講 演

日本電力 技術의 現況

—Current Status of Electric Power Engineering in Japan—

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Introduction

I deem it a great honor to have been invited by the Korean Institute of Electrical Engineers to this seminar and given the opportunity to speak on the current status of electric power engineering in Japan.

The Institute of Electrical Engineers of Japan (JIEE) was founded far back in 1888, in the very dawn period of the electric power utilities. For the past 93 years since its establishment, the JIEE has been contributing much, in the same manner as you, toward technological progress and industrial growth in many fields of electrical engineering in Japan. Now, I am very happy to say that it will certainly be a matter of great significance for the Institute of Electrical Engineers in both countries to exert their cooperative efforts for establishment of new technologies toward the future.

Today I would like to introduce you the current status of electrical power engineering in the Japanese electric utilities and to refer to the future R and D tasks coping with the severe energy situation.

1. General Outline of Japanese Electric Power Industry

1.1 Energy Situation and Electic Power Demand

The chart you look at here is prepared for easy understanding of Japan's present energy situation, showing a flow of energy supplies in the year 1978. The left side of the chart shows primary energy supply and the right shows its consumption.

These typical features are summed up in 4 points.

1) Seventy-five percent of total primary energy supply depends upon imported oil.
2) About 33 percent of total primary energy is converted into electric energy.
3) At energy consuming terminals, the industrial sector takes a larger share of a little more than 60 percent in total consumption.

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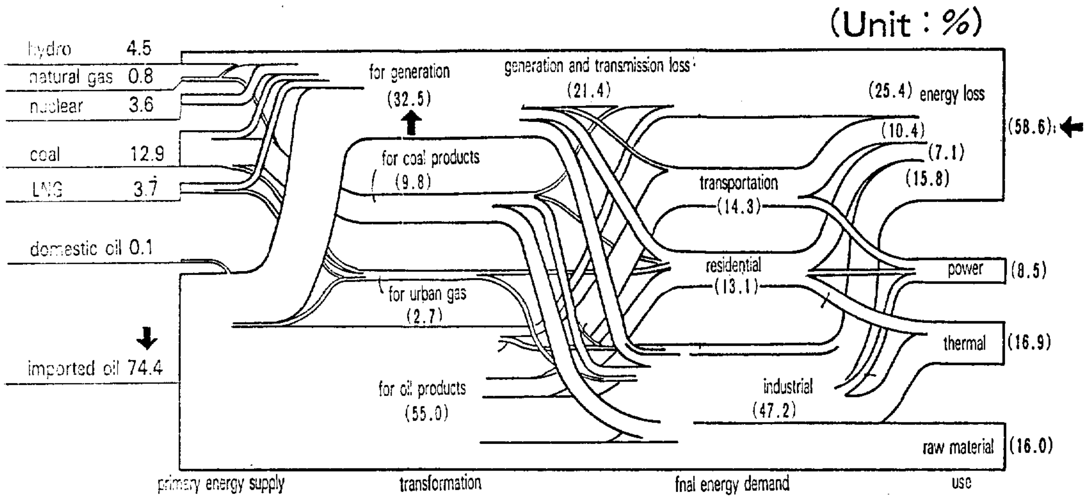


Fig. 1. Energy flow chart in Japan (1978)

4) Energy loss during the process of conversion and transmission reaches as much as about 60 percent.

Therefore, in order to cope with the severe energy circumstances from now on we think it most important to reduce excessive dependence upon oil resources by active introduction of all other alternative resources such as nuclear energy, coal and LNG and also to develop new technologies for energy conservation. As far as energy saving is concerned, considerable effect is being achieved in the manufacturing industrial sector at an average saving rate of 5 to 10 percent by such steps as improvement of productivity and recovering of waste heat.

As a general tendency, the role of electric energy in the whole energy supply structure tends to increase more and more because of its intrinsic properties such as high reliability, cleanness, convenience and easy controllability. It has been predicted that the share of electric energy may rise from the present level of 33 percent to 50 percent by the year 2000. (Two Thousand)

For instance, the annual electric energy demand within the service territory of Tokyo Electric Power Company is now recorded at some 130 billion kwh, nearly comparable to the total consumption in Italy. We estimate that it will increase at an annual rate of about 6 percent to reach the present level in France in about 5 and in West Germany in about a decade from now.

