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ELECTRIC POWER GENERATION AND DISTRIBUTION : OPPORTUNITIES FOR CO-OPERATION IN THE ESCWA REGION

Note by the Secretariat

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PREFACE

The purpose of this report is to provide and analyse basic data on the electric power situation in each of the ESCWA member countries and in the ESCWA region as a whole with the view to analysing its present state and investigating prospects for future co-operation. The basic data refer to the following: the type and capacity of the power plants both in operation and under construction in 1982 and those planned up to 1990; the name and country for the suppliers of the different generating units; the electric energy consumption in the different sectors of the country; the peak demand and the day and hour of its occurrence; the standard voltages used and the length of the transmission lines or cables used at each voltage level; and the cost of production of electric energy and its selling price to the different consumers in each country. These data are compiled by the ESCWA secretariat from replies to questionnaires supplied by various countries in the region, from official national sources or from published material. Some indicators, such as the utilization factor, load factor, electric power density and per capita installed capacity, are derived from the basic data for the purpose of analysing the electric power situation and the prospects for future co-operation.

This report and the data presented are considered only as a first step towards a solid data base on the electric power situation in the ESCWA region; in addition, they highlight some issues related to any future co-operation in that field including interconnections between electric power systems of neighbouring ESCWA member States on a bilateral or multilateral basis.

INTRODUCTION

Historically, electric utilities in the ESCWA region, as in any region in the world, began as isolated systems serving local communities. Over the last few decades, electric utilities in some ESCWA countries have followed a common trend of increasing size of equipment and degree of interconnections. Today, in some ESCWA countries, large generating units (up to 400 MW) with high voltage transmission lines (up to 500 kV) are used to provide electric power to many communities. In the meantime, some ESCWA countries (Bahrain, Egypt, Iraq, Jordan and Syria) are covered by unified electric grids with centralized control; other ESCWA countries (Saudi Arabia, United Arab Emirates) have more than one isolated grid, each supplying electric power to a certain region in the country, and a third group of ESCWA countries (Democratic Yemen, Oman, Qatar and the Yemen Arab Republic) still have small isolated systems serving local communities. However, questions have been raised regarding the efficiency and appropriateness of the centralization of electric power systems characterized by an increased scale of operations, a high degree of interdependence, and an often greater level of capital intensity and technical sophistication.

The fundamental motivations for centralization in electric power systems on the country level or on the inter-country level are higher efficiency in system-sharing and economies of equipment size.

Electrical energy is a high-quality energy that can be transmitted in bulk over long distances and distributed for use at virtually any level desired by the end-user. The transportability and divisibility of electrical energy enables a power system to be simultaneously shared by many widely dispersed users without interference with one another. System-sharing provides several sources for production efficiency as the following examples given below illustrate:

1. Load diversity: Individual end-users in power systems demand various amounts of electrical energy at different time periods. The peak demands of different user groups occur at different times. In the ESCWA region, clear examples of that on the country level is in Saudi Arabia, where the peak demand during 1982 was on 6 July in the eastern region, 10 July in the central region, 12 July in the western region and 1 July in the southern region. These regions are not interconnected at present. On the regional level, if neighbouring countries are considered, one can find that in Iraq, Jordan, Kuwait and Syria the peak demands during 1982 were on 18 August, 23 September, 10 August and 23 November respectively. The combined annual peak load of the different regions in Saudi Arabia, for example, was definitely lower than the sum of the peaks of the different regions. Similarly, on the inter-country level, the combined annual peak load of Iraq, Jordan, Kuwait and Syria, if interconnected, will be lower than the sum of the annual peak loads of each country. Consequently, the sharing of the power system by many regions on the country level, or by many countries on the inter-country level can produce considerable savings in the system-capacity requirements.

2. Reserve pooling: To maintain high availability and reliability of a power system, capacity reserves in generation, transmission and distribution systems are required. For a given unit size, the generating reserve requirements decrease in percentage with the increase of the system size. The group of ESCWA countries which include Iraq, Jordan, Kuwait and Syria had installed capacities of 4,530, 600, 5,086 and 2,575 MW respectively and had peak demands of 2,820, 247, 2,288 and 1,090 MW in 1982 respectively. The total installed capacity of this group was 12,791 MW while its peak demand should be definitely less than 6,445 MW, indicating a very high reserve capacity, which could be much reduced if the power systems of this group of countries were interconnected.

3. Mutual exchange of engery: A participating country in the interconnected system will be able to receive additional electrical energy from the other countries with the available reserve capacities should its own generation be unable to meet the load demand. This is exactly what happened between Syria and Lebanon during the 1973 war. The Lebanese power system supplied electrical energy to Syria upon demand due to failures of some power plants in Syria. It may happen, of course, that other systems are also experiencing difficulties; on many occasions, however, help will be available because of the diversity of loads and will be needed because of unit failures and other unpredictable generation interruptions in some power plants. Consequently, the reliability of systems with ties to other systems will be higher than without such interconnections for the same reserve capacities.

4. Labour specialization: The interconnection of power systems between groups of ESCWA countries will enable teams of specialists, engineers, technicians and skilled labourers of different ESCWA countries to work together on design, construction, operation, maintenance and management of power systems, resulting in the promotion of more technical co-operation between ESCWA countries.

Power system-sharing also provides economies of equipment size. The capital cost per unit capacity of a piece of electric power equipment often decreases with the capacity of the equipment. The interconnection of electric power systems permits the utilization of larger sized generating units, since the size of the largest generating unit should not exceed 10 per cent of the total installed generating capacity in the electrical network to ensure adequate supply security and operational conditions. Considering a group of ESCWA countries such as Iraq, Jordan, Kuwait and Syria, the sizes of the largest units that could operate with their systems should not exceed 450, 60, 500 and 250 MW respectively. However, units up to 1,200 MW could be included if the systems of these countries were interconnected, thus benefiting from the economy of size in capital costs, operation, maintenance and fuel delivery costs. The operation costs are generally independent of the size of the equipment; thus, the operation cost per unit capacity is less with the increase of the size. In addition, the maintenance costs are often proportional to the capital cost which decreases per unit capacity with the increase of the size of the equipment. The fuel rate, i.e. the fuel consumption per unit of generated energy in plants using fossil or nuclear fuel is smaller for the larger size of generating equipment.

