Transmission System Planning in Competitive and Restructured Environment using Artificial Intelligence

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ABSTRACT

This paper picturesquely depicts the changing trends and values under new circumstances which are developed in electric power system i.e. generation side and partly on the way in transmission and distribution network. A very clear advocacy about the changing trends from vertical integrated setup to the horizontal disintegrated setup is explained in very simple way. All utilities are passing through the phase of disintegration globally; it is obvious that the same effect is also putting impression on the electrical power sector. This effect is designated as restructuring and competitive environment of public utilities. This specific approach means, that the public now demands to break the monopolistic approach and wants that the public utilities must be operated by public themselves but under umbrella of some regulatory body who can watch their interests and legislate rules which helps the masses in getting the better service than that they have. A clear comparison is also presented between the past/existing standard practices with the future methodology of transmission system planning. It also suggests that necessary analysis may also be done on computer by using different models and with the use of artificial intelligence and the expert system is considered to be the best with its features for transmission system planning.

Key words:

Restructuring, Congestion, (n-1) configuration, load forecasting, algorithm, expert system (ES).

1. INTRODUCTION

The World has changed its pace and developed into a global village, keeping close all the different sectors.

Electrical power being such an important requirement of all the sectors and requires to be developed, from its generation sector to the distribution end, that it should be developed in a more executive fashion then at present. A lot of work has already been done in the field of generation and the distribution sector, but the transmission sector still lags behind than the later. This paper specifically focuses about the transmission system planning, with an open explanation to the problems commonly arises during transmission planning by the transmission planners.

It is important to mention that in the past and also at present, continuous efforts are made to improve and develop the electrical transmission system which is more efficient, reliable and cost effective. A number of different techniques were used.

At present, latest computerized techniques are used. The Artificial Intelligence (AI) helps to develop the new transmission plans in more versatile manner with elaborated picture and with more options.

The World has change its attitude and the trend

is now of commercialization and this commercialization develops the approach of a deregulated environment in a competitive frame of reference. The power system mainly consists of generation, transmission and distribution. Generation and the distribution system is now playing its role both in the public and private sector but uptill now, the transmission sector is only working in a public sector or to some extent under corporative culture. This does not fulfill the requirements as that of a deregulated and competitive environment requires. [1]

This indication clearly opens the vistas to explore the new means of transmission system planning using artificial intelligence, by any of its application which is more beneficial and covers all the aspects as desired by the humanity.

In order, to manage and distribute electrical power in an effective and economical way, a properly planned transmission system is the basic and key requirement. Serving as a back bone between the generation and distribution end, the transmission system planning must be done in such a way to accommodate all the important aspects which are required to supply the power in an efficient, reliable and cost effective manner. The following are the main features which needs due consideration while doing the transmission system planning:

- Transmission system planning in accordance with the forecasted load.
- Segregation of forecasted load during peak hours and off peak hours.
- Suitable room to accommodate all the power producers.
- Provision for (n-1) link in transmission network for all type of voltage levels.
- Substation/grid stations of sufficient capacity to cater the generated load.
- Alternate arrangement in transmission network, while when one is under maintenance/fault.
- Provision to accommodate 50% of the transmission line load when one line is overloaded.
- Congestion management.
- Always have the sufficient capacity in accordance with the time frame of load required.

2. STANDARD PLANNING TECHNIQUES

The Figure – 1 describes the different phases required for transmission system planning. This flow chart is a basic one and all the stages involve in this are equally applicable in the past, even at present and also fulfills the basic requirements for future transmission system planning [1].

