UDC 621.311 **DOI:10.30724/1998-9903-2019-21-3-4-38-43**

ELECTRIC POWER SYSTEM OF YEMEN, ITS STRUCTURE AND CHARACTERISTICS

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Abstract: *In this article we analyze the energy system of the Republic of Yemen, its structure and characteristics of transmission lines, power stations and substations. We also consider the prospects for development of power system in the country.*

Keywords: *Yemen, power system, power stations, high voltage line, electricity consumption.*

For citation: Ali Y.S.S., Chichirova N.D. Electric power system of Yemen, its structure and characteristics. *Proceedings of the higher educational institutions. ENERGY SECTOR PROBLEMS*. 2019; 21(3-4):38-43. (In Russ). doi:10.30724/1998-9903-2019-21-3-4-38-43.

Introduction

The Republic of Yemen is located on the Arabian Peninsula. The population of the country is about 25 million people, 70% of them are engaged in agriculture.

The main industrial potential of the country is historically concentrated in the coastal zone. The natural zoning of the country is responsible for the established centralized power supply zones, which are represented by two regions:

- Northern and central, where 17.5 mln. people live (makes up to 75% of the population);
- Southern, population in which is 7.5 mln. people.

In 1990, only 48% of the population used electricity from a centralized network. At the same time, per capita electricity consumption was only 300 kW·h per year. For comparison, the average value in the countries of South-West Asia was 1000 kW·h.

About 3 mln. people lives on elevated plateaus and in mountainous areas, where autonomous sources of electricity and relatively small sections of the distribution network are used. The eastern part of the country is smooth and mastered to a lesser extent than the western one.

In Yemen, for one person employed in power industry, there were 200 that were employed in other sectors of industry or in the service sector. In other countries of the South-East Asia the indicated characteristics is 2 times less. Developmental delay of power industry decelerates evolution of the Republic as a whole.

On May 22, 1990, two Republics were joined in one, which forced unification of their power systems.

Nowadays, Yemen's unified power grid is a complex of power plants and networks, united by a general regime and a single centralized operational management, which is developed according to the state plan. The transition to this form of organization of electric power industry creates the prerequisites and possibilities for the most rational use of energy resources and increasing the economy and reliability of power supply of the national economy and the country's population.

As the scale of the Yemen power system expands, the tasks of managing its modes become more and more responsible and complex. The special significance of these tasks is determined by

the role of electric power industry in ensuring the normal activity of all sectors of the national economy, in improving the functioning of social structures and living conditions of the population. The increasing difficulties of management are caused by the large length of electric networks of the electric power system (EPS), extremely uneven distribution of energy resources and productive forces over the territory of the country, and complexity of structure of generating capacities and schemes of the system of generating networks. All this requires the use of modern economic and mathematical methods and computer equipment for advanced and operational management. Considerable work has been carried out in the field of theory and practice of managing regimes by the Yemen power engineers. Achievements in this area are the result of purposeful joint activities of research, design and operational organizations. The research results and the experience gained in operation not only make it possible to successfully solve current management tasks, but also form the basis for solving more complex problems associated with completion of the Yemen EPS formation. So over the past 5 years, the coefficient of consumers' electrification has increased up to 70%, and construction of new HV lines made it possible to increase the network capacity by 40% and to increase the area of centralized power supply. Nevertheless, due to the lack of investments in power industry, its work is characterized by a number of unfavorable indicators, such as the tense balance of active power due to the lack of generating capacity, which necessitates consumer constraints; the use of relatively low nominal voltages for transmission of electricity over considerable distances (over 100-150 km at a voltage of 132 kV); low voltage levels at large load sites due to significant reactive power deficits; uneven development of the northern and southern parts of the power system; the presence of weak links between the northern and southern parts of the power system; lack of reliability of the main switchgear of power plants and substations; use of power equipment from various manufacturers, etc. All this determines the need to ensure more reliable operation of power system and its elements at the expense of more modern and complex technical solutions for the schemes of switching gears of stations, according to the scheme of the power system, control of its normal and emergency modes, and anti-emergency automation.

Electrical stations and their characteristics

The basis of the existing integrated system consists of 3 large thermal power plants (TPPs) and one gas turbine unit (GTU) located in the cities of Al-Hodeidah (two stations), Aden (one station) and Marib (GTU). The other stations run on diesel fuel.

