ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)

Vol 7, Issue 2, February 2021

Intelligent Scheduling of Appliances and Distributed Energy Resources for Demand Response in Smart Grid using Fuzzy Logic

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Abstract-— **New technologies are emerging gradually inorder to meet the increasing power demand. Increased power demand is the main reason for the depletion of resources and also an increase in tariff. Smart grids and smart meters are very good solutions for issues in Energy management. Smart grids are the improvised version of conventional grids which provides two-way communication between utility and consumer so that the consumer is able to know the flexible tariff and accordingly he can adjust the consumption. This paper discusses intelligent control in the consumer side to meet with the demand and to switch to renewable sources when the demand is high.**

Index Terms— **HEMS, smart grid, smart meters, IED, fuzzy, AMI**

I. INTRODUCTION

The reliability of power supply and the gap between power demand and power supply are the major issues faced by current energy management. Smart grids and smart meters are implemented as a solution for challenges faced by the power sector. Smart meters are measuring devices that can be used as sensors and it can also be used to measure the power consumption during required intervals of time . These sensors can detect a fault and send outage notification to utilities. Thereby it can reduce the duration of outages and also improves the reliability of power supply.Smart grids deals with both power flow and information flow. The communication strategy offered by Smart grids provide protection from internal and external threats that affect the normal operation of grid. Advanced Metering Infrastructure (AMI) is the heart of smart grid which collects information from the smart meters. AMI establishes a strong communication path in smart grid and allows bidirectional data transfer between consumers and the utility. The benefits of smart meters to consumers are that bills will be based on actual consumption and no need of giving access to the utility for taking meter readings. Consumers get power with improved quality. The advantages of smart meters to utilities are that the peak demand is reduced and also fast and efficient monitoring is done. The main barrier to smart metering is privacy-related issues and also the time taken for a transition to new technology [1]. Smart meters are the fundamental components of intelligent energy networks (IEN). In [2] development and deployment of smart meters are systematically reviewed. It was found that existing smart meters can be made smart by modifying it flexibly by adding smart modules into existing meters.The demand response strategy can be achieved using a master controller also[3]. In [4] an efficient energy management strategy is suggested which can be utilized for reducing the energy expenses at home.

A. SMART METER DATA FOR LOAD FORECASTING

Many new approaches have been developed for forecasting load for a short period of time and so load forecasting is becoming possible. In [5] using Internet of things (IOT) technology energy consumption data is collected for clustering. For each cluster load forecasting is done separately and peak power demand is obtained for each cluster. Then the predicted values are summed up to obtain system level total demand. In [6] the load is represented using deterministic element and a Gaussian perturbation. Load forecasting for different time periods is done using Kalman filter. ANN based model was used to forecast the load based on smart meter data in [7].

B. SMART METERS AS VOLTAGE SENSORS

In conventional voltage control system at the distribution side, the system does not monitor the low voltage (LV) at the end of distribution line. At the end of distribution line LV droops due to heavy loads. So by the conventional methods it is not able to solve the LV problem. So to resolve this problem voltage control can be done by using the

ISSN (Online) 2395-2717

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voltage measured by smart meter in[8]. Several meters are selected as the representative meters and the voltage of all the meters are calculated and regulated. Previous voltage measured by all the meters were collected. Based on similarity of waveform LV were categorized. Representative meters were picked up from each section using factor analyzing. For estimating the voltages of other meters of each section voltage relational equations were formulated. Using voltage equations voltages of other meters were calculated. A common voltage trend can be observed in the voltage trend obtained by the smart meter which can be ignored. Suitable voltage controller is used to adjust the output voltage when it surpasses the design range. In [9] to support voltage control strategies measurements coming from smart meter is used to do state estimation . In [10] voltage levels of low voltage grid is stabilized based on the information obtained from the smart meter.

C. OUTAGE DETECTION

Outage management is an important application of smart meter. Utilities have given high importance for outage detection. Impedance based fault location methods and voltage monitoring capability of smart meters was done for improving service restoration. The common method for fault detection are the impedance based method. Consequence of impedance based outage detection was that it can cause problems of multiple estimation of fault location. The smart meters can be used to obtain the voltage measurements and using that information smart meter can identify in which place actual fault happened ie, in the proximity of a fault location the voltage magnitude will be comparatively low. This low voltage area is called low voltage zone (LVZ). LVZ are the areas under distribution feeder where the system voltage is less than the threshold voltage value. It is desirable to make threshold voltage a variable value since as the fault resistance increases LVZ enlarges. For accurate identification of fault location and to make LVZ narrow adaptive threshold value is chosen [11]. [12] Discuss about the technical considerations to be taken while integrating AMI and outage management system.

