Planning A Strategic Tool to Power System Management

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Abstract

The major part of the energy which human society requires today is handled in the form of electrical energy and the system which generates, control, dispatches and finally consumes the energy is known as the electrical power system. The most important characteristics of power system is that it can neither store energy nor is it the ultimate source of energy. It simply converts the energy available from natural sources into the electrical form and then handles it in an efficient manner. The stages of these conversion are complex and as a result need adequate planning. This paper covers the basic principles in power system planning, planning methods, planning criteria and standards, system development and distribution, system economics and finance. Since energy demand and need is increasing on daily basis, there is need to have a good planning system in place. Included in the paper is also strategies for action plan.

KEYWORDS: Power system, planning methods, development, energy demand.

1.0 Introduction

Planning is defined as the process of taking a careful decision. The main input in planning is quality systematic thought. It involves selecting the vision, values, mission and objectives and deciding what should be done to attain them. Basically, the objective of power system planning is to provide satisfactory service at the lowest possible cost. In a power utility, the process seeks to identify the best schedule of future resources and actions to achieve the utility's goals.

Planning is driven by two inputs: Future needs and Time to fulfill these needs with defined priorities in master plan. Long time planning (5 – 10 years) determines the power energy forecasts and optimum network arrangements. What investment would be required and the timing of these to obtain maximum benefits. Network /power planning covers individual investments in one or two years as a medium-term planning within the period of a long term plans. A short term plan covers the current or next year i.e annual plan for each year on the horizon. This covers engineering design of each network component, smaller and more common type of investments for system improvements.

The following steps are involved in the planning process:

(i) Feasibility studies are carried out to identify, evaluate and finalize the best plan. Define the problem → Find the alternative → Evaluate the alternative → select the best one.

(ii) A project report for long, medium and short term works along with the action plan/pert chart/bar chart for each activity/work is prepared. Dates are set for mile stones i.e important events measurable along the path to the fulfillment of the plan.

(iii) Final approval is accorded after financial and economic appraisal.

(iv) Once the best plan has been selected, the next process of implementation begins.

In executing the plan, monitoring is important to developing a detail task list that supports the milestones. Without detailing who will do what and when, the plan may not be successfully implemented. The planning action is shown in figure 1 [1]

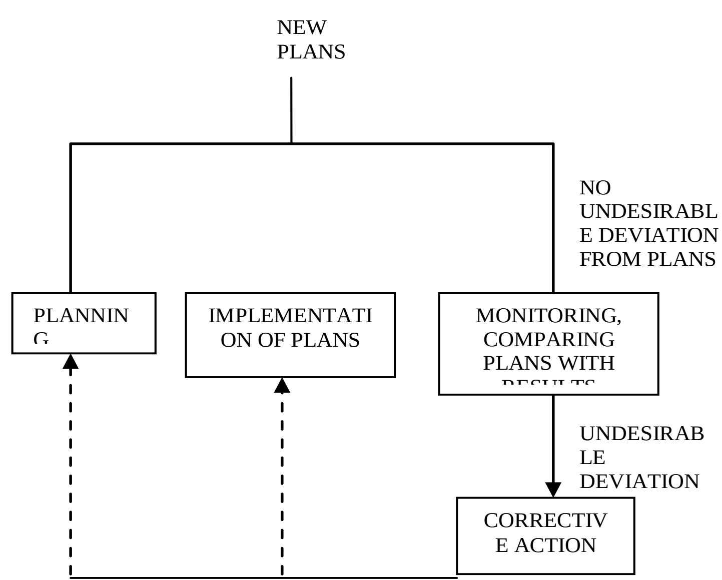

Figure 1: Planning Actions

2.0 Basic Principles of Power System Planning (Distribution at focus)

Any distribution system planned, is used to transport a certain amount of power to maximum capability from the source point at one location to another location with certain consequences. In essence, sub transmission and distribution line transport power from one bulk power location to the consumer site, and transformers change the voltage level of the power, considering the following basic principles:

- It is economical to transport power at a high voltage. The higher the voltage, the lower the cost/kw to transport power to a distant point.
- Electricity travels as per Kirchoffs current and voltage laws. It follows the least resistant path.
- Power must be delivered in relatively small quantities at a low voltage (e.g. 400/230 V) level
- Voltage drops occurs from the source point to the end location.
- Losses in power are incurred, creating a cost
- Equipment and labour come at a cost,
- Operation and maintenance add to service cost
- Future growth accounting is survival.
- When power is used for any purpose by the consumer, the responsibility lies on the consumer to share the degradation of environment on this account.
- Nominal rated system voltage is the most efficient voltage for equipment operation. A rise above this voltage tends to reduce the power factor of equipment.
- Segregation and restoring of agriculture supply on a feeder is a step in the direction of economy and to supply power at low lost to agricultural consumers.
- Electricity market: Wholesale, select retail, bilateral contracts will cut down the cost of supply if adequate power surplus and grid links are available.

