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# Long Term Load Forecasting Using Soft Computing Techniques

Dogra Sonika[1], Sidhu Darshan S[2], Kaur Daljeet[3]

**Abstract**— Load forecasting is very important for power system planning, its operation and control. It has vital importance in electric industry. There are many applications of load forecasting which includes energy purchasing and generation, load switching, contract evaluation, and infrastructure development. It is very important for energy suppliers, financial institutions, and other participants in electric energy generation, transmission, distribution, and markets. It is helpful for peak demand levels and energy consumption patterns. It is also very helpful for an electric utility to make important decisions in power system. Forecasting means estimation of active load at various load buses ahead of an actual load occurrence. A good forecasting model has to capture some important features like economy, climate, weather, human activities, interactions etc. Planning and operational application of load forecasting requires certain lead time known as forecasting intervals. Depending upon the time interval it is divided in to three categories i.e. Long term load forecasting, Medium term load forecasting, Short term load forecasting. A good forecaster takes in to account the various demographic factors which will affect the future load e.g. population, temperature, humidity etc. In case of long term load forecasting, population will affect the most, the other two factors will have more importance in short term load forecasting. For load forecasting different methodologies are adopted. The various methodologies are Artificial Neural Network (ANN), Support Vector Machine (SVM), Fuzzy Logic Models and Genetic algorithm.

This paper is devoted to study long term load forecasting of two stations. For this research work, load data for last 18 years is taken and load is calculated with the help of different curve fitting equations for both the stations. For load calculation, MATLAB program is used. With the help of this data, load is calculated for next nine years. Fuzzy logic and Genetic algorithm methodologies are used to forecast the load. Both these methodologies are compared with each other.

**Index Terms**— Load forecasting, Long term load forecasting, Fuzzy Logic, Demographic factors, Regression, DDF (Data Dependent Factors), MDF (Model Dependent Factor), ES (Expert System), Genetic Algorithm, ANN (Artificial Neural Network), SVM (Support Vector Machine).



## 1 INTRODUCTION

THE The basic necessity for the economic development of a country is energy. There is a close relationship between the energy used per person and their standard of living. More the population, more will be the per capita consumption of energy in a country, and higher will be the standard of living of its people. There are different forms of energy and most common form is electrical energy. Our modern society depends upon the use of electrical energy. Power demand of different consumers varies according to their activities. Most of the complexities of modern power plant operation arise due to variability of the load. The growing tendency of electricity system is continually confronting the different sectors of the industry, with increasing demand on planning management and operations of the network. We know that energy cannot be stored but can be changed from one form to other. Therefore the power station must produce power as and when required by the consumers [19]

Load forecasting plays an important role in power system planning, operation and control. It is very helpful for an electric utility to make important decisions in power system. Forecasting means estimation of active load at various load buses ahead of an actual load occurrence. A good forecasting model has to capture some important features like economy, climate, weather, human activities, interactions etc. Planning and operational application of load forecasting requires needs certain lead time known as forecasting intervals. It is very useful to support analysis of strengthening or expansion of existing infrastructure, implementation of maintenance scheduling or to plan the integration of dispersed, adoption of an optimized network configuration, load switching, voltage control, and infrastructure development. A number of algorithms have been suggested for solving this problem. [17]

Electric power grids are most complex manmade system because of their wide geographical coverage. These power grids differ from each other because of various transactions among different utilities, difference in individual electric power companies, differences in their layouts, their size, and different equipments which are used in these utilities. There are some other tools e.g. unit commitment, state estimation, automation generation control, security analysis, optimal power flow and load forecasting. Since there is no buffer from generation to end users, and power systems have to the meet the maximum demand, which is also called as peak load, which ensures that sufficient power can be delivered to the customers as and when it is required by them. A good forecasting model includes various factors like economy, climate, weather, human activities, interactions, salient features of electric load, etc. [17]

## 2 LITERATURE SURVEY

We know that load forecasting is very important for planning operation and control of a power system. There are various studies carried out for the load forecasting. Ghods et.al discusses the past and current practices of long term load forecasting. Different methods were used for load forecasting. Aslan performed long term peak load forecasting for Kutahya city with least square regression methods and artificial neutral networks using the load, temperature and population growth data from 2000 to 2008. The results attained were compared with real data obtained from that particular state electricity board. By comparing the forecasted results with real data, the most suitable method was proposed. Hong Tao did a formal study of long term load forecasting method in a small area based on electric load history, current and future land used information, and used those inputs to forecast load of next 20 years. S-curve trending method was used to conduct basic load forecasting**.** Kandil MS had used a knowledge-based expert system (ES) to identify the most suitable load forecasting model for medium/ long term power system planning. In their proposed ES, the detailed problem statement including forecasting algorithms and the key variables (electrical and nonelectrical variables) that affect the demand forecasts were firstly identified.

