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Electrical Power System Planning for Sudanese Network

تخطيط منظومة القوى الكهربائية للشبكة السودانية

A Project Submitted in Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) in Electrical Engineering

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الآية

بسم الله الرحمن الرحيم

﴿ إقْرَأْ بِإسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الإِنْسَانَ مِنْ عَلَقٍ (2) إقْرَأْ وَرَبُّكَ الأَكْرَمُ (3) الَّذِي عَلَّمَ
بِالْقَلَمِ (4) عَلَّمَ الإِنْسَانَ مَا لَمْ يَعْلَمْ (5) ﴾

صدق الله العظيم

سورة العلق: الايات (1-5)

DEDICATION

To my parents who cared for me,

my brothers,

and my sisters

with lots of love and fraternity.

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ABSTRACT

Continued growth in the industrial, agricultural and residential sector in the period and the recent stretch transport networks to reach new areas has led to increased consumption of electric makes it necessary to cope with the increase.

This research studies load forecast, generation, transmission, distribution and financial planning. It was chosen in the Sudanese Electricity Transmission Company (SETC), medium power system plan (2018 – 2020) as a case study.

After forecast loads of the above years and find out the stations that have been put excessive possible solutions to meet the expected load growth of the loads and it is real time solutions.

مستخلص

النمو المستمر في القطاع الصناعي ، الزراعي والسكني في الفترة الأخيرة وتمدد شبكات النقل لتصل إلي مناطق جديدة أدي إلي زيادة الاستهلاك الكهربي لذلك لابد من مواجهة الزيادة.

هذا البحث دراسة عن توقع الأحمال الكهربائية ، و التخطيط للتوليد ، و خطوط النقل والتوزيع والتخطيط المالي , حيث تم اختيار الخطة المتوسطة للشركة السودانية لنقل الكهرباء كحالة للدراسة في الفترة (2018-2020) م.

بعد إجراء توقعات الأحمال للسنين أعلاه و معرفة المحطات التي بها تحميل زائد تم وضع الحلول الممكنة لمقابلة النمو المتوقع في الحمل وهي عبارة عن حلول آنية.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 General Concepts

Planning is one of the most important functions of the management of any business. Without planning the future prospects of the company/organization will be unknown and therefore the possibility of success will be doubtful. Prudent planning practices will always lead to taking appropriate decisions. Planning covers the period from the inception of an idea, project, or activity, up to the business-as-usual of an ongoing business [1]. The aim of planning electrical power systems is to fully serve the interests of the consumers to be supplied with electricity. The active and reactive power of the supply area to be expected in the long-range planning period are taken as basic parameters. In order to determine the configuration of power system in terms of technical, operational, economic, legal and ecological criteria, planning principles have to be defined and used. High priority is to be given to the supply of consumers with a defined need for supply reliability, which can be accomplished if sufficient data are available on system disturbances (faults, scheduled and unscheduled outages) or by means of quantitative and if necessary additional qualitative criteria. The reliability of the electrical power supply system (power station, transmission and distribution system, switchgear, etc.) is influenced by:

• The fundamental structure of the power system configuration (topology) Example: The consumer is supplied only via one line (overhead line or cable) forming a radial supply system. In case of failure of the line, the supply is interrupted until the line is repaired.

• The selection of equipment

Qualified and detailed specification and tendering of any equipment, consistent use of international norms for testing and standardization of equipment guarantee high-quality installations at favorable costs on an economic basis.

• The operational mode of the power system The desired reliability of supply can be guaranteed only if the power system is operated under the conditions for which it was planned.

• Earthing of neutral point A single-phase fault with earth connection (ground fault) in a system with resonance earthing does not lead to a disconnection of the equipment, whereas a single-phase earth fault in a system with low impedance neutral grounding (short-circuit) leads to a disconnection of the faulted equipment and in some cases to interruption of supply.

• Qualification of employees

Apart from good engineering qualifications, continuing operational training of personnel obviously lead to an increase of employees' competence and through this to an increase of supply reliability.

• Regular maintenance

Regular and preventive maintenance according to specified criteria is important to preserve the availability of equipment.

• Uniformity of planning, design and operation Operational experience must be included in the planning of power systems and in the specification of the equipment.

• Safety standards for operation The low safety factor for "human failure" can be improved by automation and implementation of safety standards, thus improving the supply reliability [2]. Nowadays, power system is complex, interconnected and vary in sizes and configurations. A large amount of electrical energy is generated in thermal, hydroelectric, nuclear and gas power stations, also called conventional electric energy sources. Some amount of electricity is generated through nonconventional sources of energy. This power is also called green power as it emits less pollution. Generated electric power is transmitted to the load centers through power supply network consisting of transmission lines, transformers and switchgears. Transmission networks are commonly classified into four parts: Transmission system, sub-transmission system, primary distribution system and secondary distribution system. The main purpose of transmission system is to connect all major generating stations and load centers in the system without supplying any consumers enroot. The generating voltages are normally between 11 KV and 33 KV due to technical problems such as heating and insulation problem are stepped up with help of generating transformers to connect the and generators and the transmission lines. The generating and transmission systems are often called bulk supply system. The interconnected transmission system of a state or a region is called the grid of state or region. State grids are interconnected with the help of tie lines and form the regional grid [3].

1.2 Problem Statement

Continued growth in the industrial, agricultural and residential sector in the period and the recent stretch transport networks to reach new areas and the increase of quantity and quality in the use of electrical devices has led to increased consumption of electric makes it necessary to cope with the increase by forecasting loads in this period.

1.3 Objectives

- To be acquainted with the main concept of short term and long term planning.
- To understand the load forecasting methodology.
- To be acquainted with the categories of electric energy consumers.

- To be able to evaluate power system generation, transmission, distribution reliability.
- To understand the assessment methods of power costs.
- To be able to perform generation and transmission planning.

1.4 Methodology

The method used in this study is a statistical method (least squares technique, exponential method), collecting data by visiting the Sudanese National Corporation of Electricity (NCE). Also we use academic papers and references.

1.5 Project Layout

This research consists of five chapters as follows: Chapter one: this chapter involves general concepts as an introduction to power system planning, planning tools and planning criteria. Chapter two: contains energy and its types, electrical load and its types and characteristics, load forecast, generation planning, generation load forecast, relationship between capacity reserves and reliability, transmission system planning, distribution system planning, impact of high penetration solar PV on power system planning, and impact of variable renewable energy generation. Chapter three: is related to financial planning witch study the techno-economic viability, private participation, financial analysis, economic analysis, economic characteristics, rural electrification investment, credit risk assessment, optimum investment model and tariffs. Chapter four: this chapter include calculating of load forecast, generation and transmission planning for the years (2018 -2020). Chapter five: conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Importance of Electrical Energy

Energy may be needed as heat, as light, as motive power etc. The present day advancement in science and technology has made it possible to convert electrical energy into any desired form. This has given electrical energy a place of pride in the modern world. The survival of industrial undertakings and our social structures depends primarily upon low cost and uninterrupted supply of electrical energy. In fact, the advancement of a country is measured in terms of per capita consumption of electrical energy [7].

2.2 Resources of Energy

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy.

Energy is consumed by humans for everyday use and for their race survival, and exists in various forms, including mechanical, thermal, chemical, electrical, radiant, and atomic and are all interconvertible. The resources of energy on earth are classified as renewable and nonrenewable. These include chemical reactions (mainly combustion), nuclear reactions (fission), the effect of gravity (mainly hydraulic) and direct (photovoltaic) and indirect (photosynthesis and wind) solar energy conversion.