The main steps in planning power distribution are shown in figure 3 below. The goal is to provide electricity at
the lowest possible economic and social cost.

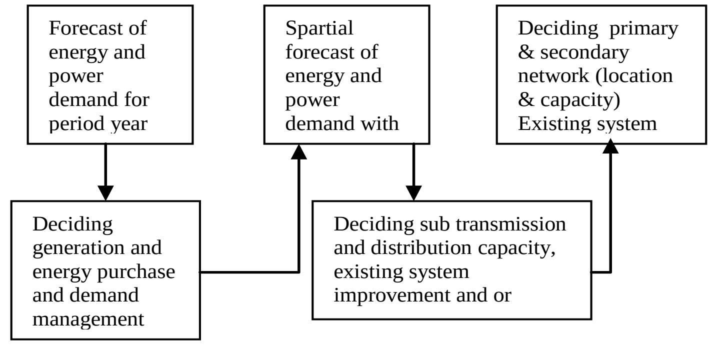

Figure 2: Steps for power system planning

3.0 Planning Methods

Planning of integrated resources requires the following two methods:

3.1 Traditional Least Cost Planning:

This is a process by which utilities minimizes the cost of supplying a given amount of electricity. It is the method of acquiring resources at the lowest cost, taking into account all possible means of meeting electricity needs and all resource costs including construction, operation, sub-trans mission, distribution, consumer and environmental costs.

Firstly the existing system inadequacies are identified as :

I. Poor voltage regulation
II. Higher system losses
III. Higher equipment failures/break down and or higher line break down/ tripping.
IV. Bad quality of power supply
V. No scope for future load growth.

The initial system improvement can be very cost-effective in removing the above inadequacies as compared to the other alternative of laying a new extended system. Thus there are two options:

(a) **System improvement:** Augmentation and strengthening of the existing system; Improving reliability and quality of supply; reduction of commercial and technical losses

(b) **Expansion of existing network:** The least cost optimal solution from various alternative schemes may be worked out considering the capital cost of the proposed works and present values of the KW and energy losses over the expected life of equipment in case of expansion of network. When the augmentation and strengthening of existing system are involved, the benefits of saving in losses (KW and energy), net revenues increase due to additional sale of power and energy after adjusting the expenditure incurred on generation of additional energy. The net present values of alternate plans are compared to choose the least cost solution. Also financial analysis of the chosen scheme is done to satisfy the funding organization.[2]

3.2 Demand Side Planning (DSP)

It is the process by which power utilities quantify and asses programme to alter the pattern and level of their consumer's demand for electricity. This is planning at the consumers level and often has a long planning period, much longer than distribution planning and often as long as that of generation. It can take years of slow progress to obtain meaningful levels of participation. According to a study, the low-cost demand side options can be

Item	Approximate cost (2000)
Implementing energy Conservation programs	RS 1500/Kw
Providing vigilance and detection energy theft	Rs 50/Kw
Providing metering	Rs 300/kw

Demand side planning (DSM) measures, require special programs that try to mobilize cost-effective savings in electricity and peak demand. Numerous studies in India, china and other countries have found that cost effective DSM programmes can reduce electricity use and peak demand by approximately 20 to 40 percent, DSM benefits households, industry, agriculture, utilities and society in the following ways:

(i) Reduces consumer energy bills
(ii) Reduces the need for power plant, transmission and distribution construction.
(iii) Stimulates economic development.
(iv) Creates long term jobs that benefits the economy.
(v) Increases the competitiveness of local enterprise
(vi) Can reduce maintenance and equipment replacement costs
(vii) Reduces local air pollution
(viii) Reduces emissions that contribute to national and international environmental problems such as acid rain and global warning.
(ix) Enhances national security by easing dependence in foreign energy resources.
(x) Can increase the comfort and quality of work spaces. Which in turn can increase worker's productivity.