A set of decision rules based on those variables were obtained and stored in the knowledge base. Thereafter, the best model that accurately reflects the typical system behavior over other models is suggested to produce the annual load forecast. Bhardwaj AK carried out a study to ascertain the electric power demand forecast for Lucknow city upto year 2023 taking into account the city temperature and population. The study was carried out in the month of June 2008 taking the 2001 Indian census as reference for forecasting. Single exponential smoothing technique was used for forecasting. Achanta Renuka applied Artificial Neural Networks (ANN) and Support Vector Machines (SVM) tools to predict electric load. When the results obtained using both the techniques were compared, the performance of SVM was found to be consistently better. Swaroop et.al used neural networks and combined Fuzzy Logic, for long term load forecasting. Here a relationship between the humidity, temperature and load was identified by carrying a case study in a particular region in Oman. Correction factor was applied by neural networks. The data for last three years were taken and the results were obtained for the fourth year. Regan Ronald C.P. et.al carried out a collaborative approach on fuzzy and neural technology. In this methodology, the historical data including different demographic factors was taken. The error obtained for this model was compared with the errors produced by the other existing methodologies. Hesham K. Alfares et.al reviewed electric load forecasting techniques. A wide range of methodologies and models for forecasting were used. The methodologies for each category were briefly described and their advantages and disadvantages were also discussed. Eugene A. Feinberg Dora Genethliou presented variety of mathematical methods for load forecasting. Various statistical and artificial intelligence techniques were reviewed for electric load forecasting. Various factors that affect the accuracy of the forecasts were also reviewed. Patel Parth Manoj et.al carried a fuzzy logic approach for short term load forecasting. Various independent variables like time, temperature were used to carry out this study. Based on these independent variables, fuzzy rule base are prepared and used for the short term load forecasting. MATLAB SIMULINK software is also used. Jagadish H. Pujar gave an algorithm to forecast long term load. The algorithm was prepared for Short term load forecasting method and extended to Long term load forecasting. Various errors were also incorporated into the forecasting and, forecasts with very high accuracy have been achieved. In this paper, the proposed fuzzy based long term forecasting has been demonstrated for small scale but the same algorithm is capable of forecasting the load for larger scale. Eisa Almeshaiei et.al presents a pragmatic methodology to construct Electric Power Load Forecasting models. This methodology was based on decomposition and segmentation of the load time series. Several statistical analyses and load features were involved in this study. The results were used to guide forecasting future needs. They studied that the segmentation process results in homogeneous regions for which polynomial trends have been identified. Khaled M. EL-Naggar et.al did a comparison of three estimation techniques namely genetic algorithms (GA), least error squares (LS) and, least absolute value filtering (LAVF). Real data was collected to perform these techniques. Form the comparison; it was found that GA technique is better than other two techniques. The advantage of various algorithms was also studied. Ajay Gupta et.al used GA-BPN model for extracting the best matrices for different layers of BPN so that forecasting done for the future is more accurate. They introduced evolution of connection weights in ANN using GA. GA-BPN was used as a tool in electric load forecasting. This study was based on a methodological selection of variables. M.A. Farahatet et.al presented a new approach for short-term load forecasting (STLF). Curve fitting techniques and time series models were used. Genetic algorithms (GAs) were used to minimize the error between actual and forecasted load. The proposed model was simple, fast, and accurate. The results obtained were quite accurate as compare to conventional techniques. This proposed model is used to forecast the load. This study was based upon Genetic Algorithm. Abbas Karimi et.al presented an approach for dynamic load balancing algorithm. They used fuzzy logic systems which make absolute outputs from uncertain inputs. In their future works, they followed the load balancing issue in parallel systems and found that response was quicker. They predicted the nodes status as sender, receiver or neutral less time complexity by using neurofuzzy techniques

