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# Integration of smart grid with renewable sources using soft computing technique

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**Abstract**
This paper presents a control strategy for achieving maximum benefits from the smart grids which are widely used in various industrial applications. A smart grid is an electricity grid that incorporates automatic, two-way communication networks for transmitting energy from a power station to households, businesses, etc. Smart grids often provide feedback to grid operators about control interferences and electricity use. It is the combination of power system, distribution, transmission, communication, and switching equipment's considering the safety purpose. The controlling technique is used in MPPT is Fuzzy logic integration which is used to find maximum point of power tracked through controller in which Mamdani control is used for better utility. The P&O Technique describe in the proposed work has an algorithm which defines the power as error and changes in it appears than after its rectification saturated output will be provided accordingly to the requirements of the system. The proposed work for power consumption with renewable energies and controlling technique is successfully achieved by comparing power of solar/wind and grid which has values of 4KW whereas that of grid is 2KW with P&O technique. The values of solar energy are increased to 8kw and grid power consumption is decreased, so higher and smooth utilization of power is obtained with Fuzzy Controller.

**Keywords:** Grid, fuzzy controller, power quality, smart meters, P&O

## Introduction
Smart grid is the balancing of load and demand. A real time monitoring system in which each device is in continuous communication with the sensors. It includes other operations as advanced metering, infrastructure, distribution boards, circuit breakers, load switches, etc. It helps in energy storage in batteries, capacitors. When there is any failure in the main power source then an uninterruptible power supply will supply the power during that short period. The supply is rectified by the rectifier converted into dc then the battery is being charged by the supply, with the help of inverter which is inverted into alternating current again as our equipment's work on ac supplied to the load. It counters global warming which is the major issue as renewable energy is the efficient, eco-friendly energy that helps in the completion of requirements with a greener environment. Smart grid is the integration of power systems with renewable sources of energy for which we require power electronics. The main purpose of a grid is to maintain the voltage level, harmonic reduction, and maintain the stability of the system for which we use various devices such as DVR, STATCOM, PWM inverters which are used to fulfill the purpose. Mainly Inverters are generally used in the smart grid. Converters that sense the voltage as per the supply then provide the firing angle. The output voltage of our given to the grid as a reference will be injected in the grid.
The sustainable power source offers elective wellsprings of energy and which are present in large amount as well as contamination-free. The wind and solar energy are normally irregular but solar would be large enough in presence of sunlight and wind would be in large amount when the flow of air is maximum still it could be used effectively to get the desired output. The apex working time for solar and wind frameworks happens at various occasions of the day for better places. The solar and wind energy framework can't give a persistent supply, it can produce power just during radiant and windy days. So accordingly, integration of both solar and wind energy framework into an ideal blend improves generally speaking proficiency of the framework [1]. The integration of PV and wind framework become progressively prudent to keep running since the shortcoming of one framework can be complimented by the quality of the other one.

A brief introduction about wind turbine generators, photovoltaic boards, and capacity batteries which are utilized to assemble a grid-connected framework including cost, unwavering quality, and outflows. Multidisciplinary configuration encourages the leader to make progressively discerning assessments [2-4]. A lot of exchange-off arrangements can be acquired utilizing the multidisciplinary approach, which offers many plan options.

