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Simulation of Solar Based Smart Grid System Using Artificial Neural Network and Fuzzy Controller

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ABSTRACT- To promote the economy and reliability of the energy trading systems, the use of interconnected smart grids is encouraging. A distributed energy management plan for the interconnected operation of the smart grid that maximizes the resident intake of renewable energy is required during operation. On the client side, possibilities and actions are being discussed in the research papers to incorporate the renewable energy sources. In this paper, the use of Artificial Intelligent Techniques to manage energy or power supply to meet the electricity demand of customers is illustrated. Simulation has been done using wind and solar power supply to manage the load demand for the client side in a smart grid system. Smart Grid has been simulated for all these energy sources to be used with the forecasted electric power requirements. All the required energy demand can be identified from the forecast data, allowing smart grids to deliver better results. For this purpose solar panels are first used in smart grids with the help of artificial neural networks and fuzzy controllers so that load shifts can be done easily and efficiently. Simulation work has been done in MATLAB/Simulink.

Keywords: Artificial Intelligence, Smart Grid, Renewable Energy Sources, Artificial neural network short term forecasting etc.

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1. INTRODUCTION

For smart grid to do smart energy management, it requires smart energy which can obtained from power grid like hydro, nuclear, wind, solar, diesel and battery systems. Energy management is very essential to maximize the energy efficiency and use of renewable energy. Energy management can be roughly divided into: smart transmission, smart distribution system and demand side. The main goal in smart transmission systems is to maximize the consumption of the energy from renewable energy sources such as hydro, nuclear, solar and wind etc. as well as the possibility of optimized the peak grid loads in demand response [1]. Ghulam Hafeez [2] discusses about the framework is an integrated framework of artificial neural network (ANN) based forecast engine and our proposed day-ahead grey wolf modified enhanced differential evolution algorithm (DA-GmEDE) based home energy management Controller (HEMC). This work is favorable for both consumers and power companies. The research paper of B. Kavya Santhoshi et al [3] describe in detail about the multidimensional purposes of grid-tied hybrid renewable system such as tracking of maximum power, increasing the power conversion efficiency, reducing the harmonic distortions in the injected current and control over power injected into the grid, author achieved this by using battery storage system for balancing the energy flow between source and grid. The proposed SVPWM gives abundant DC voltage by operating duty cycle control and curtails the harmonic content better.

Nowadays, solar energy is the most popular renewable energy source. Many consumers and industries use solar energy to meet their demand of the electricity. Since it is renewable energy, it is obtained from the sun with photovoltaic cells converting solar energy into electrical energy [4]. Solar energy is also environment-friendly as there is no fly ash, chemicals, polluted gases during the whole process of solar power generation.

Figure 1 shows a block diagram of the generation of electrical energy by solar energy using photovoltaic cells. When the sun's rays reach a photovoltaic cell, it generates electricity through an electronic process. This electricity is stored in batteries and also used in the electronic gadgets, home and large-scale businesses. In India now the use of solar panels on the roof is in trend in almost every house and many other countries are also using this pollution free energy.

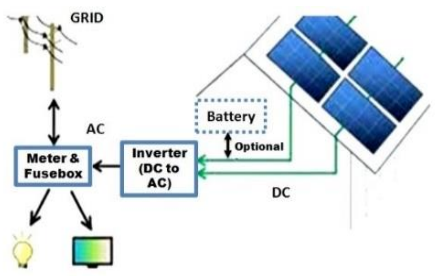

Figure 1: Block Diagram of Production of Solar Energy by PV Cell

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Table 1: Sun Radiation Table