## 3 CONTRIBUTION AND SCOPE

The main objective is to forecast the load in advance, so that it is always available to the consumer. We know that with the growing trends of industrialization and with increase in the living standards of people the demand of power is increasing day by day. Hence load forecasting is going to be very helpful in future. The same methodologies can be applied for short term load forecasting, in which the load is calculated monthly. They can also be applied for medium term load forecasting in order to calculate hourly load. By doing so load shedding in particular area can be reduced. MATLAB programming has been used for computational work. MATLAB tool box can also be used for in case of fuzzy logic methodology for load forecasting. This analysis has been proved successful for power system operation and control.

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## 4 METHODOLOGY

The main objective of this research is to forecast the load of two different stations for next nine years. The two stations chosen are Amritsar in Punjab, Mamun military station in Punjab. In Amritsar, the load growth is estimated to be commercial and residential loads, that is expected to increase rapidly every year as population and standard of living is increasing rapidly. The load in Mamun military station will be almost stagnant when compared to other station. During this study, it is proposed to utilize the load data of last 18 years, by selecting different years as base year and use Fuzzy logic rules and Genetic algorithm techniques to forecast load for next nine years.

**4.1Fuzzy Logic:** It is a very robust artificial intelligent technique. Here a general algorithm to forecast long term load is used for long term load forecasting in both the stations namely Amritsar and Mamun cantonment. It not only forecasts the values but also concentrates on the errors incorporated into the forecast. Hence, by applying the correction to the various errors load forecast with very high accuracy have been achieved. Algorithm is achieved with the help of data collected for residential sector for both the stations. The algorithm developed for long term fuzzy load forecasting can be represented as a flowchart. In order to demonstrate the algorithm, load data & data regarding factors influencing load for domestic consumers was collected for a period of 18 years (from Jan 1997- Dec 2014). The main factor which affects the load consumption of domestic consumers is number of domestic consumers. The relationship between load and these factors is linear. Following flowchart is used to forecast load for next nine years with fuzzy logic model. In this flow chart there are two models, first fuzzy model is made from actual load after applying error, and second model is made from factors affecting load forecasting. Here, with the help of first nine years of load data & data of factors affecting (year1997 to 2005), next nine years of load data can be determined (from year 2006 to 2014), in order to demonstrate the efficiency of the algorithm determined values of load is compared with available actual values. Further, load values for next nine years are also forecasted (from year 2015 to 2013). Here, Fuzzy model-I is used to determine error in forecast load value due to DDF & MDF & Fuzzy model-II is used to determine error in forecast load value due to ME. Various mathematical equations which are used to calculate the load with the help of previous data are as follows.

| | | | |
|---|---|---|---|
| Straight line | y | = | $a + bx$ |
| Parabola | y | = | $a + bx + cx^2$ |
| S-curve | y | = | $a + bx + cx^2 + dx^3$ |
| Exponential | y | = | $ce^{dx}$ |

Where a, b, c and d are coefficients y is year and x is actual load. In this technique, above mentioned fitting trend curves are used into basic historic data to reflect the growth. Other than this, the relationship between load growth and population, which is linear, is also taken into consideration. With the help of previous data, it has been found that in case of Amritsar city.