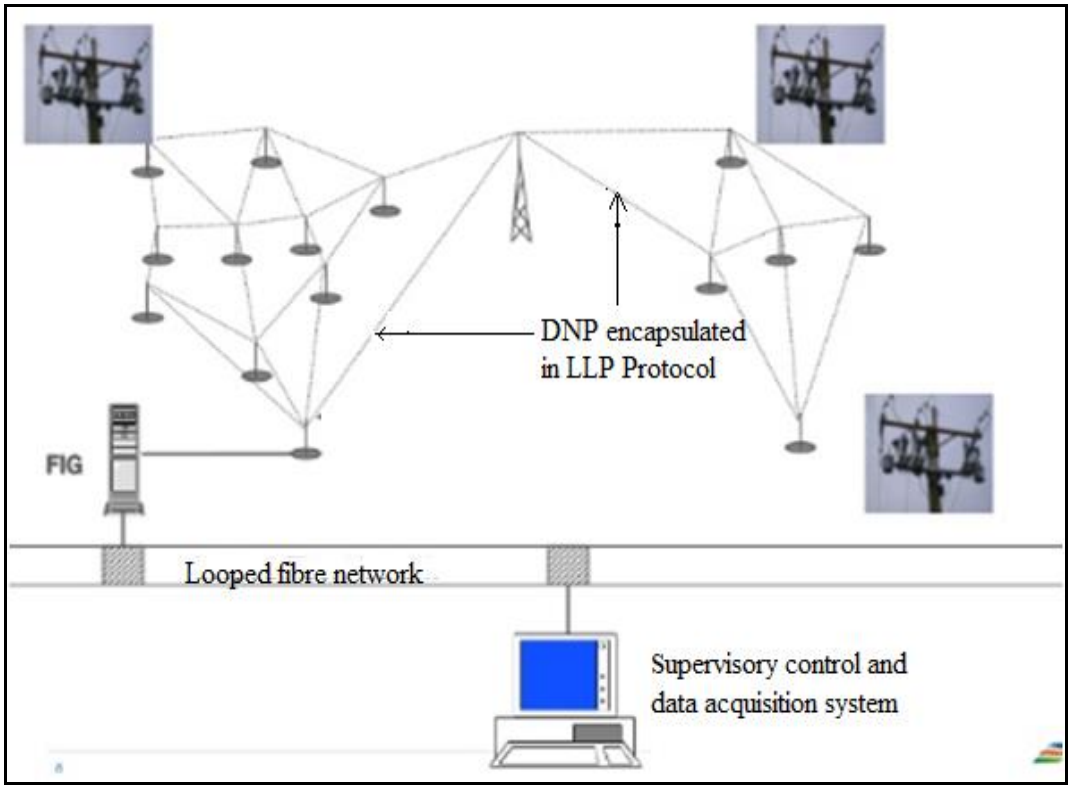


**Fig 1:** Smart grid communications protocol

As the smart grid facts rise as an innovative work subjected over a recent couple of years. Smart grid clients convey in two-manner headings by using a few remote and wired correspondence conventions, for example, Wi-Fi, Home plug, Zigbee, control line bearer, GPRS, Fibres, LET, WiMAX, and Lease line. A few programming bundles were refreshed and many are being created to oblige the new grid task, and the executives, for example, conveyance the executive's framework (DMS), geographic data frameworks (GIS), blackout the board frameworks (OMS), client data frameworks (CIS), and supervisory control and information securing framework (SCADA) [1]. Because of the smart grid advancement, some ongoing empowering advances have developed to decrease the number of correspondence conventions and also handle huge measures of information. One of the latest empowering agents for the smart grid is The Internet of Things (IoT), appeared in Figure 1.

The grid is smart as its two-way communication. It can sense the demand and load requirements as per the utility, without manual power. The smart equipment as smart meters, town servers are well interconnected in the system in such a way that every data is being displayed on the digital meters as well, if there is any change in values that are already specified in the system it will automatically change them as per the demand and load requirements.

**Control Strategy**

Smart Grid is a two-way communication as today consumers sometimes behave as the producers by installing solar roof tops, electrical vehicles, charging machines for charging, micro turbines connected in villages. The industries, residential or commercial buildings were consumers before but now they are producers too known as prosumers. There will be a flow of electricity and information both via sensor meters that if we consider a commercial building in that which equipment is on or off and what is a load of that particular area. It is a self-healing system whenever there is a deficiency of load it will raise the generation at the station and on the other part if less is required by the consumer it will automatically lower down the load at the station.

**Design of a wind turbine and Modeling**

The renewable parameters integrated plays an important role so it is precisely given as follows

Wind turbine model depends on Turbine yield power qualities, wind speed versus Wind The power of the wind.

Where, Cp= the exhibition coefficient of turbine, Pm =mechanical yield power of turbine, λ= the speed tip proportion of blade rotor, β= blade pitch point, ρ= wind thickness, A = turbine cleared territory, V wind= wind-speed [1].

That constants $C_1$ to $C_6$ are parameters-based blade and plan rotor wind turbine.

where: pK =the power gain V wind-pu of the base wind speed, Pm-pu=the power in per unit of ostensible power for specific estimations of an and ρ, Cppu=the execution coefficient Cp in the build speed of wind is express estimation of normal speed of wind in m/s [1].