MONTH	REGRESSION COEFFICIENTt(a)	REGRESSION COEFFICIENTt(b)	H_O(MJ/M^2-DAY)	H_g(MJ/M^2-DAY)	H_d(MJ/M^2-DAY)	K_T(H_g/H_o)
Jan	0.39	0.34	25.45	17.38	4.40	0.68
Fe	0.39	0.33	29.47	20.01	5.19	0.67
Ma	0.36	0.40	34.00	22.87	6.18	0.67
Ap	0.37	0.37	37.73	25.35	6.88	0.67
Ma	0.37	0.38	39.60	26.83	7.03	0.67
Jun	0.37	0.58	40.08	26.97	7.28	0.69
Jul	0.28	0.76	39.70	18.83	11.42	0.47
Au	0.19	0.80	38.30	13.50	10.98	0.35
Se	0.17	0.59	33.22	15.53	9.60	0.46
Oc	0.27	0.41	30.72	17.82	7.61	0.58
No	0.35	0.36	26.34	17.14	5.27	0.65
De	0.32	0.49	24.24	15.49	5.07	0.63

Direct current (DC) that we obtain from solar energy via photovoltaic cells is utilized using an inverter before it can be used. In India, the inverter converts DC electricity to 230 volts AC, which is then used for household appliances [5].

The electrical power from solar energy mainly depends on the sun radiation to the PV cells. The empirical model was developed based on actual solar PV operation:

$$P_{PV} = aR^5 + bR^4 + cR^3 + dR^2 + eR^1 + f$$

Here PPV represents Power of Photovoltaic cell, a, b, c, d, e, f are the regression coefficient and R represents the level of sun radiation

2. ARTIFICIAL INTELLIGENCE BASED SWITCHING AND LOAD FORECASTING

In this paper, fuzzy controller technique is used as an AI based controller for switching the power to load from grid or from renewable energy source i.e., solar power generator. Fuzzy controllers take care of the probabilistic nature of the requirement of load power. *Figure 2* shows and overview of fuzzy logic control. Fuzzy logic controllers are based on fuzzy sets. The output of the fuzzy controller is smoother than abrupt transitions from membership to non-membership. As a result, the boundaries of fuzzy sets can be abstruse and imprecise, making them suitable for approximation models.

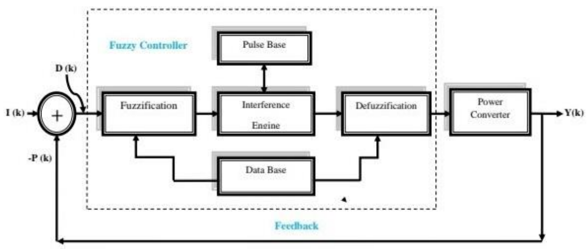

Figure 2: An Overview of Fuzzy logic Controller

During the design of a fuzzy controller, fuzzy controller's input and output variables are specified in accordance with the expected function of the controller. In this paper, fuzzy controller input variables are errors between forecasted power load and power generated by PV module [6] and also the error rate.

For forecasted power requirement, another AI technique i.e. artificial neural network is used [7]. It generates the required power for the next 3 hours based on the recorded data of the previous 30 hours. *Figure 3* shows the ANN structure used in the simulation. Two hidden layers with 10 and 5 nodes are used respectively to take care of the nonlinearity in the model for data prediction.

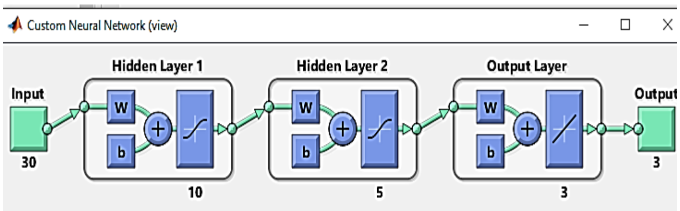

Figure 3: Neural Network Training

This ANN model is used for demand forecasting so that better switching can be provide. During the training of ANN L1 regulation is used to avoid over fitting. The forecasting accuracy of Model for prediction of power requirement is 92 %.

3. SIMULATION

In this *figure 4*, simulation scheme has been given. The simulation model consists of PV module with MPPT, grid connection, smart switches, and ANN based forecasting module and fuzzy controller. This archetypal is generated by using MATLAB/Simulink.