D. UTILITY SYSTEM

In [13] a smart meter system was introduced which have the ability to measure the active energy consumption of electrical appliances implemented in a building. Rated current of each appliance is recorded and smart meter switch off the device when the current through it exceeds the predefined limits. When current through the device exceeds the limits the system get switched to the utility which provides a minimum tariff at that moment. Current and voltage values of all utilities are send through voltage front end and current front end. Micro-controller unit is programmed in such a way that it calculate the rms values of voltage, current, active and reactive power. In [14] using fuzzy logic controller tariff at grid side and consumer side was computed along with the price that should be paid by the consumer. Consumer is alerted for own consumption which in turn allows him to give priority to load as per the demand. In [15] interaction between consumer and utility was demonstrated using switching controls in order to meet the power demand. In [16] a new approach for simplifying the monthly tariff of a hospital load system was introduced. The loads are classified as critical, intermediate and non critical. The tariff will be different as for the critical load it will be high and for the non critical load it will be low. In [17] a new design was proposed to reduce the consumer power consumption below a threshold value. The system considers consumer preferences and load priority.

This paper deals with the intelligence control at the consumer side using fuzzy logic. There is a strong communication scheme between HEMS system and the smart meter. Smart meter send information to HEMS system regarding the power consumption through fuzzy controller and then according to the logic implemented HEMS system switches the load according to the priority level.

II. THE PROPOSED SYSTEM

The utility side controller forecasts the load for an HEMS system based on the previous 1 week data obtained from the smart meters. Load is forecasted and the data is send to the smart meter using GSM technique. Smart meter consist of a fuzzy logic controller. The input to fuzzy logic controller is data from power demand curve and the SOC of battery. Based on the 2 inputs controller decides to which grid the system is to be connected, whether to main electricity grid or to the renewable sources. The basic block diagram of proposed system is shown in the figure1.

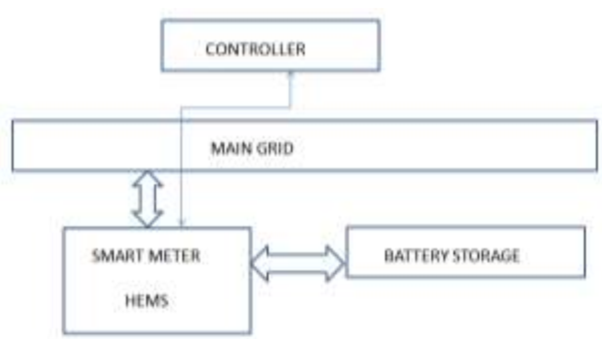

Figure 1. Basic block diagram of proposed system

In figure 1 we can see that local microgrid controller send SOC and power demand data to the smartmeter via GSM technique. The system works in such a way that if the peak demand is high and the SOC is low then the smartmeter

IFERP
ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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switch off the load to HEMS based on the priority level. In this work only one priority level is set which is the high power consuming load that can be a washing machine or iron box. So during the peak demand time high power consuming is switched off using the fuzzy logic controller. When the demand is high and the SOC is also good the system switches to renewable energy source such as a solar panel. Thereby reducing the load demand. Hence the utility gets the advantage of reducing the power demand.

A. WORKING OF INELLIGENT CONTROLLER

Fuzzy logic is a different approach in which instead of considering usual truth or false approach it provides certain degrees of truth and the values of the truth variables may be any real number between 0 and 1. In this system fuzzy logic is implemented as a controller to control the peak demand based on the inputs given to it. Two inputs are given to controller they are SOC and power demand. 3 outputs are taken they are Renewable source, Main switch, Main load which is to be switched. The range of power demand is from 1 to 24 kW. The range of SOC is from 0 to 100 %. Triangular membership functions were created to reduce the time consumption. When the power demand is between 1 - 10 kW it is taken as low demand. When the power demand is between 10 -19kW it is taken as medium demand. And when it is between 19 -24 then it is considered as high demand. Similarly when SOC is between 0-30% it is LOW, between 30-55% it is OK and above 55% it is considered to be GOOD. When the renewable output is between 0 and 0.5 then it is ON and if it is between 0.5 and 1 then it is OFF. When the Main switch output is between 0 and 0.5 then it is ON and if it is between 0.5 and 1 then it is OFF. Similarly the main load output is between 0 and 0.5 then it is ON and if it is between 0.5 and 1 then it is OFF. Fuzzy tool box is shown in figure 2.

