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Automated Demand Side Management Based On Load Prediction and Load Scheduling

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ABSTRACT:Automated demand side management encourage the consumer to use optimal energy during peak hours, or to move the time of energy use to off-peak times such as night time and weekends. Peak demand management does not necessarily decrease total energy consumption, but could be expected to reduce the need for investments in networks and/or power plants for meeting peak demands. Energy storage units helps to store energy during off-peak hours and discharge them during peak hours. For successful DSM, the study and analysis of consumer's energy usage habits is necessary. This paper offers the ideas to shift the load of consumer from peaks to valleys i.e. to even out the load curve.It also focuses on the important aspects of DSM such as, load prediction, load scheduling, and pilferage detection and communication aspects to improve the revenue collection fromconsumers. Automated DSM is based on short term load prediction and load scheduling with the help of smart meters and smart sensors for the exchange of data between consumer and utility to enhance the perpetuity of the concept of smart grid.

KEYWORDS: off-peak, DSM, valleys, load curve, load prediction, load scheduling, pilferage, smart grid.

I. INTRODUCTION

Electricity is the commodity that plays vital role in social and economic development of the nation. With ever increasing growth of industrial area, the need of electricity is increasing everywhere. If India's electricity sector is focused, it faces many issues regarding grid operation, management, control and protection. For example, a system of cross-subsidization is practiced based on the principle of the consumer's ability to pay which has worsened by government departments of India that do not pay their bills. The collective effect of all above issues is the considerable amount of gap between demand and supply [1].Energy efficiency is a privileged instrument for DSM implementation. In order to support the implementation of DSM in system operation, much more significant deployment of various sensors and advanced measurement and control devices will be required, accompanied by much more sophisticated energy metering and trading functions [2]. This will lead to wide-ranging deployment of ICT i.e. information and communication technology systems to facilitate the control of generators, loads and various network devices, their development and implementation of more intelligence distributed to control locally network primary plant. Implementation of ICT for the control of electricity networks will lead to the development of an integrated energy and communications system architecture that is intended to integrate two systems in the power industry: the 'Electrical Delivery System' and the 'Information System' (communication, networks, and intelligence equipment) that controls it. This phenomenon introduced the concept of 'Smart Grid' or 'Intelligrid' phenomenon. The smart grid is an electricity network that uses digital and advanced sensing technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end-users [2].

II. DEMAND SIDE MANAGEMENT

The 'Demand Side Management' is the Energy demand management, also known as integrated resource management (IRM), is the modification of consumer demand for energy through various methods such as financial incentives and behavioural change through education. The main objective of DSM is to shift loads from Region-1 to Region 2 or 3 or 4 as shown in Fig 1.

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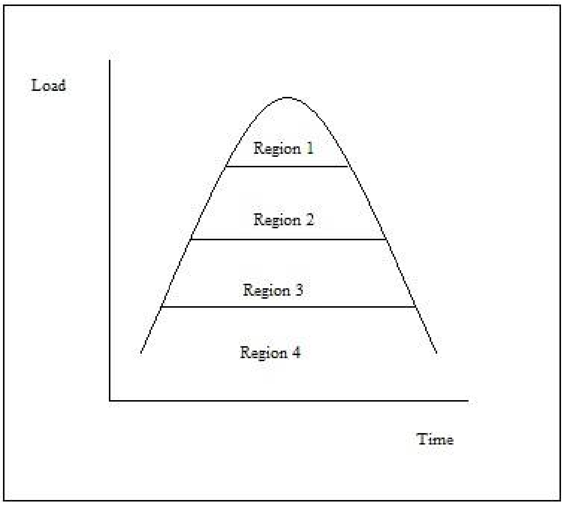

Fig. 1 Representation of Typical load profile

Power system distribution networks are designed for peak loads. For optimum utilization of network capacity, utilities employ DSM with objective of minimum possible peak load. DSM ensures maximum load factor and thus maximizing total profit of utilities [2]. Demand Response is any reactive or preventative method to reduce, flatten or shift demand.Demand Response includes all intentional modifications to consumption patterns of electricity of end user customers that are intended to alter the timing, level of instantaneous demand, or the total electricity consumption [3].

The most popular practices of demand side management are explored below.

1. Valley Filling- In this the loads during off peak hours, are increased to achieve flatter profile. This is done by encouraging consumers to increase energy consumption.

2. Load Shifting- In this the shift able loads during peak hours are shifted to off-peak hours, resulting lower peak of curve and a flatter profile. This can be done by scheduling schemes which schedule devices according to priority.