**Design of a Photovoltaic Module and Modeling**

The circuit of the solar cell model, which comprises a photocurrent, diode, parallel resistor (spillage current) and an arrangement resistor; is appeared in Figure. The general scientific model for the solar cell has been examined in the course of recent decades. 3.1 According to Kirchhoff's circuit laws and both PV cell circuit, the photovoltaic current could be introduced as pursues.

Where: IGC=the light created flow, Ipv =the photovoltaic flow, e= electric charge e=1.6*10-19C, Tc= cell's supreme temperature, Io =the dim immersion flow dependant on the temperature cell K=Boltzmann's steady, Vd= diode voltage, Rp=obstruction of parallel.

F= admiring cell factor, K=1.38*10-23 J/K [1].

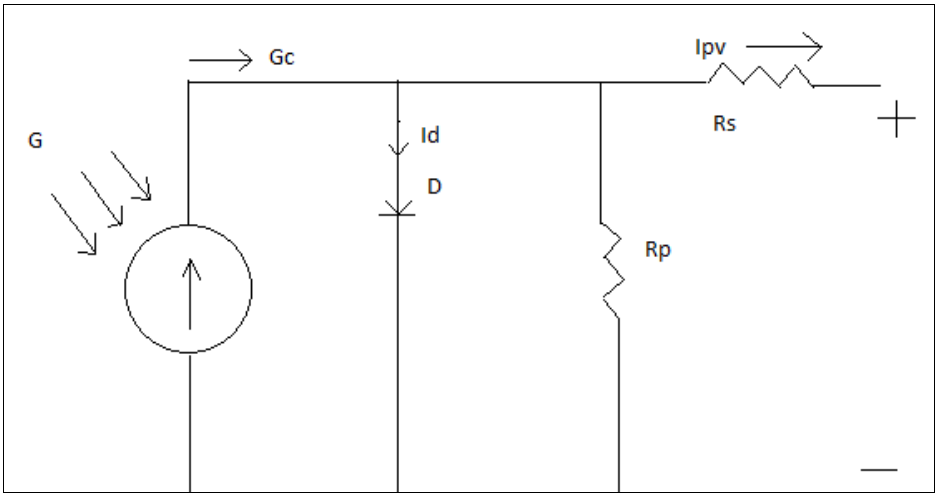


**Fig 2:** PV cell equivalent circuit Single diode

Photocurrent IGC and Cell temperature primarily rely upon irradiation solar, that is depicted as where: Tr = cell's reference temperature, μsc= temperature coefficient of cell's short out current, 1 KW/m2, G= solar irradiation in KW/m2, and ISC= cell's short out current at a 25˚C D=the diode, ID=the running streaming in diode, Rs=the arrangement obstruction.

Moreover, immersion current (Io) shifts with the temperature of the cell, which is depicted. Where: Ioα =the cell's turn around immersion current at a reference temperature and solar radiation, Vg=the band-hole power of semiconductor utilized in the cell, Voc =the cells clear circuit potential.

**Smart Grid**

Smart Grid is a two-way communication as today consumers sometimes behave as the producers by installing solar roof tops, electrical vehicles, charging machines for charging, micro turbines connected in villages. The industries, residential or commercial buildings were consumers before but now they are producers too known as prosumers. There will be a flow of electricity and information both via sensor meters that if we consider a commercial building in that which equipment is on or off and what is a load of that particular area. It is a self-healing system whenever there is a deficiency of load it will raise the generation at the station and on the other part if less is required by the consumer it will automatically lower down the load at the station. As we know that every technology has its pros and cons so it has certain disadvantages also that it requires a continuous communication network. Smart meters can be hacked by others and power can be increased or decreased.

The connected framework in the proposed work is integrated with solar and wind energy so accordingly a concise description about them is mentioned. The specified framework consists of design of photovoltaic cell and wind turbine. The description about the connected components as smart meters, town server, main server, control strategy, characteristics as well as features of the smart grid is described below.