2.2.1 Renewable energy

A RE Resource (RES) can be replaced in nature at the same rate of consumption, while a nonrenewable resource exists in a fixed amount, or is used up faster than it can be replaced in nature. Our demand for, and use of, resources sometimes exceeds the supply that is available. In general, RE usually comes from sources that are naturally replenish such as sunlight, wind, geothermal heat, etc.

however, new renewable sources are developed that include: small hydro, modern bio-mass, wind, solar, geothermal, and bio-fuels. The concept of renewability is based upon the scale of human events and if the source can be replaced during that period. For instance, wood is a renewable bio-mass energy source as long as adequate conditions are kept for reserves to be replenished. Rates of exploitation / deforestation in a number of areas are so high that bio-mass may be considered as a non-renewable source in those circumstances [2].

2.2.2 Non-renewable energy

The main nonrenewable energies are:

- Water: when water is stored at a suitable place, it possesses potential energy because of the head created. This water energy can be converted into mechanical energy with the help of water turbines. The water turbine drives the alternator which converts mechanical energy into electrical energy. This method of generation of electrical energy has become very popular because it has low production and maintenance costs.

- Fuels: the main sources of energy are fuels *viz.*, solid fuel as coal, liquid fuel as oil and gas fuel as natural gas. The heat energy of these fuels is converted into mechanical energy by suitable prime movers such as steam engines, steam turbines, internal combustion engines etc. The prime mover drives the alternator which converts mechanical energy into electrical energy. Although fuels continue to enjoy the place of chief source for the generation of electrical energy, yet their reserves are diminishing day by day. Therefore, the present trend is to harness water power which is more or less a permanent source of power.

- Nuclear energy: towards the end of Second World War, it was discovered that large amount of heat energy is liberated by the *fission* of uranium and other fissionable materials. It is estimated that heat produced by 1 kg of nuclear fuel is equal to that produced by 4500 tons of coal. The heat produced due to nuclear fission can be utilized to raise steam with suitable arrangements. The steam can run the steam turbine which in turn can drive the alternator to produce electrical energy. However, there are some difficulties in the use of nuclear energy [7].

2.3 Electrical Load

An electrical load is an electrical component or portion of a circuit that consumes electric power. This is opposed to a power source, such as a battery or generator, which produces power. In electric power circuits examples of loads are appliances and lights. The term may also refer to the power consumed by a circuit. The term is used more broadly in electronics for a device connected to a signal source, whether or not it consumes power. If an electric circuit has an output port, a pair of terminals that produces an electrical signal, the circuit connected to this terminal (or its input impedance) is the load.

Load affects the performance of circuits with respect to output voltages or currents, such as in sensors, voltage sources, and amplifiers. Mains power outlets provide an easy example: they supply power at constant voltage, with electrical appliances connected to the power circuit collectively making up the load. When a high-power appliance switches on, it dramatically reduces the load impedance. If the load impedance is not very much higher than the power supply impedance, the voltages will drop. In a domestic environment, switching on a heating appliance may cause incandescent lights to dim noticeably.

2.4 Types of Loads

A device which taps electrical energy from the electric power system is called a load on the system. The load may be resistive (*e.g.,* electric lamp), inductive (*e.g.,* induction motor), capacitive or some combination of them. The various types of loads on the power system are:

2.4.1 Domestic load

Domestic load consists of lights, fans, refrigerators, heaters, television, small motors for pumping water etc. Most of the residential load occurs only for some hours during the day (*i.e.*, 24 hours) *e.g.*, lighting load occurs during night time and domestic appliance load occurs for only a few hours. For this reason, the load factor is low (10% to 12%).

2.4.2 Commercial load

Commercial load consists of lighting for shops, fans and electric appliances used in restaurants etc. This class of load occurs for more hours during the day as compared to the domestic load. The commercial load has seasonal variations due to the extensive use of air conditioners and space heaters.

2.4.3 Industrial load

Industrial load consists of load demand by industries. The magnitude of industrial load depends upon the type of industry. Thus small scale industry requires load up to 25 kW, medium scale industry between 25kW and 100 kW and large-scale industry requires load above 500 kW. Industrial loads are generally not weather dependent.

2.4.4 Municipal load

Municipal load consists of street lighting, power required for water supply and drainage purposes. Street lighting load is practically constant throughout the hours of the night. For water supply, water is pumped to overhead tanks by pumps driven by electric motors. Pumping is carried out during the off-peak period, usually occurring during the night. This helps to improve the load factor of the power system.

2.4.5 Irrigation load

This type of load is the electric power needed for pumps driven by motors to supply water to fields. Generally, this type of load is supplied for 12 hours during night.

2.4.6 Traction load

This type of load includes tram cars, trolley buses, railways etc. This class of load has wide variation. During the morning hour, it reaches peak value because people have to go to their work place. After morning hours, the load starts decreasing and again rises during evening since the people start coming to their homes [9].

2.5 Load Characteristics

The load on a power station is never constant; it varies from time to time. These load variations during the whole day (i.e., 24 hours) are recorded half-hourly or hourly and are plotted against time on the graph. The curve thus obtained is known as daily load curve as it shows the variations of load time during the day. The variable load problem has introduced the following terms and factors in power plant engineering:

2.5.1 Connected load

It is the sum of continuous ratings of all the equipment's connected to supply system.

2.5.2 Maximum demand

It is the greatest demand of load on the power station during a given period.

2.5.3 Demand factor

It is the ratio of maximum demand on the power station to its connected load.

2.5.4 Average load

The average of loads occurring on the power station in a given period (day or month or year) is known as average load or average demand.

2.5.5 Load factor

The ratio of average load to the maximum demand during a given period is known as load factor.

2.5.6 Diversity factor

The ratio of the sum of individual maximum demands to the maximum demand on power station is known as diversity factor.

2.5.7 Plant capacity factor

It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period.

2.5.8 Plant use factor

It is ratio of KWH generated to the product of plant capacity and the number of hours for which the plant was in operation [7].

2.6 Power System Planning

Power system planning is a process in which the aim is to decide on new as well as upgrading existing system element to adequately satisfy the loads for a foreseen future. In Sudan, power system planning has become more difficult, but more important to provide the necessary information to enable decision to be made today about many years in the future. In this study, we will consider power system planning where it is necessary to treat the system as a whole and choose the part in the system so that they give the required technical performance and are also economically justified. Under such a situation, the effort will be to make the system economical and not only one particular part of the system such as generation, transmission or distribution. This framework should be flexible, not rigid with broad objectives of finding a plan which guarantees a desired degree of a continuous, reliable and least cost service. Good service or, in other words, acceptable reliability level of power system usually requires additions of more generating capacity to meet the expected increase in future electrical demands. However, In Sudan with vast, separately populated areas reliability–cost tradeoffs exist between satisfying the fast load growth by investment in additional generating capacity for isolated systems or building transmission networks to interconnect these systems and transfer power between their load centers in case of emergencies and power shortages. Therefore, reliability and cost constraints are major considerations in power system planning process [4]. Power system planning is done to ensure adequate and reliable power supply to meet the estimated load demand in both near and distant future. This must be done at minimum possible cost keeping the quality of supply satisfactory. Power system planning is needed to develop and build modern electric power systems. In general, planning time horizons lie in one of the following ranges:

1. short term (up to 1 year).

2. medium term (up to 2-3 years).

3. long term or strategic planning (between 20-30 years).

The power system planning process starts by forecasting the anticipated future loads [5]. The concern is about load (demand) forecasting and energy forecasting. Load (demand) forecasting defines the capacity needed for the system and the expansions required in the generation, transmission, and distribution systems. Moreover, load forecasting is needed for budgeting purposes and energy forecast is needed to determine future type of generating units and fuel requirements. This is usually performed at different levels including the customer (KWH), the city (MWH), and the country (GWH). Generation planning leads to determining the capacity of units to be installed that will meet the anticipated load demand. It also defines the fuel to be used in addition to the size of units to be installed over the time span. The planning should be conducted to satisfy well-defined criteria that reflect the strategies adopted within the power industry, and contributes in enhancing the security, quality, and reliability of supply at minimum cost. Transmission and Distribution (T&D) system planning objective, whether a short-term plan, targets developing a deep understanding of the existing system and prepare a roadmap for near term and future investments required to provide services that are adequate, reliable, and economical to new and existing customers. It should be obvious that it is very important to make as accurate forecasts as possible in terms of peak loads and energy demands, as this will affect the selection of generation, transmission, and distribution expansions required, in addition of defining the type of fuel to be selected which is reflected on the final electricity prices [2].