3. Peak Clipping- In this the load from peak hours is reduced like scheduled power cuts. The same can also be achieved by encouraging consumers to decrease their power consumption.

4. Energy Conservation- This is used when reduction in load is required all over the load curve. It is achieved by using energy efficient devices.

5. Load Building- This is used when increased energy consumption is required due to surplus production. Average cost per KWh is reduced.

The efficiency of conventional DSM projects is less due to some technical and non-technical factors. The first was lack of technology required. Conventionally, the measurement and verification efforts were time consuming and expensive, therefore only focussed on largest customers. The second limitation was lack of understanding among customers and one-way interaction. Also the real time data collection and processing was not possible. With the introduction of smart grid, all above limitations are cleared to make the DSM projects efficient and smart.

III. Importance Of Smart Grid Components In DSM

The smart grid provides scale and ability to resize the system according requirements of economic and convenient DSM projects. Some tiny but important components of smart grid like ‘Smart Meter’ allow users to connect to data communication network and to gain the benefits of real time [ToD] tariff [3]. The smart grid also gives ease of real

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time supply and demand balancing for utility which reduces demand supply gap and improves system load factor. These technologies give the DSM programs a number of advantages over conventional DSM techniques. The characteristics of smart grid cause successful and efficient DSM projects. Some of them are listed as follows.
A. Real time information- The smart meter allow utility to collect and analyse the information at narrow interval of few minutes to some hour instead of relying on manual monthly readings. The data can be shared to consumer via HAN (Home Area Network).

B. Two way networks- Smart meter allows collection of real time usage data and send time of day [ToD] tariff and other information to the consumer. The consumer can conserve energy by optimizing usage or submit the feedback on consumption. The network costs are low which allows utility to communicate its consumer base [4].

C. Integration of utility information systems- Smart grid allows utility to take the benefit of many IT solutions as efficient decision engines for management and control aspects of grid.

D. Shifts in consumer behaviour- The ability of real time data on energy costs and consumption makes consumer aware of cost and environmental impact of their energy usage and related price fluctuations. The Smart Grid represents the longer-term promise of a grid remarkable in its intelligence and impressive in its scope [5].

IV. DSM PROGRAMME: PLANNING AND IMPLEMENTATION

This section sets out the steps in DSM Programme Planning and Implementation. The first step in DSM programme design is to decide on its goal:

A. Should the programme target peak loads or encourage a general reduction in electricity consumption?
B. Is a “market transformation” programme needed or is the objective to reduce demand in a particular sector or area?
C. Should the programme target existing stock or new equipment?
D. Are the targeted participant’s communities and consumers in low income situations or those which can more easily afford to participate?
The answer to each of these questions will help decide on the type of programme to use. The length of the programme should be long enough to ensure complete market transformation or to achieve other programme goals. It should also be long enough to ensure that improvements in efficiency continue after the programme is over.

I. Develop end-use Demand prediction
II. Undertake Load/ Market Research to identify end-use patterns and market barriers
III. Define load-shape objectives
IV. Identify target sectors, end-uses, and measures
V. Identify sources of financing
VI. Review Cost Sharing and Viability Options
VII. programme Selection and Design
VIII. DSM Cost/Benefit Analysis
IX. Identify Local Socio-Economic and Environmental Impacts
X. programme Implementation Plan

In the approach, load prediction has been adopted to improve system efficiency which does not effect on consumer’s household demand. An hourly peak consumption pattern for the next day is predicted using prediction techniques like polynomial curve fitting, ARIMA, Fuzzy logic, ANN. These methods are compared for their accuracy of prediction. The predicted load profile along with cost function is displayed on the user network which is received by consumer smart meter. Scheduling is then done for area load based cost function using Genetic Algorithm and hence a comparatively smoother load profile is obtained. This helps each consumer to shift high power household appliances in accordance to the displayed load profile. The consumer’s actual energy usage profile would then be used in evaluating the corresponding individual load factor (LF), thus encouraging to adopt load shifting strategy in order to reduce the daily electricity bill. This would benefit the generation unit by operating at improved load factor [1].