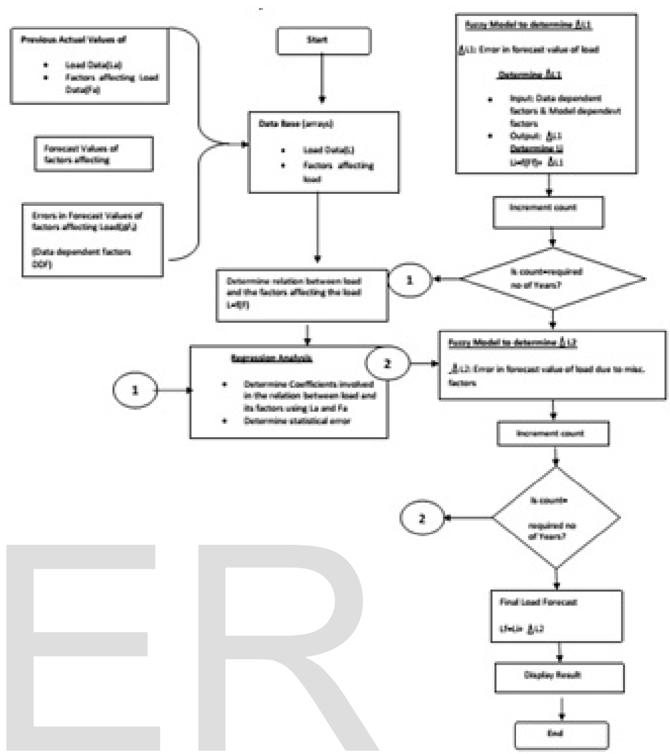


Fig 1.Flow Chart for Fuzzy Load Forecasting

### 4.2GENETIC ALGORITHM:

GA has applications in various engineering and scientific fields. It has number of advantages such as adaptability, ability to handle non-linear, ill defined and probabilistic problems. As we know that long term load forecasting of a future demands on a realistic basis is important in power planning. Mostly power projects have long gestation periods which are generally extended to 10 years. Since nineties, there has been a growing interest in algorithms. There are well known programs like genetic algorithms, simulated annealing, classifier systems, and neural networks. Genetic algorithm is based upon the principle of evolution, survival of fittest. Here population of individuals undergoes a sequence of transformations like mutation type or crossover type. After few generations, the program converges to the optimal value. GA is best suited for the problems like load forecasting. These algorithms are inspired from phenomena found in living nature. There are three important operators in genetic algorithms which are commonly used, i.e. Crossover, Mutation and Selection & survival of the fittest.

Crossover: It creates a new individual, out of two individuals of the current population. The child string is obtained after the recombination or crossover as follows:-

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(a) Slice each of the parent string in the sub strings.

(b) Exchange a pair of corresponding sub string of the parents.

c) Merge the two respective sub strings to form off springs.

Crossover Probability generally ranges from 0.25 to 0.95. For better results, it is advisable to select the crossover rate quite large than mutation rate.

Mutation: It is an important operator. It results in the contraction of the population to a point, which we want at the end of the convergence process. Mutation probability ranges from 0.001 to 0.03. It is approximately inversely proportional to the population size.

