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Estimation of India's energy demand using Artificial Immune System

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Abstract

This study presents an integrated estimation of energy demand for India using Artificial Immune System (AIS) based on economic indicators such that population, per capita Gross Domestic Product (GDP), per capita Gross Domestic Income (GDI) used during the model development. The Artificial Immune System -Energy Demand (AIS-ED) model is developed based on past data. Two forms of the AIS-ED models are developed and also different scenarios (high, low growth and trend line) are used to predict future energy demand of India. Mean Absolute Percentage Error (MAPE) is evaluating the results and selecting the best forecasting model of the AIS. Clonal selection algorithm (CLONALG) of AIS techniques is used as an evaluation criterion. The AIS-ED results are compared with the prediction of 18th Electricity Power Survey of India.

Keywords— *Energy demand, Artificial Immune System, India, Future projection*

Introduction

Energy is an important input to the social and economic developments of any country. In India, rapid urbanization, population growth and increasing per capita electricity consumption that leads to increase in electricity demand. Demand has increased from 316.60 TWh in 2000 to 694.392 TWh in 2010 with an annual average growth rate of 9.09% i.e., the demand has increased more than double in a decade.

Population is taken as input by most of the authors has been used to forecasting their own country [1-9]. Next to per capita Gross Domestic Product (GDP), per capita Gross Domestic Income (GDI) are also used. In India, population, per capita GDP, per capita GDI in the last 10 years (2000 to 2010) increased with an annual average growth 1.5%, 8.6% and 10.4% respectively. The electrical energy demand is estimated based on both economic and non-economic indicators [10-13]. Among these energy demand indicators the non-linear forms are more effectively forecasting the electrical energy demand [14, 15]. Among a variety of approaches, artificial immune system (AIS) has received attention in energy demand prediction [16, 17]. AIS techniques used in short term forecasting, artificial neural network is expert system had been discussed [18, 19]. The described combined approach of first-order one-variable differential equation and seasonal time series model and to improve forecasting accuracy, adaptive learning parameter mechanism was applied [20]. Which requires developments in methods and algorithms for forecasting of energy demand. In this paper, the energy demand is forecasted by artificial immune system (AIS) techniques.

AIS is used for the Improvement in energy demand forecasting. In this paper, AIS and in particularly the clonal selection algorithm (CLONALG) is used for energy consumption. Artificial Immune System -Energy Demand (AIS-ED) model is developed for estimating India's future energy demand based on population, per capita GDP and per capita GDI of observed data. The energy demand estimation based on a combination of economic indicators may be modelled one linear and the other nonlinear of exponential are developed. This is the first time that AIS is being used for prediction for India's future energy demand.

Ease of Use

This algorithm starts with collecting the data and selecting a demand model. Models can be linear or non-linear methods. The collected data is divided into test data and training data that used to examine the accuracy of forecasting models. To simulate the random variations in the data, probability distribution functions is need to be estimated by the algorithm. Therefore, the algorithm finds the best fitted solutions and the simulation is constructed based on these solutions. Two methods for estimation of energy demands are linear and nonlinear. These are,

The Linear form of the GA-ED model is

AIS-EDlin = W1 + W2X1 + W3X2 + W4X3 (1)

Exponential forms of these techniques can be expressed as,

AIS-EDquad=W1+W2X1+W3X2+W4X3+W5X1X2+W6X1X3+
W7X2X3+W8X1X2X3 (2)

ED model optimizes weighting coefficients wi of the design parameters Xi, which are included by model, at the same time. In ED estimating, the aim is to find the fittest model to the data. The fitness function of the model is given by equation 3.

$$MinF(x) = \frac{1}{n}\left(\sum_{i}^{n}\frac{Y_{obs} - Y_{est}}{Y_{obs}}\right) i = 1,2,3,...,n \quad (3)$$

where, Yobs and Yest are the observed and estimated electricity consumption, n is the number of observation, respectively.

Artificial immune system

Biological Immune system

AIS method works on three basic immunological principles which includes immune network theory, clonal selection principles and the mechanism of negative selection. Clonal selection algorithm is used [21, 22].

Clonal Selection Algorithm

Clonal selection algorithm uses clonal selection principle as a basic. Pinit is represented as the initial population, to build a new population Pn the n best antibodies are selected using selection process. Affinity value is the basics for the selection. These individuals of the populations are rebuild using the clonal process which leads to birth of a new population. The number of clones depends on the affinity of antibodies. The new population of the clone is built by maturation process (mutation). Higher affinity bodies are the basic of the lower mutation rate and lower affinity bodies at the basis of higher mutation rate. The best of clones is better than their parent or not and updates the memory set M by the reselection process. By the final diversity process the worst antibodies are replaced with new generates ones id. The selection, cloning, mutation find the better solution towards the population. The diversity process helps to retain the diversity of the antigens [17] generated antibodies.