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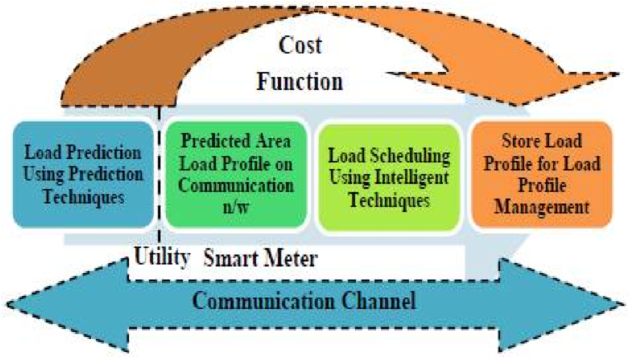

Fig. 2 Communication between Smart Meter and utility server

Fig 2. shows the various steps discussed in section IV and communications between smart meter and utility server. Consumer meter is receiving area-load profile and pricing function from utility server and providing its own energy usage to the server [8].Load prediction method with the help of fuzzy logic is discussed in section V.

V. ELECTRICAL LOAD PREDICTION

'Electric load prediction is the process used to forecast future electric load, given historical load and weather information and current and forecasted weather information'. Load prediction is vitally important for the electric industry in the deregulated economy. It has many applications including energy purchasing and generation, load switching, contract evaluation, and infrastructure development. A large variety of mathematical methods have been developed for load prediction.

The methods of load prediction are classified according to their base of operation.

*A. Qualitative methods:*These types of prediction methods are based on judgments, opinions, intuition, emotions, or personal experiences and are subjective in nature. They do not rely on any rigorous mathematical computations.

*B. Quantitative methods:*These types of prediction methods are based on mathematical (quantitative) models, and are objective in nature. They rely heavily on mathematical computations

The Qualitative methods are further classified as,

1. Executive Opinion Approach in which a group of managers meet and collectively develop a forecast.
2. Market Survey Approach that uses interviews and surveys to judge preferences of customer and to assess demand.
3. Sales Force Composite Approach in which each salesperson estimates sales in his or her region.
4. Delphi Method Approach in which consensus agreement is reached among a group of experts.

The quantitative models are further classified as,

1. Time series models: Time series models look at past patterns of data and attempt to predict the future based upon the underlying patterns contained within those data eg. ARIMA [Auto Regressive Integrated Moving Average]. Types of time series models are summarized in Table I below:

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TABLE I
TYPES OF TIME SERIES MODELS

Time Series Models	Description Of Base For Forecast
Naive	Uses last period's actual value as a forecast
Simple Mean (Average)	Uses an average of all past data as a forecast
Simple Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving the
Weighted Moving Average	Uses an average of a specified number of the most recent observations, with each observation receiving a
Exponential Moving Average	A weighted average procedure with weights declining exponentially as data become older
Trend Projection	Technique that uses the least squares method to fit a straight line to the data
Seasonal Indexes	A mechanism for adjusting the forecast to accommodate any seasonal patterns inherent in the data

2. *Associative models* **–** Associative methods (often called causal models) assume that the variable being forecasted is related to other variables in the environment. They try to project based upon those associations. In its simplest form, linear regression is used to fit a line to the data. That line is then used to forecast the development variable for some selected value of the independent variable. Fuzzy logic is one of the associative models of prediction. Some advanced methods are used for short term load prediction like Fuzzy logic, ANN etc and further, they are compared for their performance and accuracy of prediction.

Fuzzy Logic: Fuzzy logic, first introduced by Lotfi A. Zadeh in 1965, embodies human-like thinking into a control system. A fuzzy controller employs a mode of approximate reasoning resembling the decision making route of humans, that is, the process people use to infer conclusions from what they know. Fuzzy control has been primarily applied to the control of processes through fuzzy linguistic descriptions stipulated by membership functions [6]. The conventional Boolean logic has been extended to deal with the concept of partial truth – truth values which exist between "completely true" and "completely false", and what is referred to as fuzzy logic. This is achieved through the concept of degree of membership. The essence of fuzzy logic rests on a set of linguistic if-then rules, like a human operator. It has met a growing interest in many motor control applications due to its nonlinearity handling features and independence of plant modelling. Moreover, the fuzzy logic concepts play a vital role in developing controllers for theplant since it isn't needy of the much complicated hardware and all it necessitates are only some set of rules.

