ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 6, June 2015**

# Long Term Load Forecasting Using Fuzzy Logic Methodology

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**ABSTRACT**: Load forecasting means estimation of active load at various load buses ahead of an actual load occurrence. 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. firstly, Long term load forecasting secondly, Medium term load forecasting and lastly, Short term load forecasting. For good forecasting various demographic factors e.g. population, temperature, humidity etc. are taken in to consideration. Different methodologies are adopted to forecast the load. This paper is devoted to study long term load forecasting of two stations. Of these two stations, in one station load will depend on population and in other population factor is not taken in to consideration. Hence while forecasting the load for first station, population increase for past decades is also taken into consideration. Fuzzy logic methodology is used to forecast the load for nine years in both stations.

**KEYWORDS:** Load forecasting, Long term load forecasting, Fuzzy Logic, Demographic factors, Regression, DDF (Data Dependent Factors), MDF ( Model Dependent Factor ), ES (Expert System).

## I.INTRODUCTION

Energy is the basic necessity for the economic development of a country. Agricultural and industrial production increases due to large amount of energy. The subject of load forecasting has been in existence for decades to forecast the future demand. There is a close relationship between the energy used per person and their standard of living. Load forecasting helps an electric utility to make important decisions including decisions on purchasing and generating electric power, load switching, and infrastructure development. More the population, more will be the per capita consumption of energy in a country, as higher will be the standard of living of the people. There are different forms of energy and most common form is electrical energy. Power demand of different consumers varies according to their activities. 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. Similarly electrical power cannot be stored. Therefore the power station must produce power as and when required by the consumers. Since there is no "inventory" or "buffer" from generation to end users, ideally, power systems have to be build to meet the maximum demand, so called peak load, to ensure that sufficient power can be delivered to the customers whenever they need it. [16]

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 etc. Planning and operational application of load forecasting requires 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. [14]

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

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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. [14]

## II. LITERATURE REVIEW

We know that load forecasting is very important for planning operation and control of a power system. Load forecasting can be broadly divided into three categories: short-term forecasting, medium term load forecasting, long-term forecasting, which are longer than a year There are various studies carried out for the load forecasting. Ghods et.al discussed the past and current practices of long term load forecasting. Methods like neural network, genetic algorithm, Fuzzy rules, support vector machines, wavelet systems and expert systems were found out to be used. 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 was used. The results attained were validated 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 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 behaviour over other models is suggested to produce the annual load forecast. C.P. Ronald Regan 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. 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 is 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

## III.CONTRIBUTION AND SCOPE

The objective of this research 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.

## IV.METHODOLOGY

The forecasting of future loads for a relatively large lead time (months to few years) is studied in long term load forecasting. Future load demand estimation is done for different lead times, ranging from few seconds to years. These different lead times are called forecasting intervals. Overestimation of the future load may lead to financial crisis, as more money will be spent on new building. Underestimation of load may cause troubles in supplying this load from the available electric supplies. There will be shortage in the spinning reserve of the system, and it may lead to a system which is insecure and unreliable system. Not much work is done on the long-term load forecasting, because

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years of economic and demographic data is required and it not be easy to gather data for so many years. Even if we collect data, this forecasting is complex in the sense that it is affected by environmental, economical, and social factors. Different researches are being carried out in this area and numerous forecasting methods were found out.

Generally any long term load demand forecasting is inaccurate. The various long-term load demand forecasting methods can be classified in to two categories, i.e. parametric methods and artificial intelligence based methods. The artificial intelligence methods are further classified into neural networks, support vector machines, genetic algorithms, wavelet networks, fuzzy logics and expert system methods. Fuzzy Logic methodology plays a very important role in the operation and management of power systems. Forecasting of future loads for a relatively large lead time is studied here (long term load forecasting). Artificial intelligence techniques are of greater accuracy as compare to the various techniques used in forecasting load. Fuzzy Logic is a very robust artificial intelligent technique and is used in this research to forecast load on long term basis. 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. The algorithm, in this paper is achieved with the help of data collected for residential sector for both the stations. Load for last 18 years is collected and is forecasted for next nine consecutive years.

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 methodology. 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. In this case factor affecting load is population for Amritsar city.