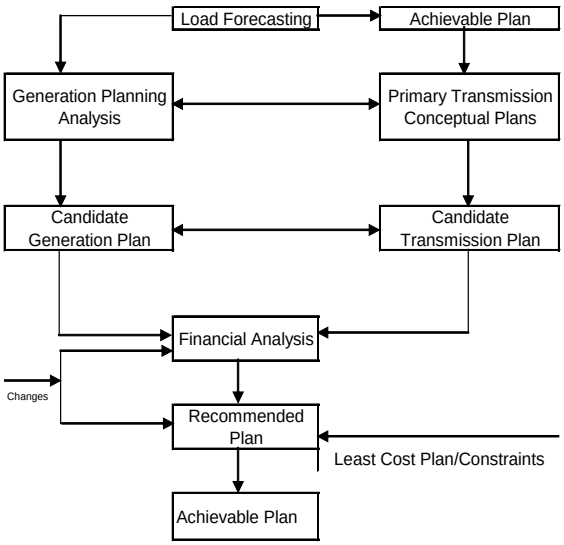

Figure: 1 Standard Practice of Transmission System Planning.

3. WHY THERE IS A D EMAND FOR DEREGULATION?

Importance of public utilities is evident right from the day, the mankind came into existence. As the generation grows and population increases, needs also increased and human beings are continuously trying to find better solutions and ways to cope-up with these. Amongst different public utilities are water, natural gas, communication network, electric power etc. Every utility has its own importance, but the electric power is at the top in the present era, right starting from its generation level to the distribution level. It is obvious that in this global era of fast track development, all the public utilities cannot be developed fully by the state due to financial constraints .Especially under-developed countries cannot take this sector fully [1].

Keeping in view, the above picture, now-a-days, there is change in all sectors including power sector globally. This global village now demands change in power sector and expects more than is available and it can only be achieved by applying different modern techniques and devise new methodologies to achieve the desired goals. In this current situation, the actual depiction of image of power sector in restructured environment demand new methodology with new principles for this deregulated, restructured and competitive environment. Further, the

approach must be rational but not limited to one state [1].

This thought of deregulation has given birth to change the system from vertically integrated system to convert it into horizontal one i.e. breaking up the monopolistic approach and with new system every one is free to come into power sector market and proves that, the services provided by his set-up is better than other, a more competitive approach in deregulated and restructured, competitive environment.

In restructured environment, especially when the services are changing mode from vertical integrated setup to a horizontal disintegrated restructured setup, there is an utmost need to have one regulatory body which regulates all the matters of power sector in all respects. [5].

4. ROLE OF REGULATORY BODY

The regulatory body is required for continuous monitoring all the activities which are going in the electrical sector and different reforms are to be formulated for the betterment of the public, like formulation of new principles, procedures, legislation, practices etc. of the electrical sector of any country. [5].

5. FUTURE METHODOLOGY OF TRANSMISSION SYSTEM PLANNING

The Figure - 2 is self explanatory and explaining the different steps involved in transmission system planning for the future. This flow chart also covers the practice followed in the past and shown as in figure-1 above and in addition to that different important aspects for which the specific care is needed are also added which gives a more better, reliable and cost effective service as compare to the past/existing standard practices [7].

See Figure : 2 as Annexure

6. SIGNIFICANCE OF AI

AI plays a pivotal role in every field existing in the world and especially in the filed of sciences and in particular in engineering sector. Its significance is evident from the fact that AI attempts to understand intelligent entities. The intelligent entities are interesting and useful. AI has produced many significant and impressive products. It is clear that computers with human level intelligence would have a huge impact on our every day lives and on future course of civilization.

AI helps in understanding how to see, learn, remember and reason could be done. In this, the computer provides a tool for testing theories of intelligence. [4]

7. DIFFERENT FIELDS OF ARTIFICIAL INTELLIGENCE

The following are the types of AI:-

i. Expert System
ii. Fuzzy Logic
iii. Neural Network [2 , 3]

7.1 Expert System

An expert system is commonly known as knowledge based system, based on computer program that contains the knowledge and analytical skills of one or more human experts related to a specific subject. [2]

The most common form of an expert system is a computer program with the set of rules that analyzes information about a specific class of problems and recommends one or more courses of user action. The expert system also provides mathematical analysis of the problem. It utilizes the reasoning capability to reach on the conclusions. [3]

7.2 Fuzzy Logic

Computers are too logical and they only deal in true or false, yes or no etc.

Fuzzy logic allows a computer to deal in every day human language and actually process terms such as probably, unlikely, quite, near etc. Such terms can take their place in computations allowing the computer to arrive at verifiable results from fuzzy inputs. The logic used is mathematically verifiable so results for the process can be trusted.