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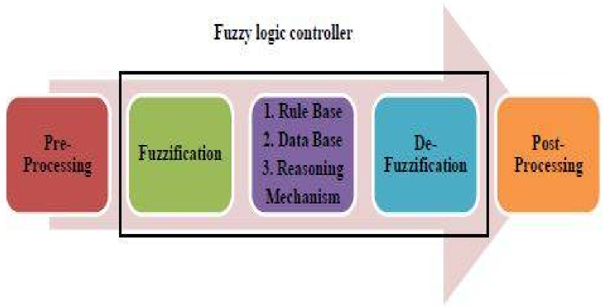

Fig. 3 Fuzzy logic controller structure

One of the reasons for the popularity of Fuzzy Logic Controllers is its logical resemblance to a human operator. It operates on the foundations of a knowledge base which in turn rely upon the various if then rules, similar to a human operator. Unlike other control strategies, this is simpler as there is no complex mathematical knowledge required. The FLC requires only a qualitative knowledge of the system thereby making the controller not only easy to use, but also easy to design [7].Short term load forecast plays a crucial role in all aspects of planning, operation, and control of an electric power system. So, the need and relevance of prediction load for an electric utility has become an important issue in the recent past. It is not only important for distribution or power system planning but also for evaluating the cost effectiveness of investing in the new technology and the strategy for its propagation [8]. However, in the deregulated market, load prediction is of utmost importance. As the utility supply and consumer demand is fluctuating and the change in weather conditions, energy prices increases by a factor of ten or more during peak load, load prediction is vitally important for utilities. Short-term load prediction is a helping tool to estimate load flows and to anticipate for the overloading. Network reliability increases if the overloading effects are eliminated in time. Also, it reduces rates of equipment failures and blackouts [6].

Fuzzification is the process of converting crisp numerical values into the degrees of membership related to the corresponding fuzzy sets. A MF i.e. membership function will accept as its argument a crisp value and return the degree to which that value belongs to the fuzzy set the MF represents. In order to express the fuzziness of data, this paper makes an arrangement of fuzzy subsets for different inputs and outputs in complete universe of discourse as membership functions. The relationship between several inputs and output may be nonlinear but linear membership functions have been used for simplicity. Here, triangular membership function is used for the inputs as well as the output. The four inputs taken are Time, Temperature, humidity and previous day load. Time is divided into three triangular membership functions which are as follows:

1. Morning
2. Afternoon
3. Night

Similarly, temperature, previous day load and humidity and are divided into three triangular membership functions i.e. Low, Medium and High. Fig.4 to Fig.6 show input and output membership functions of FIS 1.

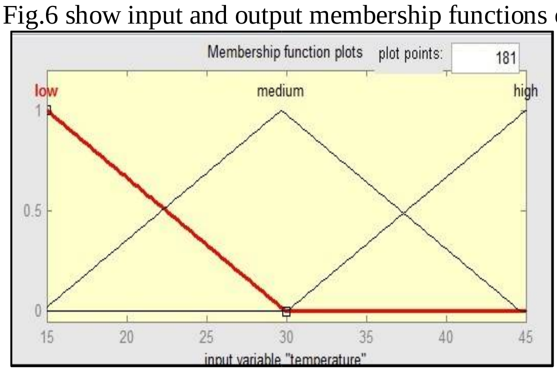

Fig. 4 Input membership functions – time

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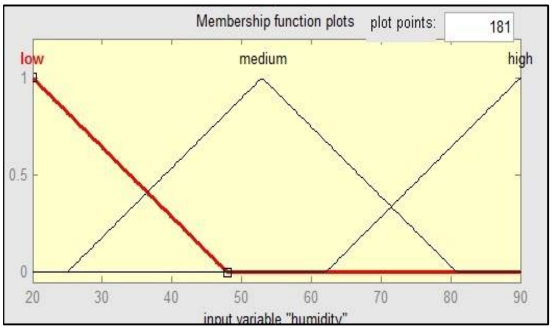

Fig. 5 Input membership functions – Humidity

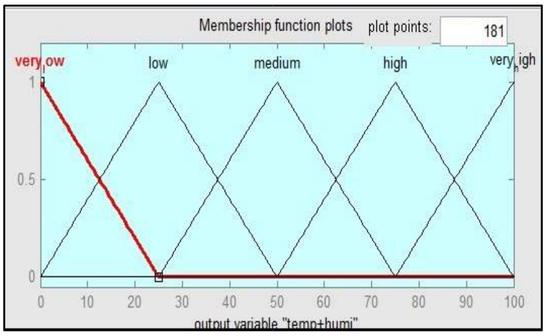

Fig. 6 Input membership functions – Time + Humidity

VI. SIMULATION WORK

The simulation of fuzzy logic methodology for short term load prediction is very useful for the analysis. MATLAB is used for the simulation purpose. The temperature and humidity are loaded as input data to Fuzzy Logic Controller 1 and the Temperature + Humidity+ Time is loaded as input data to Fuzzy Logic Controller 2. In fuzzy logic controller block ".fis" of fuzzy inference system is loaded. Temperature + Humidity+ Time+ Historical Load are loaded as input data to Fuzzy Logic Controller 3. Based on the rules prepared the fuzzy logic controller, forecasted output corresponding to the input data is obtained. Thus, final forecast of the day is obtained.