Antibody representation

In the problem of estimating electrical forecasting model, the AIS work with a population of chromosomes called antibodies which represents the solution to this problem. Each antibody consists of genes, coefficients are represented by the gene of antibody.

Initialization

For AIS beginning, it is necessary to form an initial population in which the size of space and antibodies in that space will be determined.

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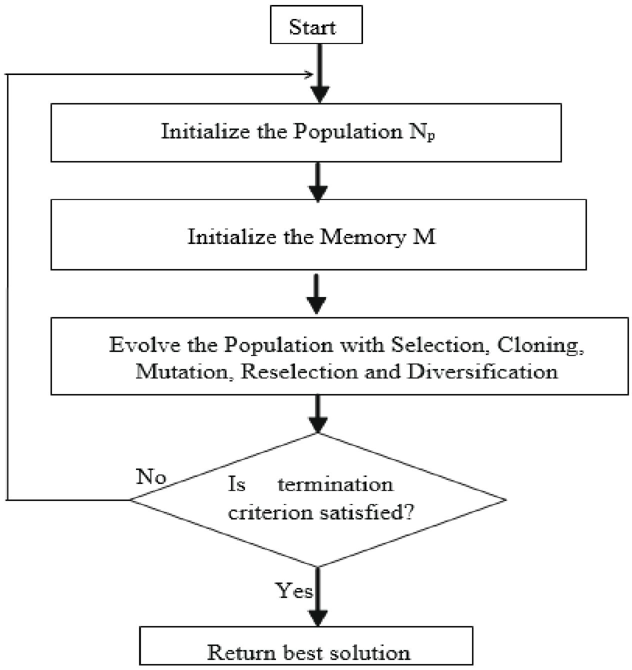

Figure 1. Flowchart of AIS

Affinity function

Each antibody should be calculated and in each generation, the individual with min difference must be returned. Randomly select the individual parameters and after putting in the model, affinity is calculated. To obtain these, the affinity function is to cover this goal and it is shown in equation-1, called as MAPE error.

Selection

To generate new population Pn, n antibodies with highest affinity are selected in this process.

Cloning

According to their affinity, antibodies must be cloned and then generate a temporary population. The number of clones for each antibody computed by

$$N_c = \sum_{i=1}^{n} C_{eil}\left(\frac{\beta \times N}{i}\right) \quad (4)$$

Where Nc is the total number of clones, B is multiplying coefficient, N is the total number of antibodies and $C_{eil}\left(\frac{\beta \times N}{i}\right)$ is the function that gets a real number.

Mutation

In the CLONALG algorithm, a mutation rate is proportional to inverse of affinity according to affinity of antibodies. If the mutation rate is less, affinity is more.

Reselection and diversification:

Finally best child clone is compared with their parent. If the child clone is better than parent means, it enters into new population. If the parent is better than their child, it remains in the population.

Simulation results

One of the features of this study is the simulated data developed for monthly consumption based on raw data. For each year is examined to estimate the parameters and to identify the P-value so as to identify the energy consumption based on probability.

Parameters	AIS
Population size	10
Iteration	100
Mutation rate	0.5
Removed threshold	0.2
Clonal selection threshold	0.0001
Diversity	0.5
Total clone number	1000
Number of weighting variable	4 for equation (1) and 8 for equation (2)
Cross over rate	0.8

Table 1. Best parameters for AIS

After application of the two type of the AIS-ED model result in the following estimated optimum (or) near optimum weighting variables (i.e. minimum MAPE). The linear form of AIS-ED model is

AIS-EDlin = 0.003960+0.61689X1+8.99579X2+0.121030X3

And MAPE is 6.482843

Exponential forms of these techniques can be expressed as,

AIS-EDquad = 0.09328+0.017117X1+0.04699X2+0.0609X3+

0.0962X1X2+0.00295X1X3+0.00076X2X3+0.00005X1.X2.X3

And MAPE is 4.829022

Two-third of the observed data is used to estimate the weighting variables and one-third of the data [8, 14] is used to test the AIS-ED model by MPPE in order to validate its performance. The objective function is to minimize the error between the estimated and observed value. The performance of the AIS-ED model for the testing period is given in Table I. The lowest average MAPE (4.8290) is in the quadratic form of AIS-ED model when compared with the linear form of the AIS-ED (6.4828) model. This form of the AIS-EDquad is selected for estimating future demand.