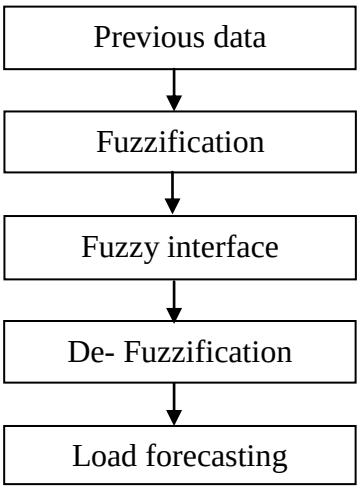


Fig.1 Flow Chart for Fuzzy Logic Methodology

## V. RESULT AND DISCUSSION

The load data of last 18 years for Amritsar is collected from the substation of Amritsar city. Similarly, population of respective years is also collected from Indian Planning Commission. It is found that the relation between load and population is linear. Which shows that with increase in population load is increasing. Load data for Mamun cantonment is also collected from substation. Base data for forecasting is as follows:

(a) Load Data (MVA): Actual values from Year 1997 to Year 2014 for both cities i.e. Amritsar and Mamun cantonment.

(b) Number of consumer's data in case of Amritsar city:-

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International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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**Vol. 4, Issue 6, June 2015**

(i) Actual values from 1997 to 2014.
(ii) Forecast values from 2006 to 2014.
(iii) Forecast values of Population from 2006 to 2014.

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

**Load = 4.5 times of population**

Below table shows the load comparision of Amritsar city for last eighteen years with straight line curve fitting technique.

**Amritsar City (SL)**

Table1: Load comparison table for Amritsar city (Straight Line)

| Years | Actual Load | Calculated Load | % Error in Load Calculation |
|---|---|---|---|
| 1997 | 40.65 | 40.65 | 0 |
| 1998 | 41.85 | 43.49 | -3.92 |
| 1999 | 42.08 | 46.34 | -10.12 |
| 2000 | 45.73 | 49.19 | -7.57 |
| 2001 | 43.21 | 52.04 | -20.44 |
| 2002 | 62.02 | 54.88 | 11.51 |
| 2003 | 60.43 | 57.73 | 4.47 |
| 2004 | 63.58 | 60.57 | 4.73 |
| 2005 | 63.42 | 63.42 | 0 |
| 2006 | 73.01 | 70.26 | 3.76 |
| 2007 | 71.92 | 78.61 | -9.3 |
| 2008 | 105.09 | 86.96 | 17.25 |
| 2009 | 111.02 | 95.3 | 14.16 |
| 2010 | 114.49 | 103.64 | 9.47 |
| 2011 | 114.44 | 111.99 | 2.13 |
| 2012 | 129.04 | 120.34 | 6.76 |
| 2013 | 129.21 | 128.69 | 0.405 |
| 2014 | 140.36 | 137.03 | 2.37 |

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

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**Vol. 4, Issue 6, June 2015**

Load comparison of Amritsar city for last eighteen years can be shown graphically. The graph shows the comparison between actual load, calculated load and error between the two.