Results:

Table 2 show the actual load, forecasted load and also the percentage error in the forecasted load and Fig.7 shows graphical comparison between actual and forecasted load. The load forecast is done by using fictitious data. The percentage error in forecast can be calculated as,

% Error = [Actual Load Forecasted Load / Actual Load]× 100

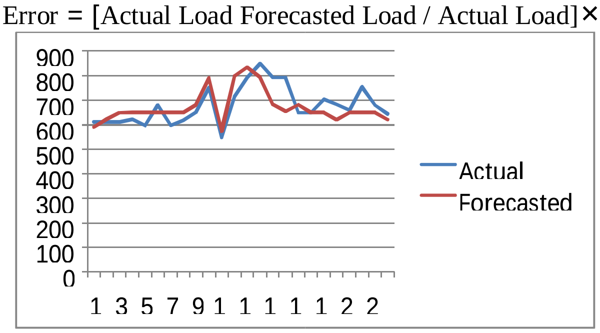

Fig. 7 Graphical representations of results using Fuzzy - logic

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TABLE III

Typical five Hourly Load Forecast by using Fuzzy Logic.

Time [Hrs]	Temp [^{0}c]	Humidity [%]	Historical Load [kW]	Actual Load [kW]	Forecasted Load [kW]	%Error
1	12	61	7202	6115	5903	3.46688471
2	13	63	6516	6115	6233	- 1.929681112
3	14	63	6173	6115	6494	-6.19787408
4	15	64	6173	6225	6500	- 4.417670683
5	17	65	5830	5958	6500	-9.09701242

Average Error = 0.549021015
The results and graph of fuzzy logic are given above. The % error of load prediction is -0.549021015.

VII. ELECTRICAL LOAD SCHEDULING

The 'Load Scheduling' is the process of load balancing by shifting/clipping the electric load with respect to the time of usage. While scheduling the load, the factors to be considered are listed as follows:
a. Load Rating and Total Load Connected In Respected Premises
b. Time of Usage Per Day in Hours
c. Priority of Load [Low/Medium/High]
d. Possibility of Load Clipping Without Affecting Comfort Level
e. Possibility of Load Shifting Without Affecting Comfort Level
The 'Electrical Load Schedule' is an estimate of the instantaneous electrical loads operating in a facility, in terms of active, reactive and apparent power. The load schedule is usually categorised by switchboard or occasionally by sub-facility / area. Preparing the load schedule is one of the earliest tasks that need to be done as it is essentially a pre-requisite for some of the key electrical design activities. While considering the new installations, the load schedule is necessary to know about load characteristics and habits of different user categories. In case of smart grid management and control, the load scheduling plays a vital role in automated load management. It supports the time varying tariffs and helps to enhance the success of DSM projects [9].
The basic steps for creating a load schedule are:

- Collect a list of the expected electrical loads in the facility
- For each load, collect the electrical parameters, e.g. nominal / absorbed ratings, power factor, efficiency, etc
- Classify each of the loads in terms of switchboard location, Duty Cycle and load criticality
- For each load, calculate the expected consumed load.
- For each switchboard and the overall system, calculate operating, peak and design load.

Normally the loads are separated by distribution board and operating, peak and design loads for each distribution board (one for the overall system) are computed. However, for the sake of simplicity, the loads in this example are all lumped together and only one set of operating, peak and design loads are calculated. The scheduling with new intelligent algorithms gives more accurate results than scheduling with calculation [10].
This analysis is an intelligent scheduling to modify pattern, by proposing a time scheduling consumers, such that they can maintain their welfare while saving benefits from time varying tariffs; a model of household loads is proposed; constraints, including daily energy requirements and consumer preferences are considered in the framework, and the model is solved using MATLAB linear programming and ANN.