2.7 Traditional Power System Planning

Traditionally, power system planning has been mainly related to generation expansion planning. This is due mainly to the fact that the investment in transmission lines is a relatively small fraction of the investment in the construction of power stations and that investment in the distribution of electric energy to customers, although sizeable, is to a large extent independent of the generation and transmission system [5].

2.8 Power System Planning Today

In general, the definition of an electric power system includes a generating, a transmission, and a distribution system. In the past, the distribution system, on a national average, was estimated to be roughly equal in capital investment to the generation facilities, and together they represented over 80% of the total system investment. Today, most power systems are facing drastic challenges such as, the integration of large-scale renewable and distributed power generation, the introduction of smart grid technologies, an increasing degree of automation, faster and more detailed communications, and demand growing faster than capacity [6].

2.9 Planning in The Future

When planning for the future, the main characteristics of the present system should be studied and data collected, e.g. electrical energy demand and peak load demand, rate of growth of energy consumption in the last 20 years, energy production, type of generation plant and its size, transmission, interconnection and sub transmission systems [6].

2.10 Planning Tools

There are many tools of planning:

● Planning engineer's primary requirement is to give power supply to consumers in a reliable manner at a minimum cost with due flexibility for future expansion.

● The criteria and constraints in planning an energy system are reliability, environmental economics, electricity pricing, financial constraints, society impacts.

● reliability, environmental, economic and financial constraints can be quantified. Social effects are evaluated qualitatively.

● The system must be optimal over a period of time from day of operation to the lifetime.

● Various computer programs are available and are used for fast screening of alternative plans with respect to technical, environmental and economic constraints [6]. The main steps in power system planning may be summarized as follows:

- Study of the electric load forecast 5 to 30 years into the future, based on the most reliable information.

- Evaluation of the energy resources available in the future for electricity generation and the foreseeable trends in technical and economic developments.

- Evaluation of the economic and technical characteristics of the existing system of generating units and of the plants that are considered as potential units for system expansion. These characteristics include capital investment cost, fuel cost, operation and maintenance costs, efficiencies, construction times, etc.

- Determination of technical and cost characteristics of the plants available for expansion.

- Determination of the economic and technical parameters affecting decisions such as discount rate, level or reliability required from the generating system, etc.

- Choice of a procedure to determine the optimal expansion strategy within the imposed constraints.

- Qualitative review of the results to estimate the viability of the proposed solution. The determination of most of these data must take into account the present and future economic and technical environment within which the electric sector is expected to operate [2].

2.11 Planning Criteria

Planning criteria, in general, constitute a set of decision parameters or design variables with which the planner controls the planning scenarios. These criteria are similar to guiding principles and limitations placed on the scenarios for the purpose of narrowing down the selection process. Usually these criteria are defined and set by consensus after careful studies and analyses. Previous practices and experiences shape and form such planning criteria. However, they need to be revised every now and then in order to reflect changes in the power system, demand structures, and degree of acceptable risk. Moreover, planning criteria represent boundary conditions that serve to eliminate unfeasible solutions and keep only the feasible ones. Therefore, they are needed in expansion studies of power systems to guarantee that the scenarios selected are all acceptable by the planners. Close coordination and continuous dialogue among power companies (generation, transmission, and distribution) are strongly recommended for proper planning in order to meet consumers' demands and satisfaction. Usually planning criteria are set by management, although some input from planners is needed [2].

2.12 Traditional Practices in Power System Planning

Traditional electric power systems are designed on the premise of power production in central generating stations and its delivery to the points of end use via transmission and distribution systems. The role of generating stations is clear, they produce electric power or, more precisely, convert energy from another source into electric energy. The roles of transmission and distribution systems are more interrelated; both are concerned with power delivery, so additional clarification might be helpful. The role of transmission systems is to interconnect many generators and loads across entire regions and over state and country boundaries. Transmission systems enable the transfer of power over long distances, and thus facilitate economic and system benefits. They are designed and operated to optimize the use of the generation portfolio. They make it possible to supply loads from the most economical sources of power and to operate generating stations flexibly, allowing for optimization of their maintenance schedules and improved overall system reliability. Conversely, distribution systems are the part of electric delivery infrastructure that brings the power to the loads; they "touch" the load. The interface point between the transmission and a distribution system is a (distribution) substation. A distribution system usually includes the substation and all other infrastructure between the substation and the load, including primary circuits (feeders and laterals), service transformers, secondary circuits, and customers' meters. Generally, distribution systems are designed for unidirectional power flow from the substation to end-use loads, and it is implicitly assumed that there is a sufficient supply of power from the transmission system (at the high-voltage side of the substation) [9].

2.13 Generation Planning

When the planning requirements have been determined, the next problem is to determine the type and size of generation station that will be required to supply power and energy. The selection of a site for the location of the generating stations depends on many factors including the cost of transmitting the energy to the consumers, of transporting fuel to the stations, the viability of sound foundations, the cost of land, the availability of cooling after and the avoidance of atmospheric pollution. Steam station should be located at the coal pits or as near the coal as possible to avoid transport cost and time of transport. For most economical distribution and the lowest cost of power and energy, the power station should be located at the center of gravity of load, if a suitable site is available. There is a trend for in the size of generator unit to be used in large power systems. This reduces the cost per kw and improves the efficiency of the station. Careful choice should be made of the composition and characteristics of the generation plant and it should be possible to continue studies every time a new event occurs such as energy crisis which may affect the conclusions reached. The choice of sitting new thermal and unclear plants is studies as optimization problem using linear programing. The points considered are costs of production,

transport and interaction with the environment to the minimum [4].

2.14 Generation Load Forecasting

Total system load generally is well known and a wealth of historic data is available. In the short term, load can be forecast with great accuracy, and this is performed daily to determine generation units' commitment. Load forecasting for the purpose of generation planning, however, requires a substantially longer time horizon, because system expansion projects require long lead times, often between 2 and 10 years.

The outputs from a load forecast are a forecast of annual energy sales (in kilowatt-hours), and the annual peak demand (in kilowatts). There are two widely used methods in energy sales forecasting: econometric regression analysis, and end-use electricity models.

The usefulness of each method depends on data availability, customer segmentation, and the degree of detail required. Generally, the accuracy of predictions depends on the accuracy of assumptions, and the predictions can't be made with absolute certainty end-use electricity models are physical, engineering-based methods that often are used in forecasting the residential load, and sometimes for commercial and industrial loads forecasting the peak demand is done based on forecasted energy sales by multiplying forecasted energy with an empirically determined load factor coefficient. Peak load is extremely sensitive to weather, and both the historic data and the forecast must be adjusted consistently to normalize them relative to the weather. After this baseline prediction is made it is adjusted based on the sensitivity to weather and the peak load is then predicted with the desired degree of confidence. To illustrate the consideration of weather effects, suppose that a baseline prediction is made that a system will have a future peak load demand of 10 gigawatt's (GW) for an expected daily high (temperature) of 77° F. Let us further suppose that the daily high conforms to a normal distribution with a standard deviation of 3°F, and that the historically observed correlation between temperature and peak load is 300 megawatts (MW)/°F. It can then be concluded with 95% confidence that the peak load will be below 11.8 GW; 95% confidence corresponds to two standard deviations away from the mean, and this further corresponds to 6°F and 1800 MW of additional load. Note that this example is intentionally oversimplified; several other factors influence peak load, including wet bulb temperature (to account for humidity), wind speed, solar intensity, weather conditions over the past two days (thermal buildup effect), time of day, and time of year.