Fuzzy logic is derived from fuzzy set theory dealing with reasoning that is approximate rather than precisely deduced from classical predicate logic. It can be thought of as the application side of fuzzy set theory dealing with well thought out real world expert values for a complex problem.

7.3 Neural Network

Traditionally, the term neural network had been used to refer to a network or circuit of biological neurons. The modern usage of the term often refers to artificial neural networks, which are composed of artificial neurons or nodes. Thus the term 'Neural Network' has two distinct usages. [9]

- Biological neural networks are made up of real biological neurons that are connected or functionally related in the peripheral nervous system or the central nervous system. In the field of neuroscience, they are often identified as groups of neurons that perform a specific physiological function in laboratory analysis.

- Artificial neural networks are made up of interconnecting artificial neurons (programming constructs that mimic the properties of biological neurons). Artificial neural networks may either be used to gain an understanding of biological neural networks, or for solving artificial intelligence problems without necessarily creating a model of a real biological system.

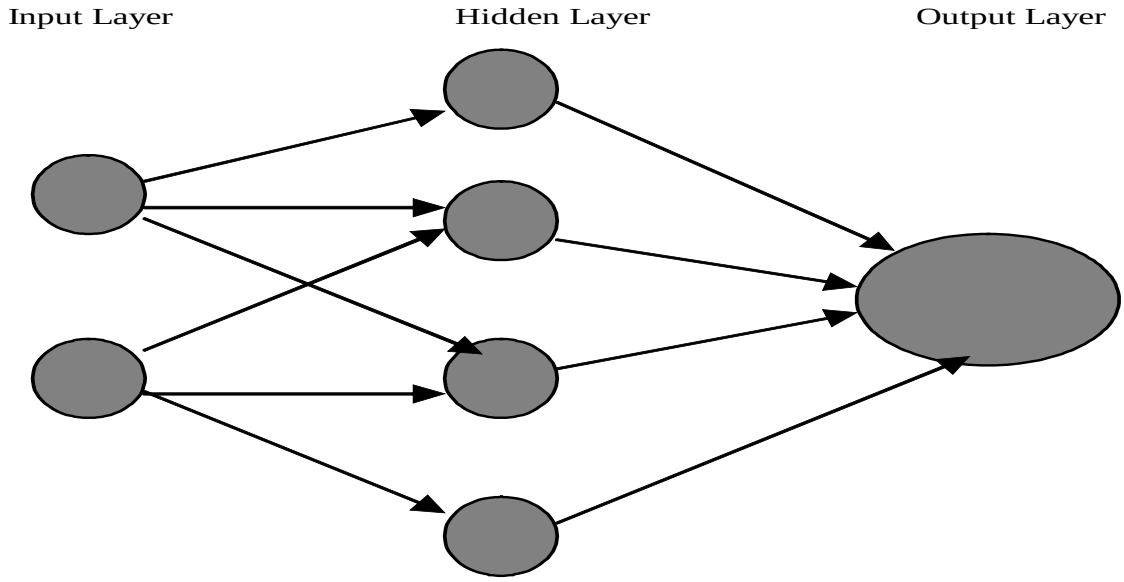

Figure – 3 Simplified view of an artificial Neural Network

8. ELECTRICAL TRANSMISSION NETWORK WITH DIFFERENT VOLTAGE LEVELS.

In any country, the electrical transmission network is always consists of different voltage levels, according to the needs of the area linked with. This electrical network also shows the location of generating stations at different point's along with the generating capacities. This addition of power changes the voltage profile of the electrical network and stables the voltage level. This addition of power also improves the power factor of the system.

The Figure – 4 is a part of complex electrical network with different voltage levels i.e. 220KV and 132KV.