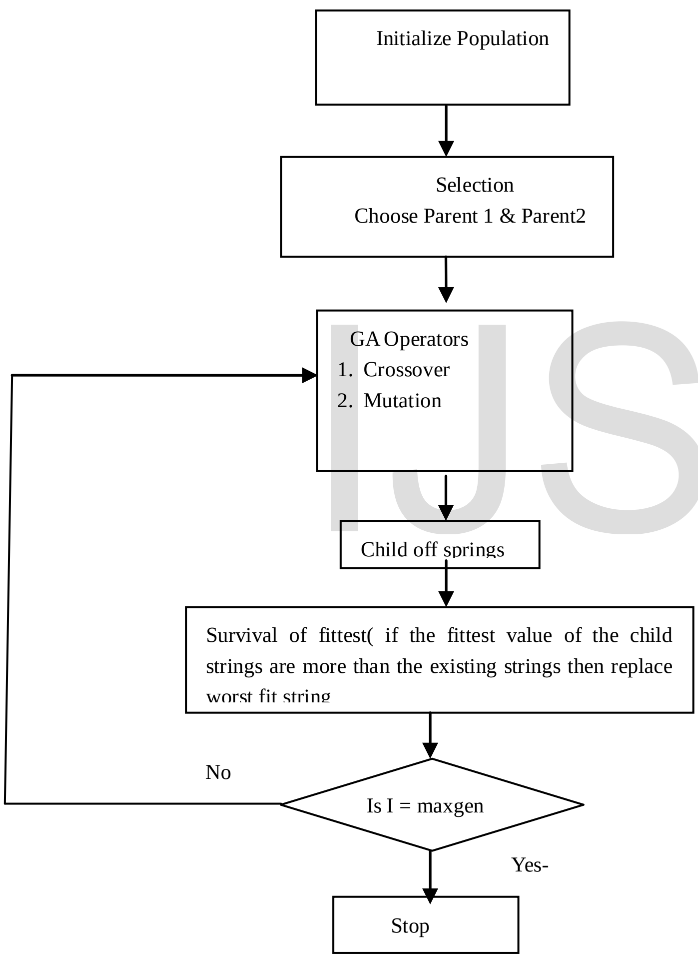


Fig 2: Flow Chart of Genetic Algorithm

# 5.RESULT

## 5.1Load Comparison for Amritsar city (S-Curve)

Table1: Load comparison table

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 1997 | 40.65 | 40.66 | -0.25 |
| 1998 | 41.85 | 43.26 | -3.37 |
| 1999 | 42.08 | 46.08 | -9.51 |
| 2000 | 45.73 | 49.14 | -7.46 |
| 2001 | 43.21 | 52.53 | -21.57 |
| 2002 | 62.02 | 56.33 | 9.17 |
| 2003 | 60.43 | 60.67 | -0.397 |
| 2004 | 63.58 | 65.76 | -3.43 |
| 2005 | 63.42 | 71.96 | -13.47 |
| 2006 | 73.01 | 75.42 | -3.3 |
| 2007 | 71.92 | 85.24 | -18.52 |
| 2008 | 105.09 | 96.89 | 7.8 |
| 2009 | 111.02 | 107.21 | 3.4 |
| 2010 | 114.49 | 115.08 | -0.511 |
| 2011 | 114.44 | 121.19 | -5.9 |
| 2012 | 129.04 | 126.17 | 2.2 |
| 2013 | 129.21 | 130.39 | -0.916 |
| 2014 | 140.36 | 134.07 | 4.48 |

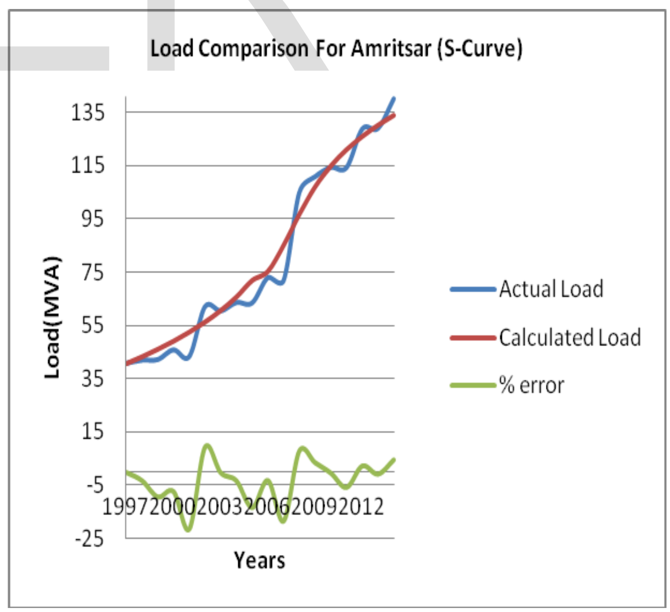


Fig. 3: Load comparison (S-Curve)

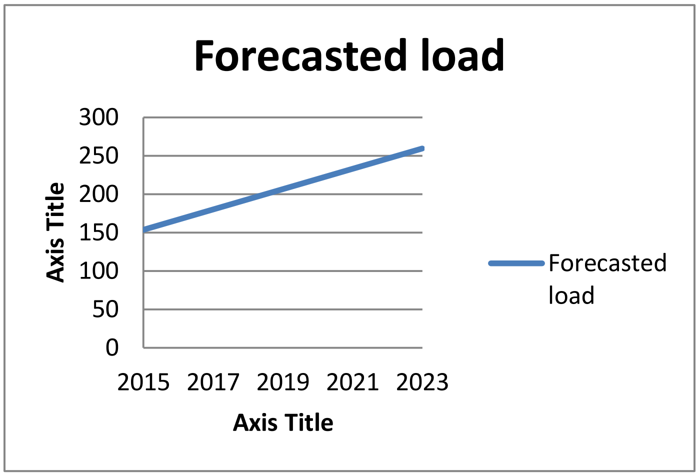


Fig.4: Forecasted load for Amritsar city (S-Curve)