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Results:

On the basis of consumer habit, the duty cycles are marked and according to necessity, load priorities are decided without affecting on consumers comfort. Then the load shifting and load clipping are carried out to obtain flattened load profile. As this is the prescribed load, the unnecessary loads can be switched off unlike area wise load scheduling. While performing the load scheduling, following factors are taken into account-

1. The consumers comfort is on highest priority. All the loads are prioritised on the basis of demand of consumer.
2. The load shifting is obtained by using switching on/off the load at particular time.
3. The load is scheduled on per hour basis. Once a load is switched on, it is assumed to be remaining on upto next 'switch off' command. The load schedule of load is shown in Fig. 8

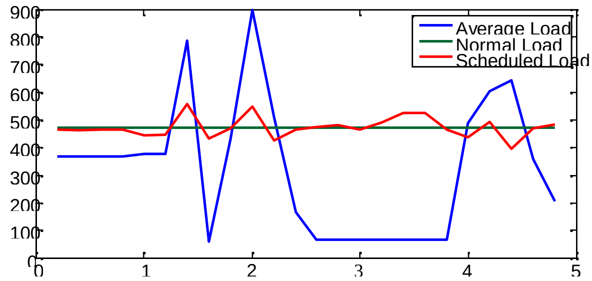

Fig. 8 Graphical representations of showing load scheduling.

VIII. CONCLUSION

The ever increasing demand of electricity has led to widening the gap between demand and supply. To address this issue, it has been proposed to have coinciding graphs of demand and supply as per requirement. Certain methodologies for DSM automation leading to concept of smart grid that addressed the limitation of conventional grid have been introduced for this purpose. Table II concludes the five hourly load forecasting leads to average error of 0.549. The requirement of flattening the load profile that forms one part of DSM automation and different techniques of load prediction through intelligent algorithms and to schedule the same have been proposed varying customer's needs. The proposed techniques for load flattening in achieving the DSM have shown effective results as shown in Fig.8. From results and discussions, it is concluded that, the successful DSM project needs use of smart grid components like smart meter which improves efficiency and reliability of power system. Further, it is proved that, Practical implementation of Smart meter for automated demand side energy management leads to satisfactory load profile management; load scheduling, pilferage detection and improvement in revenue collection. The application ofToD tariff exemplifies users to shift their loads as per minimum tariff hours. Hence, it is clear that, DSM automation acquired by use of smart grid having two-waycommunication network is going to be an essential part in future grid over the years to come.

REFERENCES

[1] N. Kunwar, Yash K and R. Kumar – "Area-Load Based Pricing in DSM through ANN and Heuristic Scheduling", IEEE Transactions.
[2] Amir-Hamed Mohsenian-Rad, Vincent W. S. Wong, Juri Jatskevich, Robert Schober and Alberto Leon-Garcia- "Autonomous Demand-Side Management Based on Game-Theoretic Energy Consumption Scheduling for the Future Smart Grid", IEEE Transactions.
[3] Amir-Hamed Mohsenian-Rad and Alberto Leon-Garcia, - "Optimal Residential Load Control with Price Prediction in Real-Time Electricity Pricing Environments", IEEE Transactions.
[4] T. Rashid and T. Kechadi- "A Practical Approach for Electricity Load Prediction", World Academy of Science, Engineering and Technology International Journal of Electrical, Electronic Science and Engineering Vol: 1, No: 5, 2007.
[5] Xi Fang, Satyajayant Misra, Guoliang Xue and Dejun Yang, "Smart Grid – The New and Improved Power Grid: A Survey", IEEE Transactions.
[6] Di Wu, Dionysios C. Aliprantis, Lei Ying, "Load Scheduling and Dispatch for Aggregators of Plug- In Electric Vehicles", IEEE Transactions on Smart Grid, Vol-3, No 1, March 2012.
[7] Armin Dehnad, Hamed G. Shakouri, "A Novel Model of Intelligent Electrical Load Management by Goal Programming for Smart Houses Respecting Consumer Differences", Energy and Power Engineering, 2013, 5, 622-627.
[8] Ahmad Reza Malekpour, Ali Reza Seifi, "An Optimal Load Shedding Approach for Distribution Networks with DGs Considering Capacity Deficiency Modelling of Bulked Power Supply", Modern Applied Science, Vol-3. No-5, May 2009.

[9] Muhammad Buhari and Sanusi Sani Adamu - 'Short-Term Load Prediction Using Artificial Neural Network', Proceedings of international multi-conference of enginers and computer scientists-2012 Vol-I IMECS 2012, March 14-16, Hong Kong.

[10] Di Wu, Dionysios C. Aliprantis, Lei Ying, "Load Scheduling and Dispatch for Aggregators of Plug- In Electric Vehicles", IEEE Transactions on Smart Grid, Vol-3, No 1, March 2012.