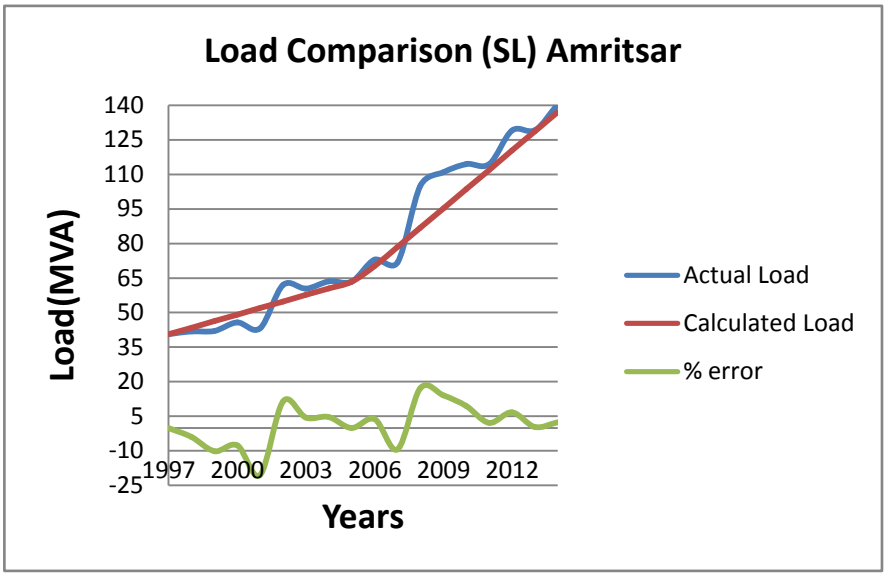


Fig.2 : Load comparison (Straight Line) Amritsar city

With the help of above data the load is forecasted for next nine years. It has been found that forecasted load for year 2023 with straight line curve fitting technique is found to be 264 MVA.

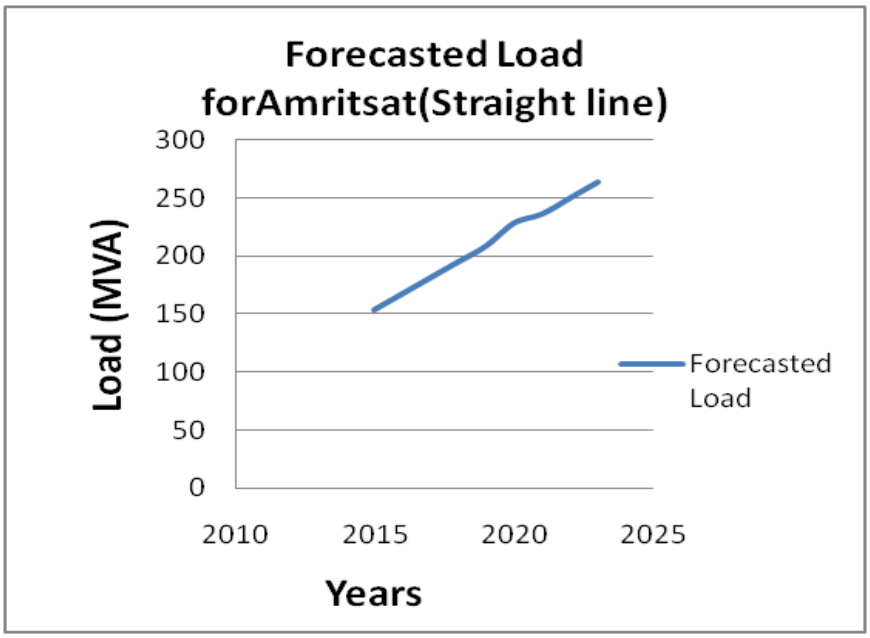


Fig 3: Forecasted load for Amritsar city (SL)

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ISSN (Online): 2278 – 8875

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**Mamun Military Cantonments(SL)**

Load comparison of Mamun cantonment area for last eighteen years with straight line curve fitting technique is shown in below table.

Table 3: Load comparison table for Mamun Cantonment (Straight Line)

| Years | Actual Load | Calculated Load | % error |
|---|---|---|---|
| 1997 | 5.71 | 5.71 | 0 |
| 1998 | 5.84 | 5.82 | 0.34 |
| 1999 | 5.91 | 5.93 | -0.34 |
| 2000 | 6 | 6.04 | -0.67 |
| 2001 | 6.08 | 6.16 | -1.32 |
| 2002 | 6.02 | 6.27 | -4.15 |
| 2003 | 6.11 | 6.4 | -4.75 |
| 2004 | 6.46 | 6.5 | -6.2 |
| 2005 | 6.6 | 6.66 | 0 |
| 2006 | 6.61 | 6.92 | -4.69 |
| 2007 | 6.73 | 7.32 | -8.69 |
| 2008 | 6.76 | 7.72 | -14.2 |
| 2009 | 6.86 | 8.12 | -18.44 |
| 2010 | 7.9 | 8.52 | -7.84 |
| 2011 | 10.5 | 8.92 | 15.01 |
| 2012 | 9.26 | 9.33 | -7.5 |
| 2013 | 10.21 | 9.73 | 4.66 |
| 2014 | 10.27 | 10.14 | 1.28 |

Load comparison of Mamun cantonment for last eighteen years can be shown graphically. The graph shows the comparison between actual load, calculated load and error between the two.