In order to make the future projection for the demand using AIS-ED model, the population, per capita GDP and per capita GDI values of India are used. Observation showed that the growth rate of India's population, per capita GDP and per capita GDI have been increasing between 0.9 - 1.2 %, 6-9 % and 8-12% respectively in the last 10 years. Three different scenarios are assumed here.

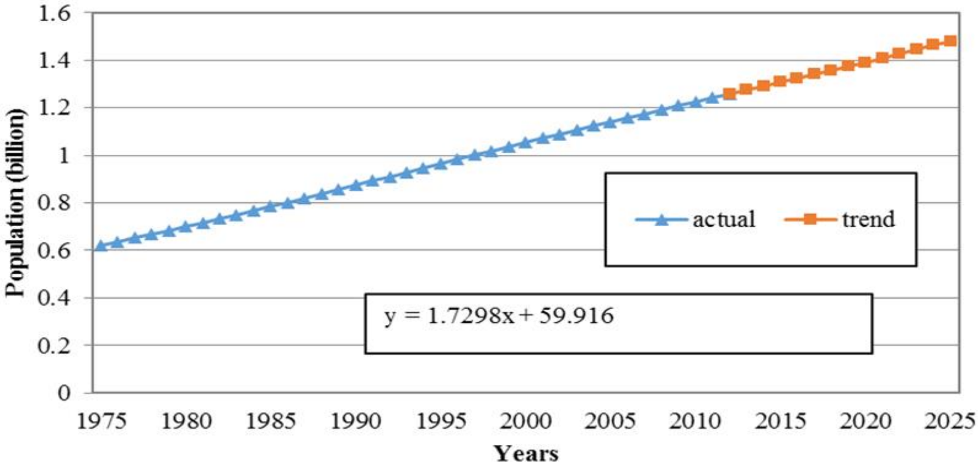

Figure 2. Actual values and trend data of Population

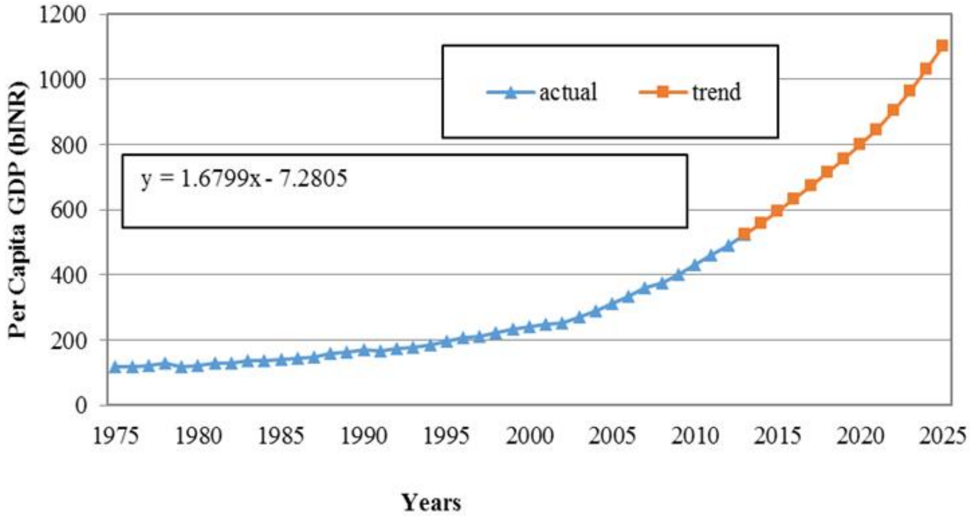

Figure 3. Actual values and trend data of Per Capita GDP

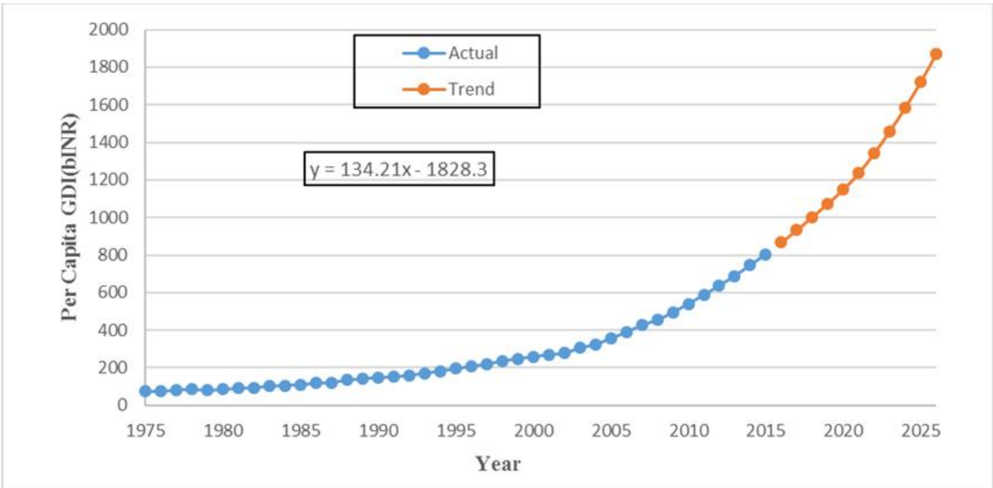