However, the interconnections have some disadvantages such as the following: increased transmission requirements; complexities in interfacing between systems with different voltages and/or frequencies which is the case in interconnections between most of the ESCWA countries; additional risks of large system failures; organizational and operational complexities; and potential conflict with local regulatory bodies.

To examine the opportunities for co-operation among ESCWA countries in the area of electric power, including possibilities for interconnections between their electric networks, it is necessary to have detailed information on the present state and future developments of electric power generation, transmission and distribution in each country. The first part of this report is a step forward towards achieving this objective.

I. ELECTRIC POWER SUPPLY SITUATION IN THE ESCWA MEMBER COUNTRIES

A. Bahrain

Bahrain is covered by an electrical network at 66 kV connecting all the power plants in Manama, Muharraq, Sitra, Rifa'a, at BAPCO (Bahrain Petroleum Company) and ALBA (Aluminium Bahrain). Ties at 220 kV link Rifa'a and Sitra power stations with the substation in Umm Al-Hassan. The ALBA complex (300 MW) and refinery (60 MW) power plants provide electrical energy mainly for the aluminium factory and the refinery with a very minor contribution to the main network of Bahrain. The Manama power plants have 12 gas turbine driven generators with a total installed capacity of 123 MW and four diesel driven generators with a total capacity of 4 MW.

The plant in Muharraq is a 39 MW dual purpose plant for electric power generation and seawater desalination. Sitra is also a 26 MW dual purpose plant but with steam turbines as prime movers. One more unit of 25 MW is being added to this power plant. Rifa'a is the largest plant in Bahrain, with five gas turbine driven units of 50 MW each. The extension of this power plant, Rifa'a II, which is expected to operate at full capacity by 1986 will add six units of 75 MW capacity each. Bahrain has the highest installed power density (856 kW/km^2) in the ESCWA region. The per capita installed capacity in Bahrain makes it rank fourth in the region after Kuwait, Qatar and the United Arab Emirates. However, the installed power belonging to the Bahrain State Electricity Department is a very small portion of the installed capacity in the region (1.6 per cent). The utilization factor (0.828) in Bahrain is the highest in the region. This is apparently correct, but in fact this is due to the exclusion of the installed capacities in ALBA and the refiner from the calculations even though they supply an appreciable amount of energy to the network at peak hours.

The load factor in Bahrain is the lowest in the region, since the load is mainly a household one (81.4 per cent) the bulk of which is air-conditioning. The total number of disturbances in 1982 was 68 and only 14 of the disturbances resulted in loss of supply to consumers. The number of disturbances which resulted in under-frequency relay operation was only one in 1982.

There is a possibility of interconnecting the Bahrain grid with the eastern region of Saudi Arabia; it should be studied in depth if such an interconnection could be realized by submarine cables or by an overhead line.

B. Egypt

A 500 kV double circuit overhead line extends from the High Dam Power Plant (2,100 MW), located south of Aswan City, along the Nile valley to Cairo with a total length of more than 1,500 km. A 220 kV network covers the Nile

Delta and extends to westwards to Sidi-Krir, about 40 km west of Alexandria, and eastwards to Suez and El-Soukhna covering most of the populated area of Egypt. Both systems are interconnected at a substation located near the Pyramids, south-west of Cairo. Upper Egypt, where the major industrial load centres are located (the fertilizer factory in Aswan and the aluminium complex in Nagah-Hammadi), is supplied with electrical energy by a 132 kV system covering all the populated areas from the High Dam in the south up to Beni Souif in the north (Beni Souif lies about 125 km south of Cairo, while the High Dam lies about 800 km south of the capital).

The unified network of Egypt is supplied by energy from about 30 power plants. Two of them are hydropower plants (High Dam of 2,100 MW and Aswan Dam of 300 MW), 11 are steam power plants scattered all over the populated areas of Egypt with installed capacities ranging from 45 MW up to 350 MW, and the rest are gas turbine driven power plants with installed capacities ranging from 17 MW up to 192 MW.

The hydro units used have capacities ranging fom 11.5 MW up to 175 MW, which is the largest hydro unit size in the whole ESCWA region. The steam units sizes range between 10 MW and 100 MW. The gas turbine unit sizes range between 12.5 MW and 42 MW. Ten power stations are under construction which are supposed to be commissioned starting from 1983 up to 1986. Four of them are gas turbine driven plants and the remaining six are steam power plants. The total installed capacity which will be added by the end of 1986 to the network is about 4,000 MW, increasing the total capacity of Egypt's unified grid to more than 9,000 MW. Steam units up to 300 MW capacity will be used for the first time in Egypt. The Egypt Electricity Authority (EEA) of the Egyptian Ministry of Electricity (MOE) plans to construct nine more power plants: two of them are hydro electric plants. Aswan II with a capacity of 300 MW and Isna with a capacity of 100 MW. The rest are steam power plants with capacities up to 1,200 MW a gas turbine driven plant with a capacity of 33 MW and a pumping storage plant with a capacity of 300 MW. The Nuclear Power Authority (NPA) of the MOE has already issued a tender on the first two nuclear power units, each with a capacity of 900 MW, to be installed in Dabba to the west of Alexandria. However, negotiations are still going on concerning the financing of this huge project. By the end of the year 1986 the installed capacity of the unified network in Egypt will be increased by about 3,989 MW to reach more than 9,000 MW, and then the addition of a 900 MW nuclear power plant could be possible. More than 6,500 MW will be added to the network by the year 1990 to increase the network capacity to around 17,000 MW.

