5.5-2 shows the case with constant generation terminal voltage control by AVR, and Table 5.5-3 shows constant transmission line voltage control simulating the installation of PSVR to generators more than 300 MW. In both cases, generator terminal voltage is set to be same in normal condition. Then, the response is analyzed when demand in Region 1 is increased by 10%.

Table 5.5-2 Study on the Effect of PSVR (a) AVR

(Unit : pu)

Plant	Normal		With increased demand	
	V_h	V_l	V_h	V_l
A	0.98	1.0124	0.9589	1.0124
B	1.00	1.0186	0.9973	1.0186
C	1.00	1.0296	0.9956	1.0296
D	1.00	1.0284	0.9890	1.0284

Table 5.5-3 Study on the Effect of PSVR (b) PSVR

(Unit : pu)

Plant	Normal		With increased demand	
	V_h	V_l	V_h	V_l
A	0.98	1.0124	0.98	1.0350
B	1.00	1.0186	1.00	1.0196
C	1.00	1.0296	1.00	1.0318
D	1.00	1.0284	1.00	1.0368

Table 5.5-4 Difference of Loss by PSVR

	Active loss	Reactive loss
(a) AVR	654MW	2922MVar
(b) PSVR	635MW	2542MVar

As a result, in case (a), generator terminal voltage (V_l) is kept constant, but transmission voltage (V_h) drops. On the other hand, in case (b), transmission voltage is controlled to be constant, and consequently generator terminal voltage is raised. In addition, as shown in Table 5.5-4, in case (b), there is an effect that increase of active and reactive loss is restrained because system voltage is kept high. Thus, PSVR has an effect to keep system voltage against system disturbance such as rapid demand increase.

For the application of PSVR, the place to be installed shall be studied and selected, because it requires additional installation cost which is almost same as AVR. It is better to install PSVR to generators with large capacity such as more than 300 MW and large reactive margin, because PSVR utilizes reactive output margin of generator. In addition, because application of PSVR raises installation cost, it is necessary to describe in the rules such as grid code so as to force generators including IPPs to install PSVR.

Both PSVR and previously mentioned on-load tap changer to step-up transformer have similar effect of utilization of the margin of reactive power from generator. Therefore, when they are applied, it is better to make a best choice in consideration with characteristics of both measures. A comparison of PSVR and on-load tap changer is listed in the table below. Generally, PSVR has advantage on fast reaction against voltage change, and on-load tap changer has advantage on the amount of reactive power to be utilized.

Table 5.5-5 Comparison of PSVR and On-load Tap Changer

Item	PSVR	On-load tap changer
Limit of utilization of reactive power	Limit of generator terminal voltage	Reactive output from generator can be fully utilized when tap range is selected properly.
Speed of reaction against voltage change	Fast (Excitation system reacts after the detection of voltage deviation at sending end)	Slow (Tap changing is mechanical operation)
Additional cost for installation	Additional cost almost same as AVR	A little expensive than PSVR
Installation for existing facilities	Relatively easy to install because auxiliary equipment is attached to existing AVR	Replacement of existing transformer may be required. Relatively difficult to install.
Possibility of failure	Possibility of failure is relatively low because it is basically electric control device	Possibility of failure is higher than PSVR because it contains mechanical structure.

5.5.2 Frequency

Countermeasures against frequency fluctuation can be classified into normal and emergency frequency controls.

[Measures for normal frequency control]

1) Application of penalty
2) Bidding classified by operation type
3) Application of tariff for middle and peak type generators
4) Application of Capacity Fee

[Measures for emergency frequency control]

5) Proper calculation of system frequency characteristics
6) Detailed system frequency characteristics considering K_G and K_L

Details of each measure are described below.

Measures for normal frequency control

1) Application of penalty

In case ramp rate is lower than designed value or a generator does not follow operation order, which obstructs frequency control, application of penalties for generators can be suggested. When an IPP doesn't produce energy instructed by operation order, penalty as example in the table below could be applied. In this example, comparing operation order and actual generation for every 30 minutes, deviation within 3% is considered to be normal fluctuation of demand and supply, and imbalance fee which is necessary for utility to adjust imbalance of demand and supply is charged to IPPs. On the other hand, expensive penalty no less than 3 times of imbalance fee for standard range is imposed to IPPs for the deviation of over 3%.

Table 5.5-6 Example of the Application of Penalties

Item	Example
Criteria	Generated energy should be as same as ordered energy for every 30 minutes.
Penalty unit price	[Standard range (within 3% of ordered energy)] Imbalance Fee = [Imbalance adjustment cost]/[The amount of imbalance] = Variable fee + [4%*1 of total fixed cost]/[3.7%*2 of generated energy] [Excess over standard range] 3 times*3 of Imbalance Fee
Description	Description in documents such as Grid Code and PPA
Way of levy	Deduction from payment of income

*1: Corresponds to spinning reserve
*2: Demand fluctuation factor 1% + Generation fluctuation factor (Outage etc.) 2.7%
*3: Considering level of trading spot price, and moral hazard and entry barriers for IPP

2) Bidding classified by operation type

In general IPP bidding, base load type generators have advantage on feasibility, and middle and peak load type generators which are capable for frequency control are not likely to be installed. Middle and peak load type generators would be competitive by the application of bidding classified by the type considering operation patterns.