1.2 Nine Electric Power Companies and Wide-Area Coordination

Now, I would like to make brief mention of Japanese electric power utilities. The electric power utilities in Japan has a long historical background about 100 years since its inaugural operation in 1833. In the process of development to this date, many utilities had been amalgamated or reorganized gradually, and the present system comprised of private utilities was established in 1951.

Today, main electric utilities in Japan constitute 9 private electric power companies, each undertaking integrated business operation of generation, transmission and distribution in their own regional territories, the Electric Power Development Company (EPDC) as the wholesale company undertaking a part of generation and transmission services throughout the country, and the Japan Atomic Power Company (JAPC) being operated for exploitation and realization of nuclear power generation.

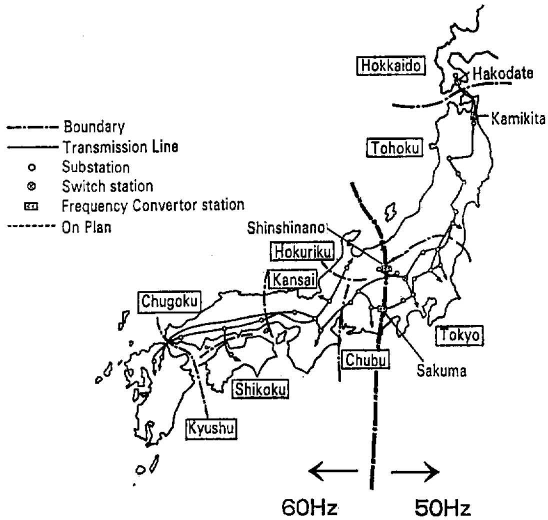


Fig. 2. Electric Utilities in Japan (Inter-Regional Cooperation) (March of 1981)

In order to make effective use of regional diversities in power demand and fluctuations in generating capability between 9 power companies and also to reduce the spinning reserve and operating cost, the wide-area coordinated system operation was inaugurated in 1958 by nine electric power companies and the EPDC. As the result, the interconnection system has continued to be strengthened, and now, each of the whole power companies are interconnected by extra-high voltage transmission lines across the country. Since the whole nationwide service territory is divided into two frequency areas that is, 50Hz in the eastern part of Japan and 60Hz in the western part. Two frequency conversion stations are operating at Sakuma (300MW) and Shin-Shinano (300MW) for interconnection between those two different frequency areas.

Recently, the DC transmission system has been completed by the submarine cable line to interconnect both Hokkaido and the Mainland. In addition, the 500KV tieline has been completed for interconnection between four utilities in the western region. By use of those facilities the wide-area coordination is being operated for power accomodation and economic power exchange. Some cooperative effort is being made in the field of procurement or pooling of primary energy resources such as natural uranium and LNG, as instanced by the recent signing of joint venture between Tokyo Electric Power Company and Tohoku Electric Power Company on the Arun LNG Project in Indonesia.

With regard to the plant siting problem, there have been brisk activities for joint construction of a power plant with a view of making effective use of the limited land area allowable for power plant siting.

1.3 Future Expansion Plan of Electric Power System

In terms of the whole business scale, Japanese utilities has the total installed generating capacity of 120 million KW producing 520 billion KWh in the year 1979, and about 25 percent of which is shared by Tokyo Electric Power Company.

A recent survey estimates that power demand will grow to 1.8 times of the present need by the Year 1990.

To comply with such demand increase, the

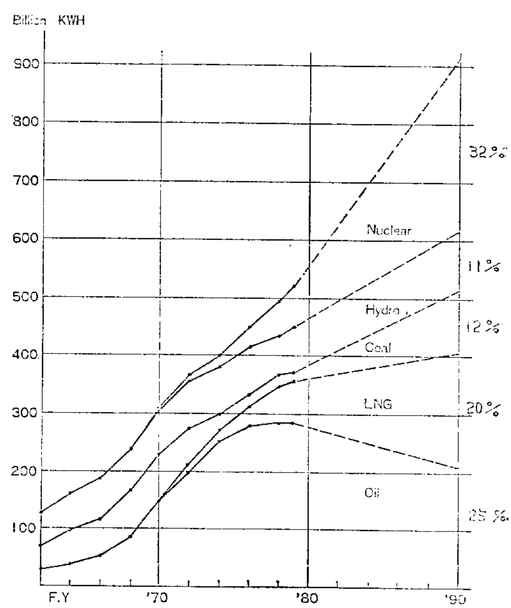


Fig. 3. Electric Energy Production (Electric Utilities)

power development program which aims at using alternative energy resources such as nuclear, coal and LNG will be carried out so that total generating capacity should become 240 million KW by 1990. And this generating capacity constitutes 46 million KW of hydro power, 140 million KW of thermal power and 51 million KW of nuclear power. As a result, by increasing the share ratio of nuclear power from the present 12 percent to 22 percent and coal fired power from 4 percent to 13 percent, the share ratio of the oil-fired power will be reduced from 46 percent to 24 percent.