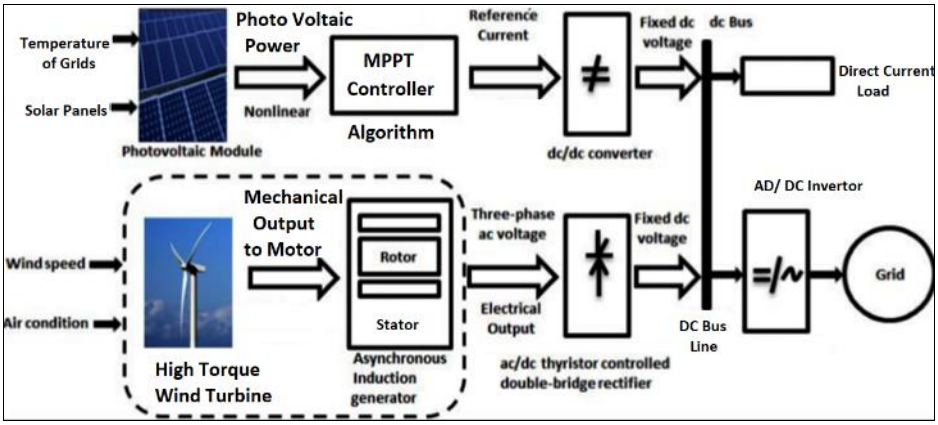


**Fig 3:** Smart grid System [1]

**System description of Smart grid**

The grid consists of various components mainly dependent on 2 inputs as temperature and irradiance is provided to the photovoltaic module and wind speed is given to the wind turbine. The output from the panel is assigned to the maximum power point tracker which has fuzzy control technique inside it. On the other side the output from the wind turbine goes to asynchronous induction generator for the generation of power. For dc loads the energy is rectified which is then converted by inverted to collect ac requirements for the station.

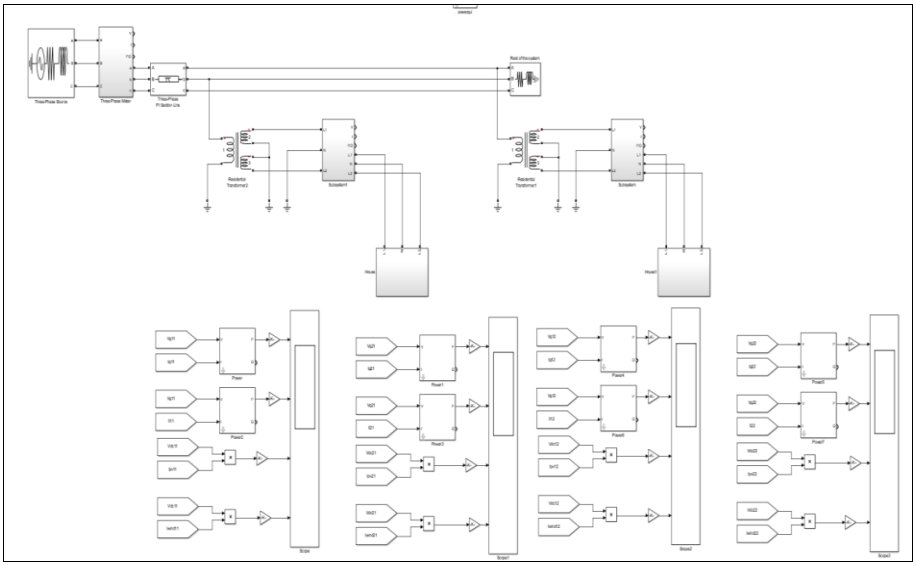

**Fig 4:** Implemented model circuit using fuzzy logic

The four main parts of the fine framework, which will cooperate to conquer every one of those issues which are disadvantages of past frameworks, these are:

- Town Server.
- Smart House System.
- Smart Meter.
- Main Server.

**Town Server**

Town server connects all the system in which meters are connected to the sensor for the continuous communication. At every hour each information holds out spare at MS(Main Server) while TS main town server forward determined unit of power up to that opportunity to the MS so that later information of current month will be displayed. The TS(Town Server) is associated with MS for correspondence utilization by PSTN. Forwarding the information after every hour is intended to evacuate the likelihood of overloading of transmission capacity and to decrease the data transfer capacity to extensively less dimension than the past smart framework. TS is worked by performing various tasks constant working framework and ongoing programming which are intended for the reason that at whatever point MS goes to down than the Method incorporated inside TS consequently change to regulatory technique. This technique is the one that TS carries on like MS for itself and carry information connections are of significant except if MS isn't connected up. While TSs are associated with one another utilizing PSTNs and utilizing energy lines to see entire administration between TSs which are conceivable those two connections which are used on the off chance that still lack continue TS will check its SHs these could give energy through their regenerative origin to repay energy in sufficiently.