### 5.2 Load Comparison for Mamun Cantonment (S-Curve)

Table 2 : Load comparison table

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 1997 | 5.71 | 5.66 | 0.876 |
| 1998 | 5.84 | 5.72 | 2.05 |
| 1999 | 5.91 | 5.79 | 2.03 |
| 2000 | 6 | 5.86 | 2.33 |
| 2001 | 6.08 | 5.93 | 2.47 |
| 2002 | 6.02 | 6.01 | 0.166 |
| 2003 | 6.11 | 6.09 | 0.3273 |
| 2004 | 6.46 | 6.18 | 4.33 |
| 2005 | 6.6 | 6.28 | 4.85 |
| 2006 | 6.61 | 6.5 | 1.49 |
| 2007 | 6.73 | 6.63 | 1.42 |
| 2008 | 6.76 | 6.78 | -2.42 |
| 2009 | 6.86 | 6.94 | -1.157 |
| 2010 | 7.9 | 7.15 | 9.451 |
| 2011 | 10.5 | 7.46 | 28.961 |
| 2012 | 9.26 | 9.58 | -3.441 |
| 2013 | 10.21 | 10.03 | 1.792 |
| 2014 | 10.27 | 10.28 | -0.114 |

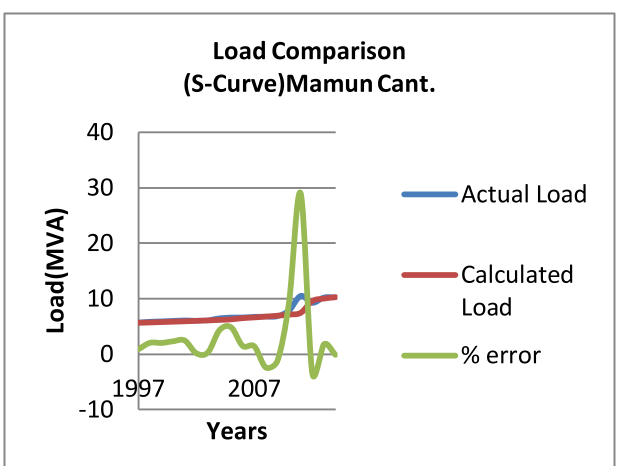


Fig.5: Load comparison (S-Curve)

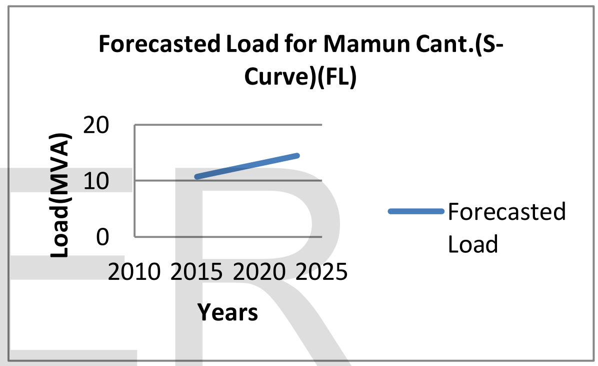


Fig.6:Forecasted load for Mamun Cantonment (S-Curve)FL

### 5.3Load Comparison for Amritsar (S-Curve)(GA)

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Table3: Load Comparison Table

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 1997 | 40.65 | 40.66 | -0.25 |
| 1998 | 41.85 | 43.26 | -3.37 |
| 1999 | 42.08 | 46.08 | -9.51 |
| 2000 | 45.73 | 49.14 | -7.46 |
| 2001 | 43.21 | 52.53 | -21.57 |
| 2002 | 62.02 | 56.33 | 9.17 |
| 2003 | 60.43 | 60.67 | -0.397 |
| 2004 | 63.58 | 65.76 | -3.43 |
| 2005 | 63.42 | 71.96 | -13.47 |

