POWER SUPPLY SYSTEMS AND ELECTRICAL EQUIPMENT FOR DESALINATION PLANTS

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Contents

Summary

Experience gained over the last 30 years from working with 39 desalination plants of 9 different sizes and types, from 6 different manufacturers were considered. Various types and sizes of electrical equipment were utilized in these plants in accordance with pertinent industrial and technological developments, in addition to the on-site harsh climatic conditions. The salient features of various types of electrical systems in operation are discussed. They cover medium and low voltage switchgear, HV and LV motors, power transformers, different configurations of power supplies, load analysis

and short circuit calculations for the reliable verification of the selected electrical networks for desalination plants.

1. Introduction

Over the last 30 years a wealth of experience has been accumulated in the field of engineering and maintenance of desalination plants. Electrical power systems and equipment are very significant components of such complex facilities and contribute greatly to their input and output functions. Their development and augmentation, together with the application of power system analysis and modern computer technology, has greatly enhanced plant efficiency, reliability and safety.

As the total capacity and number of desalination plants gradually increased, many significant advances were made in the development of their power supply systems and electrical equipment. This paper presents a survey of the design and configurations of such systems as well as the specifications of the key components such as motors, transformers and the switchgear in practical use.
Examples of detailed power system analysis and calculations for the proper selection of the electrical equipment of the desalination plants are also presented.

2. Electrical System Network for Desalination Plants

Three electrical system configurations for the three types of desalination plants given in Table 1 representing different capacities and generations of plant development are discussed next.

Plant type	No. of distillers	Distiller capacity tons day^{-1}	Year commissioned
1	4	14415	1977
2	4	27360	1986
3	6	57600	1996

Table 1. Examples of different types of desalination plants.

(a) The electrical network shown in Figure 1, for plant type 1, is typical of the first desalination plants installed in the Middle East during the 1970s. It shows that:

- The desalination plant and station auxiliaries load are met with three voltage levels: 33, 6.6 and 3.3 kV. 6.6 kV system is mainly used for brine pump motors, waste heat boiler feed waters pumps and other plant large loads such as gas turbine (GT) starting motors.

- The 6.6 kV bus bars consists of three bus sections with 7.5 MVA transformers supplying each section. The system is designed in such a way that all three transformers can be operated in parallel with 50 per cent spare capacity and in case of tripping the other two transformers can take the total load.

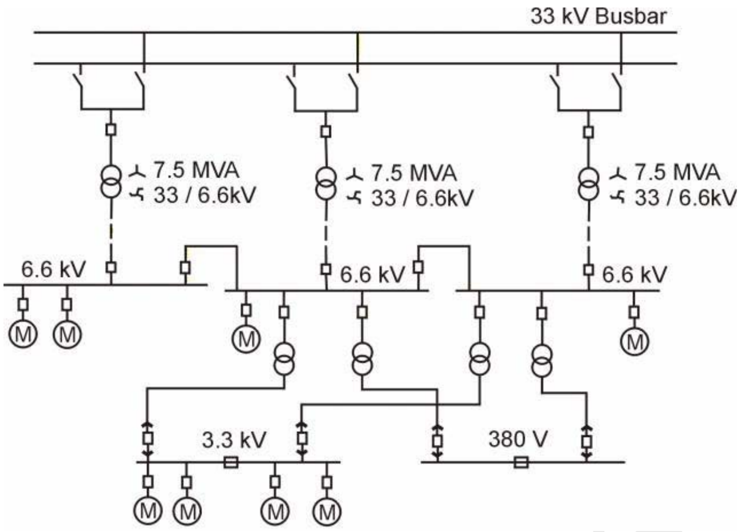

Figure 1. Example of electrical system for Type 1 desalination plants.

This system is extremely reliable but not very economical as the short circuit ratings of the bus bars and associated equipment must be high enough to sustain the short circuit current supplied by all three transformers.