The Egyptian network will be extended to cover Sinai and hence there will be a possibility of interconnection between this network and the network of Jordan which is supposed to be extended to Aqaba. The only means of interconnection is by a submarine cable crossing the Gulf of Aqaba and interconnecting Taba in Egypt to the city of Aqaba in Jordan. The length of the submarine cable will be a little more than 10 km.

C. Iraq

Iraq is covered by a 400 kV electric network with 10 substations at this voltage level. The length of the 400 kV lines is around 5,000 km. There are

three hydropower plants with generating capacities of 50, 240 and 400 MW, four steam power plants with capacities of 200, 800, 840 and 1,200 MW, and four gas turbine driven power plants with capacities of 140, 150, 160 and 250 MW. The capacities of the hydro units are 25 and 80 MW, of the steam units 100, 200 and 210 MW, and of the gas turbine driven units 20, 25, 30 and 35 MW. The State Organization for Electricity (SOE) is planning to construct six more power plants. Two of them will be gas turbine-driven plants with capacities of 160 and 220 MW, and the remaining four will be steam power plants each having four 300 MW units, thus adding more than 5,000 MW capacity to the network which currently has a capacity of 4,430 MW.

Iraq, which is located between Syria and Kuwait, has two 400 kV substations, one in Khor Al-Zouber, approximately 50 km away from Safwan on the Kuwaiti border, and the other in Al-Kaem, about 25 km from the Syrian border. These two substations are the appropriate candidates to constitute to the interconnecting points between Kuwait and Iraq from one side and Iraq and Syria from the other. The networks in the three countries (Iraq, Kuwait and Syria) are in a state that could be interconnected after an in-depth study of the parameters and the operating characteristics of each network to determine the type, capacity specifications, etc., of the interconnecting ties and the interfacing equipment.

D. Jordan

Jordan has a mix of diesel, gas turbines and steam turbine-driven power plants. However, all the units to be installed are steam units, which indicate that the Jordan Electricity Authority (JEA) is switching more and more to steam rather than diesel power. Until recently, privately owned power companies in Jordan were responsible for electric power generation, transmission and distribution within their concession areas. However, at present, JEA has undertaken the responsibilities of electric power generation and transmission all over the country and distribution outside the concession areas of the private companies. JEA has constructed an interconnected power system to link all areas in Jordan. By the end of 1982, many regions were interconnected by the 132 kV network which was extended to cover most of Jordan in 1983. A 400 kV line linking Amman with Aqaba is planned for completion by 1986. More than 80 per cent of the installed capacities in Jordan are the property of JEA and less than 20 per cent are owned by different private utilities. The share of JEA will be increased by additing one more unit of 66 MW capacity to the Hussein Thermal Power Station (HTPS) to be commissioned by 1985 and two units each of 130 MW capacity to be commissioned by 1986. The total capacity owned by JEA in 1982 was 509.5 MW and will be increased to 835.5 MW in 1986 against 90.5 MW owned by other utilities.

The Jordanian network is interconnected with the Syrian network by two tie lines at Irbid. The capacities of the interconnecting lines are 100 MVA and 10 MVA, with voltages of 230 kV and 66 kV respectively; each extends for 17 km inside Jordanian territory.

Other possible connections with neighbouring ESCWA countries are the interconnection with Saudi Arabia, the border of which is only 30 km from the

Jordanian grid, and the interconnection with Iraq. However, the length of interconnecting ties with Iraq will be more than 350 km inside Jordanian territory.

E. Kuwait

By the early 1970s, Kuwait had completed the construction of a 145/132 kV interconnected network. The capacity of this network by the end of 1982 was little more than 5,000 MW, if the Doha West power plant which was working under testing conditions during 1982 is included. The addition of the Doha West power plant, with eight units, each having a capacity of 300 MW, increased the capacity of Kuwait's power to almost double its capacity before 1982; the addition also introduced larger sized units of 300 MW to the system. By 1987, an additional eight units, each with a capacity of 300 MW, will be connected to the unified network, increasing its capacity by around 47 per cent. Another 2,400 MW will be added to the network by 1990 when the Al-Zour North power plant will be completed. The 600 MW generators planned for installation in this plant will be the largest generators operating in the whole ESCWA region in 1990, assuming that Egypt's first nuclear power plant will not be commissioned before 1990. It is worth mentioning that Kuwait depends mainly on dual purpose (electric power generation and seawater desalination) steam power plants, since the output of desalinated water from these plants represents the major fresh water resources for the country. Therefore, gas-turbine driven generators (362 MW) represented a small percentage (7 per cent) of the total installed capacity in operation by the end of 1982. This small percentage will decrease to 4.8 per cent when the Al-Zour South power plant is commissioned in 1987 and 3.6 per cent when the Al-Zour North power plant is commissioned in 1990. The gas turbine driven generating units serve certain specific purposes.

It should also be noted that, while increasing the capacity of the network, larger sized units are utilized keeping the size of the largest unit less than 10 per cent of the network capacity; thus the system benefits from the economy of size and at the same time preserves the technical performance (stability, reliability, etc.) within the permissible limites. Kuwait, which lies between Iraq and Saudi Arabia and whose electric power grid passes at distances of about 20 km from both the Iraqi and Saudi borders, could be interconnected with the Iraqi network. A line of a length of about 70 km (20 km in Kuwaiti territory and 50 km in Iraqi territory) could link the networks of Iraq and Kuwait. In addition, the Kuwaiti network could be connected to the eastern region in Saudi Arabia with a tie line of a length of about 90 km (20 km in Kuwait territory and 70 km in Saudi territory). However, such interconnection needs very careful investigation, owing to the special features of the electric power situation in Saudi Arabia concerning the utilized commercial frequency (60 Hz), the interconnection between the different power plants in the same region, the interconnection between the different regions, etc.