Peak load forecasting is important because it directly influences the required generation capacity on every day of the year there must be enough available generation to feed the peak load [4].

2.15 Relationship Between Capacity Reserves and Reliability

Generating stations require regular maintenance, which means that during some periods of the year they are not available to serve the load. The stations also can be out of service due to unforeseen equipment failures; these outages, called forced outages, also contribute to reduced availability. Assuming that maintenance requirements are known, and that forced outages can be characterized by probability, a natural question arising is, what is the appropriate capacity of generation for a given load forecast. Appropriate in this context is directly tied to reliability of service, and it then follows that we need to find a mapping between capacity and service reliability or, more precisely, between capacity margins and service reliability. Capacity margin is a better measure of reliability because it represents the difference between capacity and peak load (capacity alone is meaningless) [4].

2.16 Transmission System Planning

The major transmission requirements of a power system and their associated cost are much influenced by the location of future generation capacity. The object of transmission planning is to select the most desirable transmission network for each of the generation expansion patterns under consideration. Both economics and reliability are considered in the problem. The application of a digital computer in automated transmission planning allows the system planner to consider and investigate many alternatives quickly. The ultimate selection of generation expansion plan is ten done by considering transmission planning allows the system planner to consider and investigate many alternatives quickly. The ultimate selection of generation expansion plan is then done by considering transmission as an integral part of the total cost.

A basic problem in transmission line planning is the determination of transmission adequacy under the forced outage of various systems components. A more consistent approach to transmission planning would be to consider the reliability. The investment in transmission improvement is made the desired location in the system, in terms of an acceptable risk level at the loading point.

The transmission system planned to satisfy the bus voltage and line loadings under normal operating condition may be adequate only if high risk level is acceptable. The cost of transmission improvements increase as higher reliability levels are expected. The use of quantitative reliability criterion facilities optimum utilization of the investments in transmission improvements [4].

2.17 Distribution System Planning

Since the system variable are quite complex, it is necessary to make a thorough analysis while planning distribution system. The problem to be studied in the total system environment for the purpose are (a) selection of most economical combination of sub-transmission and distribution voltage levels, (b) determination of the economical sizes of substations, and (c) combination of different methods of regulating voltage. Some of the important factors that should be considered are the actual geographical distribution of lads, configuration of the existing system, step by step expansion of the distribution system with time, and load growth and comparative reliability of the various arrangement [4].

2.18 Impact of High-Penetration Solar PV on Power System Planning

Defining penetration by energy quantifies energy supplied to the system from renewable sources of interest, and such a definition relates directly to displaced fossil generation and the associated savings in fuel consumption and lowered emissions. The energy-based definition is very useful in consideration of large systems and is used in many Renewable Portfolio Standards. The inherent complication of using this definition is that it implicitly depends on the quality of a resource. To achieve equal penetration, more equipment is needed in regions with lower insolation, so the same level of penetration can result in different underlying circuit behavior when evaluated in different regions, depending purely on the quality of the resource. A power-based definition provides for a more consistent relationship between penetration and circuits' problems—it is defined as nameplate capacity of intermittent generation (installed in a circuit or system) divided by the peak load (of that circuit or system) [9].

2.19 Impact of Variable Renewable Energy Generation

The variability of renewable energy sources is a key challenge associated with their integration into the power system. Generation planners think in terms of peak load and generation capacity—at any time, they must have enough available capacity to serve the peak load. To illustrate the notion of availability, compare a 200-MW thermal power plant with a 200-MW wind farm. Assuming a 6% outage rate, a thermal power plant generally can provide its full 200 MW during 94% of considered hours, whereas a 200-MW wind farm might be anywhere between zero and 200 MW depending on the available wind.

The uncertainty associated with renewable generation variability adds complexity to the planning process, and generally results in more demanding operation of the balance of generation portfolio. Non-renewable generators now have to maneuver more in order to accommodate the variability of renewable sources. This increases the operating costs per unit of energy from thermal generation but it also results in lower overall thermal generation and, thus, lower cumulative fuel usage, lower cumulative fuel costs, and lower emissions. These beneficial effects are the exact reasons for the industry's move towards using renewable energy, but this is of little value to the owners of thermal plants whose operating costs per unit of produced energy become higher [9].

CHAPTER THREE

FINANCIAL PLANNING

3.1 Economic Planning History

A major attribute of planning in all most all endeavor is reduction of cost. Criteria on service quality and standard must be met and guide lines must be followed but within those limits the planner's goal is to minimize the cost. Every alternative plan contains or implies certain costs: equipment, maintenance, losses, and many others as installation, labor operating well. Alternatives vary not only in the total cost, but often, equally, important, when the costs are incurred (how much must be spent now, and how much later).

Traditionally electrical utilities have been given a monopoly franchise for electric services in a region, which carried with it both an obligation to serve and a requirement to work with in a regulated price, structure. Regulated price are based on cost and regulated utility planning on cost minimization. The utility can expect to make reasonable return on its investment and recover all its costs, but it must work to reduce its costs as much as possible [10].

The capital structure of the electricity boards is built up with loans from the state governments, financial institutions like banks, and market borrowing They are also expected to generate internal resources from their statutory earnings after meeting the liabilities of operating expenditure, interest on loans, capital and depreciation. Financial planning ensures the availability of right amount of finances at the right time at lowest cost. The capital finance debt and or equity is required for fixed capital long term) for land building machinery materials, construction etc. and working capital (short term) for raw material such as fuel for two months etc. Working capital has highest interest rates. Competitive financial markets are emerging. The innovative approach by various financial institutions has made funding a complicated process. The broad options are:

- Issue of bonds by the central corporations, electricity boards.
- Internal resources generation by utilities.
- Subscriptions of shares debentures from public.
- Loans from power finance corporations.
- Promoter's money.
- State plan resources for state electricity boards.
- New budgetary support from the government.
- Joint ventures between public and private sectors.
- Bilateral assistance on selective basis in terms of grant, equity and loans
- Multilateral assistance from world bank in terms of grant, equity and loans.
- Loans or equity from financial institutions.
- Loans from specialized corporations.
- Lease financing to power utilities [6].

3.2 Techno-Economic Viability

One of the basic objectives of the power project report is to determine techno-economic viability for the project identified and also to obtain the investment for construction of generation plants and interconnecting links which ensures an economic and reliable supply. Analytical tools used should be capable of assessing the options for both capacity and transmission linkage expansion and distribution in an integrated fashion to achieve an optimal solution for the future evolution of the system. The project must be clear from the point of regulatory clearances before seeking finance from investment agencies For example the main choices confronting the system planner in case of thermal power are the question of optimal unit size and generation reliability, the location transportation network for coal and extension to higher voltage level of transmission grid For purpose of investment planning it then becomes important to examine the trade-offs between the efficiency of capital allocations to different transport nodes and locations e.g. .rail versus barge and coastal setting, in the context of transmission network additions [11].

3.3 Private Sector Participation

Private power projects are important as a part of country's investment resources raising and least cost expansion plan for the supply of electricity. The private sectors may be generating companies, transmission or distribution companies. Another advantage of private sector participation is that it opens up new work and management skills for timely execution of the project and delivery of quality in work and service. The public sector and private sector power utilities have different financial structures. Various private sector options like turnkey contract. BOOT, BOO, BOL, ROL etc. BOO (Build-Own-Operate), BOOT (Build-Own-Operate-Transfer) are the most common schemes for new projects. ROL (Rehabilitate-Own-Lease) are common for old plants and BOM (Build-Own-Maintenance) for new transmission lines. Privatization improves efficiency and productivity of the system in the more competitive environment in the country’s economy [11].