Utility DSM programes generally fall into three main categories.

3.3. Conservation Programs

Reduce energy use with programmes to improve the efficiency of equipment (like lighting and motors), building and industrial processes as per the energy conservation

3.4 Load Management Programs

Redistribute energy demands to spread it more evenly throughout the day. Some of the ways of doing this are, load shifting progrmmes (reducing air conditioning loads during periods of peak demand and shifting these loads to less critical periods), time-of –use rates (charging more for electricity during peak demand) and interruptible rates (providing rate discounts in exchange for the right to reduce consumer's electricity allocation each year during a few hours when electricity demand is the highest)

3.5 Strategic Load Growth Programs

Increase energy use during some periods e.g encouraging cost- effective electrical technologies that operate primarily during periods of low electricity demand

Within these categories, the following approaches can be used :

i) General information programmes to inform consumers about generic energy efficient options.
ii) Site specific information programmes that provide information about specific DSM measures appropriate for a particular industry and home agriculture.
iii) Financing progrmmes to assist consumers to pay for DSM measures including loans rebates and shared-saving programmes
iv) Direct installation programmes that provide complete services to design, finance and install a package of efficiency measures
v) Alternative tariff programmes including time-of –use tariffs, interruptible tariff and load shifty tariff. These programmes generally do not save energy but they are effective ways to shift loads to off-peak periods.
vi) Bidding programmes in which a utility solicits bids from consumers and energy service companies to promote energy in the utility's service area.
vii) Load limiters are effective in demand side management, as they limit the maximum power that the consumer draws from the supply. Wide spread use of load limiters for low consumption rural/urban slum consumer instead of meters can result in substantial saving on transmission, distribution and generating equipment.
viii) Market transformation programs that seek to change the market for a particular

technology or service so that the efficient technology is in wide spread use without continued utility intervention.

The process of designing and implementing DSM programmes generally consists of the following steps:

- ❖ Identifying sectors, end uses and efficiency measures to target;
- ❖ Developing programme designs;
- ❖ Conduct cost effective screening
- ❖ Preparing an implementation plan
- ❖ Implementing programmes
- ❖ Evaluating programmes [1]

4.0 Planning Criteria and Standards

Criteria and standards form a set of requirements against which the planning process can compare alternatives in the evaluation and final choice. A distribution plan must provide good economy and also satisfy various criteria and standards. Criteria are rules or procedures. Standards are specifications to ensure that the system is built with compatible equipment that will fit and function together when installed and maintained in an economical manner. Standards and criteria and their applications to the planning process depend upon vision, mission and the value system of the utility. Criteria and standards covey directions in the master plan.

The following are the typical criteria for planning:

a. A perspective plan for the next 15 years to meet the anticipated load growth and forecast load centers. The plan will be reviewed yearly on the basis of annual plans with respect to targets achieved.

b. Detailed project reports be framed to identify the system strengthening works on long term and short term basis:

   i) Feeders having poor performance: re-configuration (bifurcation or trifurcation, etc) of feeder or augmentation of line conductors and distribution transformers:

   ii) New technology deployment for system improvement

   iii) Loss minimization plan.

c. Demand side management project reports be undertaken on pay-back period financial analysis to achieve tangible reduction in demand and energy consumption in the planned horizon year.

d. Security:

   i) In industrial cities, alternative source of supply be provided by using subtransimission open ring circuit of 33 or 66 or 132 or 220 Kv.

   ii) 11Kv open ring main system be provided in all urban estates.

   iii) in case of important or essential low voltage consumers, altemate supply arrangement from adjacent distribution transformer be provided.

   iv) Separate independent feeders be laid down for major industrial consumers.

   v) Incase of rural areas, separate feeder be provided.

e. The following voltage levels be used for release of power connection to consumer:

   i. connected load upto 10KW to be supplied at 230V single phase, two wire.

   ii. connected load between 10 kw and 50kw to be supplied at 415/230 V, three phase, four wire

   iii. Load demand between 50kw and 5MW to be supplied at 11kv.

   iv. Load demand between 30MW and 50MW to be supplied at 33kv or 66kv

   v. Load demand between 30MW and 50MW to be supplied at 132kv

   vi. Load demand above 50MW to be supplied at 220kv

f. Economic appraisal of alternate plans be done on least net present values.