Example of the bidding classified by operation type is described below. IPP can choose operation pattern from base, middle and peak before bidding. Bidding price consists of capital fee, O&M fee and fuel fee. The upper limit of fuel fee is set for each type of generators. Table 5.5-7 shows the example of standard capacity factor and the limit of fuel fee by each operation type.

Table 5.5-7 Example of Standard Capacity Factor and the Limit of Fuel Fee

Operation pattern	Base	Middle	Peak
Capacity factor	70%	50%	30%
Limit of fuel fee	3cent / kWh	5cent / kWh	7cent / kWh

If middle or peak load type is chosen, because bidding price itself is not competitive compared to base load type, bidding price is converted to equivalent evaluation price considering capacity factor as follows, and evaluated;

Evaluation Price of Peak Load Type = Bid Price x [30% / 70%]

Thus, middle and peak load type generators become competitive against base load type generator in bidding evaluation. Putting the application of specific tariff described below together, investments for middle and peak load type generators are considered to be driven. In actual bidding, in order to secure ability of IPP generators to follow load fluctuation, it is better to describe following items in the documents such as grid code and bidding document in advance;

- Start up time

- Velocity of output change
- LFC velocity and capacity
- Requirement of Governor free
- Penalty for violation of operation order

3) Application of tariff for middle and peak load type generators

In past IPP bidding in Indonesia, tariff was set assuming base load type operation. However, it is difficult for middle and peak load type generators to secure profit with cheap tariff for base load type, because operation hours are short and fuel cost is high.

On the other hand, in other countries, specific tariff for peak and middle load type generators considering operation pattern is already applied. For example, tariff system of IPP project in Southeast Asia is shown in table below. This tariff system would make it easy for middle and peak load type generators to secure profit despite of short operation hours.

Table 5.5-8 Example of Peak Tariff

Item	Tariff (cent/kWh)	Operation hours	
		Weekday	Holiday
Primary Energy	7.0	16 hours (6-22)	N/A
Secondary Energy	4.2	8 hours (22-6)	24 hours

4) Application of Capacity Fee

It is important to utilize IPP investment as well as generators of PLN in order to keep enough supply against steady growth of demand in the future. In general, power purchase agreement with IPP is based on energy (kWh). However, especially for middle and peak load type generators, this system raise the risk that fixed cost is not recovered, because income of IPP fluctuates in accordance with traded energy. Against this problem, as shown in Fig 5.5-6, application of capacity fee where minimum payment despite of actual generation is secured can be suggested. With this fee, it is considered to enable IPP to recover fixed cost easily and to prompt investment by IPP for middle and peak load type generators.

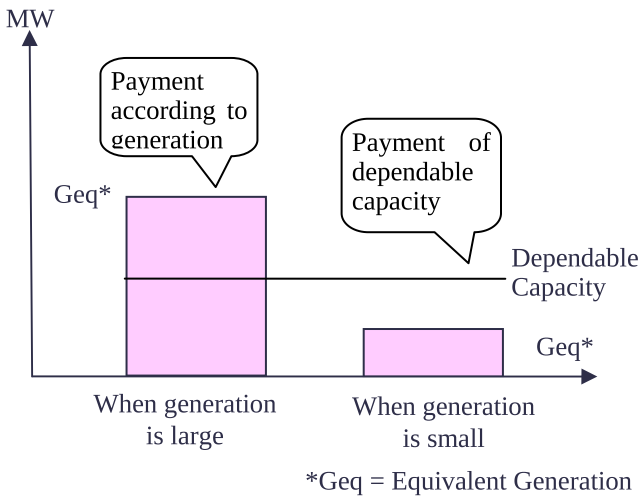


Fig.5.5-6 Concept of Capacity Fee

Emergency frequency control

5) Proper calculation of system frequency characteristic

For frequency control under emergency condition, system frequency characteristic which represents change of frequency against large change of output such as trip of generator shall be ascertained. When system frequency characteristic is calculated, not only the tripped capacity of generators itself (MW/Hz), but also whole system capacity at the time of trip shall be considered, and tripped capacity shall be represented by the ratio to system capacity (%MW/Hz).

In addition, there is a large difference between the case where data is managed with root mean square (RMS) and the case where data is managed with worst case. Fig. 5.5-7 shows the result of data process on the generator trip record in PLN in order to calculate system frequency characteristic. As shown in the figure, system frequency constant K is 4.3 (%MW/Hz) when it is calculated through RMS, while system frequency constant K is 1.1 (%MW/Hz) when it is calculated through worst case. This means that calculation with RMS, which is currently applied by PLN, is not in safety side. Therefore, when system frequency characteristic is determined, not the value itself calculated through RMS but the value with some margin in consideration with past record and metering error shall be used.