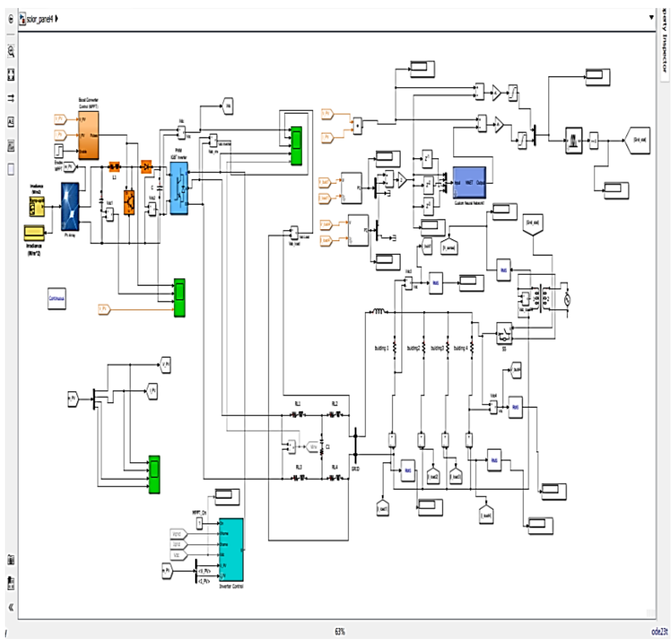

Figure 4: Simulation Modal of Solar Panel and grid connected

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3.1 PV Module
It tracks the operating voltage to achieve the maximum output of PV array. It uses perturb and optimization based algorithm for achieving the desired function.

3.2 Maximum Power Point Tracking
Model of maximum power point tracking is shown in *figure 5*. It tracks the operating voltage to achieve the maximum output of the PV array. It uses perturbation and optimization-based algorithms for achieving the desired function.

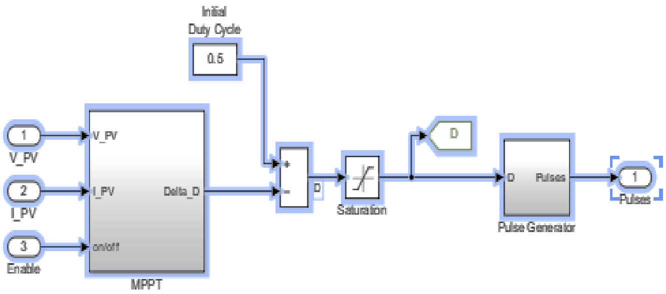

Figure 5: Boost converter control MPPT

3.3 Inverter Control
Figure 6 shows how inverter control can be used in conjunction with a controller to adjust the boost converter duty cycle to account for varying load. The inverter is implemented by using IGBTs to speed up simulation.

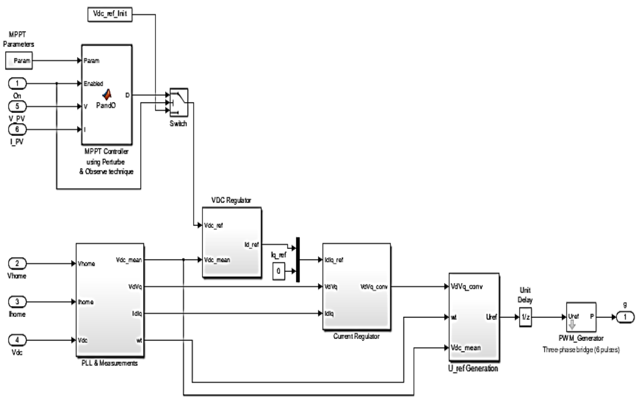

Figure 6: Inverter control scheme

The simulation result can also be plotted. Utilize the simulation model to simulate the PV panel and design the boost converter stage of the inverter.