F. Lebanon

Lebanon has a mixture of hydro (260 MW), steam (450 MW) and gas turbine (100 MW) power plants. This of course does not take into consideration many

diesel generator sets which are scattered all over Lebanon and owned by individuals or by private companies, factories, etc. Lebanon plans to construct a steam power plant, Zouk II, including three steam driven units of 150 MW each, to be commissioned in 1988, and another 150 MW single unit plant in the north to be commissioned in 1989.

The electric network of Lebanon is interconnected with the Syrian network by a 66 kV line. This tie played a significant role in providing Syria with electrical energy during the 1973 war. However, the energy transfer through this line has been insignificant during the last years.

The utility taking the responsibility for electric power generation, transmission and distribution in Lebanon is the Electricite du Liban (EDL). It is anticipated that EDL will reconsider its plans for reconstruction and renovation of the transmission and distribution networks and perhaps also for electric power plants once the rehabilitation programme for Lebanon comes into effect.

G. Oman

The utility responsible for electric power generation and distribution in Oman is the Ministry of Electricity and Water (MEW). The main source of power generation in Oman is the Ghabra power plant which provides the Muscat area with Electric energy. This power plant has about 55.5 per cent of the total installed capacity in the country. It includes five steam-driven generating units, which are the only steam units in operation in Oman; two of them are of 50 MW capacity each and the remaining three are of 8.5 MW capacity each. Besides the steam units in the Ghabra power plant there are eight gas turbine driven generators each with a capacity of 20 MW. Except for the cement factory, which has a gas turbine power plant of a total capacity of 52.5 MW, representing about 10 per cent of the total installed capacity in Oman, all the other power plants are diesel-driven plants with capacity ranging from a fraction of megawatt up to 41.5 MW. Two plants (Ghabra and the cement factory in Suhar) have around two thirds of the total installed capacity in the country and the remaining 27 plants have only one third of the total installed capacity. Two new power plants are under construction in the meantime: the first is the Rosal plant with an installed capacity of 250 MW gas turbine driven generators; and the second is an addition of 30 MW generators at the power station serving the Suhar Copper Complex which will provide energy to the border town of Boraini, currently supplied with electricity from Abu Dhabi. Both plants were supposed to be in operation by 1984. Each power plant is operated as an isolated system serving a certain city or community, and no interconnection between any of the power plants exists. However, once grid interconnection is established in Oman, it could be easily interconnected with the United Arab Emirates via the city of Suhar and to the People's Democratic of Yemen via the city of Salalah provided that both countries will establish interconnected networks.

H. Qatar

The main power plants in Qatar are Ras Abu Aboud (RAA) and Ras Abu Fontas (RAF). In RAA there are four steam-driven generating units, each with a

capacity of 15 MW and eight gas-turbine units with different capacities (15, 17.5 and 25 MW). RAF, which is the largest power plant, has 14 gas turbine-driven generators, six of them with capacities of 44 MW each, six with capacities of 56 MW each, and the remaining two with capacities of 15 MW each. The main grid in Qatar connects the RAA and RAF power plants. However, this main grid does not cover the whole country and there are other isolated small networks at Dukhan, Abu Samra and other places. These isolated networks are fed by diesel generator units.

The Qatar Electricity Department (QED), the utility in charge of electric power generation and distribution, is constructing a 60 MW power plant (two gas turbine-driven generators each with a capacity of 30 MW) in Ras Laffan which was expected to be commissioned in 1985. Furthermore, an extension to the RAF plant is under construction and will add six gas turbine units each with a capacity of 70 MW; it is expected to be in operation by the end of 1984.

I. Saudi Arabia

Saudi Arabia has the highest installed capacity in the ESCWA region (more than 13,000 MW) and relies on a mix of thermal stations (steam, gas turbines and diesel) for electricity production (9,375 MW) and water desalination (3,949 MW). In the past electricity was provided by small urban utility companies, as many as 100, which operated small isolated grids with different frequencies and voltages. Later on, Saudi Arabia succeeded in standardizing the frequency (60 Hz) and the service voltages, and in consolidating the numerous small companies into five regional groups (eastern, central, western, northern and southern regional groups). At present, these five groups are combined in one company known as the Saudi Consolidated Electricity Corporation (SCECO). A portion of the Kingdom's electricity is now supplied by the desalination plants operated by the Saline Water Conversion Corporation (SWCC). The Saudi Government owns the General Electricity Corporation (GEC), which has the responsibility for implementing rural electrification programmes.

SCECO operates five isolated networks covering the five regions of Saudi Arabia. The eastern region network is supplied by 11 gas turbine stations with a total capacity of 2,742 MW and one steam station with a capacity of 1,600 MW using the largest size of steam turbine units (400 MW). The total installed capacity in this region is 4,342 MW, representing 46 per cent of the total capacity run by SCECO. The eastern region network covers cities such as Dhahran, Dammam, Jebail, Qaisumah and Salwa. Any future interconnection between Bahrain, Kuwait, Qatar and Saudi Arabia should be made via this region. In addition, SWCC is operating a dual purpose plant in Jebail in the eastern region with a capacity of 1,300 MW (1,000 MW steam units and 300 MW gas turbine units). The planned additions to the eastern region are three plants, a steam plant with a capacity of 1,200 MW in Qaryah to be commissioned by 1988 using 600 MW units, a gas turbine driven plant with a capacity of 440 MW in Uthmanya and another steam power plant with a capacity of 400 MW in Safaniya.

The central region, which includes the capital city of Riyadh, is provided with electricity from about 43 power plants either gas turbine and/or diesel-driven plants having a total capacity of 2,358 MW and representing about 25 per cent of the total installed capacity run by SCECO. With the

exception of three power plants, namely Riyadh 4, 5 and 7, all the other plants in operation have capacities of less than 100 MW. At present, SCECO is constructing three new gas turbine driven plants with capacities of 800, 540 and 17 MW and 11 small diesel driven plants of capacities ranging between 2 and 6 MW. SWCC operates a 500 MW dual purpose plant in Azzizia.