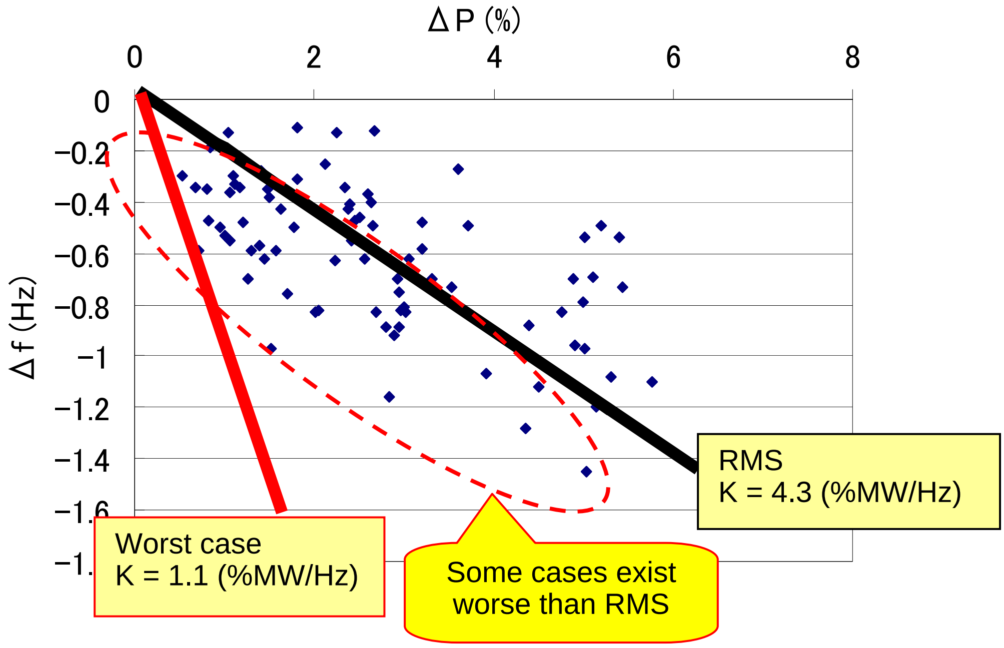


Fig. 5.5-7 Example of calculation of system frequency characteristic

6) Detailed system frequency characteristic considering K_G and K_L

For precise calculation of system frequency characteristic, effect of governor free capacity in accordance with tripped capacity shall be considered. In case of large frequency drop such as generator trip, although governor free generators increase output in response to frequency decline, they reach limit and exhaust output margin if frequency drops further.

Thus, system frequency characteristic (K) up to the limit of governor free is represented as follows;

$K = K_L + K_G$

(K_L : Load Frequency Characteristic, K_G : Generator Frequency Characteristic)

After the limit of governor free, it is represented as follows;

$K = K_L$

As an example of study, the result of data process on generator trip records in 2006 is described below. Suppose that there is an effect of governor free up to 0.15Hz frequency drop;

When f <= 0.15

$$\Delta P = (K_L + K_G) \times \Delta f$$

When f > 0.15

$\Delta P = K_L \times \Delta f + 0.15K_G$

The formula calculated by RMS through data process on the record of $\Delta f > 0.15$ is as follows;

$\Delta P = 3.9 \times \Delta f + 0.3$

Therefore, $K_L = 3.9$ (%MW/Hz)

Also, $K_G = 0.3/0.15 = 2.0$ (%MW/Hz)

For reference, governor droop is stipulated to be 5% in the Grid Code. Therefore, in case all connected generators secure governor free capacity, theoretically, K_G will be as follows;

K_G (theoretical) = 1/0.05/50 x 100 = 40 (%MW/Hz)

However, as mentioned above, K_G calculated from past record is 2.0 (%MW/Hz).

This implies that governor free capacity in actual system is significantly small.

Actual record of generator trip and calculated system frequency characteristic is illustrated in the right figure.

In order to study much adequate amount of load shedding, appropriate amount shall be studied with the calculation of system frequency characteristic in consideration of actual governor free capacity.

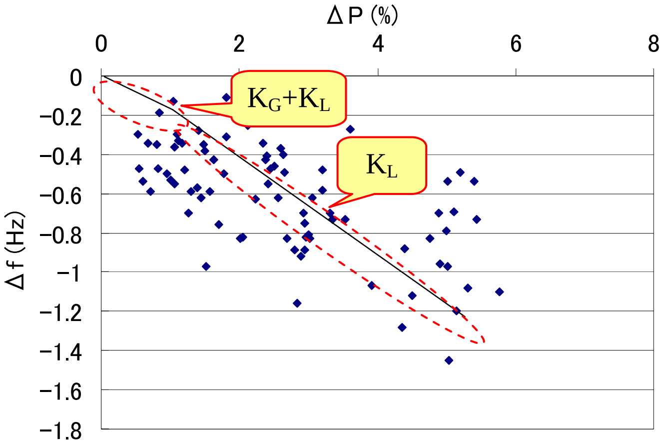


Fig. 5.5-8 System Frequency Characteristic considering K_G and K_L

5.5.3 Outages

As discussed in Section 2.4.6, major reason for frequent outage in Jamali is the problem of facilities.

For improvement on the problem of outage, following items can be suggested;

1) Measures for same type of equipment
2) Establishment of quality management system
3) Cooperation with manufacturer
4) Planned installation of facilities based on N-1 criteria
5) Appropriate calculation of system frequency characteristic
6) Installation of fault extension prevention relay

Details of each item are described below;

(1) Measures for Same Type of Equipment

It is effective to take measures for same type of equipment against failure of equipment. When failure occurs to some equipment, the same type of failure is likely to occur on the same type of sound equipment in the near future. Therefore, it is important to execute measures not only for the equipment where failure occurred but for all same type of equipment, after analysis of cause of the failure.