(b) Type 2 desalination plants. The MV bus bar systems of the late 1980s Type 2 desalination plants were equipped with a quick transfer system. The auto transfer system has been used to advantage for obtaining uninterrupted supply for motors and other auxiliary equipment. This system transfers load from the first system to the second system with negligible dead time. The transfer system is equipped with electronic phase comparison relays, which provide for permanent measurement of the angle and frequency difference between the voltage of the regular supply and the supply to be connected. When any variation to the admissible limits are sensed by the transfer control device in the supply system an automatic transfer is initiated.

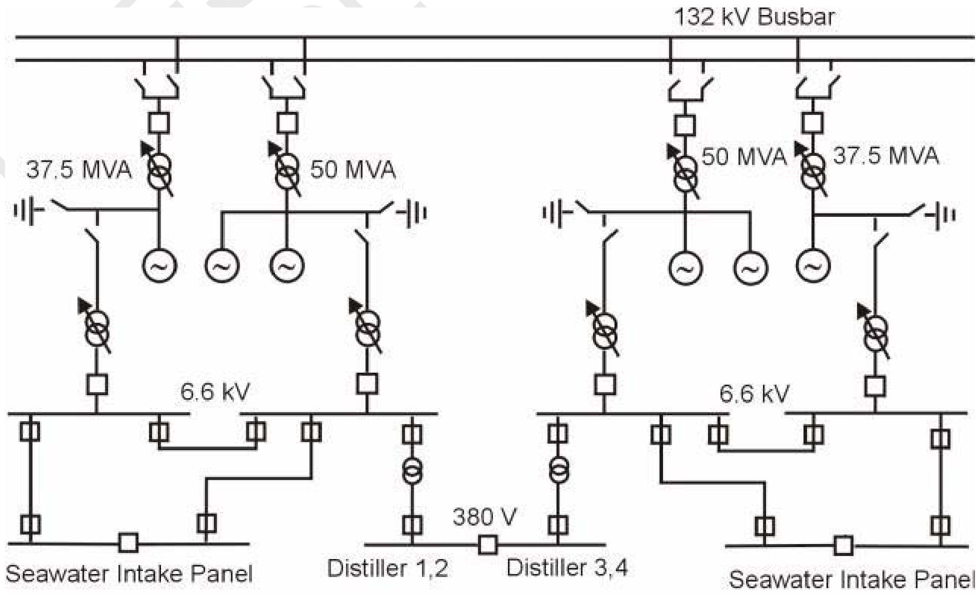

Figure 2. Example of electrical system for Type 2 desalination plants.

(c) Type 3 desalination plants. State of the art technology is represented in the design of the latest Type 3 desalination plants. Each distiller is required to have a varying production capacity ranging from 45 000 to 57 000 tons day^{-1} (10 to 12.5 MGD) of distillate depending upon the brine temperature. These are the largest single unit distillers in production so far in the world. The electrical system for the six units of this type have been arranged in the twin unit configuration, viz. units 1 and 2, units 3 and 4 and units 5 and 6.

The electric power for the desalination plants is supplied by three 132/11/11 kV 80/40/40 MVA transformers each with three windings (see Figure 3). Each transformer is provided with a tertiary delta connected compensating winding and equipped with on load tap changers.