g. Power utility would create and use load research facilities in order to identify consumer load profiles in the respective geographical area of the system to forecast change in the load.

h. The distribution system for historical buildings of national importance be underground

i. The number of 11 KV outgoing feeders at the distribution substation should not be more than 15. The length of 11 KV out going feeder. Emanating from the substation should not be more than 12Km.

j. Loss minimization could be achieved by the following measures

   (a) LT line not exceeding 0.8km

   (b) Improved metering, this means that electronic meters be provided for all types of consumers

(k) Three phase fault levels should not exceed 2000MVA and 750 MVA respectively at 66 and 33 KV not to be more than 350 and 250MVA in urban and rural areas respectively.

(L) Total harmonic distortion at any voltage level should be within 5 percent. Planning standards exist for reasons of efficiency, to achieve the greatest economy or utility convenience e.g a code of practice for equipment design, layout, loading, performance, voltage and service quality standards, location of substation and methods of economic evaluation assures the electrical needs of its consumers. The system may conform to various standards. Rural electrification corporation standard, IEC, ISO, IEEE and the electricity Act 2003. Better, improved or additional criteria and standard may be required by a power utility to achieve their objectives.

The planning standards could be of the following types:

(i) Development of standard cost structure FOR material and labour rates for different voltage system to be used in the estimation.

(ii) The load growth for at least 10 years will be taken into account to prepare new or system improvement schemes.

(iii) Fixed LT capacitors on the distribution transformers shall be installed.

(iv) Shunt capacitor fixed/switched type shall be installed in the distribution system at substations to improve the power factor and voltage profile and reduce transmission distribution losses. The size and location will be determined by load flow studies for maximum load conditions.[3]

5.0 System Development

Large amount of power are generated at power plants and sent to a network of high voltage (220,110, 66 or 33KV) sub-transmission lines. This system deals with longer distances and increased power requirements. These lines supply power to distribution centers (distribution substations) feeding distribution primary system, which supply power to the lower voltage (0.415KV) distribution secondary system. Thus, the total network is a complex grid of interconnected lines .

This network has the function of transmitting power from the point of generation to the point of consumption. Power utilities should plan their investment programme 5 to 10 years in advance through annual plans with a detailed list of investment. The route and location of sub transmission lines and distribution substation is made after carrying the computer based load flow studies of various alternatives. The distribution system is particularly important to an electrical utility for two reasons: its proximity to the ultimate consumer and its high investment cost.

The objective of distribution planning is to ensure that the growing demand for electricity, with growing rates, can be satisfy in an optimum way, mainly to achieve minimum total cost of the distribution system expansion. Therefore, the distribution system planner partitions the problem of planning the total distribution system into a set of sub problems that can be handled by using available, usually heuristic methods and techniques. [4]

5.1 SubTtransmission

The sub-transmission designates the circuits which deliver energy from the transmission system to the primary distribution system. Usually the sub transmission system is supplied by the transmission sub-stations and is still referred to as the sub transmission. Many sub transmission systems were previously the transmission lines local growth and demand for more power resulted in the transmission voltage being too low. As a result, voltage from 220Kv down to 33KV are found in sub-transmission system

Distribution is considered as consisting of four elements. Its sub-transmission, the substation itself, the feeder system and the consumers. A substation contains all equipment involved in the switching or regulating of electricity. Substations can be large or small. Their control can be automatic or manual.

Power transformers constitute an important part of the sub-station. The transformer is a static device which transfer electrical energy from one circuit magnetically coupled with another and transforms voltage levels. On-load tap changing transformers are used to regulate voltages. Switch gear constitutes an essential component of the substation. Under normal operating conditions, it provides the means to perform routine switching operations, e.g. disconnecting and isolating various equipment for maintenance, inspection or replacement, transferring load, isolating regulators, etc. Under abnormal conditions, witch gear provide the means for automatically isolating parts of the system in trouble to prevent damage and to localize the problem. The main components of the switch gear include circuit breakers, disconnecting switches, fuse instrument transformers, buses and connections, supporting insulators, protective and connections, supporting insulators, protective and control relays and control switches.

For the development of the system, the spatial load demands are worked out and imposed on the existing system, in order to assess the inadequacy of the system to meet the demand in the year.