Electric power-generation for the western region, including the Holy Cities Mecca and Medina, the largest Saudi port of Jeddah, and Al-Taif, is provided by 22 plants. The plants capacities vary between little more than one megawatt and a little less than 20 MW except those plants found in the four above-mentioned important cities where capacities may reach 944 MW. As in the central region, all the generation is provided by either gas turbine or diesel-driven units. However, the first steam power plant to be introduced in the western region is a 1,000 MW plant under construction in Rabigh. There are also some diesel-driven plants under construction in this region with capacities of 10 MW and less. There are plans to construct some other diesel-driven plants in the western region, but with capacities of up to 20 MW; one gas turbine driven plant of capacity 27 MW is also included in the SCECO plans. The total installed capacity in operation in this region is 2,109 MW, constituting 22.5 per cent of the total installed capacity run by SCECO.

SWCC is operating a number of dual purpose plants in the western region, four of them in Jeddah with capacities of 120, 84, 200 and 500 MW, and one plant with a capacity of 250 MW providing fresh water to Medina and Yanbu. Three more dual purpose plants are under construction and to be commissioned in 1984 to provide fresh water to Mecca and Taif (400 MW), Amlag (10 MW) and Alwajh (15 MW).

The northern region, which is bounded by the Iraqi and Jordanian borders, has a number of small (less than 100 MW) power plants with gas turbine or diesel driven units. The total installed capacity in this region is about 250 MW representing a small fraction (2.69 per cent) of the total installed capacity run by SCECO. However, larger power plants with capacities of 135 and 340 MW are planned to be constructed in Al-Gawf and Haql. Other small plants are included in future plans for a 60 MW plant in Tabuk, a 10 MW plant in Timah and a 15 MW plant in Rafha. In addition, SWCC is constructing three dual purpose plants in the northern region; a 10 MW plant in Dabaa, a 10 MW plant in Haql and a 400 MW plant in Tabuk. All these plants are to be commissioned during the period between 1982 and 1984.

It is worth mentioning that any future interconnection between Saudi Arabia and either Iraq or Jordan should take place via the northern region.

The southern region, with its 22 power plants, mostly diesel-driven, has a total installed capacity of 510 MW representing around 5 per cent of the total installed capacity run by SCECO. In the meantime SCECO is constructing a number of new plants mainly gas turbine-driven in the southern region. The gas turbine plants have capacities ranging between 30 and 150 MW. SCECO plans to establish one steam power plant with a capacity of 400 MW, which will be the largest in size and the first of its type in the southern region. This region will be the interconnecting area between Saudi Arabia and either the Yemen Arab Republic or the People's Democratic Republic of Yemen.

J. Syria

Syria has completed a 230/66 kV unified electrical network interconnecting all Syrian governorates. In addition, the lines interconnecting Syria with both Jordan and Lebanon at 230/66 kV are in operation at present. The Ministry of Electricity has approved the establishment of a 400 kV network to cover the country and has already initiated the installation of the first 400 kV line linking Damascus with Aleppo. This line will be the backbone of the 400 kV Syrian unified grid.

The power plants operated by the Public Establishment of Electricity (PEE) are a mix of different types and sizes. One large hydropower plant (800 MW) and three small plants with capacities of less than 10 MW are in operation. Four more hydroplants of sizes 60, 400, 35 and 250 MW are either under construction or in the planning phase. The five steam-driven plants in operation have capacities of 300, 340, 120, 35 and 22 MW. The remaining plants in operation are gas turbine-driven with or without diesel reserve units. The total installed capacity operated by PEE is 1945 MW. PEE is constructing a 300 MW steam plant in Wadi Al-Rabie. Other than PEE, there are some ministries (Ministry of Oil, Ministry of Industry) and sectors which operate a number of power plants having a total installed capacity of 630 MW (108 MW steam, 122 MW gas turbine and 400 MW diesel).

K. United Arab Emirates

Each of the Emirates (Abu Dhabi, Dubai, Ajman, Al-Fujayrah, Ras Al-Khaimah, Sharjah and Um Al-Quwain) has its independent electric power system. None of the systems are interconnected and they are operated by different utilities, namely, the Ministry of Electricity and Water (MEW), the Water and Electricity Department (WED) and the Dubai Electric Company (DEC). WED runs seven power plants in Abu Dhabi with a total installed capacity of 993 MW representing 33 per cent of the total installed capacity in the Emirates. The plants operated by WED have different types of prime movers (steam turbines, gas turbines and diesel engines).

MEW operates 18 power plants of different types and sizes in the Emirates of Ajman, Um Al-Quwain, Sharjah, Ras Al-Khaimah, and Al-Fujayrah; most of them are diesel and gas turbine plants, with the exception of two steam power plants, one in Ras Al-Khaimah and the other in Sharjah. The total installed capacity of the generating units run by MEW is about 1,197 MW, representing 40 per cent of the total capacity in the Emirates. DEC is in charge of electric power in Dubai and operates four plants with a total capacity of 779.6 MW representing 26.3 per cent of the total installed capacity in the Emirates.

A number of single purpose and dual purpose plants were under construction in the different Emirates; these plants were to be commissioned by 1983-1984. In addition, there are plans to construct five more plants, four of them in Sharjah and one on the West Coast which will be a dual purpose plant. These plants are expected to be commissioned in the years 1985-1987.