Prior to unification of the Republic, the power system (PS) of southern Yemen had only one large TPP (5x25 MW) of the Soviet production. The other stations are diesel, of low power. In the northern power system of Yemen, there were two TPPs of Italian production of 5x33 and 4x40 MW.

The other generating capacity was composed of diesel stations. Peaks of load in various parts of Yemen did not coincide in time during the year, and it was necessary to have a significant rotating reserve in both parts of the PS.

On May 22, 1990, the two republics were joined into one, the Republic of Yemen, which forced unification of their energy systems. The unification of Yemen was accompanied by an increase in production. New factories opened, new hotels were built, etc. This caused the need to build new stations. The unification of Yemen also caused construction of new power transmission lines (PTLs), which connected the two power systems to ensure the flow of power between them. However, this did not solve the problem of power supply of the capital of the republic - Sana. And two diesel stations with a total capacity of 130 MW were built. Characteristics of generating sources of the Republic of Yemen are given in the Table.

Table

General characteristics of power plants in Yemen

Name of station	Type	Type of fuel	Generator capacity, MW	Amount of generators	Installed capacity of station, MW
Hiswa	TPP	Mazut	25	5	125
Ras-Katheeb	TPP	Mazut	33	5	165
Al-Makha	TPP	Mazut	40	4	160
Al-Manswra	Diesel	Diesel fuel	8	8	64
Sana	Diesel	Diesel fuel	40	2	80
Kor-Maksar	Diesel	Diesel fuel	2/4	4/6	32
Marib (Safir)	GTU	Gas	115	3	345

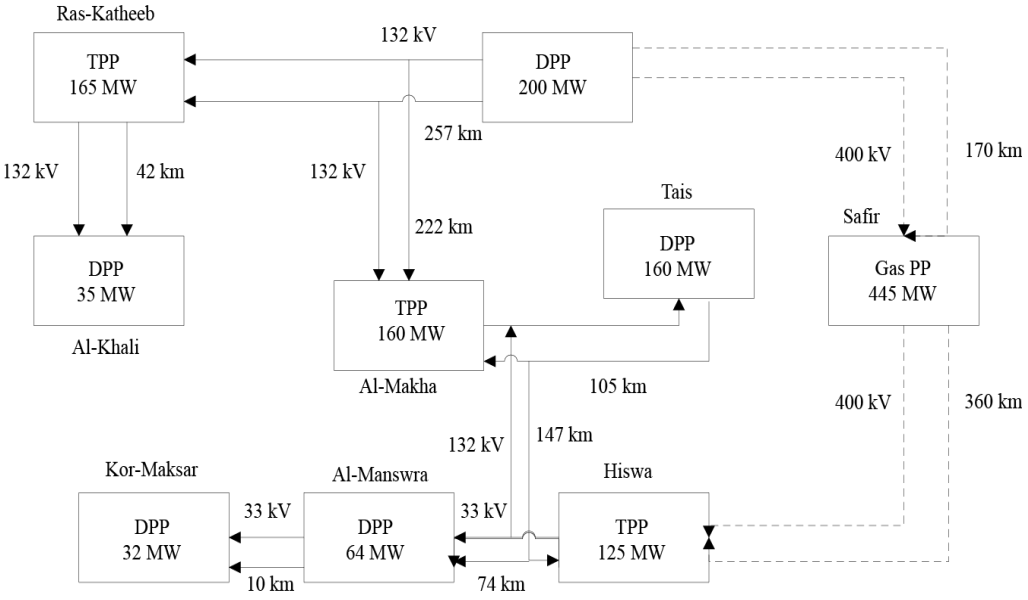

Fig. 1. Scheme of connections between power plants in Yemen.

Figure 1 presents a 400 kV double-circuit overhead line (OHL) (Safir - Sana and Safir - Hiswa) with a length of 170 km. To ensure operability, the power line is equipped with sequential and transverse control devices, which maintain the voltage at 400 kV (± 5%). Autotransformers of 400/132 kV and transformers of 132/33 kV are installed at the substations. Diesel generators are provided to reserve their own needs at substations.

Electricity consumers and their characteristics

In 1992, the implementation of the global program for electrification of the agricultural regions of the country was launched in Yemen. The project developed by the national energy company (*Office National de L'Electric ale, Casablanca*) provides electrification of 40 ths. settlements throughout the country by 2025. The program provides supply of electricity to many localities which do not have their own sources and development of the existing power supply system.