The existing augmentation/strengthening are then worked out to meet the proposed demand and as well as to identify the constraints in the back up system. The options are:

(i) Augmentation of power transformer at capacity at the existing distribution substation (66 or 33kv).

(ii) Re-arranging or reconfiguring the sub-transmission (66 or 33kv) feeders from the new transmission substation (e.g 220/66kV) nearby, augmenting the line conductors.

(iii) Establishing new 66/11 or 33/11kv substation nearer to the load centres and redistributing the load between the existing and new substations as also strengthening the existing 11kV feeders and adding new 11kv feeders.

Load flow studies enable the computation of losses for various alternatives. The least cost optimal solution is worked out by considering the capital cost of the proposed works and the present values of peak demand KW losses and energy losses over the expected life of the equipment.

Power utilities should prepare as a code of practice for Network expansion and a demand side management to meet the increasing demand and to improve the reliability and quality of supply. This includes determining planning standards, criteria and strategies. System expansion for the purpose of releasing of power connections is done as per the distribution code. The other consideration could be design as regard the design code and construction standards.

5.2 Distribution Substations Sitting

Planning of substation is best done by considering the impact of any sitting or sizing decision on all four levels. The main criteria for selecting a substation site are:

(a) Proximity of load: Some sites are close to existing transmission lines or can be reached at low cost. Other sites require lengthily or underground access, thus adding to cost.

(b) Outgoing feeder space: Getting a feeder out of a substation required right of way.

(c) Geographic: Nearby terrain or public facilities may constrain feeder routing and raise costs.

(d) Site preparation: The slope drainage and underlying soil and rock determines the cost of preparing the site for a substation and building the foundation.

(e) Cost of land: some sites cost more than others.

(f) Weather exposure: Sites on hill tops are more exposed to lightening and adverse weather, increasing some operation and maintenance costs.

5.3 Size

As a rule, the minimum economical capacity (MVA) for a substation is approximately equal to one-fourth of high side voltage (Kv). A 66KV can serve about 16MVA [5].

5.4 Service Area Location

The service area for a substation should be as far as is practical, circular. The consumer should be served from the nearest substation. This will make the supply line distance as short as possible to reduce losses, costs and service interruption exposure. To apply this concept, the best approximation is made by the perpendicular bisectors rule. It consists of the following steps [6].

(a) Draw a straight line between a proposed substation site and each of the substations surrounding it.

(b) Then draw a perpendicular bisect of each of these lines.

(c) The area enclosed by the perpendicular bisectors around the proposed substation will be the service area. See the figure 4 below.

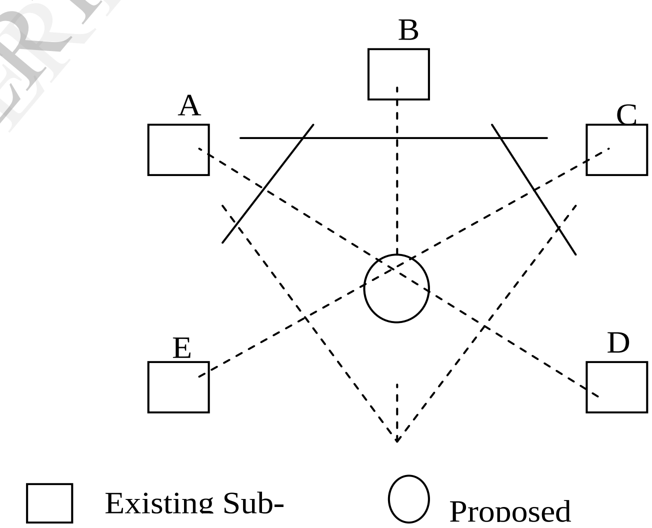

Figure 3: Process of Substation Sitting

(d) The shifting of the load of nearby substations can be determined from the area falling within the polygon. Let us say the purpose is to shift the specific load of a substation “C”. If this is not accomplished, then the proposed site should be moved closer to that substation and repeat the above three steps.

(e) The optimal site for a new substation is determine by an iterative process.

5.4 Feeder System

Feeder is part of the distribution system tailored to load locations and needs. Voltage drop, power flow, power quality and cost are important points of consideration. More than 80% of the distribution worldwide is accomplished using a radial feeder in which there is only one path between any consumer and substation. In most cases, the feeder system is physically interlinked with normally open switches at suitable points, which are operated as radial. The various types of feeds are:

(i) **Radial feeder:** These are low cost circuits and easy to analyze and operate though reliability is low. Any equipment failure will interrupt service to at least all the consumers down stream from it.