L. Yemen Arab Republic

The utility responsible for electric power generation, transmission and distribution in the Yemen Arab Republic is the Yemen General Electric Corporation (YGEC). YGEC is running about 28 power plants, only three of them with capacities of more than 5 MW, the rest have small capacities. The three major power plants provide the main cities of Sana'a (44.6 MW), Hodeidah (26 MW) and Taiz (22 MW) with electricity. The small power stations are scattered all over Yemen to provide the smaller towns with electricity. The total installed capacity of the power plants run by YGEC is about 120 MW. However, two major steam power plants are under construction in Ras Katenib (150 MW) and in Mokha (160 MW). The plant in Ras Kantib was commissioned in 1983 and some units are already in operation at the time of writing. At present, there is no interconnected system linking all the power plants in Yemen. However, there is a 132 kV transmission line connecting the three main cities of Sana'a, Hodeidah and Taiz.

There are prospects for interconnection between Yemen and the southern region of Saudi Arabia via Sana'a-Abha. Furthermore, studies are being carried out on an interconnection between Yemen and Democratic Yemen and there are various proposed alternatives for this interconnection, such as the following ones: (i) a high voltage tie line between the main substation in Taiz (Yemen) and the planned power station in Heswa (Democratic Yemen); (ii) a high voltage line between Turbah (Yemen) and the planned Heswa plant; (iii) a tie line linking Yarim (Yemen) with Heswa; and (iv) a tie linking the Dhamar (Yemen) substation with Aden.

M. People's Democratic Republic of Yemen

The electric power supply situation in Democratic Yemen was under intensive study by a consulting firm. The draft report of the study, entitled "Techno-Economic Study of the Electric Power, PDRY" was expected to be finalized by the end of 1984. However, a brief review of the situation in Democratic Yemen is presented in this report.

In Democratic Yemen there are four isolated power systems in Aden, Abian, Wadi Hadramout and Mukalla, in addition to a number of small (200-700 kW) generating stations which are spread all over the six governorates of the country.

The main power system in Democratic Yemen is that of the Aden Governorate. Three power plants (Al-Mansourah, Khor Maksar and Ragaif) with a total capacity of 110.5 MW are linked to this system. These plants include mainly diesel-generator units, with the exception of five gas turbine units each of a single megawatt capacity located in the Ragaif power plant. The installed capacity in the Aden system represents more than 77 per cent of the total installed capacities run by the Public Corporation for Electric Power (PCEP)

The first steam power plant in Democratic Yemen is expected to be commissioned by 1986-1987 in Al-Heswa with two units each of a capacity of 25 MW. Another steam power plant of 100 MW is under study at the moment.

PCEP is completing the extension of the Ja'ar and Khalaf plants by additional diesel units of a total capacity of 4 MW for each station. The Shahar power plant which was to be commissioned by 1985 has three diesel units of 2.2 MW capacity each.

Concerning the interconnection between the different systems, the 132 kV Aden-Abian link, which is currently under study, will be the first step towards an interconnected system, if the ongoing study on electric power in Democratic Yemen proves the techno-economic feasibility of such a system. It will cover the whole of Democratic Yemen and facilitates the interconnection of Democratic Yemen with the neighbouring countries of Oman, Saudi Arabia and the Yemen Arab Republic.

II. ELECTRIC POWER GENERATION

The generation capacities in the ESCWA member States are classified according to the type of prime mover. Some indicators which could be useful when considering any future co-operation between ESCWA member States include the installed capacity per capita and per unit area; the capacity of the largest generating unit for each type of prime mover; the installed capacities of the hydro, steam, gas turbine and diesel driven generators in each ESCWA member States as a percentage of the total installed capacity in the country; and also as a percentage of the total installed capacity for the same type of prime mover in the whole region.

The largest installed capacity (9,375 MW) in the whole region is found in Saudi Arabia, which also has the largest installed capacity of gas turbine driven generators (6,753 MW), the largest sized steam turbine units (400 MW) and the largest sized gas turbine unit (90 MW). Kuwait has the largest per capita installed capacity (3,307 W/capita) and Bahrain has the largest installed capacity per unit area (856 kW/km^2). The Yemen Arab Republic has the smallest capacities according to such indicators (120 MW, 17 W/capita and 0.6 kW/km^2). Egypt has the highest hydro-electric potential (2,445 MW) and utilizes the largest hydro-electric units (175 MW) in the region. As far as dependence on a certain type of prime mover is concerned, Egypt ranks first in depending on hydro-electric power since it represents 47.6 per cent of its total installed capacity. In Kuwait 93 per cent of installed generation capacity are steam units, and in Qatar the same percentage (93 per cent) are gas turbine units, while in the Yemen Arab Republic all electric power was generated from diesel units till the end of 1982. Egypt has the highest percentage of hydro-power units in the ESCWA region (56 per cent), Kuwait has the highest percentage of steam generators (32.9 per cent); and Saudi Arabia has the highest of both gas turbine-driven units (57.6 per cent) and diesel-driven units (52.0 per cent). In the whole region, the shares of different types of prime movers are as follows: 4,340 MW (13.3 per cent) hydro; 14,362 MW (44.1 per cent) steam; 11,811 MW (36.3 per cent) gas turbines; and 1,979 MW (6.1 per cent) diesel. These figures make for a total installed capacity of about 32,492 MW.

III. ELECTRIC POWER DEMAND

The peak demands of individual ESCWA countries do not occur at the same time, i.e. there are clear load diversities between the different ESCWA member States, and also between the different isolated electric power networks in the same country in those countries that have not yet established a unified electric grid. The peak demands in the ESCWA countries located in the Arab Peninsula and in Iraq are characterized by extremely hot weather in summer and always occur during the summer months (June, July and August). This is quite reasonable since a major part of the electric power production is consumed in air cooling during the summer. However, the peak demand in Jordan occurs in September, in Syria in November and in Egypt in December. These three countries have relatively cooler climatic conditions in summer and therefore air cooling does not represent a major part of the electric power demand. The same applies for Lebanon and most of the Yemen Arab Republic, although the data on the occurrence of the peak demands in both countries were not available. The utilization factor which is defined as the ratio of the peak demand to the installed capacity varies in the ESCWA region between 0.41 and 0.828. The upper limit of the utilization factor is the figure for Bahrain, which is an apparent value, since in calculating the installed capacity in Bahrain the installed capacities in ALBA and the refinery are not taken into consideration although these plants supply a part of the load to the Bahrain network at peak hours. In fact, the highest utilization factor is that of Egypt, which indicates that Egypt has the smallest reserve capacity. In the ESCWA region the load factor for the different electric networks ranges between 0.406 and 0.73 (the load factor is defined as the ratio of the annual average load to the peak load). The highest load factor corresponds to Egypt, owing to the fact that the industrial sector consumes the largest percentage of electrical energy, while in those countries having small load factors the household sector is the main consumer of electrical energy.