The necessity of the measure for same type of equipment can be studied from the following aspects;

- Level of outage
  There was, or might be, supply outage
- Condition of the failure
  Parts : Importance and university of parts (Major part or accessory)
  Cause : Functional shortage, Human error, Nature
  Condition: Existence of significant decrease in function
- Influence and probability of recurrence
  Probability : Frequency of occurrence
  Influence : Major equipment (Tr, CB), Voltage level
  Difficulty of finding: Probability of finding failure by patrol, inspection and surveillance

According to the result of study, when measure for same type of equipment is required, measures will be executed considering target range and emergency. In order to execute such measures, specifications such as model, manufacture and installation year of all equipment shall be managed properly.

(2) Establishment of Quality Management System

As a reason of equipment failure, there might have been shortcomings in performance from the time of installation. It is appropriate to prompt installation of equipment by manufacturers with high quality through the reinforcement of requirements in bidding document, and the consideration of failure rate of each manufacturer in bidding evaluation. Currently, it is deemed to be difficult to exclude manufactures with bad quality record immediately, but it is important to recognize manufacturers with bad quality through managing failure records and quality of installed equipment.

In order to keep quality of manufacturers high, installation of quality management system is suggested. Example of quality management system, when a manufacture applies for the adoption of their product, is shown in the figure below.

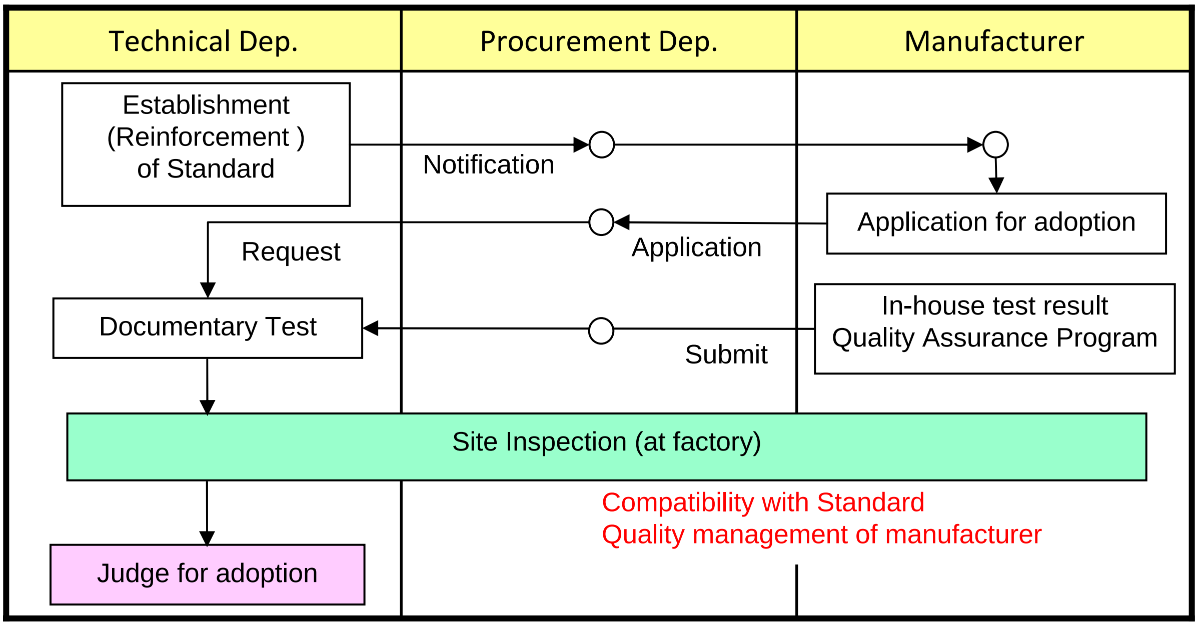


Fig 5.5-9 Outline of Quality Management System for new adoption

When technical standard for some equipment is established or reinforced, it is announced to manufacturers through procurement department. After reception of the notice, manufacturers can apply for adoption of their product. With an application, the result of manufacturer's internal testing is submitted, and it is reviewed by technical division in utility to check conformity to the standard. In addition, quality assurance program which describes quality management system of the manufacturer is submitted, and it is reviewed by technical division in utility to check the quality management system of the manufacturer.

When documentary test is passed, site inspection at manufacturer's factory in the presence of utility is conducted. In this inspection, conformity of the equipment to the standard and quality management system of the manufacturer is actually checked by staff of utility. Technical division judges the adoption of the equipment based on the result of the inspection, and procurement division can buy equipment from the manufacturer after then.

This quality management is not only for the beginning of procurement. Periodic inspection shall be executed for continuous adoption of the equipment. Fig. 5.5-10 shows the outline of quality management system for periodic maintenance. Every year, technical division selects equipment for periodic inspection and makes a plan of test, which will be executed in the year. For the selected equipment, manufacturer shall submit quality assurance program, and utility conducts site inspection, if necessary. If some problems are found in documentary or site inspection, the manufacturer shall make improvement on the problems. Based on the result of the inspection and the improvement by the manufacturer, technical division judges continuous adoption of the equipment. If manufacturer failed, adoption is cancelled and the equipment is not purchased furthermore from the manufacturer. Generally, periodic inspection is recommended to be conducted every 3-5 years for major equipment such as circuit breaker.