**System of Smart house**

Smart-house is the client house that comprises wise apparatuses. Gadgets are smart because of the establishment of a wise remote card. Outline of smart remote card and it comprises of.

- Microcontroller.
- Meter Digital.
- Simple remote card.
- Sensor.

Utilizing the smart apparatuses, correspondence among gadgets and smart metering will be finished utilizing little attachment (SM) Smart Meter. To detect power utilization sensor is incorporated. It additionally chooses the current quality while the computerized meter is a gadget that will display energy and owned value. The microcontroller is the gadget that controls the progression of energy additionally, machines need energy which is displayed on the microcontroller and send this information through SM straight forward remote card which has commonly associated gadget that interfaces SM to the smart remote card by remote correspondence.

**Smart Meter**

Smart-meters are like better Metering Infrastructure meters as appropriate information is provided by them and they give a correspondence way to analyse the requirements as per the demand of the consumers. These consists of power management and measuring unit and communication units. Electrical grid (smart-attachment) and extra smart-grid-empowered gadgets with computerized meters that use data continuously are replaced by simple mechanical meters.

**Main Server**

MS is legitimately worked by the head office of the specialist co-operation. Also, MS could begin or block the entire usefulness and running of specific SH/TS by utilizing a few sorts of directions or key word. The principle server (MS) is focal gadget around which all framework works. It carries estimations, records, charges, a record of the client,

division's topology of energy of smart-grid/power stations for its servers of town and so on. Each TS is associated with MS using PSTN (public switched telephone network) because of several causes, the specialist organization could block the running of several TS under extreme circumstances. MS currently creates a systematic synopsis toward the month's end for every S-M and every T-S. MS illuminates clients about their energy utilization and report by utilizing one of their chose media (post, and email, SMS on so that they get the appropriate and correct information needed.

**Implementation of MPPT Using Fuzzy Logic**

To understand the operation of the model we have used Fuzzy Logic Controller in which Mamdani control has been implemented. The model consists of two houses and two industries which have simulation results of power distribution as per load requirements. The technique is based on the criteria of error and change in error as two inputs and five Membership function as NB, NS, Z, PS, PB i.e. (5^2=25 set of rules are assigned) which has given in MPPT, in such a way if the required output is as per the load requirements than it will be fed to the grid otherwise feedback will be given to the input side to fulfill the load requirements as per the necessities and desired output will be provided. The simulated results of the output have been discussed below.

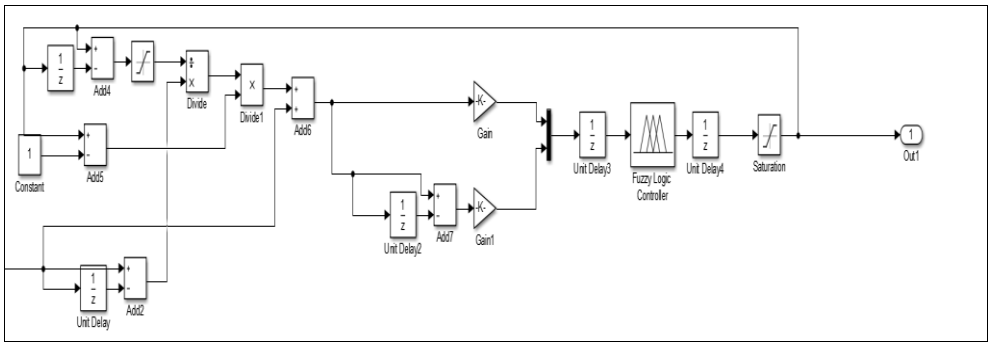


**Fig 5:** Fuzzy logic based MPPT controller

The figure 5 shows Fuzzy Logic based MPPT controller. This system improves the power utilization. The control system considering inputs we get our error and change in error fed into fuzzy logic controller. We gets saturated output but if it has certain error than it would be resolved by the feedback given back again to the input side, otherwise it will give the output of duty cycle than through duty cycle afterwards it moves to delay which saturate the output and final duty cycle is inserted in MPPT controller through which it goes to boost converter and provides dc output fed to dc loads and then converter into ac by inverter than it is finally fed to the grid. The applications of house and industry considered that shows daily consumption.