3.4 Financial Analysis

Financial analysis is investigation of financial profitability of investment. It determines whether financial costs are properly estimated and whether the project funding is ensured and whether the project is financially viable. The capital and operating cost are worked out at market prices. For generation project, cash flow is prepared for the projected cost and the generation flow of energy in each year of their occurrence covering the entire economic life of the project. The costs and units generated and discounted at a rate of discount are specified by the regulatory body to work out the unit cost of generation. For transmission project, the cost and units transmitted are discounted similarly to work out unit cost of transmission In financial analysis, the average cost of capital for the proposed project is calculated on the basis of debt to equity ratio, loan interest rates and repayment periods and required return on equity investment. The electricity authority needs to carry out the appropriate analysis for a project developed by a private company which is a financial analysis when evaluating the avoided cost [12].

3.5 Economic Analysis

Economic analysis and financial analysis are complementary, the project should not be financed unless it represents a desirable use of national resources and will be able to sustain itself financially either with or without a subsidy. Economic analysis usually starts with financial accounts, converting these in to economic measures by certain adjustments. Economic analysis is used to evaluate the total economic effects on society by extending the criteria of financial profitability. The primary objective of the economic analysis of power projects is to determine the cost of generation transmission at their true resources cost to the economy as the financial cost of generation transmission may not reflect the true cost of power to the economy on account of distortion inherent in the market prices While working out the economic cost of generation, transmission both the costs and power generated have to be valued at their true sources cost. This process involves removal of taxes and duties from the costs as they are not costs to the society. Similarly, the subsidies are also hot taken into account as they are only transfer payments. Total generation costs have to be divided by the annual electricity production (provided this is constant) in order to receive the specific energy cost, example of small hydro power which can be easily compared to the respective cost figure of a conventional e energy system e.g. Thermal, diesel generation [10].

3.6 Economic Characteristics

Economic characteristics for generation and transmission are discussed below:

3.6.1 Generation units

The economic characteristics of a generating unit are those which determine the cost at which it produces electrical energy. This cost has three components: cost of fuel, cost of operation and maintenance, and capital, or investment cost.

In generation economic studies, one is usually dealing with units to be installed at some future time which makes it necessary to estimate future, not current, plant costs. The conventional way of doing this is to start with a detailed costs estimate using known materials and labor costs for the present year. This would be the cost if the plant could be built instantaneously, as it were. A construction schedule is then developed form which on estimate is made of year-by-year expenditures throughout the construction period. It is necessary to be careful, complete and consistent in defining the plant costs used in generation economic studies.

3.6.2 Transmission

It is widely an accepted that the separation of generation, transmission and distribution is a key step to improve the overall efficiency and effectiveness of power sector in a country. It will encourage private investment in the three separate components of power system. once separation has been achieved it become relatively easy to introduce private sector participation in the transmission sector.

There are three main areas for transmission investment:

● New connection: the commissioning of new power stations requires investment in the transmission system.

● Improved efficiency and security: Investment may be required to improve the efficiency and security of an existing transmission system so as to reduce losses.

● Interconnections: The interconnection of separate grid system is beneficial because it allows generation and demand to be pooled, thereby reducing the required plant margin and reserve, and increases economy of operation by allowing the cheapest stations available to meet demand [6].

3.7 Rural Electrification Investment

It is not quite correct to judge rural electrification purely on the criterion of the financial returns on the investments made. A number of indirect socio-economic advantages like harnessing of ground water, resources for increased food production, promotion of rural industries and rural employment, prevention of migration from rural to urban centers, saving in diesel and so on should not be ignored. The real advantages of rural electrification are not limited to the immediate or long-term financial returns but go far beyond and can be truly evaluated by a benefit-cost analysis [10].

3.8 Credit Risk Assessment

There are numerous financial, contractual, and regulatory risks which must be allocated to assure that someone will be responsible to pay off the debt if the project is not built or does not operate properly The sensitivity analysis should be done in order to evaluate the project's proposal risk mitigation in respect of:

- Current capital cost fluctuations (i.e. +20%, +50%, 100%).
- Interest rate fluctuations.
- Escrow accounts requirements.
- Risk premiums (insurance, exchange)
- Debt sources ratios offshore (commercial, local commercial, public).
- Construction time over run (ie+20%, +50%, 100%).
- Operational assumptions.

3.9 Optimum Investment Models

It is a mathematical approach to minimize the costs and develop a mathematical relation of various variables. ISPLAN and EGEAS models are used in some utilities in power plan studies. The model must satisfy conflicting requirements:

- It must be sufficiently realistic or accurate to provide meaningful results.
- It must not be complicated to apply. It would be useful to define the problem in mathematical programming as problem-solving techniques of finding best values of an objective function. There are many forms of solutions such as linear dynamic, quadratic programming, etc. [8].

3.10 Tariff

The rate at which electrical energy is supplied to a consumer is known as tariff. Although tariff should include the total cost of producing and supplying electrical energy plus the profit, yet it cannot be the same for all types of consumers. It is because the cost of producing electrical energy depends to a considerable extent upon the magnitude of electrical energy consumed by the user and his load conditions. Therefore, in all fairness, due consideration has to be given to different types of consumers (e.g., industrial, domestic and commercial) while fixing the tariff. This makes the problem of suitable rate making highly complicated.

Objectives of tariff. Like other commodities, electrical energy is also sold at such a rate so that it not only returns the cost but also earns reasonable profit. Therefore, a tariff should include the following items:

- Recovery of cost of producing electrical energy at the power station.
- Recovery of cost on the capital investment in transmission and distribution systems.

There are three main objectives of a sound pricing structure consumer tariff:

● Financial: ensuring that the revenue yield from the application of tariff to the consumer is sufficient.

● Economics ensuring that tariffs charged to consumers enable them to make rational and optimal choices in the use energy. discourage waste and promote efficient allocation of resources.

● Social: ensuring that the price structures take into account fair distribution of costs among various classes of consumers, subsidization of target etc. [7].

2.11 Load Forecast

One of the crucial tools of planning is to attempt to foretell or foresee the future. The term forecast stands for predictions of future events and conditions. The process of making such predictions is called forecasting. The process of attempting to predict the future encompasses many business activities such as: following up technological evolutions, estimating sales, knowing cost trends and competition, maintenance requirements, and replacement of major plant or equipment. Forecasting has evolved over the years into an exact science and many models and tools are presently available commercially. The main purpose of forecasting is to meet future requirements, reduce unexpected cost and provide a potential input to decision. Energy has always received great attention from countries and individuals since it represents a commodity essential for comfortable life. With the advent of increased civilization and economic development energy has become a life-sustaining commodity. No one can dare to imagine what would be the status of life without energy. However, conventional energy resources on earth are limited and will last for only a certain period of time. Therefore, it is of paramount importance that people look for new energy resources; especially environmentally benign and renewable ones. It is also essential that exact methodologies for predicting the future load for energy be developed to meet future supply. This, in turn, will guarantee that energy is used rationally and that exploration and development efforts are not wasted. Moreover, the precise knowledge of future energy load will help countries to plan their development activities correctly, thus, avoiding under-or over-planning of future supply. Extreme deviations (under or over) predictions are considered to be waste of resources as the former leads to supply shortages, while the latter leads to unnecessary extra cost of supply.

In many societies electricity constitutes a major share of the total energy requirements and sometimes it is termed “clean energy,” although some electricity generating plants are great environmental pollutants.

Nevertheless, electricity has the least pollution record compared to all other energy sources if one considers the transportation of energy from source to final destinations. Furthermore, electricity networks lend themselves to be utilized as sources of live or on-line information about electricity consumption. In operating a power system, the mission of the utility/company, from the forecasting point of view, is to match load for electric energy with available supply, in addition to meet the expected peak load of the power system. Electrical load forecasting provides input to the planning of future resources. Here, the focus is on total annual consumption of electric energy that leads to predicting system requirements. The electrical energy requirements to be supplied by generating units and/or load imports/exports comprise the sales to consumers, and the associated generation, transmission, and distribution losses. In this chapter the terms load and load are considered to provide the same meaning from the forecasting point of view, and they will be used interchangeably [4].