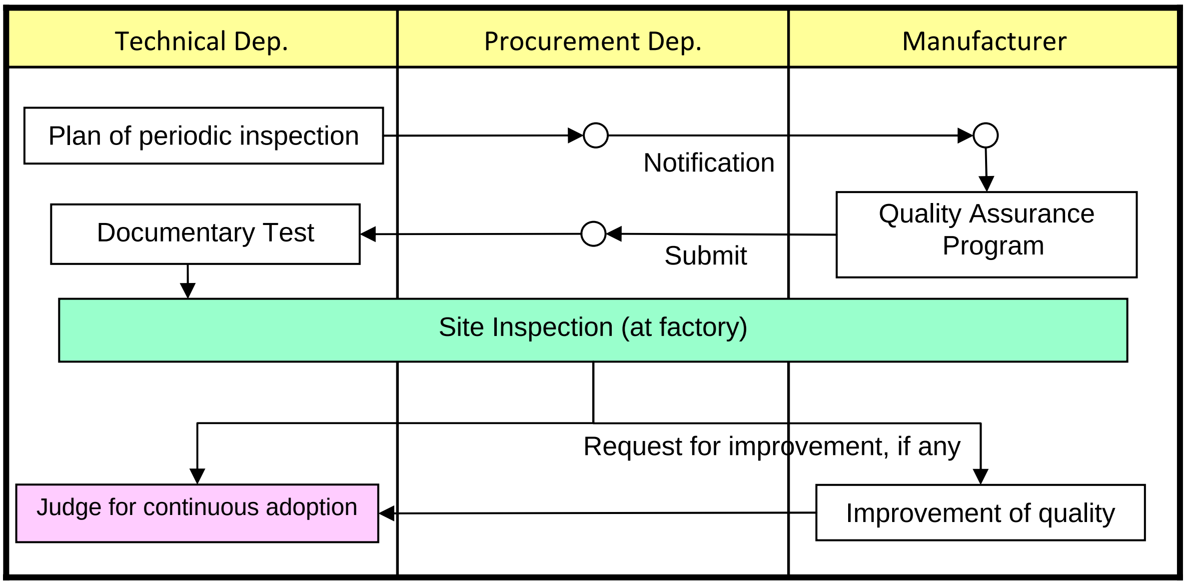


Fig 5.5-10 Outline of Quality Management System for periodic maintenance

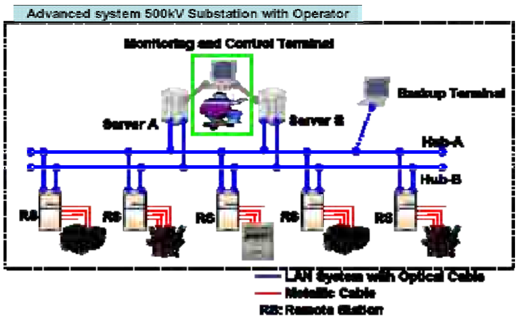
(3) Cooperation with Manufacturer

Currently, so many manufacturers have supplied equipment to PLN, and PLN could not get enough support from all of them. In order to improve quality of equipment to be installed and receive continuous support from manufacturers, it is essential to keep good relationship with manufacturers. Many products are supplied from manufacturers abroad at present, but it is preferable that equipment with high quality will be procured from local manufacturers in Indonesia in the future. For that purpose, it is vital to cooperate with manufacturers with local factories and offices.

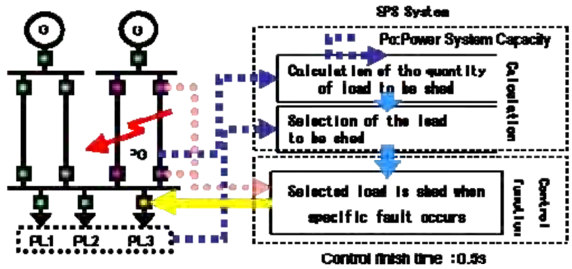
In order to enhance cooperation with manufacturers, joint technical development and research among utility and manufacturer are considered to be effective. In Japan, as shown in Fig 5.5-11, many new technologies have been developed in accordance with needs from utilities through joint development with manufacturers from the past. Continuous joint activities have enhanced cooperation among utilities and manufacturers. It is important for utility to collaborate with manufacturers, so as to improve quality of equipment to be installed and get enough and continuous support from manufacturers.

Lighting Protection Device

Life assessment of equipment



Advanced Monitoring and Control System



Special Protection Scheme

Fig. 5.5-11 Example of Joint Development in Japan

(4) Planned Installation of Facilities based on N-1 Criteria

In PLN, OLS (load shedding system against over load) is used as unavoidable measure against system failure where N-1 criteria is not satisfied, and many outages are caused by the operation of OLS. Fundamentally, generation and transmission facilities shall be planned and installed so as to satisfy N-1 criteria.

(5) Appropriate Calculation of System Frequency Characteristic

With regard to load shedding, not only to secure enough capacity, but also to study the amount of load shedding through proper calculation of system frequency characteristic, as previously mentioned, is required.