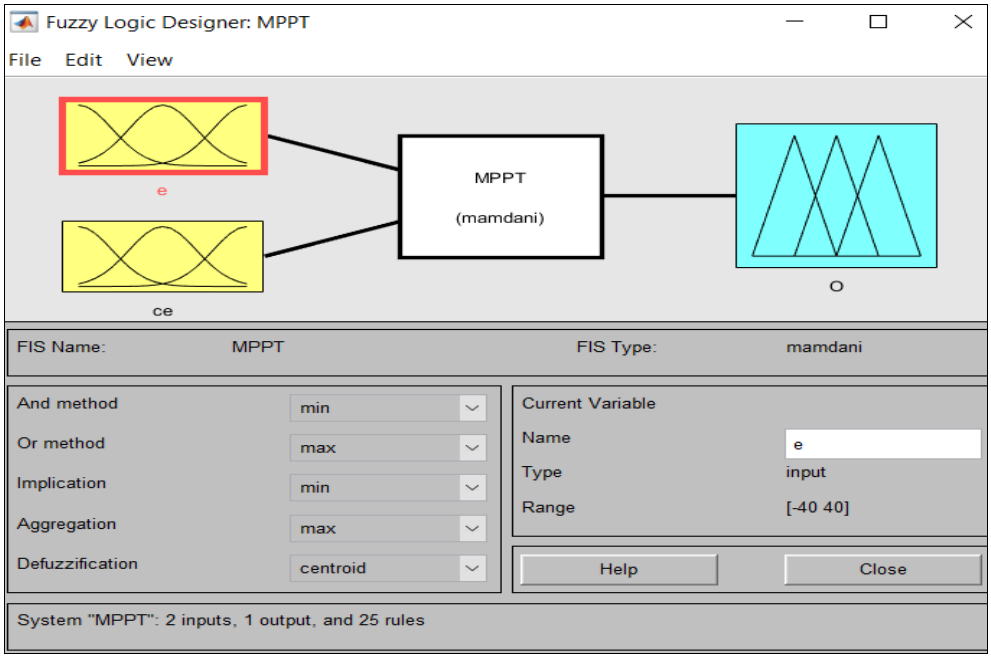


**Fig 6:** Fuzzy logic toolbox

The figure 6 shows the fuzzy logic toolbox. This is a fuzzy logic designer which has 25 set of rules with 2 inputs as error and change in error. The defined membership function for tracking power point by hit and trial method are Negative Big(NB), Negative Small(NS), Zero, Positive Big(PB), Positive Small(PS), so 5 membership functions with two inputs are considered.

**Table 1:** Rule Table

| Error / Change in Error | NB | NS | Z | PS | PB |
|---|---|---|---|---|---|
| NB | Z | Z | Z | NS | NB |
| NS | PB | Z | Z | NS | NB |
| Z | PB | PS | Z | NS | NB |
| PS | PB | PS | Z | Z | Z |
| PB | PB | PS | Z | Z | Z |