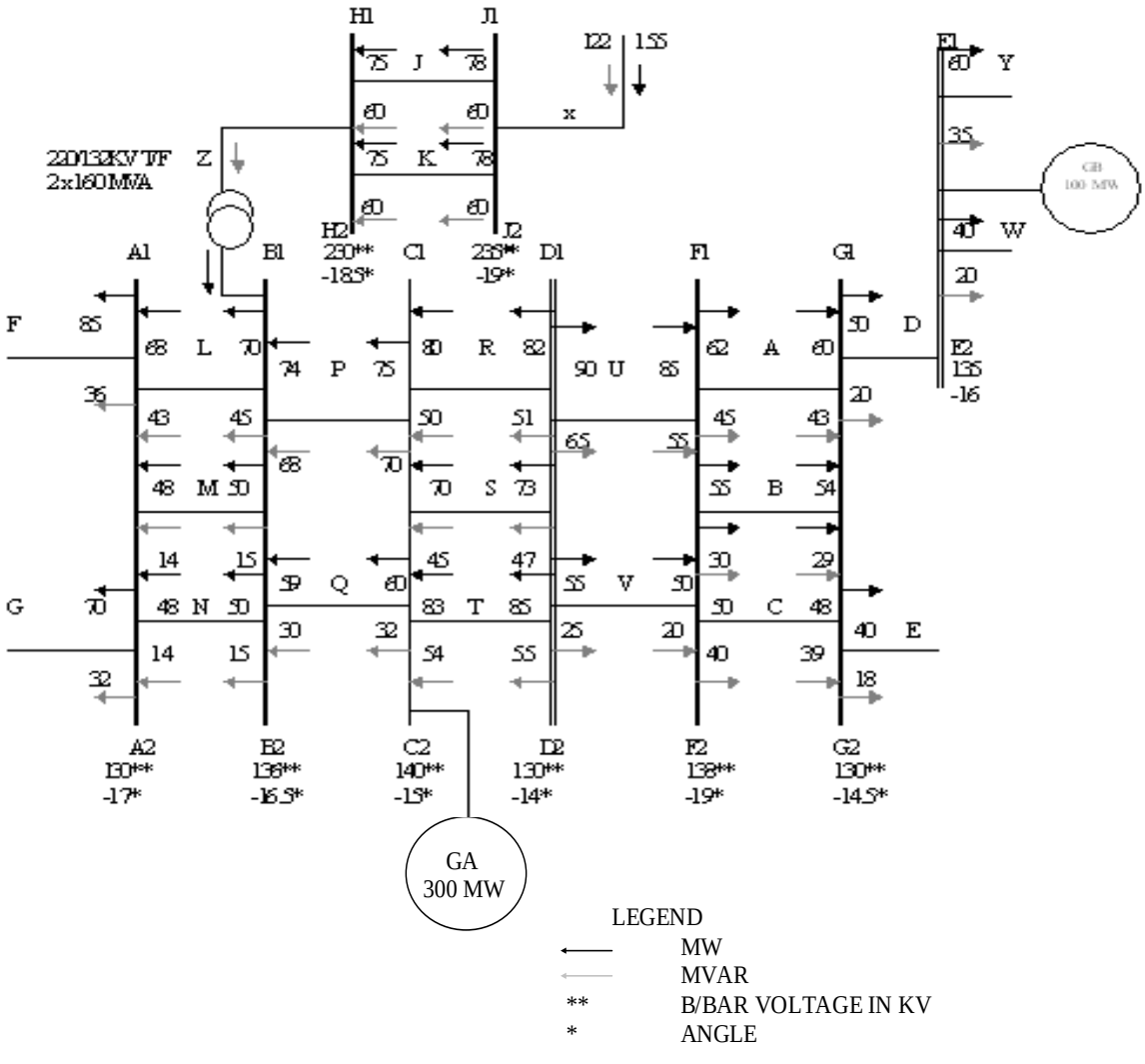

Figure 4:- A part of 220 KV and 132KV Complex Electrical Transmission System

9. TRANSMISSION SYSTEM PLANNING IN TRADITIONAL SETUP VS RESTRUCTURED ENVIRONMENT.

A comprehensive comparison of the transmission system planning in traditional setup and deregulated setup is given under: -