(6) Installation of Fault Extension Prevention Relay

It is important to minimize the area of influence by the outage when serious outage occurs in system. In Jamali, although basic protection system such as under frequency load shedding relay is installed, improvement is possible in terms of the prevention of fault extension, and installation of fault extension prevention relay utilized in Japan is recommended. Installation of SPS (Special Protection Scheme) would be appropriate as a fault extension prevention relay.

Without SPS, in case large-scale outage occurs in system such as trip of large generator or multiple transmission lines, supply and demand balance may collapse and frequency may drop significantly. When frequency drop is significant, large-scale load shedding is executed by under frequency load shedding relay. Outage area will be large and wide in this case. On the other hand, with SPS, as shown in Fig.5.5-12, required load is shed based on the amount calculated in advance when specific large-scale outage occurs. Fig.5.5-13 shows the difference of frequency fluctuation when large-scale outage occurs with and without SPS. Without SPS, frequency recovers through load shedding by UFR. In this case, the amount of load shedding will possibly be large because load is shed after the detection of frequency drop. On the other hand, with SPS, when outage occurs, adequate amount of load is shed speedily according to the calculation in advance. Thus, consequently, the amount of load shedding may be small and the time for restoration can possibly be shortened.

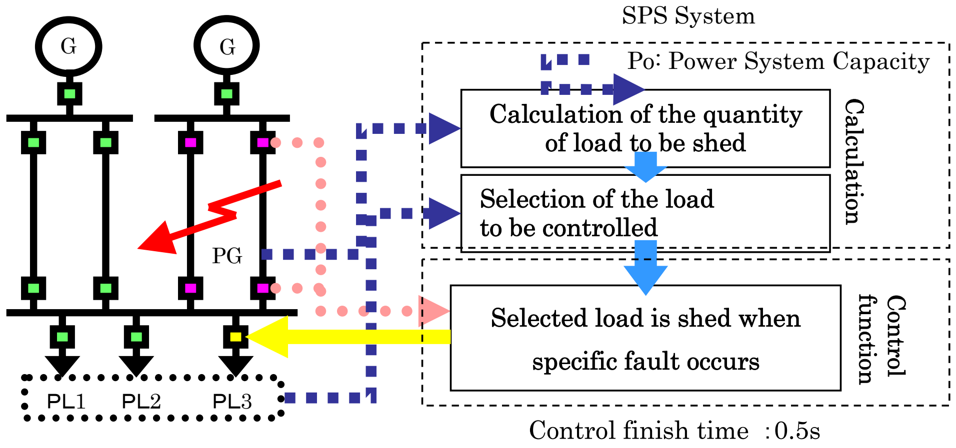


Fig. 5.5-12 Outline of SPS

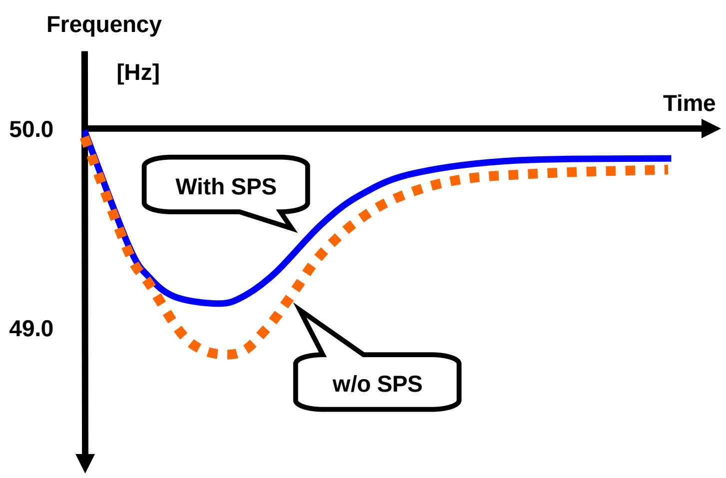


Fig. 5.5-13 Effect of SPS

For the installation of SPS, following items shall be studied;

- Share of roll with other protection such as under frequency load shedding relay
- Target of frequency after operation of SPS
- Target outage to be protected (Bus failure, Trip of multiple units, Trip of multiple routes, etc.)
- Place of master unit, outage detection device, and load shedding unit
- Method of selection of the load to be shed
- Detailed study of system frequency characteristic

6. RECOMMENDATIONS

On the basis of the results of this study, the issues to be recognized and actions to be taken are summarized below, in order for the Government of Indonesia and national power utility, PLN, to proceed to the realization of the optimal power development plan. It should be emphasized here that those projects scheduled for next 7 – 8 years in the power development plan and the matters described below related to such projects need immediate actions to be taken by relevant parties.

6.1 Power Source Development

(1) Coal-fired Thermal Power Plant

- New 29 locations are required for the future development of power plants except the ongoing fast track program projects. Inventory study on new candidate sites including possibility of land acquisition shall be commenced as soon as possible.
- Study on an introduction of supercritical plants, which is a proven technology, is recommended because of its capability for flexible operation (base to middle load operation) and higher thermal efficiency resulting in fuel saving and reduction of emission.
- With respect to the utilization of LRC, developing coal-fired thermal plants at mine-mouth in Sumatra, and possibly in Kalimantan in the long term, and using LRC there, would make the best use of LRC for its physical properties
- Advantage of LRC use is its price per calorific value being much lower than HSD/MFO and its availability from domestic mines. Therefore, the benefit of scrapping existing HSD/MFO burning power plants and replacing with LRC burning coal thermal should also be studied.
- More stringent mitigation measures for air pollution will be required as the number of coal-fired thermal power plants will be increasing rapidly.