(ii) **Loop feeder:** Two feeders can be constructed and operated as loop feeder circuits and are tapped for consumers in which the power flows into each end of a feeder. There is a null point somewhere on the loop where no power flows. This is basically a dynamic radial circuit with an open point (null point) shifting as the load changes, when constructed and properly protected, it provides a high level of reliability for the consumer.

(iii) **Feeder network:** This consist of a group of feeders which are interconnected so that there is always more than one route between any two points in the feeder network. It is designed with sufficient capacity protector throughout. This system gives a very high level of reliable power to the consumer. The cost is very high compared to the radial system. Voltage drop, fault behavior and load flow studies are some what complicated. Computer program is the key aid to carry out such studies [7].

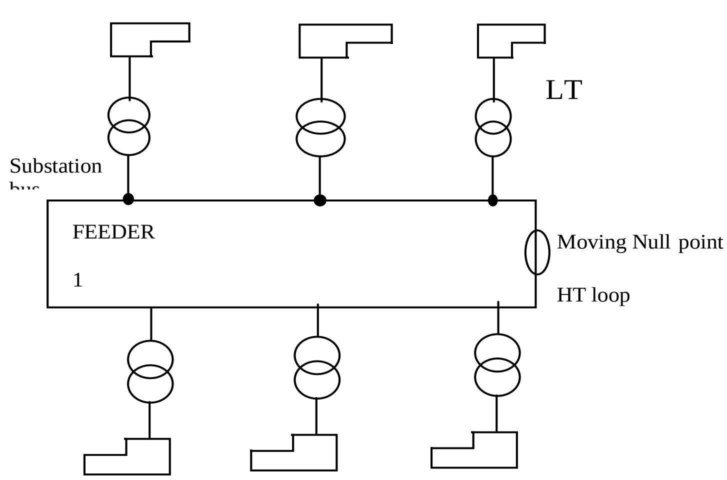

Figure 4: HT and LT loop feeders

6.0 Distribution System Economics & Finance

Economic analysis is carried out to determine the low cost plan among various alternatives. Financial analysis determines the rate of return and risk involved on the investment to be made on the plan.

The finance to carryout the planned distribution projects are tied to the following.

- ❖ Annual expenses: this is obtained from the operating revenue
- ❖ Capital Expenditure this is obtained from financing, reinvested reserves, reinvested earnings, consumer's, contribution for service connections
- ❖ Both annual expenses and capital expenditure.

Investment decisions is made on alternative proposals with the following methods.

6.1 Economic Analysis

Minimum Revenue Requirement; A choice is made on the basis of the present value of all future annual costs. That is the economic choice is the one with the lowest present value of all future costs. The economic comparison between alternatives involves two steps:

i. For each alternative, estimate the annual cost each year
ii. If the annual cost are not uniform, calculate their present value.

6.2 Time value of money

Money has time value and interest on its use has to be paid. The rate of interest is determined by the reserve bank of Nigeria or the country in question. At international level, there is a machine to determine the interest rate.

Alternative which requires the least expenditure immediately would be the best.

The process of taking money and finding its equivalent value at some future date is called future value calculation. The process of finding the equivalent value at earlier time is called present value calculation. Present value is the reverse of future value calculations.

6.3 Revenue requirement of investment

The total revenue requirement of investment is the sum of the annual charges extending over the service life. It includes

a) Return on investment
b) Depreciation
c) Insurance expenses
d) Operating and maintenance expenses
e) Interest on loan capital and working capital
f) Taxes

The above charges can be conveniently estimated as a percentage of the original investment

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7.0 Conclusion

The objective of power system planning is to provide satisfactory service at the lowest possible cost. In a power utility, the process seeks to identify the best schedule of future resources and actions to achieve the utility's goals. System planning is essential in power systems to ensure that future expansion is carried out without creating problems to the consumers during the period of the expansion. As a result of this, the paper has treated the principle of power system planning, planning methods, demand side planning and system development.

This is to ensure that all critical aspect of planning is treated and to ensure that effective planning culture is carried out to ameliorate the problems in our power systems,

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