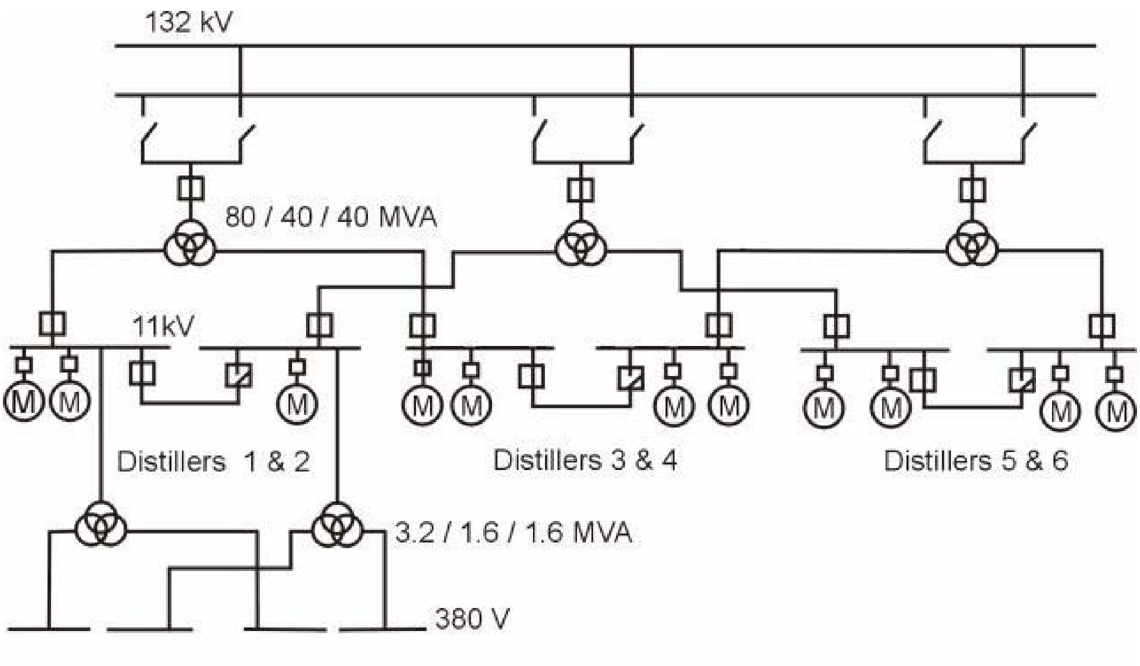

Figure 3. Example of electrical system for Type 3 desalination plants.

Due to the high current ratings of brine pump motors, sea water intake pump motors and other power plants pumps, the 11 kV system has been adopted for Type 3 desalination plants, instead of 6.6 kV as used in previous types. Double secondary windings served the purpose adequately, not only due to high capacity of the transformers (80 MVA) but they also provided the redundant supply to each group of bus bars.

Each transformer is sized at least for the following simultaneous load operations:

- Four distiller units under full load operation;
- All related common loads connected to the four 11 kV desalination switchboards.

The load and short circuit analysis shown in paragraphs 6.4 and 7.3 respectively applies to the electrical network of Type 3.

3. Medium Voltage Switchgears

The specification for the medium voltage (MV) switchgear bus bar system has also been gradually improved to achieve a system which not only has the least maintenance requirements but is also safe to operate, reliable and robust. Some of the salient features that have been incorporated in the specifications of the MV switchgear for the latest Type 3 desalination plants are as follows:

– The SF6 hermetically sealed metal chamber encapsulates all the life components and offers a high degree of protection against humidity contamination from corrosive gases, dust, moisture and rodents, for all the 11 kV switchgears .
– The MV switchgears and motor control panels are specified to be metal clad and completely enclosed with a class of enclosure protection of IP52 according to IEC298. The enclosure protection of IP52 is also maintained when the circuit breaker is in the test position. The cubicles, which are installed outside, are required to be of protection class of IP55 with sunshades if required.
– The floor openings under the cubicle panels desk are covered and/or sealed to be both fire- and vermin-proof. Individual switchgear panels are segregated into four compartments with metallic partitions:

- The circuit breaker compartment
- The bus bar compartment
- The control and monitoring compartment
- The power cable compartment

– The degree of protection of these zones is at least IP4X according to IEC298.
– MV system of Type 3 desalination plants are equipped with a system of detectors and auxiliary relays to protect the switchgears from any fire break out. The system consists of a pressure switch and an ionization smoke detector located in each compartment. The devices are arranged to cut off the electric supply to the faulty zone by tripping all the incoming supplies within 50 milli-seconds (ms).
– In addition each cable compartment is equipped with its own individual fixed fire protection system.