3.4 ANN Forecasting
ANN is designed to solve complex problems, it is designed to imitate function and structure of the brain. To do practical and complex problems ANN is mostly used. In order for the ANN to create the control pulses for the inverter, the reference tracking error information is provided through a suitable scaling factor as input. In both online and offline modes, the inverter is controlled by maintaining a steady operating frequency. High level of fault tolerance is provided by the functional mapping estimation of ANN controller. The inverter model is not necessary for ANN controller design, but thorough knowledge of the inverter's functional behavior is required [3]. In the feed forward loop, an offline ANN trained using the back propagation algorithm was used to estimate the reference voltage [9]. Finding the network parameters, such as weights and others that enable accomplishing the intended target based on the accessible training sets constitutes the core of ANN training. Multi-layer feed forward neural networks are often trained under supervision. In this instance, the training approach is back-propagation.

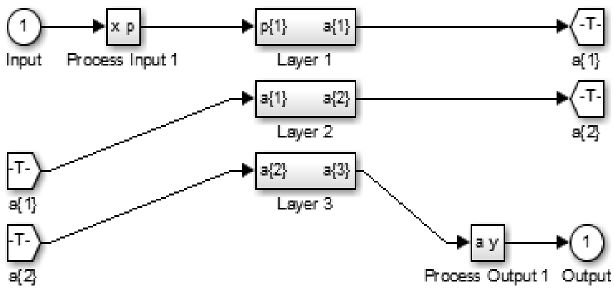

Figure 7: Neural Network 1

In this *figure 7* of neural network 1 the number of neurons is to be selected to be used in hidden layers. For each input, a number of delayed values is to be selected. In this we can generate training data and it should be plotted to get results.

3.5 Fuzzy Interference System
Figure 8 shows the mamdani fuzzy interference system for controlling the switch which is used to shift the load between grid and solar power.

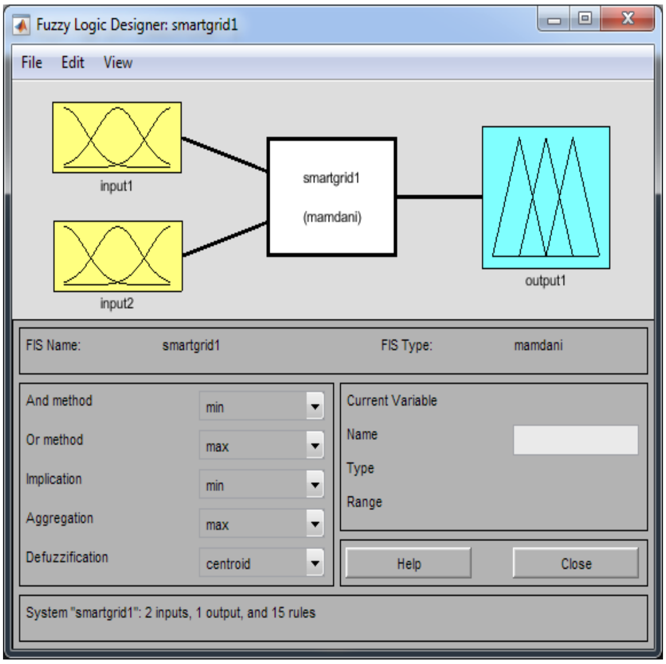

Figure 8: Fuzzy Interference System

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The error and change in the error between generating solar power and needed load are the inputs to the Fuzzy inference system in *figure 11*. The load is intelligently switched between solar generation, solar power generation, solar power, and grid power via this control system. Dealing with the probabilistic nature of input is a key feature of this controller. The input is assigned to a number of membership functions, and the probabilistic output is used to control the switch.

4. SIMULATION RESULT

The solar system is simulated with the real data recorded for a typical day. The irradiation is shown in the *figure 9*.