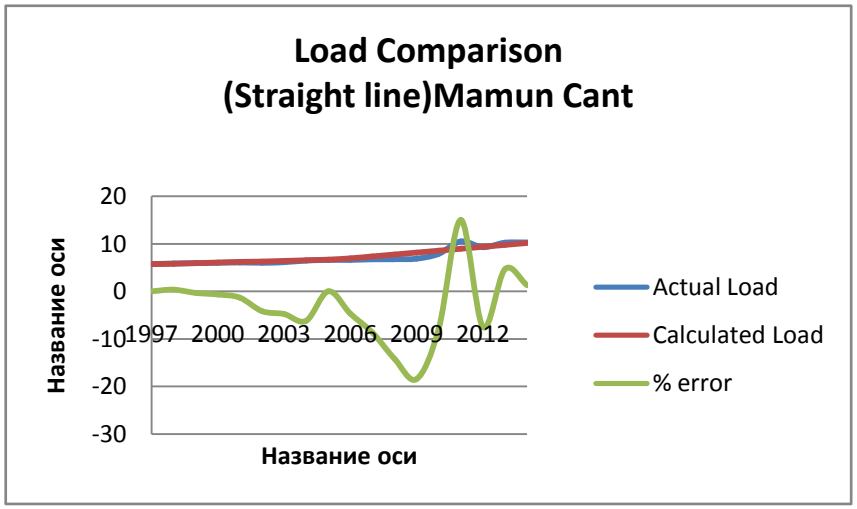


Fig.4: Load comparison (Straight Line) Mamun Cantonment

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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**Vol. 4, Issue 6, June 2015**

With the help of above data the load is forecasted for next nine years. It has been found that forecasted load for year 2023 with straight line curve fitting technique for Mamun cantonment is found to be 14MVA

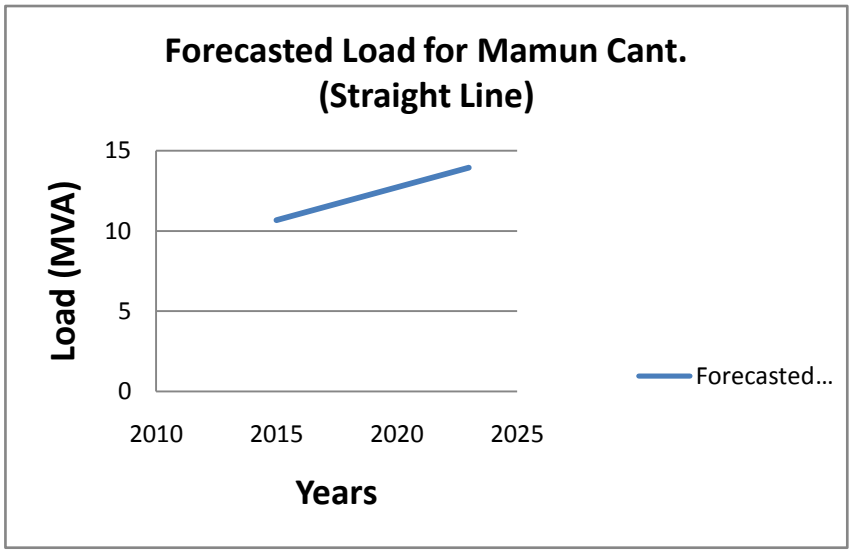


Fig. 5: Forecasted load for Mamun Cantonment (SL)

Above figures show the load comparison and forecasted load for Amritsar city and Mamun Cantonment using straight line curve fitting technique and Fuzzy Logic methodology. Same graphs can be obtained for both the stations using different curve fitting techniques.

## VI.CONCLUSION

Long term load forecasting using fuzzy logic methodology in Amritsar and Mamun Military Cantonment area has been discussed. It is concluded that by using population and data of previous years as input, and by formulating rule base of fuzzy logic using available data, forecasting can be done with certain margin. This paper can be used as a base paper to compare the Fuzzy Logic and Genetic Algorithm methodologies. By comparing them we can conclude that which methodology can be the best for long term load forecasting.

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