With regard to the power transmission system, further effort is to be made for expansion of the 500KV grid system hereafter. Together with that, we estimate that the introduction of the 1,000KV UHV transmission system will be required during the 1990s.

In addition, for power supply in the high density consuming area, 500KV underground cable system would be required in the future.

As shown in these graphs, the future scale of the transmission system by 1990 throughout the country will be supposed to be 80,000km in total overhead transmission route length, 10,000km in total underground transmission route length and 500 GVA in total substation capacity.

2. Present Status of Electric Power Engineering and Future Tasks

Now, I would like to mention about the next subject on the 'Present status of Power Engineering and Future Tasks'

2.1 Nuclear power

More than a quarter century has passed since Japan started research and development activities of nuclear power in 1955, and now Japan has become one of the largest nuclear power generating countries, ranking the third in the world after the United States and France. The first commercial nuclear reactor was initiated by the gas-cooled type which was put into commercial operation in 1966 by the Japan Atomic Power

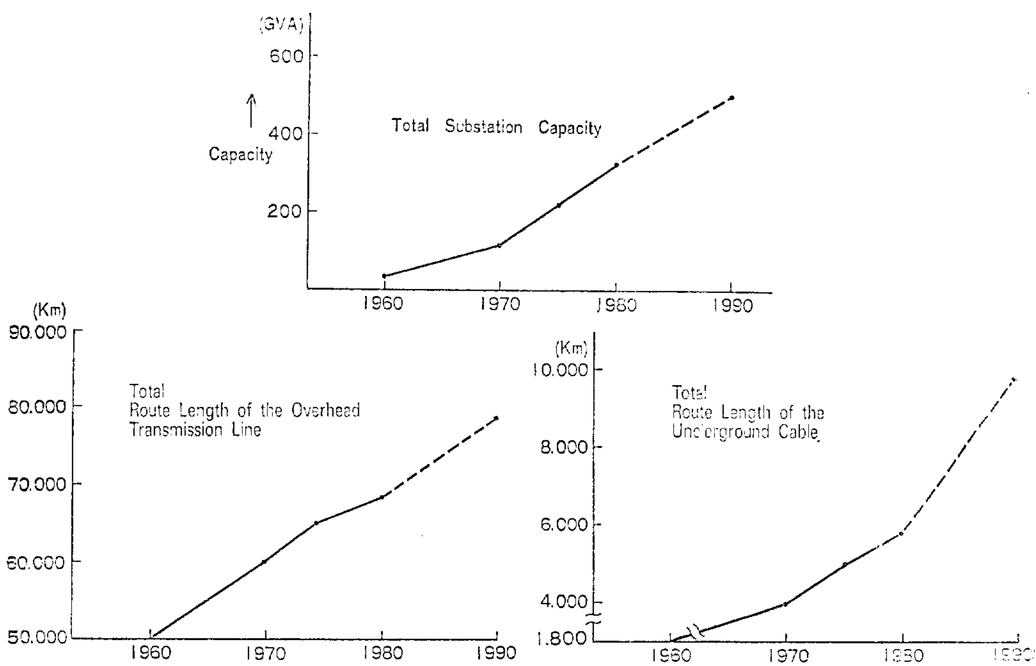


Fig. 4. Transmission and Substation (Electric Utilities in Japan)

Co. Afterwards, the light water reactors of two different types, BWR and PWR were introduced into our country with their accumulated operating experiences in the United States. All the reactors installed and operated by the Japanese utilities from that time on have been of light water type without any exceptions. At present, Japan's nuclear power generation consists of 10 PWR units of some 7,400MW output and 11BWR units of some 8,000MW output.

Fig. 5. shows Fukushima No. 1 Nuclear Power Station being operated by Tokyo Electric Power Company. Tokyo Electric Power Company has been making efforts for expansion of the unit capacity up to 800MW and 1,100MW by its consistent use of the BWR type since the initial commercialization of the 460MW unit in 1971.