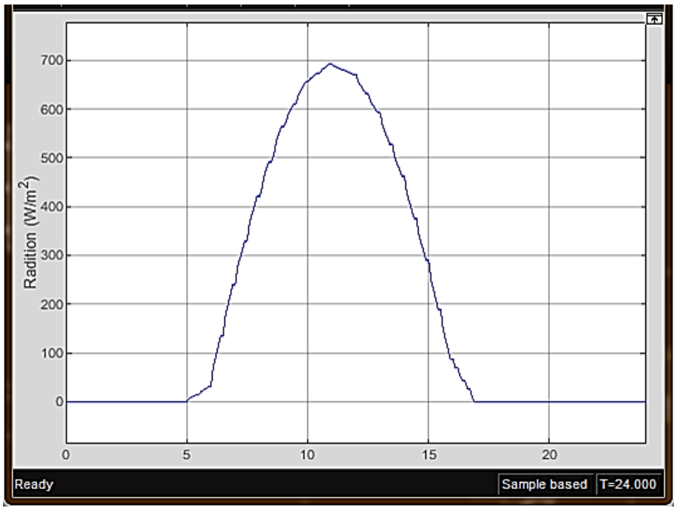

Figure 9: Typical irradiation data of a typical day

There is clear day, hence the irradiation of the day is following the normal trend and maximum ~ 12:30 of the day. It can be seen from the *figure 9*, the temperature is raising faster compare to decay down even the radiation follows the same way during increasing and decreasing trend. That generate the unsymmetrical power production through the solar panel.

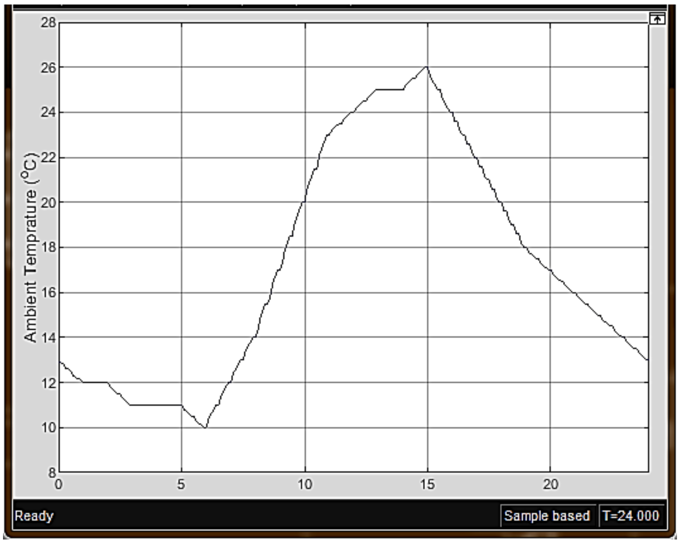

Figure 10: Ambient temperature variation in a particular day

For same day, the ambient temperature was also taken in the simulation. The variation of the ambient temperature is shown in the *figure 10*. The main aim of the solar power in smart grid is to use the renewable power for shifting the peak load for the grid system. A fuzzy logic controller is used in this simulation to identify the switching of the load.

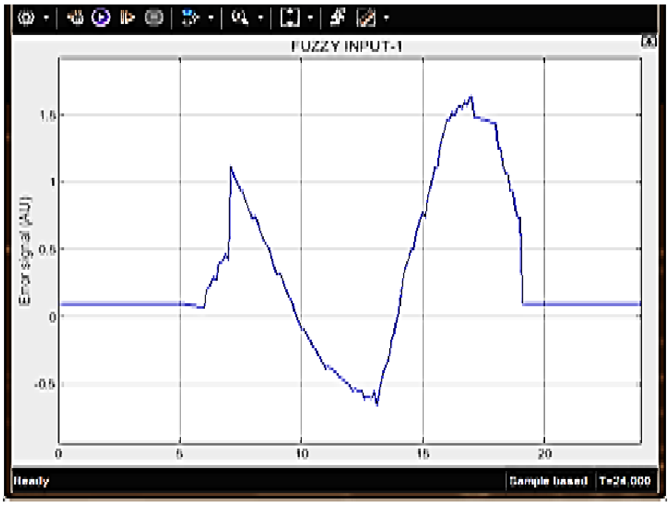

Figure 11: Input 1 of FIS Controller

Figure 11 depicts the nature of error signals, which have a variety of patterns. It ranges from 0 to 1.5. In the same way, the second FIS input is displayed in *Figure 12* there are very minor changes in the real-time data, which is likewise acceptable. When there is cloud in the environment, this error rate may be substantial. As a result, the solar panel's power decreases.