IV. ELECTRIC ENERGY CONSUMPTION

The gross electric energy consumption in the ESCWA member countries in some selected years during the 1970s and the 1980s, and the available information on the forecasted electric energy demand up to the year 2000, provides a picture of the various ESCWA countries with regard to electric energy consumption structure and level. It is clear that, except for the two Yemens and Lebanon, the period from 1970 up to 1980 is characterized by a very high rate of growth in electric energy consumption in all ESCWA countries, while the period from 1970 to 1975 is marked by a slower rate of growth in eletric energy consumption. This is, of course, a reflection of the high development rates that took place in most of the ESCWA region after 1973 due to the remarkable increase in their national income from the oil revenues. The total consumption of the ESCWA region increased from 71,094 GWh in 1980 to 79,424 GWh in 1982, with a growth rate of 11.7 per cent, while the average growth rate in the period 1975-1980 was 30 per cent. In 1982, electric energy consumption in the ESCWA region reached 79,424 GWh, i.e. 16 per cent more than the figure corresponding to the year 1981. This could be explained as due to the fact that the consumption in some ESCWA countries, as in Iraq in 1981, was less than that in 1980, i.e. the rate of growth between these two years was negative. This may be due to the Gulf war, since in the first year of this war the Iranian air force was still active and strict limitations on lighting were observed in Iraqi cities.

28.5 per cent, 20.4 per cent, 14 per cent and 12.9 per cent of the total electric energy consumption of the ESCWA region in 1982 were consumed in Saudi Arabia, Egypt, Iraq and Kuwait respectively. In contrast, the remaining nine ESCWA countries consumed less than 25 per cent of the total consumption of the region during that year. As far as the per capita electric energy consumption is concerned, Kuwait is ranked the highest in the region with a figure of 7,800 kWh/capita; Bahrain followed with 5,544 kWh/capita; United Arab Emirates with 4,620 kWh/capita; and Saudi Arabia with 2,544 kWh/capita. The Yemen Arab Republic has the lowest per capita electric energy consumption (27 kWh/capita) in the region. The household sector is the major consumer in most of the ESCWA countries. In 1982 it consumed more than 81 per cent, 70 per cent, 49 and 46 per cent of the total electric energy consumption in Bahrain, the Yemen Arab Republic, Kuwait and Saudi Arabia respectively. However, the industrial sector was the major consumer in 1982 in Egypt (55.5 per cent) and Syria (41 per cent). Electric energy consumption in the industrial sector in Saudi Arabia and Jordan represents an appreciable portion (38 per cent and 32 per cent) of total consumption; however, it is still less than the consumption in the household sector. The figures for the sectorial consumption in Iraq were not available; otherwise, the industrial sector of Iraq could have appeared as a major consumer of electric energy in that country.

V. STANDARD VOLTAGES AND FREQUENCIES

The transmission and distribution of electric energy in the different ESCWA countries play an important role in any future co-operation in that field between those countries. The network configuration, the choice of the standard voltages on the different transmission and distribution levels and the value of the commercial frequency are considered as the determining factors when the feasibility of the interconnection between the electric networks of the different countries is investigated. The highest transmission voltage in the ESCWA region is that of the overhead line transmitting the power generated by the High Dam and Aswan Dam power plants in southern Egypt to a substation near Cairo at 500 kV level to be interconnected to the Egyptian national grid at 220 kV level. Other ESCWA countries are using (Iraq) or constructing (Syria and Jordan) systems at 400 kV. Saudi Arabia uses 380 kV in some of its five isolated networks, and Kuwait adopted the voltage of 300/215 kV as the standard HV for its network. The voltage 230/220 kV is currently used in many ESCWA countries (Egypt, Jordan, Saudi Arabia and United Arab Emirates), and it will soon be used in Bahrain. Networks of 132 kV are widespread all over the region in Egypt, Iraq, Jordan, Kuwait, Qatar, Saudi Arabia, the United Arab Emirates and the Yemen Arab Republic. The use of 115 kV and 110 kV is limited to some regions in Saudi Arabia. The situation for the standard high voltages is more unified in most of the ESCWA countries since most of the ESCWA countries adopted the 66 kV and the 33 kV as standard transmission voltage, with two exceptions where Saudi Arabia adopted the 69 kV as the higher transmission voltage and Syria adopted the 20 kV as the lower transmission voltage. With regard to the subtransmission voltage, the 11 kV is adopted in almost all ESCWA countries except Saudi Arabia where the 13.8 kV was adopted. Some countries in the region (Egypt, Jordan and Kuwait) use more than one subtransmission voltage, i.e. the voltages 6.6 kV and 3.3 kV are used in addition to the 11 kV. Two standard low distribution voltages are used in the ESCWA region, namely the 380/220 volt (Bahrain, Egypt, Iraq, Jordan, Saudi Arabia, Syria and the Yemen Arab Republic) and the 415/240 volt (Kuwait, Oman, the People's Democratic Republic of Yemen, Qatar, and the United Arab Emirates). In addition, the 220/127 standard voltage is used in some parts of Saudi Arabia.

The standard commercial frequency in all electric power systems of the region is 50 Hz, except in Saudi Arabia where the standard frequency is 60 Hz.