(2) Java-Sumatra Interconnection

- PLN should exercise an extreme caution in managing the implementation schedule of IPP coal-fired thermal plants in Sumatra to assure that the Java-Sumatra Interconnection will be able to send power to Jamali system in 2014 on schedule.

(3) Geothermal Power Plant

Although the country is endowed with the world-largest geothermal potential, and the government places a priority on geothermal development in his energy policy, necessary regulations/standards in relation with geothermal development have not been put in place, which leaves private entities considering investment in geothermal business with many uncertainties and risks. To encourage and promote private investment in the development, provisions of institutional arrangements and efforts to lower risks are urgently required.

<u>Institutional Arrangement</u>

- As bidding for geothermal development license is administered by local governments, and regulations/standards concerning its procedure have not been provided, there are many uncertainties to investment in geothermal. Standard procedure including bidding process, bidder evaluation criteria, information provided in bidding documents, etc., should be established and put in place as soon as possible.
- With respect to the provision of such arrangement, PLN can contribute by giving technical supports to local governments in project formulation, bid evaluation, etc., which may greatly improve the efficacy of the procedure.
- For a geothermal project located in and around protected forest, it is important to avoid such project being terminated after it is licensed to a private company. Some institutional arrangement is required that enables the confirmation of permission availability at the early stage of project formation, such as setting up an inter-ministry coordination board.
- To develop geothermal resources more efficiently by employing the knowledge of private developers, a bidding process that offers more candidate sites than to be developed and to have bidders select their preferred sites in their bid can be an effective device.

<u>Reduction of Risks</u>

- Among many risks involved in geothermal development, exploration risk allocated to developers is the one most significant. Preliminary FS level exploration study should be carried out prior to license bidding by PLN of local governments, and its information provided to bidders.
- In case that local government lacks the finance necessary for such a pre-bid exploration, setting up a revolving fund to supply necessary resources may be effective.

<u>Others</u>

- PLN has in-depth technical and operational know-how in geothermal business and it should keep its advantage as the sole electric utility in the country. Such technical supports as an introduction of the latest technologies and financial supports should be considered and provided to PLN, when necessary.

(4) Nuclear Power Plant

- As nuclear power development plan may well face a delay, a study on additional coal-fired thermal plants to substitute for nuclear power would be required.

(5) Gas-fired Thermal Power Plant

- For the purpose of improving operational flexibility of gas-fired thermal power plants being provided by gas pipelines, CNG (Compressed Natural Gas) Storage System, which allows the same plant to operate for middle and peak load, is recommended.
- Middle- to small-sized gas fields, which are not suitable for LNG export, may be suitable for supplying fuel to thermal power plants using CNG vessel. Study on such development is recommended. This will also enables conversion of HSD-fired PLTG to CNG-fired PLTGU.

(6) Hydropower

- Re-evaluation of hydropower potential, as a domestic resource of energy, in Jamali is required.
- Pumped storage power plants will be able to fully exploit the advantage of low cost power supply from coal-fired thermal and nuclear power plants for its pumping energy after 2020. As a pumped storage project requires a long lead time, earlier preparation of implementation is recommended.

(7) Solar and Wind Power

- Specific measures to encourage use of and investment for solar power and wind power should be considered and implemented.
- It is recommended to establish Environmental Impact Assessment guidelines and/or criteria for solar and wind power development, in cooperation with Ministry of Environment.

(8) General

- To respond to the climate change, measures to promote energy conservation and use of renewable energy shall be taken.
- To expedite the finding of power plant site, economic measures, such as a support for regional development and/or a subsidy scheme to relevant communities, shall be studied and introduced.
- Initiative in land acquisition for power plants and transmission lines should be taken by local government or PLN, not by private investors.
- Bidding process for power plant/transmission development should be monitored and supervised by an independent body.
- Continuous efforts to evaluate and improve bidding process, particularly concerning the details of tendering information and participation of wide range of bidders should be made.

- Cases of significant delays in project schedule should be studied and their solutions to their causes be found and implemented.
- Technical requirements of bidders for IPP projects should be revised on the basis of the results of the study on improvement of power system operation.

6.2 Environment

(1) Air Pollution

- Siting of a coal-fired power station shall be conducted upon due consideration on whether additional air pollution load is acceptable or not, after the present level of air pollution at the proposed site is clarified.
- Construction of a power station in an area already with noticeable air pollution requires installation of a desulfurization/denitrification facility or electrostatic precipitator.
- Continuous monitoring of emission and ambient air quality shall be conducted.

(2) Thermal Effluents

- Thermal power generation and nuclear power generation produce majority of electricity, and they discharge substantial amounts of thermal effluents. There are many coral reefs off Jamali area, so special attentions shall be paid to potential impacts of thermal effluents on corals.
- In Indonesia, it is required to reduce the temperature of thermal effluents down to less than 2 degree Celsius above the temperature of receiving water, while thermal effluents are required to be less than about 6 degree Celsius in Japan. Indonesian requirement is not practical, and it is desirable to conduct rather an impact assessment through the simulation on diffusions of thermal effluents.