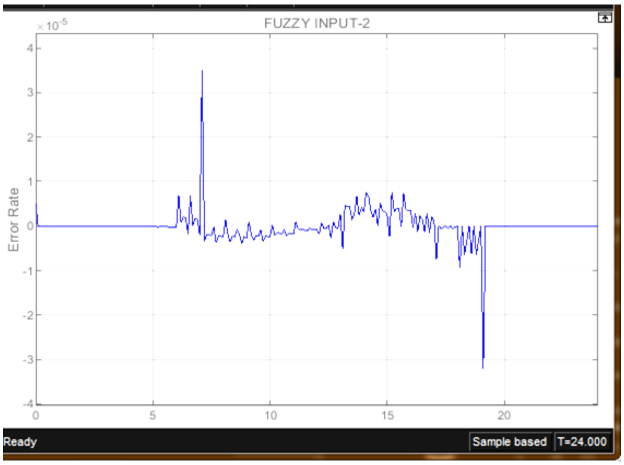

Figure 12: Input 2 of FIS controller

As shown in *figure 12*, the input 2 of the fuzzy controller indicating the change in error has changed from 40 ppm to -30 ppm. Although the weather was clear at the time of taking this data. So, this input doesn't seem to have much effect on the performance of the solar power generation hence control signal levels are intact.

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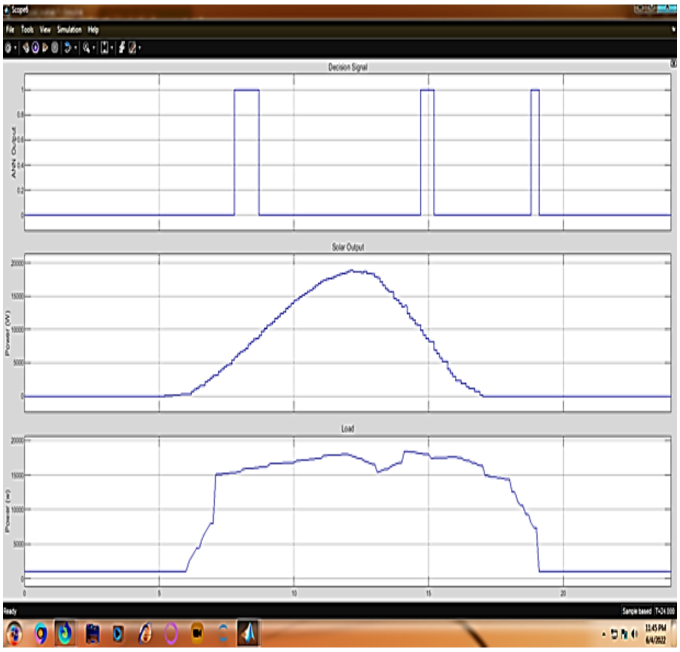

Figure 13: Simulation result for Solar based smart grid system

Figure 13 shows three graphs. The power load of the customer is shown in the third graph. A steady increase in load can be seen from 7 o'clock onwards. At 8 o'clock, there is a requirement of about 15 kW of power, which goes up to a maximum of 19 kW. Solar power generation is shown in the second graph, which is below 5 KW till 8 o'clock but at the time of peak load the solar power generation has exceeded 19 KW. Therefore, solar power has been used instead of grid power during the peak load. This can be seen from graph 1 which is the output signal of the ANN controller.

5. CONCLUSION

This paper simulates the use of solar energy with the use of renewable energy to shift peak loads in smart grid systems. In this simulation, artificial intelligence technology, which is a fuzzy logic controller, was used for efficient load switching. Since user demand is constantly changing, the rate of demand and demand change is treated as input to the fuzzy controller and 30% load reduction is taken. Switching back to the power grid using both wind power and solar power in the future can easily maintain forecast demand and actual demand while reducing costs.

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