Today, this Nuclear Power Station is the world's largest as a single independent nuclear power generating source, which is capable of generating some 4,700MW. Furthermore construction of Fukushima No. 2 Nuclear Power Station with the final output of 4,400MW and Kashiwazaki Nuclear Power Station with the final output of 8,000MW is now underway and joint efforts are being made with Tohoku Electric Power Company at the site of Shimokita.

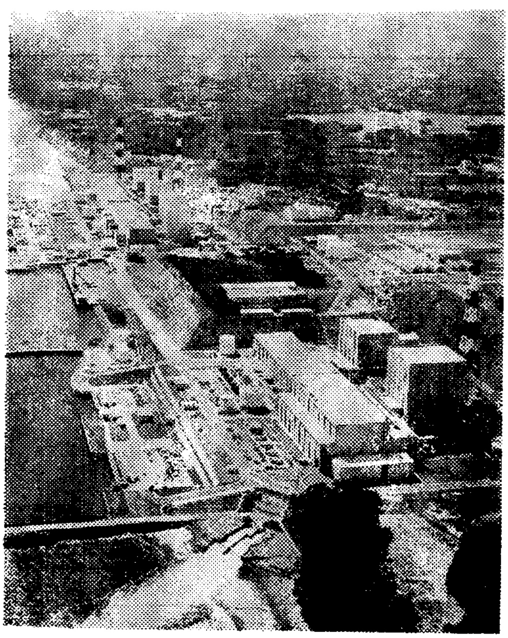


Fig. 5. Fukushima No. 1 Nuclear Power Station

Although the nuclear power technology in Japan has already reached a stage of maturity, at the early stage of commercialization we experienced many troubles such as initial operational problems, small tube leakage of the steam generator, stress corrosion cracking of stainless pipes. However, we have overcome such difficulties by every possible means and improved the yearly availability factor up to about 60 percent in the year 1980.

Because of the significance involved in the future nuclear power development by light water reactor, the joint work started in 1975 for improvement and standardization of the light water reactor in cooperation with the government.

By this joint work we are now establishing domestic LWR technologies more suitable for Japan based on constructional and operational experiences gained so far.

In the case of the BWR type, for instance, the main items of improvement and standardization include configurational improvement of the reactor containment for easy maintenance work, and remote-control and automation of the testing equipment. As these advanced technologies are to be applied from Fukushima No. 2 Nuclear Power Station, higher availability will be obtained in the future.

At present, the nuclear power generation serves as the base load station. However, as the nuclear power will increase its share ratio in the future, the plant will be required gradually to cope with any possible load changes. So, promotional efforts are being made to develop new fuel of high efficiency to be unaffected by such load changes. Toward innovative development of the Advanced BWR (ABWR) for the next generation which is superior in operability, reliability and economy, the Japanese power industry plans demonstration tests and development in collaboration with the BWR manufacturers in the United States and Sweden as well as at home.

Besides that, in order to make effective use of uranium resources, the fast breeder reactor(FBR) is being developed now as the national project:

the experimental reactor 'Joyo' has been put into test operation and the prototype reactor 'Monjyu' of 280MW output is now undergoing safety licensing examination. Furthermore research has begun on the large size demonstration reactor. The new type advanced thermal reactor (ATR) 'Fugen' of 165MW has been already developed and put into operation.

Meanwhile, technical research effort is being made toward establishment of the independent nuclear fuel cycle.

As a step in this direction, the reprocessing plant has been in operation with a capacity of one ton per day since 1977. In succession to that test plant, necessary preparation is being made to develop the commercial reprocessing plant.

With regard to uranium enrichment, the pilot plant (50 ton-swu per year) is already partially in operation. After construction and operation of the prototype plant (about 200ton-swu per year), the commercial plant (about 3,000 ton-swu per year) will be constructed with supply capacity to meet about one third of the nation's total demand by the year 2000.

2.2 Thermal Power

Today, thermal power is one of the main electric power sources sharing 65 percent of the total generating capacity, and the unit capacity has been increased up to 1,000MW.

The fuel resources constitute 66 percent of oil 28 percent of LNG and 6 percent of coal.

Since the first LNG fired power plant was comissioned at Minami-yokohama thermal power plant of Tokyo Electric Power Company in 1970, many of these kind of plants have been constructed because of their no-sulfur advantage. As for Tokyo Electric Power Company, the share ratio of LNG fired power plants is about 33 percent of the total generating capacity.