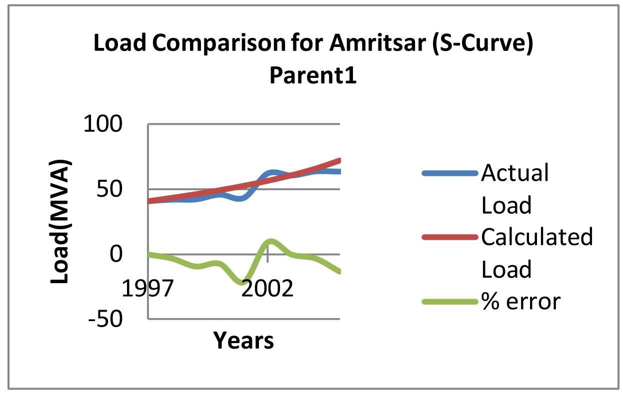


Table 4: Load Comparison Table

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 2006 | 73.01 | 75.42 | -3.3 |
| 2007 | 71.92 | 85.24 | -18.52 |
| 2008 | 105.09 | 96.89 | 7.8 |
| 2009 | 111.02 | 107.21 | 3.4 |
| 2010 | 114.49 | 115.08 | -0.511 |
| 2011 | 114.44 | 121.19 | -5.9 |
| 2012 | 129.04 | 126.17 | 2.2 |
| 2013 | 129.21 | 130.39 | -0.916 |
| 2014 | 140.36 | 134.07 | 4.48 |

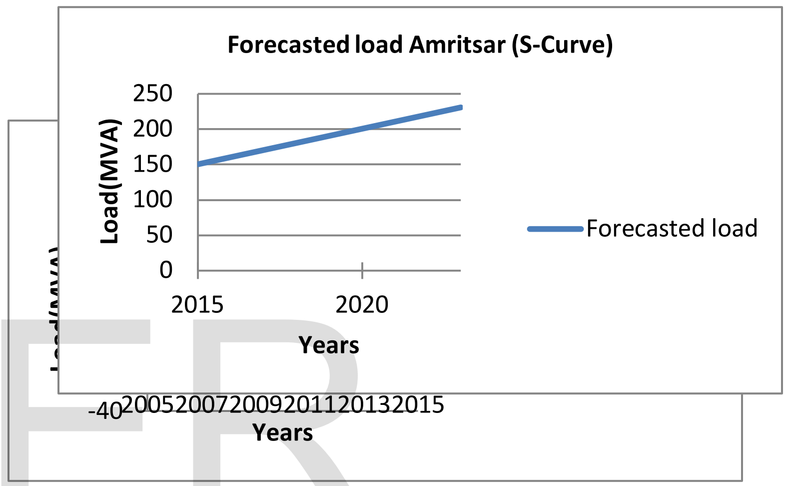




Fig 7 :Load Comparison Parent 1

Fig 8: Load Comparison Parent 2

Fig 9: Forecasted load for Mamun Cantonment (S-Curve) (FL)

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Table5: Load Comparison

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 1997 | 5.71 | 5.66 | 0.876 |
| 1998 | 5.84 | 5.72 | 2.05 |
| 1999 | 5.91 | 5.79 | 2.03 |
| 2000 | 6 | 5.86 | 2.33 |
| 2001 | 6.08 | 5.93 | 2.47 |
| 2002 | 6.02 | 6.01 | 0.166 |
| 2003 | 6.11 | 6.09 | 0.3273 |
| 2004 | 6.46 | 6.18 | 4.33 |
| 2005 | 6.6 | 6.28 | 4.85 |

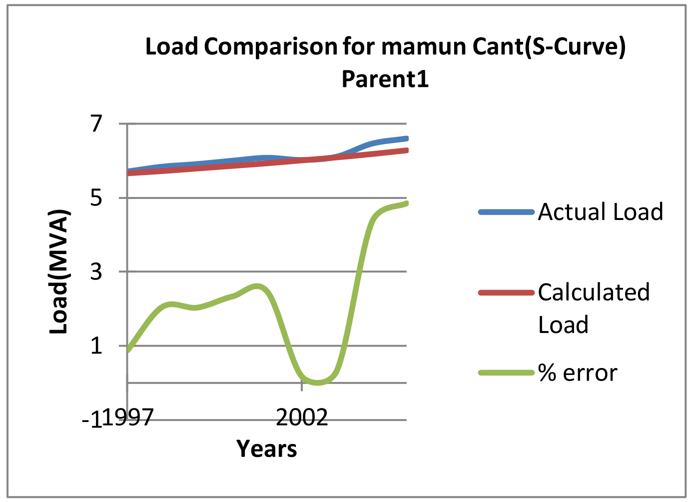


Fig 10: Load Comparison for Mamun Parent1

Table 6: Load Comparison Table

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 2006 | 6.61 | 6.5 | 1.49 |
| 2007 | 6.73 | 6.63 | 1.42 |
| 2008 | 6.76 | 6.78 | -2.42 |
| 2009 | 6.86 | 6.94 | -1.157 |
| 2010 | 7.9 | 7.15 | 9.451 |
| 2011 | 10.5 | 7.46 | 28.961 |
| 2012 | 9.26 | 9.58 | -3.441 |
| 2013 | 10.21 | 10.03 | 1.792 |
| 2014 | 10.27 | 10.28 | -0.114 |