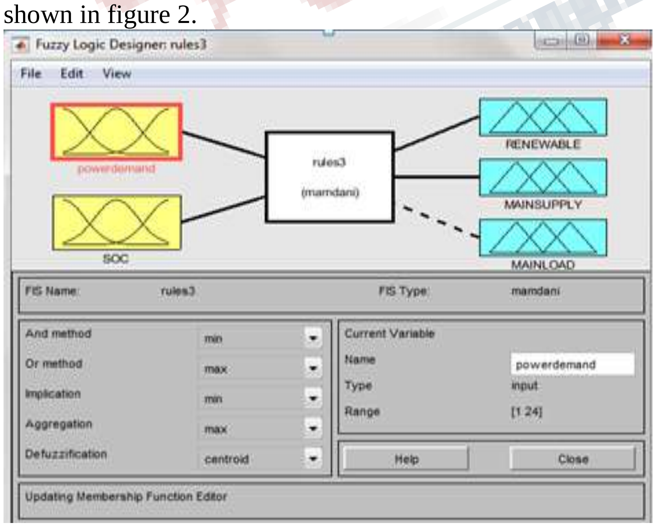

Figure 2. Fuzzy toolbox showing inputs and outputs

Fuzzy rule box is shown in the figure 3. 9 sets of rules were formulated based on the logic.

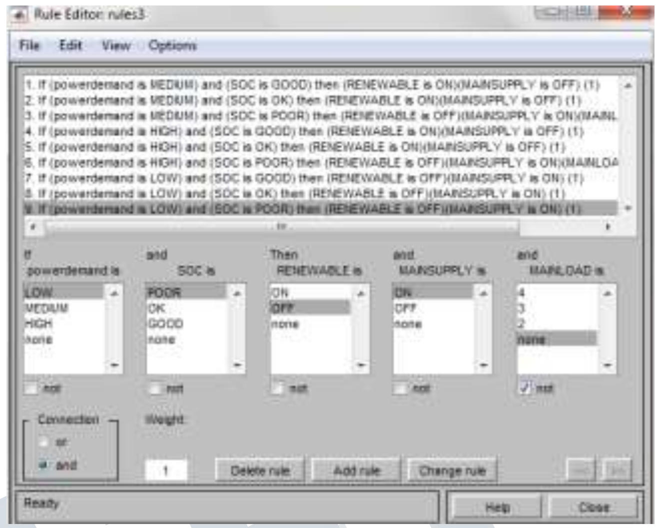

Figure 3. Fuzzy rule box showing 9 set of rules formulated

If the power demand high in such cases renewable sources are connected. But if the SOC levels are low then low priority load of HEMS is switched off. If the power demand is low then we can go with main utility.

B. SIMULATION OF FUZZY CONTROLLER

The system is represented using a single fuzzy controller. The system was simulated in MATLAB. Logic table was tabulated as per the below figure 4 . These are the test conditions. The system is simulated as per the test conditions.

POWER DEMAND (KW)	SOC (55-90%)	SOC (30-55%)	SOC (BELOW30%)
1-10	Renewable	Renewable	Main utility
10-19	Renewable	Renewable	Low priority OFF
19-24	Renewable	Renewable	Low priority OFF

Figure 4. Test conditions for fuzzy logic controller

Figure 5 show the expected set of results for the case when power demand is very high and SOC is very poor. So the system continues with the main utility grid and the low priority switch is switched OFF.

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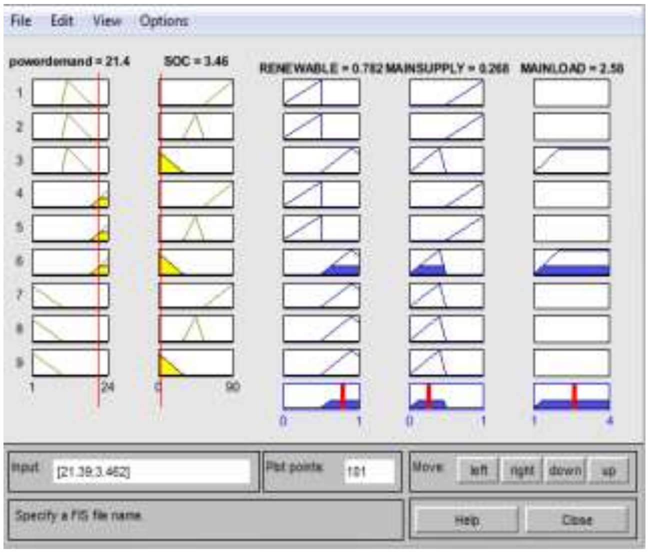

Figure 5. Results when power demand is high and SOC is poor

III. CONCLUSION

In this paper an effective communication between smart meter and HEMS system is trying to be implemented. Fuzzy logic controller is the brain of the proposed system which act as intelligent control device. The forecasted load from the utility based on smart meter data is send to fuzzy controller of HEMS. SOC and power demand are the two inputs given to the controller. Based on the input, logic is evaluated and controller decides whether to switch to the renewable source or to continue with the Main utility and switch OFF the low priority load. Through this system peak demand can be reduced. So it reduces the burden of utility to supply additional supply. It also facilitates the condition for switching to renewable sources during peak time when the SOC is good. Instead of fuzzy controller advanced intelligent controllers can be used to make controlling action more advanced. In future instead of switching one low priority load more number of loads can be switched OFF based on preset priority levels. Simulation output was observed in MATLAB..

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