Figure 4. Actual values and trend data of Per Capita GDI

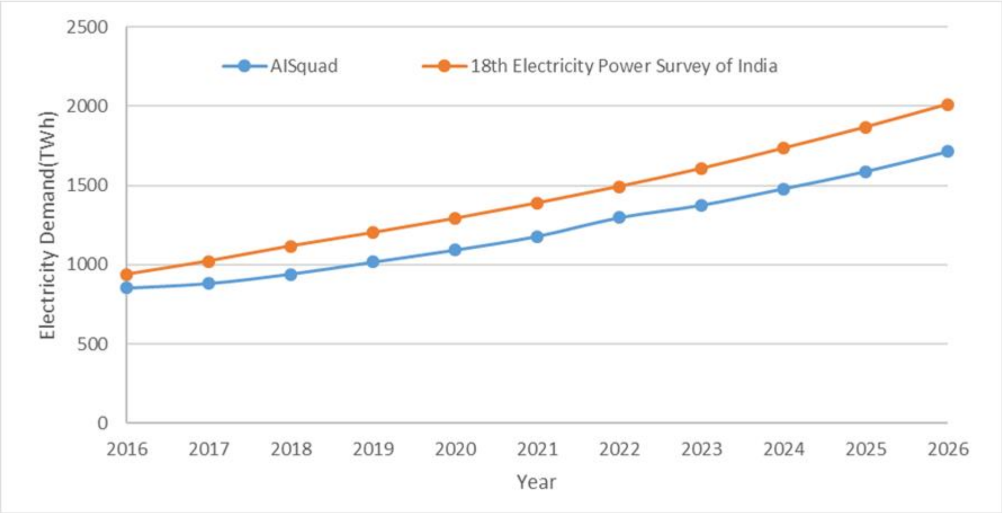

Figure 5. Energy demand projection of India for low growth scenario

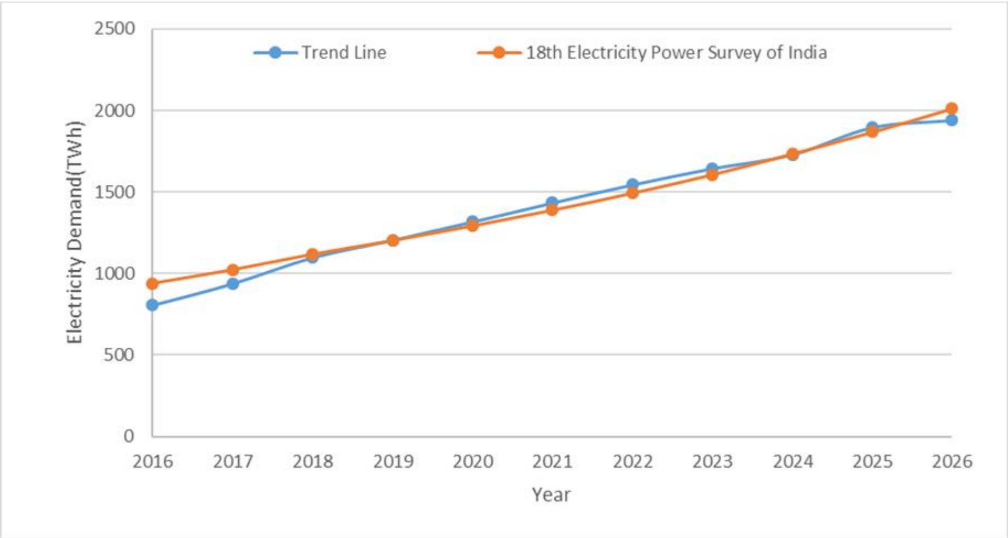

Figure 6. Energy demand projection of India for trend line scenario

Year	Observed energy Demand (TWh)	Estimated energy Demand (TWh)		MAPE (%)	
		AISlin	AISquad	AISlin	AISquad
2001	322.459	329.0656	337.2594	-2.0488	-4.5899
2002	339.598	348.668	363.4411	-2.6709	-7.0210
2003	360.937	368.240	388.9347	-2.0235	-7.7569
2004	386.134	393.023	420.5648	-1.7842	-8.9168
2005	411.887	419.560	419.5601	-1.8629	-1.8629
2006	455.749	490.009	490.8389	-7.5173	-7.6994