(3) CO_2 Emissions

- If a legally binding emission reduction target is established in future for greenhouse gas emissions from Indonesia, it will be required to reduce CO_2 production through improvements of generation efficiencies in thermal power generation, or to sequester CO_2 in the atmosphere through afforestation.

(4) Water Quality Management in the Reservoir of Hydroelectric Power Stations

- Reservoir-type hydroelectric power generation will emit methane of significant greenhouse effects when water quality in a reservoir goes down. It is required to prevent eutrophication through uncontrolled discharges of domestic sewage into reservoirs for prevention of water quality degradation there.

(5) Industrial Wastes from Nuclear Power Generation

- Appropriate treatment of spent fuel from nuclear power generation is required.

6.3 Promotion of Private Investment

(1) Retail Tariff

- PLN's profit margin should be increased to allow for future investment. Such measures as a revision to the calculation method of BPP shall be considered.
- In relation to the increase of PLN's profit margin, limiting electricity subsidy to customer category R-1, 450 VA is recommended, in order to reduce the government subsidy payment.
- Further, a possibility of introducing cost-pass-through system to the electricity tariff should be studied.

(2) Project Schedule

- The causes of project delay should be studied. Particularly, financial closing process for foreign lending needs to be streamlined.

(3) Standardization of IPP wholesale price

- Regulation on PPA price capping needs to be revised taking into consideration of the difference of plant operation and resulting cost difference.
- As geothermal development cost varies in one project to another, setting PPA price capping on geothermal IPP may preclude investors/developers from participating in bidding. The regulation and its effect should be monitored and, if necessary, revised.

(4) Use of domestic inputs and increase of local currency portion

- A method of valuing higher a bid with larger L/C portion should be considered.

(5) Limitation of Foreign Capital Ownership

- The current regulation on the limitation of foreign capital ownership of power plant, 95% maximum, can be one of factors that impede foreign investment. The efficacy of the regulation in the promotion of domestic industries and private investment in the power sector should be studied and verified.

6.4 Power System Expansion Plan

(1) Land Acquisition

- Right-Of-Way for planned transmission lines and substation facilities should be acquired prior to their construction so that the land acquisition would not cause any delay in their realization.

(2) Countermeasures to Avoid Large Power Failure

- Countermeasures against frequency drop, such as an installation of simple load-breaking system by sending trip signal, should be studied.
- Introduction of system disconnection devices as a countermeasure against the whole system collapse should be studied.

(3) Introduction of Higher Voltage to Transmission and Distribution System

(4) Securing Governor Free (GF) Capacity at Nighttime

- To cope with the increase of base load plants such as coal and nuclear, and to meet the demand for quality electricity in night time, methods to secure the governor free (GF) capacity, such as an introduction of Daily Start Stop thermal power plants (DSS Units) and/or Adjustable Speed pumped storage hydro, should be studied.

(5) Study on Power Supply Method to High Load Density Areas (Jakarta)

- Economic power supply method to high load density areas, such as Jakarta, should be studied comprehensively, which may include raising voltage of middle-voltage system and direct connection of 500 kV system.

(6) Java-Sumatra Interconnection

- Countermeasures against upward frequency deviation, which may occur in the Sumatra system in the case of an interruption of Java-Sumatra Interconnection, should be studied.

(7) Other Considerations

- Phase modifying systems will have to be introduced in large numbers. The balance of the installation of the systems as well as their locations must be examined in the whole-region and sub-region scales.
- At load dispatching facilities for 150 kV systems and the below, manual operation is not effective in coping with voltage collapse. It is recommended to provide automatic voltage controllers (e.g., SVC) at limited locations and the breakers using voltage-down relay.

6.5 Improvement of System Operation

(1) The result of analysis of current conditions on the system operation

- The important issues to be considered on the system operation are related to voltage, frequency and outages. The suggestions on measures for the improvement of the system operation in terms of these issues are described below:

(2) Voltage

- The reasons for system voltage drop in Jamali are that reactive power source to maintain proper voltage is fundamentally lacked and existing reactive source is not fully utilized. Against these reasons, the following countermeasures are suggested.

- As short term measures, in order to make best use of the reactive supply capability of the existing generators, a) Raise of system standard voltage and b) Introduction of incentives and penalties for reactive power supply are suggested.

- As long term measures, planning of reactive supply equipment is required. In addition, in order to follow deviations of voltage, a) Installation of on-load tap changer to step-up transformer and b) Installation of PSVR (Power System Voltage Regulator are to be considered.

(3) Frequency

- Countermeasures against frequency fluctuation can be classified into normal and emergency frequency control.
- As measures for normal frequency control, a) Application of penalty, b) Bidding classified by operation type, c) Application of tariff for middle and peak type generators, and d) Application of Capacity Fee are effective.

- As measures for emergency frequency control, a) Proper calculation of system frequency characteristics and b) Detailed system frequency characteristics considering K_G and K_L are effective.

(4) Outages

- Major reason for frequent outage in Jamali is the problem of facilities.

- For improvement on the problem of outage, a) Measures for same type of equipment, b) Establishment of quality management system, c) Cooperation with manufacturer, d) Planned installation of facilities based on N-1 criteria, e) Appropriate calculation of system frequency characteristic and f) Installation of fault extension prevention relay are effective.