2.12 Methods of Load Forecasting

The following methods are normally used for calculating load forecasting:

2.12.1 Extrapolation technique

In this method the future load predicated from the past historical data available, the maximum demands of the past years are plotted against time.

Some standard analytical functions are used in trend curve fitting, including:

Straight line:

$$y = a + bx \tag{1-1}$$

Parabola:

$$y = a + bx + cx^2 \tag{2-2}$$

S-curve:

$$y = a + bx + cx^2 + dx^3 \tag{2-3}$$

Gompertz:

$$y = e^{a+bx} \tag{2-4}$$

Where

y is a variable to be fitted.

x is the time in assigned frame in (day, week, year, etc.)

a, b, c, and d are coefficients to be calculated [8].

2.12.2 Scheer's method

This method is found to be more suitable in our country as it works on the basis of per capita consumption of energy. The load is shared by industry, agriculture, commercial, domestic, public lighting. The increase of population also increase the load demand, more employment opportunities need to be created, more industries are established necessitating more electrical power.

Scheer's method of load forecasting takes into consideration this factors such as economic condition of people, policy of government, rainfall and mineral resources [8].

2.12.3 End-use method

End-use method is a modified form of extrapolation. In the method of extrapolation only the system yearly peak demand of the past years is plotted and future years' demand is obtained by the trend curve of the past.

End-use method, the demand of different categories of loads are projected separately [8].

2.12.4 Probabilistic extrapolation correlation method

It is well documented that most system peak demands occur as a result of seasonal weather extremes. The weather variables usually are dry-build temperatures, humidity and wind-velocity. For example, the impact of heat wave during summer peak [8].

CHAPTER FOUR
SETC-MEDIUM TERM PLAN (2018 – 2020)

4.1 Introduction

Forecasting is the backbone of any planning process in all fields of interest, it has a great impact on future decisions and this is reflected as profits or losses to the institute at this study report is covering the period (2018 - 2020). The investigations undertaken in this study has identified the most technical feasible and economically viable generation and transmission projects which satisfies the system requirements as options for further detailed studies to ascertain it is viability to National Electricity Corporation (NEC), these plans are summarized below and further detailed in this chapter of the study.

4.2 Calculating of Load Forecasting

To calculated loads forecasting for the years of (2018– 2020) and through the use of exponential method (method of least squares).

The forecasting demand may be expressed by the analytical function:

$$P_i = e^{A+BX} \tag{4-1}$$

$$X = \frac{(X_i - X_0)}{P} \tag{4-2}$$

Where:

$P_i \equiv$ total load in MW in the i^{th} year.

$X_i \equiv$ the i^{th} year in which the total load is considered.

$X_0 \equiv$ the basic year.

A and B are constants.

$P \equiv$ the length of the period (here $P = 1\ year$).

The following table express forecasting for total demand in the years (2018-2020).

Table 4.1: Forecasting for total demand in the years from 2018 to 2020

Year	Total demand MW	Forecasting MW	| Error | MW
2010	6,027	5744.52	282.48
2011	6,686	6744.3	58.3
2012	7,608	7744.08	136.08
2013	8,604	8743.86	139.86
2014	9,709	9743.64	34.64
2015	10,578	10743.42	165.42
2016	11,790	11743.20	46.8
2017	12,948	12742.98	205.02
2018		13742.76	
2019		14742.54	
2020		15742.32	
			Average = 97.15

Total load of 2011 is 6686 MW, up 10.93 % from the previous year

Total load of 2012 is 7608 MW, up 13.80 % from the previous year

Total load of 2013 is 8604 MW, up 13.09 % from the previous year

Total load of 2014 is 9709 MW, up 12.84 % from the previous year

Total load of 2015 is 10578 MW, up 8.95 % from the previous year

Total load of 2016 is 11790 MW, up 11.46 % from the previous year

Total load of 2017 is 12948 MW, up 9.82 % from the previous year

Average ratio = 12.65

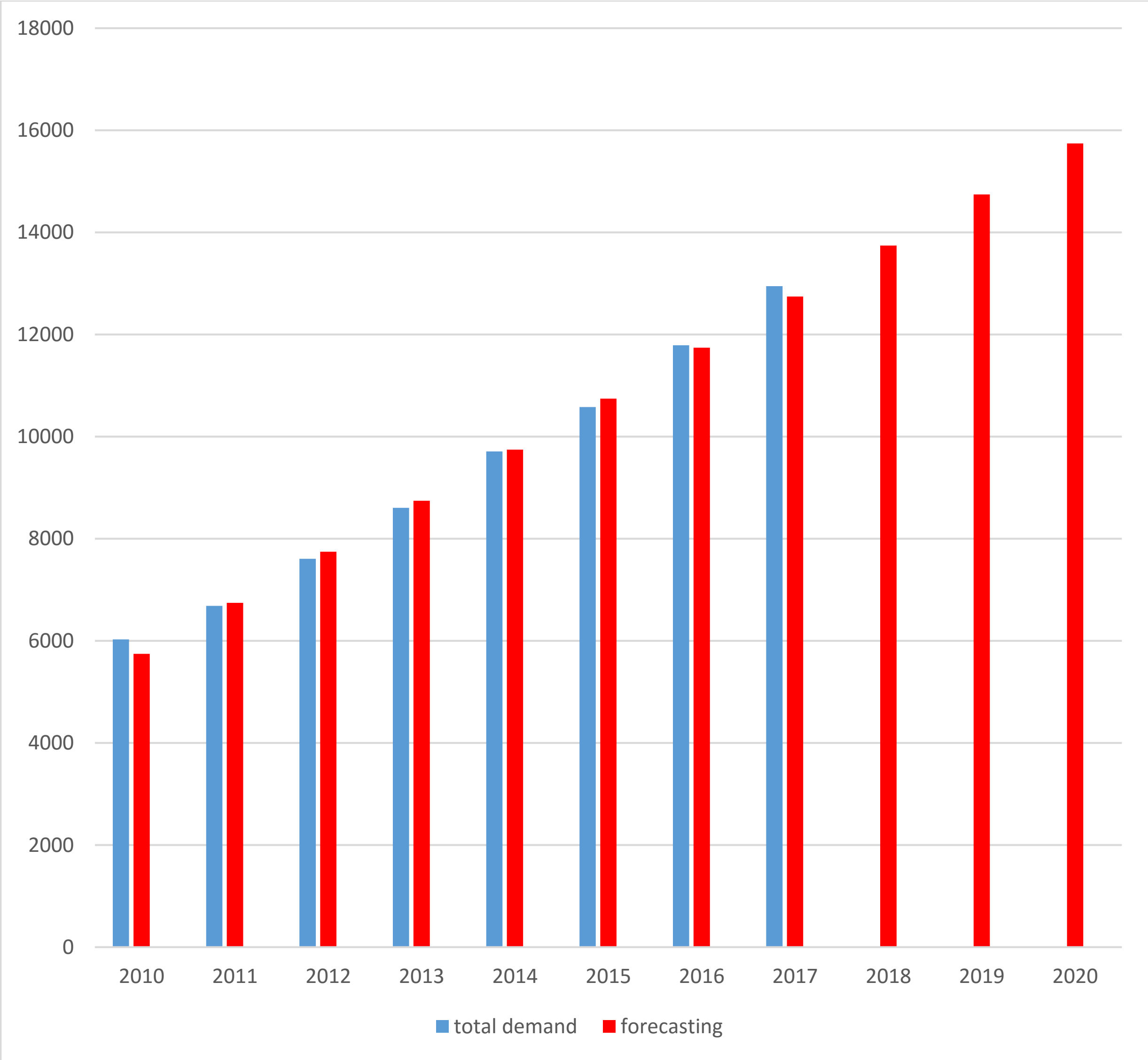

Figure 4.1: The total demand (MW) in each year

4.3 Generation Planning

The status of the grid system generation is briefly reviewed below:

Table 4.2: Existing hydro power capacity in the national grid 2017

Plant	No of Units	Total Installed Capacity MW
Marwi	10	1250
Roseires	7	280
Sennar	2	15
Kashem El-Girba Kashem El-Girba Pump	2 3	10.6 7.2

Jebel Aulia	8	30
UPPER ATBARA AND SETIT DAMS	3	240
SUB-TOTAL HYDRO	107	1833

Table 4.3: Existing thermal power capacity in the national grid 2017

Plant	No of Units	Total Installed Capacity MW
Khartoum North 1&2 3&4 5&6/Steam	2 2 2	60 120 200
Gerri I CC & I I/CC	6 6	210 225
Gerri 4	2	110
Kosti	4	500
SUB-TOTAL THERMAL	24	1425

4.4 Transmission Planning

At the side of electricity transmission has been the case study of the stations voltage level of 110 KV and that by forecasting the required load of each station and to know increasing load in each station has been the use of growth factor in the load and was found that a very small change in the growth factor in the load and therefore has been considered as fixed for the years under study It is equal to 12.65%.

The following tables clarify the status of the stations of the year:

Table 4.4: Peak load forecast for Khartoum area (2018-2020)

Capacity	ACT. S/S MW	FOR 2018 (%12.65) MW	FOR 2019 (%12.65) MW	FOR 2020 (%12.65) MW

S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Kilo X	135	108	89	100.26	**112.941**	**127.228**
Shagara	270	216	116.3	131	147.585	166.254
Mugran	200	160	**191.4**	**215.612**	**242.887**	**273.61**
Giad	60	48	34	38.3	43.146	**48.6**
Faroug	120	96	**133.5**	**150.388**	**169.412**	**190.84**
Khartoum East	200	160	**180.5**	**203.33**	**229.055**	**258.03**
LOM	200	160	**177.6**	**200.06**	**225.37**	**253.88**
Bagir	70	56	**61.6**	**69.39**	**78.17**	**80.06**
El Jaili	100	80	62.8	70.74	79.69	**89.77**
Afraa	200	160	57.3	97.23	109.296	123.122

Table 4.5: Peak load forecast for the North area (2018-2020)

Capacity			ACT.S/S MW	FOR 2018 (%12.65) MW	FOR 2019 (%12.65) MW	FOR 2020 (%12.65) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Shendi	100	80	46.1	51.93	58.5	65.9
Atbara	200	160	**217.1**	**244.56**	**275.5**	**310.35**
Merawi Town	80	64	32	36.048	40.6	45.745
El Dabba	80	64	27	30.415	34.26	38.6
Dongula	80	64	42	47.303	53.30	60.04
Wawa	120	96	0.7	0.7886	0.8883	1
Wady Halfa	120	96	1.7	1.915	2.157	2.43

Table 4.6: Peak Load forecast for Bahri area (2018-2020)

Capacity			ACT.S/S MW	FOR 2018 (%12.65) MW	FOR 2019 (%12.65) MW	FOR 2020 (%12.65) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Izergab	270	216	124.7	140.47	158.24	178.26
Kuku	90	72	**83.7**	**94.288**	**102.215**	**119.65**
Izba	200	160	146	**164.469**	**185.97**	**208.71**
Eid Babiker	200	160	73.8	85.977	96.85	109.1
Free Zone	80	64	28.6	32.2	36.27	40.86

Table 4.7: Peak load of forecasting for Aljazeera area (2018– 2020)

Capacity			ACT.S/S MW	FOR 2018 (%12.65) MW	FOR 2019 (%12.65) MW	FOR 2020 (%12.65) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Maringan	155	124	100.4	113.1	**127.4**	**143.52**
Hasaheisa	70	56	26.7	6.077	6.85	7.712
New Hasaheisa	300	240	28.7	32.33	36.42	41.027
Hag Abdalla	35	28	16.4	18.47	20.81	23.444
Managil	35	28	**36**	**40.554**	**45.684**	**51.463**
Genaid	120	96	50.5	56.888	64.084	72.19

Table 4.8: Peak load forecast for the Blue Nile area (2018-2020)

capacity			ACT.S/S MW	FOR 2018 (12.65%) MW	FOR 2019 (12.65%) MW	FOR 2020 (12.65%) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Sennar Junction	110	88	34.1	38.41	43.27	48.74
Miaernu	52.2	42	15.8	17.8	20.05	22.58
Singga	200	160	14.9	16.78	18.9	21.3
Rosaris	120	96	28.8	32.44	36.55	41.17
Rank	120	96	0.13	0.146	0.165	0.186

Table 4.9: Peak load forecast for the East area (2018-2020)

Capacity			ACT.S/S MW	FOR 2018 (12.65%) MW	FOR 2019 (12.65%) MW	FOR 2020 (12.65%) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Gadaref	200	160	38.6	43.48	48.98	55.18
Fao	25	14	9.6	10.81	12.18	13.72
Showak	200	160	0.9	1.014	1.142	1.286
Khashim Algirba	200	160	23.5	26.47	29.82	33.59
Kassala	200	160	29.9	33.68	37.94	42.74
Halfa	200	160	22.2	25	28.172	31.735
Port Sudan	200	160	109.3	123.126	138.7	156.25

Table 4.10: Peak load forecast for the White Nile area (2018-2020)

Capacity			ACT.S/S MW	FOR 2018 (12.65%) MW	FOR 2019 (12.65%) MW	FOR 2020 (12.65%) MW
S/S	MVA	MW	JUN 2017	JUN 2018	JUN 2019	JUN 2020
Mashkoor	95	76	30.7	34.58	38.95	43.886
Rabak	120	96	93.9	**105.778**	**119.159**	**134.23**
Tandelti	120	96	1.7	1.915	2.157	2.43
Umrwaba	120	96	7.3	8.223	9.2637	10.435
Obaid	120	96	43.4	48.89	55.075	62.05
Rabak	17.5	14	0.0	0.0	0.0	0.0

Table 4.11: Peak load forecast for Omdurman area (2018-2020)

Capacity			ACT.S/S (%12.65) MW	FOR 2018 (%12.65) MW	FOR 2019 (%12.65) MW	FOR 2020 (%12.65) MW
S/S	MVA	MW	2017	2018	2019	2020
Omdurman	200	160	158	**177.987**	**200.5**	**225.866**
Banat	200	160	148.2	**166.95**	**188.066**	**211.856**
Mahadia	170	136	**172.1**	**193.87**	**218.395**	**246.022**
Jamueya	170	80	26	30.29	34.121	38.438

Hint:

[The **Bold** number means that the peak power more than the capacity]

4.5 Projects for Remedying Problems

It is not possible that the old transmission lines and substations can transfer that energy efficiently so we had to support the transmission lines and stations as follows:

4.5.1 Khartoum reinforcement project

Table 4.12: Khartoum reinforcement project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	**2018**	GARRI	ELKBASHI	2	27	220
2	**2018**	ELKABASHI	ELEZIRGAB	2	28	220
3	**2018**	ELEZIRGAB	ELMAHDIA	2	15	220
4	**2018**	ELMOGRAN	ELSHAGARA	2	12	220
5	**2018**	ELSHAGARA	JABELAWLIA	2	25	220
6	**2018**	ELGOMOIA	ELMOGRAN	2	17	220
7	**2018**	EIDBABIKER	KUKU	2	3	220