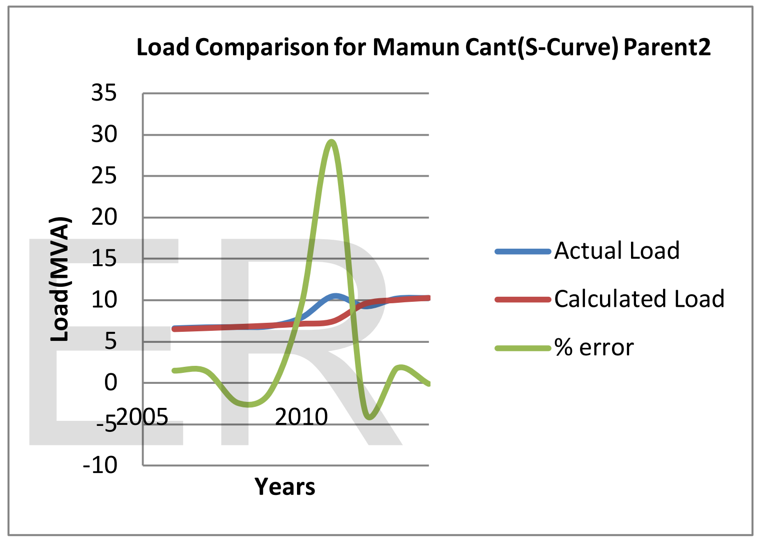


Fig 11: Load Comparison for Mamun Parent2

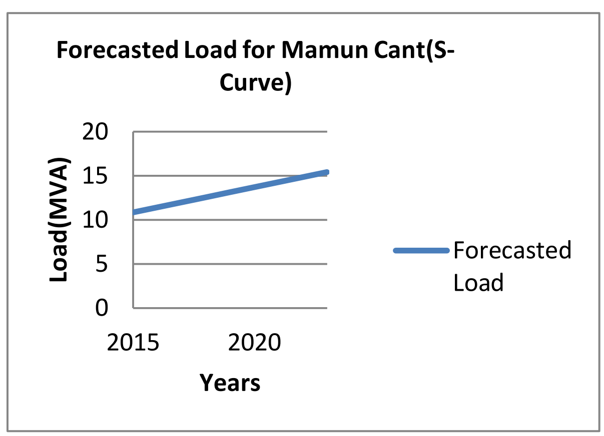


Fig.12: Forecasted load for Mamun Cantonment(S-Curve) (GA)

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# 6. CONCLUSIONS AND FUTURE SCOPE

Long term load forecasting, in a power system, is very helpful to predict the load well in advance so that any electrical utility can plan for it. In this research work, last eighteen years load for Amritsar city and Mamun cantonment has been taken. For Amritsar city the load is commercial in nature, and with increase in population in this city the load demand is also increasing every year. Whereas, the population of Mamun cantonment is almost stagnant, hence for load forecasting the population factor is not included. Methodologies presented have been divided into two categories: Fuzzy Logic methodology and Genetic Algorithm methodology. Load calculation for both the stations is done with both these methodologies. Various curve fitting equations are used. To obtain the results from Fuzzy Logic methodology error corrections are applied individually where as in case of Genetic Algorithm the correction is applied in groups. From the result it is observed that avg. error variation with fuzzy logic methodology is 1.425% to -3.42% for Amritsar and 3.19% to -6.03% for Mamun cantonment. On other hand with Genetic Algorithm this variation is 3.19% to -6.03% for Amritsar and 7.58% to -3.19% for Mamun cantonment. By comparing above two results we can conclude that Fuzzy Logic methodology is better than Genetic Algorithm for forecasting the load of a particular station.

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