Item	Traditional Setup	Deregulated Setup
Load forecasting	This is done but not on the actual basis, without having a in depth look of economic growth and other parameters	Of immense importance and to be done on actual basis.
Segregation of load	Totally neglected	For accurate transmission planning and to create the hedge, segregation of load is required between peak and off peak hours
Availability of transmission line	Independent power producers (IPP's) were invited but the system lacks to accommodate the generated power	Key feature, in order to develop a reliable and cost effective transmission system, suitable room must be provided before

n-1 link	Already n-1 links are available but at certain points, this provision is not available	This must be given to all the links, irrespective of load requirement
Substations/ grid stations	These must be augmented according to the load requirements in order to provide reliable and stable electrical power	Giving equal importance as that of transmission system planning, if augmentation or construction of new grid station are required, these must be planned in parallel to the transmission planning
Alternate arrangement and to accommodate 50% of the required load	Proper alternate arrangement is not available to accommodate the 50% of the required load during maintenance or overloading	During transmission planning, the network should be designed as having the capacity to accommodate at least 50% of the load requirement
Congestion management	Totally neglected	Key feature during the transmission planning and even of more important nature in deregulated setup when there are number of IPP's desire to supply power on the system

10. KEY FEATURES IN TRANSMISSION SYSTEM PLANNING.

Transmission system planning is the most important sector of electrical network and has the following key aspects:

- Load forecasting
- Primary transmission conceptual plan
- Generation planning activities
- Candidate transmission plan
- Candidate generation plan
- Financial analysis
- If no constraints and the plan is technically feasible and economical viable then
- Recommended plan
- Approval from regulatory body
- Achievable plan

In both the setups i.e. traditional and deregulated, the above noted are the key features to have a proper transmission plan.

All the features have significance but the key feature in the transmission system planning is the load forecasting. This is the load forecasting which actually gives the signal in the system and then directs the attentions of the engineers to study and make necessary changes in the system according to the requirements. No transmission system can be planned without having proper forecasted figures.

It is the load forecasting which indicates that the requirement of electrical power is increased from the present load requirement and in accordance to that new-projected figures of load, different transmission plans are required to be proposed in connection with the increase of power demand, which diverts the attention to install new power plants. This study ultimately leads to have a candidate transmission plan and at the same time, the requirement of a new power plant.

After the selection of candidate transmission and generation plan, financial analyses are to be made in order to calculate the benefit cost ratio. If no constraints are there, the project is discussed with the approving authority and if the authority agrees with all the aspects, the project is called the achievable plan.

There is no specific change in the ways of transmission planning as of traditional setup with the deregulated setup except a special attention towards the environment is required as an international law.

Again coming back, showing the key importance of load forecasting, if this is done on actual grounds, the transmission system planning is automatically be the actual one.

11. TRANSMISSION CONGESTION MANAGEMENT

Transmission congestion occurs when there is

insufficient transmission capacity to simultaneously accommodate all requests for transmission service within a region. Historically, vertically integrated utilities managed this condition by constraining the economic dispatch of generators with the objective of ensuring security and reliability of their own and/or neighboring systems.

The top priority items during transmission system planning:

- Congestion management
- Cost recovery
- Market monitoring
- Transmission planning
- Business and reliability standards
- Transmission rights

11.1 Congestion zones

The zones are defined such that each generator or load within the zone has a similar effect on the loading of the transmission lines between zones. Once zones are defined, any imbalance between load and generation within a zone is assumed to have the same impact on inter-zonal congestion. Zone boundaries are reexamined annually to see if generation, load, or transmission patterns have changed enough to warrant changing the zones. The zones are designed to capture the "commercially significant constraints".

11.2 Improvements in congestion management

Effective transmission system planning also addresses to start charging customers directly for the commercially significant congestion as proposed by the regulatory body.

Deregulation and policies of open access, allocation of scarce transmission resources has become a key factor for the efficient operation of electricity markets as well as reliability and control of market power. This trend emphasizes for the re-enforcement and expansion of the transmission capacity in accordance with the demand of power and the emerging trend to transfer power over long distances. These trends are important for congestion management to structure and facilitate economically efficient allocation of transmission capacity.