VI. ELECTRIC ENERGY PRICING

It is well known that the cost of generation depends on several factors such as capital investment in the power plant, fuel costs, operation and maintenance cost and the discount and interest rate on the capital investment. Therefore, the generation cost differs from one ESCWA country to the other. It ranges between $13/MWh in Egypt and $146/MWh in the Yemen Arab Republic. The low cost of generation in Egypt is due to the fact that more than 40 per cent of the energy generated is produced by hydropower with zero fuel cost, as well as to the fact that the hydropower plants were constructed during the 1950s and 1960s at a comparatively very low cost. In addition, the Egyptian Government heavily subsidizes the fuel sold to the Ministry of Electricity. In contrast, the cost of a generated unit of electric energy is the highest in the Yemen Arab Republic, where comparatively very small sizes of gas turbines and diesel engines are used as prime movers in the power plants. As mentioned before, the capital investment per installed kilowatt increases rapidly with the decrease of the size of the generating set, and also the fuel rates of smaller units are higher than those for larger units. Consequently, countries such as Oman, the People's Democratic Republic of Yemen, the United Arab Emirates and the Yemen Arab Republic which use relatively smaller units in their power plants suffer from the high cost of electric energy generation. The transmission costs depend to a great extent on the network size and configuration, the current loading on the low voltage distribution, the values of the transmission, subtransmission and distribution voltages, etc. It is worth mentioning that interconnection between electric networks of two or more ESCWA countries leads to an increase in the transmission costs.

Regarding the subsidies provided by the governments towards electric energy prices, it is quite clear that all ESCWA countries except Jordan are subsidizing electric energy. Each country has, of course, its own philosophy towards the issue of subsidy. Kuwait, Oman and the United Arab Emirates are the countries that heavily subsidize electric energy, while the Peopl's Democratic Republic of Yemen and Egypt provide the lowest subsidies. Jordan charges end-users the real cost of electricity, plus a certain amount which may cover administrative overhead or other expenses.

VII. GENERAL PROBLEMS OF CO-OPERATION WITH RESPECT TO ELECTRIC POWER NETWORKS

The co-operation with respect to electric power networks in the ESCWA region or in other words, the interconnection between the electric grids of the neighbouring ESCWA member States has its political and financial aspects, as well as its technical problems. The technical problems raised by co-operation in the ESCWA region include the varying conditions for the rational construction and operation of power stations; the different technical parameters of the existing electric power networks in particular the rated voltage and frequency used; power flux distribution; short circuit current levels; stability conditions; control strategy; reliability level; difference in current density and type offtake; the geographical distribution of areas with power surpluses or shortages; and, lastly, major or minor obstacles impeding the construction of transmission lines and substations.

The political aspects arise from the differences in the political, economic, social and geographic circumstances of the ESCWA member countries.

The financial problems arise from the fact that it is difficult to make an objective assessment of the overall advantages of co-operation, or to determine the benefits or disadvantages pertaining to individual countries.

The joint operation of electric power networks and the establishment of interconnection between networks involve the installation of equipment for use by several countries, and at the same time they affect the operation of national power systems. Hence it is necessary to assess objectively the share of individual countries both in the advantages and in the disadvantages of interconnection and, accordingly, to arrange for an appropriate system of economic compensation.

This is an extremely complicated task, not only because of the multiplicity of the factors involved but also because accurate calculations would call for an enormous number of input data, which may change at any moment.

Organizational difficulties also arise from the fact that the effects of joint operation are usually of a multilateral nature, therefore agreements should also be on subregional or regional levles.

CONCLUDING REMARKS

Talks about co-operation in electric power among the Arab countries, including the ESCWA member States, started in the mid sixties. However, after almost twenty years of meetings and discussions, very little has been achieved.

The meetings and discussions concentrated on the technical aspects of interconnection of electric power networks between neighbouring countries. However, it is believed that the main issue is primarily a political one and that techncial and economic problems can be resolved after the political issue is solved.

Once a political decision is taken to establish a unified electric grid at regional, subregional or even bilateral levels, the technical experts and economists could then meet together and take action towards implementing the decisions made by the politicians. A clear example of this is the activity undertaken in the Gulf Co-operation Council (GCC).

However, some concluding remarks related to the electric power situation in the ESCWA member States should be made. These remarks may be of some benefit to policy makers, when any decisions concerning the interconnection of electric power systems are to be taken. They will also be useful to the technical experts who may be assigned to undertake techno-economic pre-feasibility or feasibility studies for interconnection at regional or subregional levels.

These remarks include the following:

1. Some ESCWA countries have already established unified electric power grids covering all the territories of the countries. Others are in the process of establishing their unified grids and a third group of countries are still far from establishing a unified power networks.

2. The capacity of the power networks largely differ from country to country. It ranges from 140 MW up to 9375 MW. The capacity of the largest units also differ from one country to the other, and range from 50 MW to 400 MW.

3. The specifications and the standards of electric equipment, especially the larger equipment such as turbines, generators, etc., differ from country to country and also from one power plant to another in the same country and even from one unit to another in the same power plant.

It is also clear that about twenty suppliers from about thirteen countries including France, Japan, United Kingdom, United States, USSR, etc. are on the list of those who have both supplied and are contracted to supply power plants to countries in the ESCWA region.

4. The transmission voltages at the ultra high voltage level differ from one country to another in the ESCWA region (500 kV in Egypt, 400 kV in Iraq, 380 kV in Saudi Arabia, etc.). In addition, the operating frequency in

Saudi Arabia is 60 Hz, while it is 50 Hz in all other ESCWA member States. The differences in the transmission voltage and frequency add complications to interconnecting equipment between the different networks.

5. The cost of generation of a unit of energy differs greatly from one country to the other ($13/MWh up to $229/MWh) depending on the type of power plant, cost of labour, cost of fuel, etc. This should be carefully taken into consideration when undertaking techno-economic feasibility studies for interconnection on bilateral or multilateral basis.