To meet environmental control laws, low sulfur oil is being used, so average sulfur content in the power plant fuels has been reduced from 1.8 percent in 1966 down to 0.1 percent in 1977.

For control of nitrogen oxide, it is effective to keep the boiler in the slow pace of burning at a moderate temperature. To achieve this purpose all the existing boilers adopt the 'gas recirculation method' or the 'two-stage combustion method', moreover the nitrogen oxide removal system has been put into practical use.

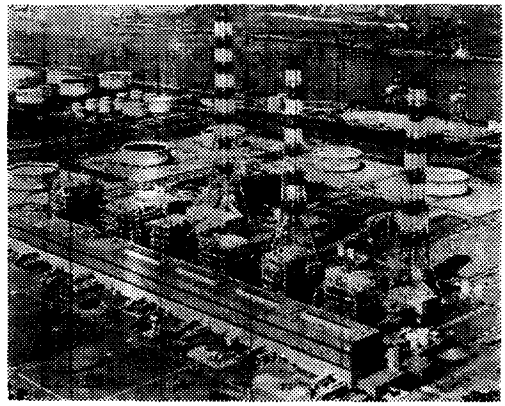


Fig. 6. Typical Thermal Power Plant

Fig. 6 shows the typical thermal power plant which adopts not only pollution control technologies but also improves appearances with trees and plants harmonized with the local scenic view.

As shown in this Fig. 7, after constructing larger capacity and higher efficiency units since the middle of the 1950's, the average efficiency was improved up to 38 percent in 1979.

Recently, in accordance with the increase of nuclear power capacity, thermal power has been required to meet not only base load but also middle load. With this tendency, it has become necessary to stop operation during the night at 350MW units and 600MW units. So, sliding pressure operation has been adopted to comply with such operational needs as increasing the operating efficiency at partial load, shortening the time of start and stop, and boosting speed for output variations.

To minimize dependency upon oil resources, enlargement of the coal utilization will become necessary. To establish the pollution control technology for large pulverized-coal fueled power plants, research effort has been made toward development of the integrated flue gas treatment

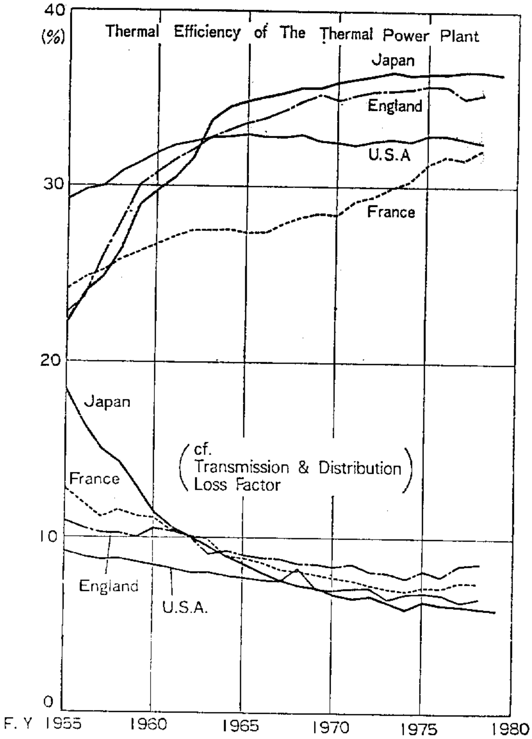


Fig. 7. Thermal Efficiency of the Thermal Power Plant and Transmission Distribution Loss Factor

equipment for desulfurization, denitrification and dust precipitation, and encouraging prospect for future utilization has been obtained.

To divert fuel from oil to coal at the current oil burning boilers, development of COM is now under way. COM is a mixture of coal and oil with a weight mixing rate of 1 to 1, and is expected to be ready for practical use in 1984.

Moreover, coal gasification and liquefaction technologies have to be developed as future coal utilization technologies.

On the other hand, because of the difficulty of improving the steam condition moreover, it is believed that the efficiency of the thermal power plant using present steam turbine has already reached its upper limit. To cope with this situation, we are putting forward the plan to improve the thermal efficiency up to 42 percent or so, by adopting the gas-steam combined power generating system. Inlet flue gas temperature of this gas turbine is designed at 1,100°C, but if this temperature is raised to 1,300°C, the thermal efficiency of this system will improve up to 47 percent.

So we are carrying out the development of higher temperature gas turbine by joint cooperative research with the national government.

As another energy conservation technology, cryogenic power generation has been developed, which makes it possible to generate 10MW per 1,000MW unit by use of cold energy from LNG before being burned as fuel.