The possible scenarios for the projected increase in electricity consumption in the energy system of Yemen (ESY) until 2025 are shown in Fig. 2

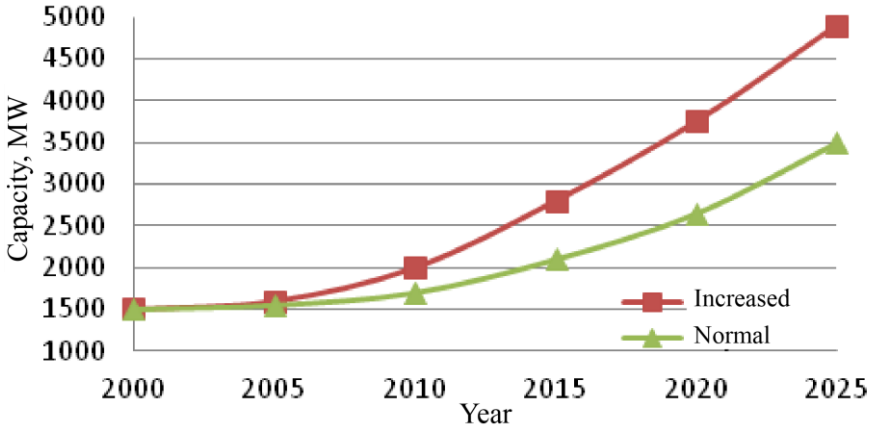

Fig. 2. Charts of the projected increase in power consumption in ESY.

The presented charts show that the power consumption in ESY will increase by 3–6 times by 2025.

This will ensure the growth of electricity consumption by the population, will provide an opportunity to solve a number of social problems and electrify agricultural production.

Prospects for development of electricity Yemen

Describing the evolution of electricity in Yemen, it can be noted that in 1990 only 48% of the population used electricity from a centralized network. The operation of the power system was characterized by a number of unfavorable indicators. The funds received for the payment of electricity do not provide repairs and recovery work, and investments for development of power industry are insignificant.

Along with a broad program of privatization of the electric power industry, the state retained its rights as the main regulatory body.

The main directions of reforming the country's electric power industry were as follows:

1. All issues related to operation and development of the generating complex are concentrated in individual state-owned companies.

2. Planning for the growth of demand for electricity is the responsibility of the established Committee on the Economy. Also it gathers data on generating power companies. It also provides them with raw materials for planning and subsequent development of the generating complex.

3. Monitoring of price indicators and preparation of materials for formation of financial policies.

4. Organization of the relevant department responsible for ensuring the quality of electricity in the power system and at consumers (voltage levels, frequency deviations, presence of harmonics, etc.).

All organizational and technical changes in electric power industry carried out in recent years in Yemen have yielded positive results. Thus, over the past 5 years, the coefficient of consumers' electrification rate has increased up to 70%, and construction of new OHL made it possible to ensure the growth of network capacity by 40% and increase the centralized power supply zone. At the same time, data on development of the electric power industry in the southern region indicates its significant lag behind the northern and central parts of the country. In order to meet the growing needs and, above all, the needs of mining industry in the southern region, it is necessary to increase the generating capacity, to build overhead lines and substations.

Conclusions

1. The basis of the existing unified power system is 4 large power plants located in the cities of Al-Hodeidah (two stations), Marib and Aden. A significant share of the installed capacity of the power system is autonomous operating diesel stations with a capacity of 2 to 8 MW.

2. Unification of two republics into one Republic of Yemen entailed the need to build new power lines, which connected the two power systems to ensure the flow of power between the power companies.
3. A specific feature of the Yemen's ES is predominance in the northern part of Yemen of the load in the form of heaters, used mainly in winter, as it is located in a mountainous region. In southern Yemen, the main share of load is made up of air conditioners and fans, mainly used in summer. Since the maxima of load in the north and south do not coincide in time, the power flows in the system are significant.
4. A feature of electrical equipment work and, above all, transformers, is high ambient temperature, which in the southern regions of the Republic can exceed 40 ° C.
5. The possibility of formation of significant power shortages in case of disconnection of communication lines in power system is obvious. The presence in the power system of a significant share of autonomously operating diesel stations, as well as the prospects for their inclusion in parallel operation with the power system of Yemen, requires the study of their frequency and power control systems. To conduct such studies, it is necessary to develop appropriate software, as well as to use modern methods for analyzing transient processes in various modes for various control systems and their tasks.

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Received ***December, 24 2018***