4. Circuit Breakers

As in other branches of industry, designers of desalination plant equipment take advantage of the latest technological developments and make use of advanced technology. The following table shows the various types of breaker technology that have been used in different desalination plants.

Plant type	Type of circuit breakers	Voltage	SC Rating
1	Minimum oil circuit breaker	6.6 kV	500 MVA
2	Vacuum contactor and air circuit breaker	6.6 kV	40 kA
3	SF6 type circuit breaker	11 kV	40 kA

Table 2. Circuit breakers at different desalination plants.

The use of vacuum and SF6 medium voltage circuit breakers has considerably reduced the level of maintenance and the number of spare parts required. The availability and dependability of the switchgears has also improved. Incidents of rupturing which were experienced with minimum oil circuit breakers and accidents resulting in human fatalities and the inadequacy of safety aspects in the switchgear have been eliminated by the use of SF6 type and vacuum type breakers thus enhancing the safety features which were incorporated in the specifications.

5. Induction Motors

The choice of squirrel cage induction motors with deep slots or double cage type has been adopted for the desalination plants. This design of motor develops high starting torque and low resistance while operating at rated conditions which reduces the running electrical losses and improves efficiency. A summary of the motor specifications implemented in desalination plants is given below.

5.1. Ratings

The service voltage of the motors are 11 kV, three-phase, 50 Hz for motors above 400 kW and up to 10 MW design; 6.6 kV, three-phase, 50 Hz for motors from 250 to 400 kW and 380 V, three-phase 50 Hz for motors below 250 kW. However for motors above 150 kW voltage drop calculations are performed to decide if the motor is to be connected directly to the 380 V supply, supplied through a MV/LV transformer or whether a star-delta starting system should be used. All motors are specified to be capable of operating continuously under the following conditions:

- At any frequency between 48 and 52 Hz;
- At any voltage variation between 90 per cent to 110 per cent of the nominal voltage;
- A transient over voltage of 130 per cent nominal voltage is also to be sustained;
- The pull out torque is specified to be 160 per cent of the rated motor torque.

5.2. Service Factor

The service factor is the ratio of the installed motor output to the required power output at the shaft of the driven machine at its expected maximum power demand. All motors are specified to operate at a 10 per cent excess of the pump's rated capacity.

Power demand	Service factor
Up to 1 kW	1.3
1 kW-10 kW	1.2
10 kW-50 kW	1.15
50 kW and above	1.1

5.3. Starting Current

AC motors are designed for direct on-line starting. The maximum starting current is not to exceed five times the rated current for MV motors (6.6 or 11 kV) and seven times the rated current for LV motors (380 volts).

5.5. Insulation Class

The insulation of all motors is specified to be class "F" according to IEC85 with class "B" temperature rise during the starting as well as at the steady state operation at full load. MV motors controlled by vacuum type switchgear are equipped with lightning arrestors for suppression of over voltages generated at switching operations. It is worth mentioning that all motors are specified to be totally enclosed fan cool type protection class IPW54 as minimum due to severe ambient conditions.

6. Load Analysis

6.1. General

In power systems, power flows from the generating centres to the load centres. In this process, many parameters require investigation, such as the profile of the bus voltages, flow of MW and MVAR in transmission lines, effect of rearranging circuits and installation of regulating devices, etc. for different loading conditions. Modern power systems have become so large and complex that these investigations should be done with some sort of simulation of the system. This simulation and subsequent assessment of power flow is commonly known as load flow analysis.

Load flow study thus aims at arriving at a steady state solution of complete power networks. Load flow study is done during the planning of a new system or the extension of an existing one. This is also needed to evaluate the effect of different loading conditions of a system and its elements.

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Bibliography and Suggestions for further study

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