In addition, demonstration tests of the 4.8MW fuel cell system are to be carried out from 1982.

2.3 Hydro Power

Today, the share ratio of the hydro power capacity is 23 percent in total electric utilities. Recently pumped storage power plants for peak load have been constructed mainly, and now they share 39 percent of the total existing hydro power generating capacity.

Pumped-storage power plants being constructed now will have a high effective head of as much as 520m. Furthermore, we have a prospect of developing 800m class in the future.

Such a high effective head and a large generating capacity are made possible by the highly-developed technological achievements of civil engineering and high-head pump-turbine. Besides

Fig. 8. The Dam Tokyo Electric Power Company's Shintakasegawa Hydro Power Plant

that, the development of large size construction equipment and progress in the analysis technology using computers enabled construction of large scale dams.

Fig. 8. shows the dam of Tokyo Electric Power Company's Shin-takasegawa hydro power plant. This power plant is a complete underground power plant with effective head of 229m and maximum generating output of 1,280MW consisting of four units of 367MW pump-turbine.

In the future the development of pumped-storage power stations will be required furthermore. Nevertheless, the conventional hydro power plants will be developed with greater interest, because of the stringent energy situation in recent years. Though the developments of conventional hydro power plants are not expected on a large scale, we are to promote development with ample researches for natural energy utilization.

2.4 Electric Power System

Having mentioned the outline of the Japanese electric power system, now, I would like to explain the power systemı composition by taking up, mainly the case of Tokyo Electric Power Company.

Fig. 9 shows the transmission network within the service territory of Tokyo Electric Pcwer Company. The trunk line system consists of the main transmission lines outgoing from the large remote generating sources and incoming into the outskirt of Tokyo Metropolitan Area. The system also includes 500KV and 275 outer loop lines forming up a power pool in connection with those main transmission lines from generating sources and the 275KV underground cable lines introduced into Tokyo metropolitan area.

The regional system exists for the purpose of serving each region and includes many distribution substations of 66/6KV(by) and 154/6KV.(by)

The distribution system is mainly composed of 6KV systems and serves end consumers at 100 volts or 200 volts. However, the 22KV distribution service is carried out in the city center.

As a system planning criteria, a strict rule for the trunk transmission system has been est-

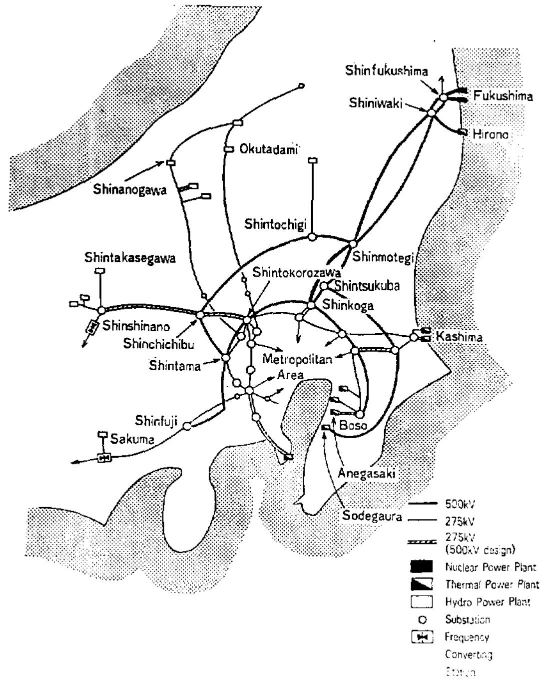


Fig. 9. Electric Power System in the Tokyo Electric Power Co. Ltd. (As March of 1981)

ablished which says that power service should not be suspended in the event of a single unit power fault. In practice this means a fault at a single unit of generator or transformer or a single circuit of transmission line. In the regional transmission system the established rule is to recover power service in a short time in case of a single unit fault. For this reason, we make it a basic rule for formation of the complete system to install more than 2 circuits pereach route for overhead transmission line and 3 circuits per each route for the underground cable line. Especially in the case of the trunk line system, 500KV transmission system is capable of 10GW transmission for its single route (2 cct) by use of six conductors of thermo resistive ACST (Aluminum Cable Steel Reinforced) with the cross section area of 810mm². As shown in Fig. 10 the 500KV substation normally consists of four banks of 500KV transformer with the capacity of 1,000 MVA cr 1,500CMVA. Now ther, as you krcw,