12.0 OPERATIONAL POLICIES

The importance of policy, procedures etc. are definite in every field. The same is the case with the electrical power. Operational policy is required in both the cases whether the system is a regulated one or a deregulated. Globally, different type of operational polices were in practice, when the electric utility is state owned and governed by the state. Now, the trend is changing and the process of disintegration of electric utility is on its way and also the approach is now more inclined to a horizontal deregulated setup. In this regard, the important features which must be taken into account and considered while devising the transmission system plans. This operational policy helps in explaining the importance and need for measurement and standards for planning the transmission network in competitive and deregulated setup [5].

The under mentioned points must be taken into account while doing the transmission system planning.

- Increased growth in the number and complexity of transactions.
- Increased number of market players and their information needs.
- Competitive metering of energy generation—including distributed generation—and ancillary services at the supplier and customer levels.
- Monitoring bulk power flows and transactions.
- Monitoring transmission and distribution system conditions [5].
- Monitoring power quality along these systems and in customer facilities.
- Tracking/tagging of power flows to assign cost responsibility for congestion on overloaded lines and constrained interfaces.

In general, deregulation will lead to changes in several important electrical power industry characteristics:

- Services will be unbundled, and is necessary to separately evaluate each type of transaction.
- Time frames will shorten. New services will be measured over seconds and minutes instead of hours.
- Transaction sizes will shrink. Instead of

dealing only in hundreds and thousands of MW, it will be necessary to accommodate transactions of a few MW and less.

- Supply flexibility will greatly increase. Instead of services coming from a fixed fleet of generators, service provision will change dynamically among many potential suppliers as market conditions change.
- Who will pay the cost of Reactive power [5]

Finally, the different issues discussed above are also of key importance but certain other technical features that must be taken into account before developing transmission system plans in competitive and restructured environment. These are

- Increased transmission demand,
- Service quantification,
- Reliability criteria,
- Real-time electric pricing,
- Unbundling of ancillary services,
- Reduced generator and transaction sizes,
- Power quality, and
- Supplier choice.

13.0 EXPERT SYSTEM (ES)

The significance of artificial intelligence (AI) and the philosophy of AI were already discussed in preceding paragraphs. Further, different systems were also discussed and prove that ES is better then the others.

As already discussed the importance of load forecasting with reference to transmission system planning, so an expert system is designed for electrical load forecasting based on multiple linear regression.

The model for the hourly load at each of the considered time intervals has the form;

$$Yi(t) = Ai + Bi(Td(t) - Tci) + Ci(Td(t) - Tci)2 + Di(Td(t) - Tci)3 + Ei(Tp(t) - Tpi) + Fi(Tava - Tavb) + Gi(Td(t) – Td(t - 1)) + Hi(Td(t - 1) – Td(t - 2) + Ii(Td(t -2) – Td(t - 3))$$

and where

yi(t) = load at hour t in the interval of the day

AI = base load component (regression constant coefficient)

Bi through Li = regression coefficient of weather sensitive component

Td(t) = dry bulb temperature at time t, f=deg F

(which will be clamped at the cut off value if necessary)

Tp(t) = dew point temperature at time t, f=deg F

(which will be clamped at the cut off value if necessary)

Tava = average dry bulb temperature of previous 24 hours to the time t, deg F

Tavb = Tava lagged 3 hours, deg F

Tci = cut off dry bulb temperature for the interval I in the season, deg. F

Tpi = cut off dew point temperature for the interval I in the season, deg. F

v(t) = wind speed at time t, miles/hour

we have the values of above parameters estimated for different time intervals

The Figure – 5, shows the flow for the Algorithm and results are shown as in Figure – 6.