Table 4.13: Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018	ELEZIRGAB	2	150/150/15	220/110/11
2	2018	ELSHAGARA	2	150/150/15	220/110/11
3	2018	KUKU	2	150/150/15	220/110/11
4	2018	ELMOGRAN	2	150/150/15	220/110/11
5	2018	Extension at ELMAHDIA Substation			
6	2018	Extension at ELGOMOIA Substation			
7	2018	Extension at EIDBABIKER Substation			
8	2018	Extension at GARRI Substation			
9	2018	Extension at JABELAWLIA Substation			

4.5.2 500 KV around Khartoum project

Table 4.14: 500K.V around Khartoum project **(**Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018	ELMARKHYIAT	JABEL AULIA	2	80	500
2	2018	JABEL AULIA	ELBAGER	2	30	500
3	2018	ELBAGER	ELKABBASHI	2	75	500
4	2018	ELKABBASHI	ELMARKHIAT	1	37	500

Table 4.15: Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018	JABEL AULEA	3	400/400/75	500/220/33
2	2018	ELBAGER	2	400/400/75	500/220/33
3	2018	Extension at ELKABBASHI Substation			
4	2018	Extension at ELMARKHIAT Substation			

4.5.3 Mashkoor– El Managil project

Table 4.16: Mashkoor– El Managil project (Transmission lines)

No	**Year**	**From**	**To**	**No of circuits**	**Length (KM)**	**Voltage (KV)**
1	2018/2019	MASHKOOR	ELMANAGIL	2	100	220

Table 4.17: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2018/2019	ELMANAGIL	2	100/100/40	220/110/11
2	2018/2019	Extension at MASHKOOR Substation			

4.5.4 Eidbabker –New Halfa project

Table 4.18: Eidbabker –New Halfa project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018/2019	EIDBABKER	NEW HALFA	2	320	220

Table 4.19: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2018/2019	Extension at EIDBABKER & NEW HALFA Substation			

4.5.5 South Kurdufan project A.C transmission line

Table 4.20: South Kurdufan project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018/2019	UMRWABA	RASHAD	2	137	220
2	2018/2019	RASHAD	KALOGI	2	128	110
3	2018/2019	DIBEBAT	KADOGLI	2	190	220
4	2018/2019	KADOGLI	TALODI	2	82	110

Table 4.21: Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018/2019	RASHAD	4	100/100/15 35/35/10	220/110/11 110/33/11
2	2018/2019	KADOGLI	4	100/100/15 35/35/10	220/110/11 110/33/11
3	2018/2019	TALODI	2	35/35/10	110/33/11
4	2018/2019	KALOGI	2	35/35/10	110/33/11
5	2018/2019	Extension at UMRWABA & DIBEBAT Substations			

4.5.6 Ethiopia interconnection–Rabak – JabelAulia (500 KV) project

Table 4.22: Ethiopia interconnection– Rabak – JabelAulia (500 KV) project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018	ETHIOPIA	RABAK	2	350	500
2	2018	RABAK	JABEL AULIA	2	260	500

Table 4.23: Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018	RABAK	2	400/400/75	500/220/33
2	2018	JABEL AULIA	3	400/400/75	500/220/33

4.5.7 El Kabbashi – Atbara – Portsudan project

Table 4.24: El Kabbashi – Atbara – Portsudan project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018	ELKABBASHI	ATBARA	2	270	500
2	2018	ATBARA	PORTSUDAN	2	510	500

Table 4.25: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2018	PORTSUDAN	2	400/400/75	500
2	2018	Extension at ATBARA & ELKABBASHI Substations			

4.5.8 El Obiad – Bara project

Table 4.26: ELObiad – Bara project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018/2019	ELOBIAD	BARA	2	63	220

Table (4.27): Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018/2019	BARA	2	60/60/15	220/33/11
2	2018/2019	Extension at ELOBIAD Substation			

4.5.9 Abuzabad – El Nehood project

Table 4.28: Abuzabad – El Nehood project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018/2019	ABUZABAD	ELNEHOOD	2	92	110

Table 4.29: Substations

No	Year	Substation	No of transformer	Capacity(MVA)	Voltage (KV)
1	2018/2019	ELNEHOOD	2	35/35/10	110/33/11
2	2018/2019	ABUZABAD	2	100/100/15	220/110/11

4.5.10 Adeela – Ellait – El Twisha – Kalamindo – Dar El Salam – El Fasher project

Table 4.30: Adeela – Ellait – El Twisha – Kalamindo – Dar El Salam – El Fasher project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2020/2019	ADEELA	ELLAIT	2	65	110
2	2020/2019	ELLAIT	EL-TWISHA	2	65	110
3	2020/2019	EL-TWISHA	KALAMINDO	2	75	110
4	2020/2019	KALAMINDO	DAR ELSALAM	2	50	110

5	2020/2019	DAR ELSALM	ELFASHER	2	90	110

Table 4.31: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2020/2019	ELLAIT	2	35/35/10	110/33/11
2	2020/2019	ELTWISHA	2	35/35/10	110/33/11
3	2020/2019	KALAMINDO	2	35/35/10	110/33/11
4	2020/2019	DAR ELSALAM	2	35/35/10	110/33/11
5	2020/2019	Extension at ADEELA & ELFASHER Substation			

4.5.11 Neem- El Fula project

Table 4.32: Neem- El Fula project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2018/2019	NEEM	ELFULA	2	110	220

Table 4.33: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2018/2019	NEEM	2	60/60/15	220/33/11
2	2018/2019	Extension at ELFULA Substation			

4.5.12 El Dmazeen- Krnkrn project

Table 4.34: El Dmazeen- Krnkrn project (Transmission lines)

No	Year	From	To	No of circuits	Length (KM)	Voltage (KV)
1	2020/2019	ELDMAZEEN	KRNKRN	2	90	220

Table 4.35: Substations

No	Year	Substation	No of transformer	Capacity (MVA)	Voltage (KV)
1	2020/2019	KRNKRN	2	60/60/15	220/33/11
2	2020/2019	Extension at ELDMAZEEN Substation			

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Power system planning process, planning categories i.e. long, medium and short term planning and objective of each category with their time range are studied. The base (first step) of any power system planning is load forecasting. It has three categories according to the planning type. From load forecasting, build generation, transmission and distribution planning. Also generation type was studies, criteria of planning, and its environmental effect. In transmission planning, types of transmission lines (AC or DC), voltage level selection, and planning criteria are discussed. Distribution types and its criteria had been studied. Finally, execution of the plan and its viability depends on financial planning.

In the case study, it is found that the Sudanese Electricity Transmission Company (SETC) used the end use approach for agriculture and domestic load forecasting, which is considered to be more accurate and is used by many utilities in the world.

The load was forecasted for the considered years. The growth coefficient was calculated in the load. It was deficit in generation, and the side of the transmission processing has been studied 110 KV manufacturing plants palm of a case study were predicted loads for years above the stations found that the stations by an excessive load was developed solutions to these problems, and these solutions at low cost.

The planning of SETC for remedying the shortage of power has clarified in this stusy.

5.2 Recommendations

The following is recommended:

The Use of the HVDC transmission instead of AC because the economy in DC transmission is that only two conductors per circuit are need rather than the three required for AC. Consequently, DC transmission towers carry less conductor dead weight, and they can be smaller, less costly, and easier to manufacturing.

- Refer to the information of historical load growth and the percentage of the growth in each year to be used as a guide for the subsequent plan.
- Increase in capacity due to under construction and committed power plant projects, introduction of new consumption areas due to transmission lines and distribution networks expansions, give chance to boost demand.
- Distribution plan must be included in the next medium term plan.
- Find out the level of implementation of the previous plan for each ministry, regarding their requirement of electric power, and use it as a factor to determine the future demand.
- Further studies must be carried for load forecasting and environmental impact.
- This study may expand to involve Solar Energy Plan.

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