2007	501.977	465.569	512.8412	7.2528	-2.1643
2008	553.995	497.022	550.0342	10.2840	0.7150
2009	612.645	530.161	588.1178	13.4635	4.0035
2010	694.392	762.342	659.3696	-9.7856	5.0436
2011	776.8597	829.043	824.9443	-6.7173	6.189607
2012	828.643	899.814	837.0798	-8.5889	1.018153
2013	883.821	974.654	832.5923	-10.277	5.796305
				6.48284	4.829022

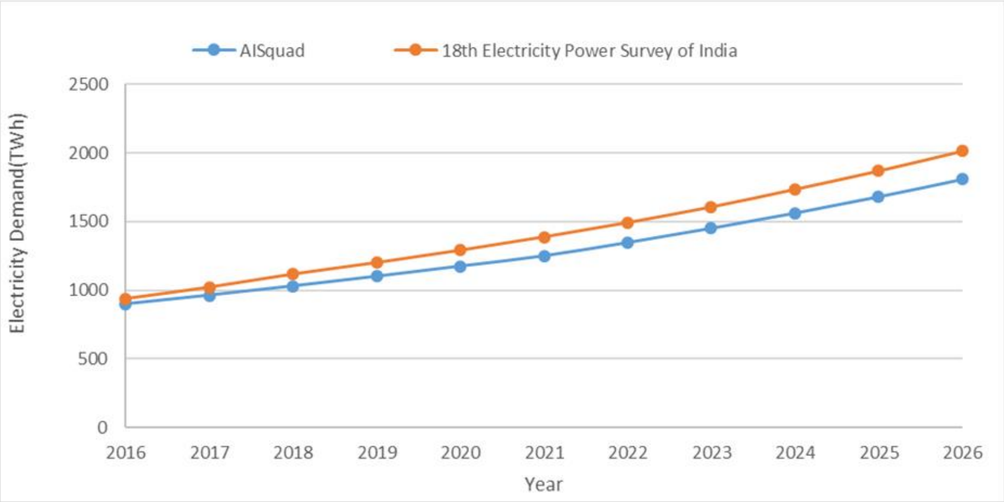

Figure 7. Energy demand projection of India for high growth scenario

MAPE between observed and estimated values in the AIS-ED model for energy demand

Low growth scenario

It is assumed that average growth rate of population is 0.9 %, per capita GDP is 6 % and per capita GDI 8% during the period of 2014-2026. The quadratic form of AIS -ED model is extended to estimate the future energy demand. As can be refered from Figure 5, the estimated value for the exponential AIS -ED model and 18th demand power Survey of India are given for low growth scenario. The energy demand in 2026 with the AIS-EDquad for low growth scenario will be about 1813.8 TWh.

Trend line model scenario

To predict the energy demand in India, individual variables (population, per capita GDP and per capita GDI) is to be analyzed and their trends for the future should be forecasted first (Figures 1-3). Future energy demand for the year 2013 to 2026 was calculated with estimated population, per capita GDP and per capita GDI. The “18th electric power survey of India”, prepared by Central Demand Authority, Government of India, predicted the energy demand by using time series and end use methodology and the results are validated by econometric model

High growth scenario

It is assumed that average growth rate of population is 1.2 %, per capita GDP is 9% and per capita GDI 12% during the period of 2014-2026 as shown in Figure 6. The quadratic form of AIS -ED model results are compared with the 18th Demand Power Survey of India for high growth scenarios. The energy demand in 2025 with AIS-EDexp for high growth scenario will be about 1983.9 TWh.

Conclusion

An estimation of energy consumption with random variables and for efficient forecasting based on AIS algorithm has been presented in this study. The described algorithm is used for estimate the energy demand models and the output obtained is compare with original data and simulated data. Then the performance is compared with MAPE. Finally, AIS method with CLONALG is considered as correct method for estimating the energy demand and gives the satisfactory results.

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