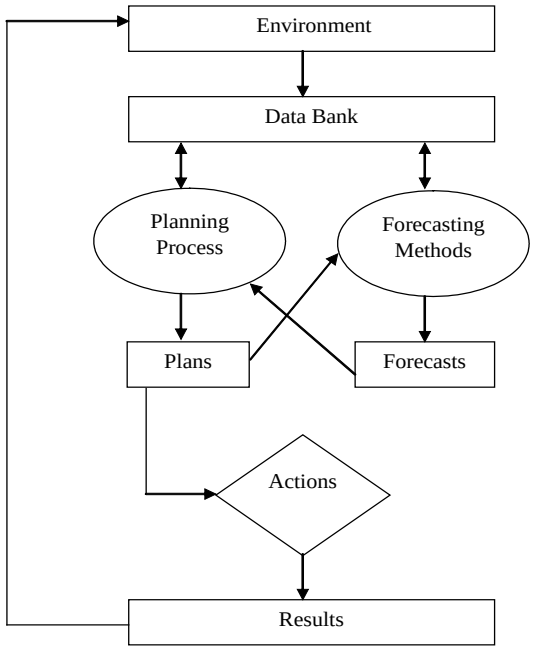

Figure – 5: Flow Diagram for Algorithm

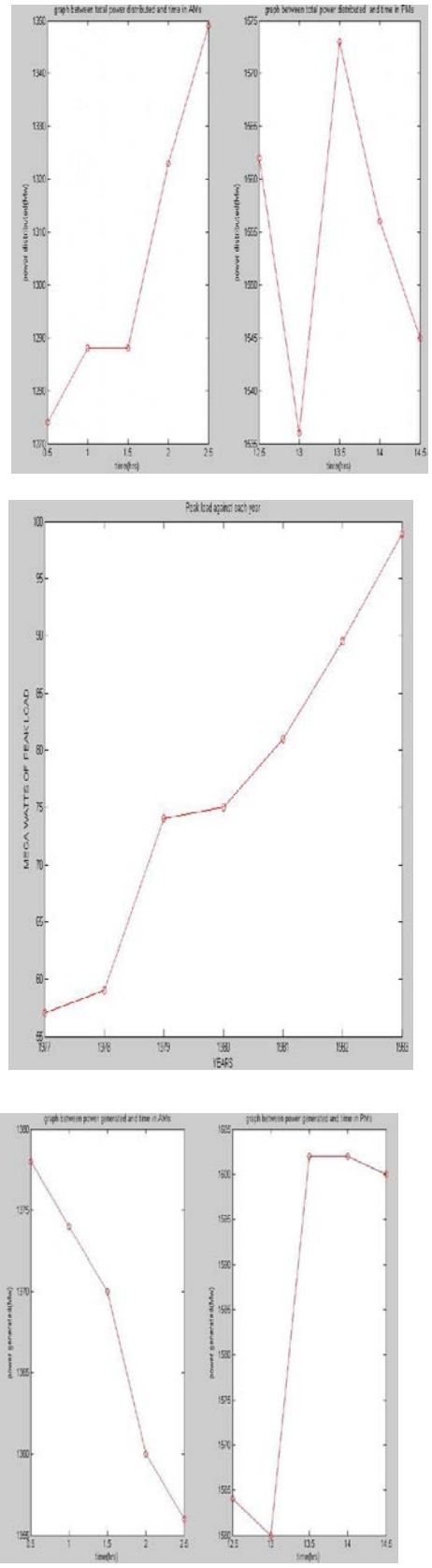

Figure 6 : Graphs

14. CONCLUSIONS

The electrical power transmission system is the backbone of the electrical network. In order to develop, an efficient, reliable and cost effective system, this needs specific attention towards the planning part. Effective planning gives better results and more reliable service to all categories of consumers, with an open, fair and free access on discriminatory basis.

Effective planning can only be done with the help of artificial intelligence and expert system. In this present modern era, the role of computerized technology is in all the fields and in order to study over wide options and to do the better planning of the existing system and to develop the new ones, expert system is the most effective solution.

The transmission system planning serves as a backbone in the electrical network system. All the parameters involved in electrical network have unique importance but in transmission system planning, the load forecasting is the primary feature to develop the stable, reliable and cost effective system. In order to obtain the better results, the use of artificial intelligence is made and an algorithm is develop in ES, so as to have better load forecasted figures which helps to plan the system in better way and in less time.

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