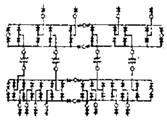
Item	Outline
Capacity of The Substation	6,000MVA (1,500MVA×4 Bank)
Main Transformer	Auto Transformer 500kV±5%/275kV/63kV Bank Capacity 1,500MVA
Bus Connection	Double Bus Bar With 4 Bus Tie Circuit Breaker 
Number of The Transmission Line	500kV 4cct, 275kV 8cct
Area	Air Insulation System 300,000㎡ All Miniclad System 100,000㎡

Fig. 10. Outline of the 500KV Substation

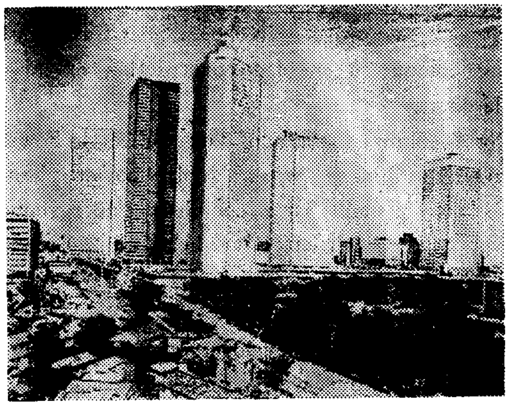


Fig. 12. Underground Substion Constructed under the Public Park near the Skyscrapers Area in the Shinjuku Subcenter of Tokyo

the Tokyo Metropolitan Area is densely populated and therefore is known for its highdensity power demand. As recorded in the year 1978, the power demand density in the city area is nearly two times that of New York.

To supply electricity to such a densely populated area the electric system is composed as shown in Fig. 11 Recently the substations which supply the area of highdensity power demand, are mostly located underground. Now, one hundred underground substations are operating in this area.

Fig. 12 shows the 275KV underground substation constructed under the public park near the skyscrapers area in the Shinjuku Subcenter of Tokyo.

The above-ground level part of the building serves as the public library. Such an urban transmission system is based on the 275KV underground substations and is composed of 66KV

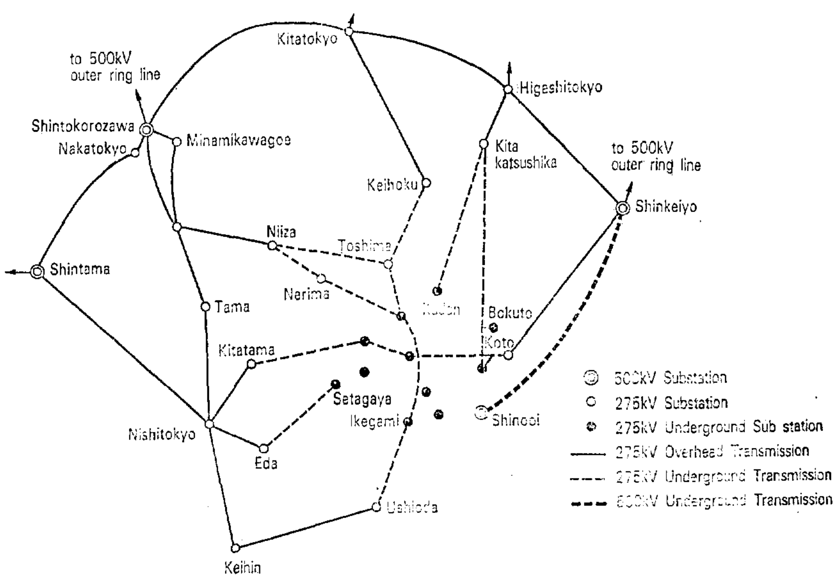


Fig. 11. 275KV Transmission System of the Metropolitan Area (as March of 1986)

and 154KV systems.

These important substations consist of three units, each having its independent supervisory control and protection system as well as its own main circuit. Although housed in the one building the substation actualy function as three independent substations.

By adopting this unit system we could attain of high reliability, confining any trouble to a limited area.

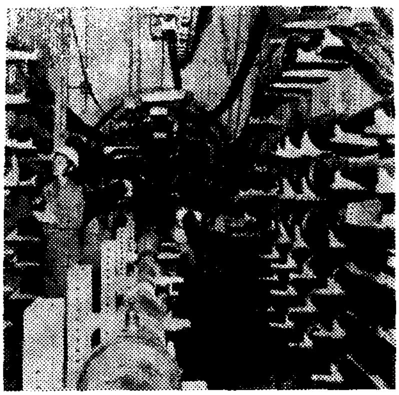


Fig. 13. Underground Substation of the of Cable

The power line connected to the 275KV underground substation makes use of the of cable and is laid, as shown in this slide, through the tunnel route. Cooling water for indirect cooling is supplied through pipes in the tunnel.

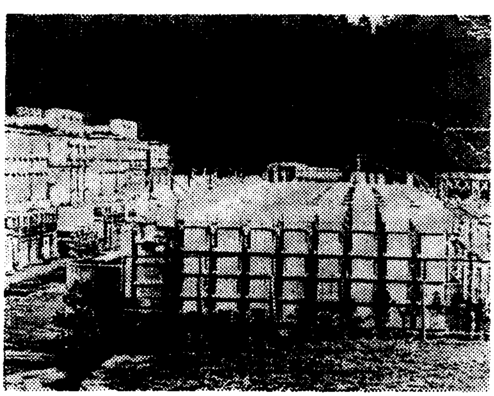


Fig. 14. Miniclad

Next, I am going to show you, with special interest, the equipment named 'Miniclad' as you can look at in this slide. This has been developed as the compactsize switching equipment of high reliability and easy maintenance so as to help resolving the difficulty in the site acquisition for construction of substations in the urban areas.

It is designed by solid insulation up to the 22 KV rating and SF_6 gas above the 22KV. At present, the 500KV complete Miniclad substation is under construction.

		66kV	154kV	275kV	500kV
Volume	Miniclad System (m^3)	136	331	414	75,000
	Air Insulation System(m^3)	1,360	8,075	28,800	322,000
	Ratio (%)	10	4.1	1.4	2.3
Area	Miniclad System (m^2)	21	36.8	46	5,000
	Air Insulation System(m^2)	123.5	475	1,200	75,000
	Ratio (%)	17	7.8	[illegible]	6.7

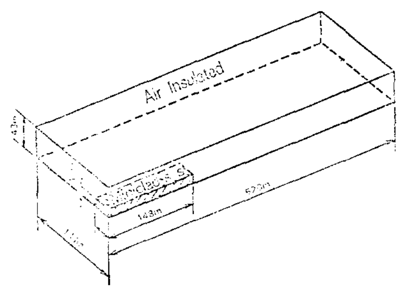


Fig. 15. Reduction Ratio of the Switch Yard with Miniclad

If 500KV substations can be installed completely by Miniclad, the land area to be required for each circuit of transmission line can be reduced to about one twentieth of that for conventional air insulation type substations.

As the future tasks in the area of transmission technology, the first thing to do is to develop new technologies to meet the remote siting of bulk power sources and the increasing tendency of short circuit power. So, research effort is now being made to develop the UHV technology with the nominal voltage of 1,000KV and the UHV DC technology of plus/minus 500KV rating. At present, the AC 1,000KV test line with three towers has been completed at the Central Research Institute of Electric Power Industry for various experimental test studies.

Meanwhile, in order to provide adequate power supply to the metropolitan area where the tendency of overpopulation is still being accelerated, we have worked out the plan to introduce the 500KV transmission system into the urban area. Though the 500KV of cable is already used at the outlet of the power plant, we are now working to solve various problems before the application for long distance and large capacity transmission such as the 1,200MW per route.

In addition, the integrated computerized automatic control system covering dispatch station, substation and distribution system is now being developed in order to ensure high reliability in the operation of the future transmission system.

Closing Remarks

After my briefing about Japan's power engineering today, I would like to emphasize that it will become more and more necessary for each country to make international cooperative effort for research and development of new technology in order to tide over the present and future energy crisis prevailing on the global scale.

From this point of view, the JIEE is cooperating closely with the IEEE of the United States and any similar organizations in other countries. There are also international activities in other organizations such as CIGRE, World Atomic Power Conference and IERE (International Electric Research Exchange). Joint research or commissioned study has been agreed upon between Japan's Central Research Institute of Electric Power Industry and the EPRI of the United States. In order to improve the nuclear power availability factor, for example, joint research activities are now being carried out by the nuclear power manufacturers in Japan, the United States, Sweden and Italy.

If this seminar provides the opprtunity to produce the cooperative relations between people in the Republic of Korea and us in Japan to cope with the energy crisis, I as the speaker will be more than pleased.

Thank you very much for listening to me. Thank you!