Rule table of Fuzzy Controller

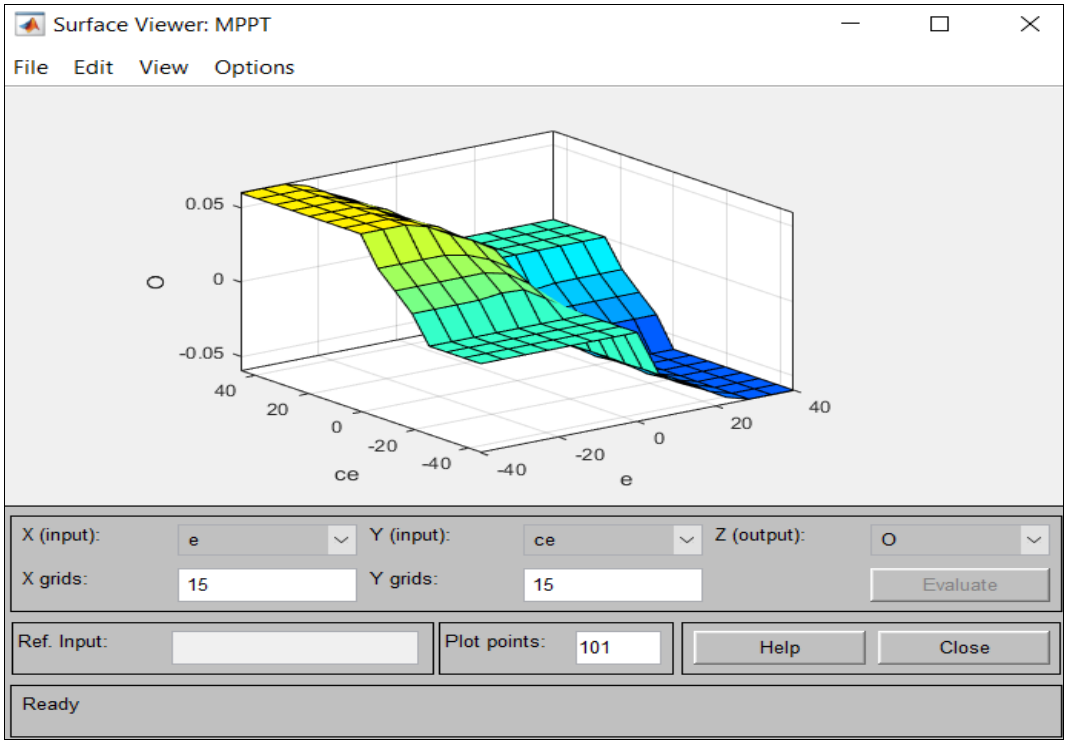


**Fig 7:** Fuzzy Logic Rules Surface View

The figure 7 shows the fuzzy logic rule surface view in which x axis shows input of error and y axis has another input of change in error according to which our output is shown at z axis.

**Result**

To understand the operation of the smart grid simulation are shown in the fig 8 and 9 which shows the output of the two houses and industries (fig 10, 11) varying their load curve as per the requirements.

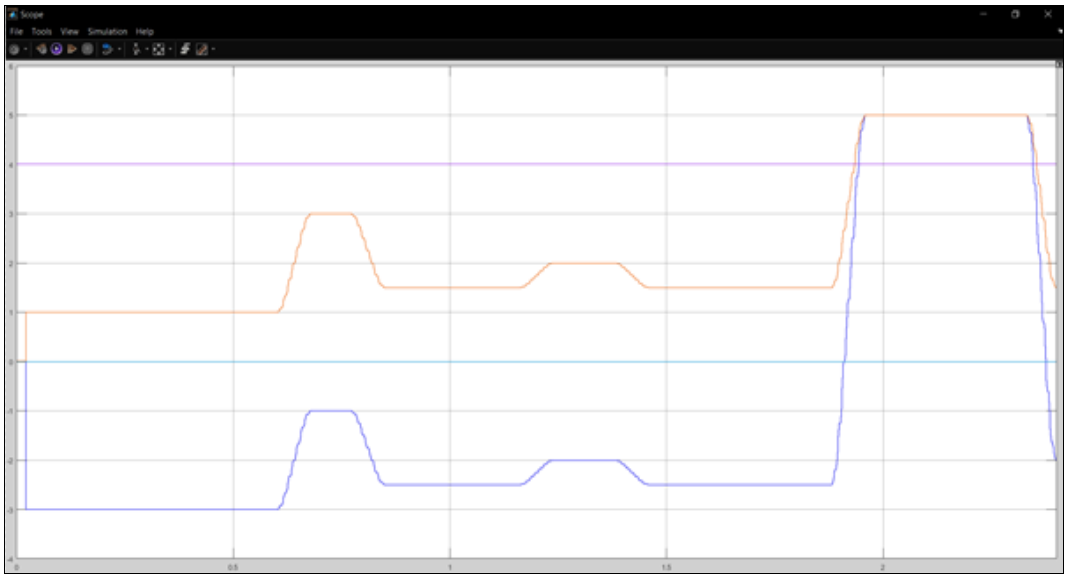

**Fig. 8:** Power Utilization of House 1

The figure 8 shows the simulation of House 1. The house stays confined from GEN until 7:00 am where a moment pinnacle of 4KW of energy is provided by wind turbine, suddenly as the time passes by the household consumption

starts increasing as more appliances are switched on, so a peak of 3KW is observed at 10:00am which will be compensated by wind energy only. Then consumption decreases to 2KW at 12:00pm. The another peak of 5KW is observed as after 12:00pm every appliance becomes more active, now wind turbine energy cannot satisfy that requirement difference of 1KW, so now the GEN will fulfill the requirement till night.

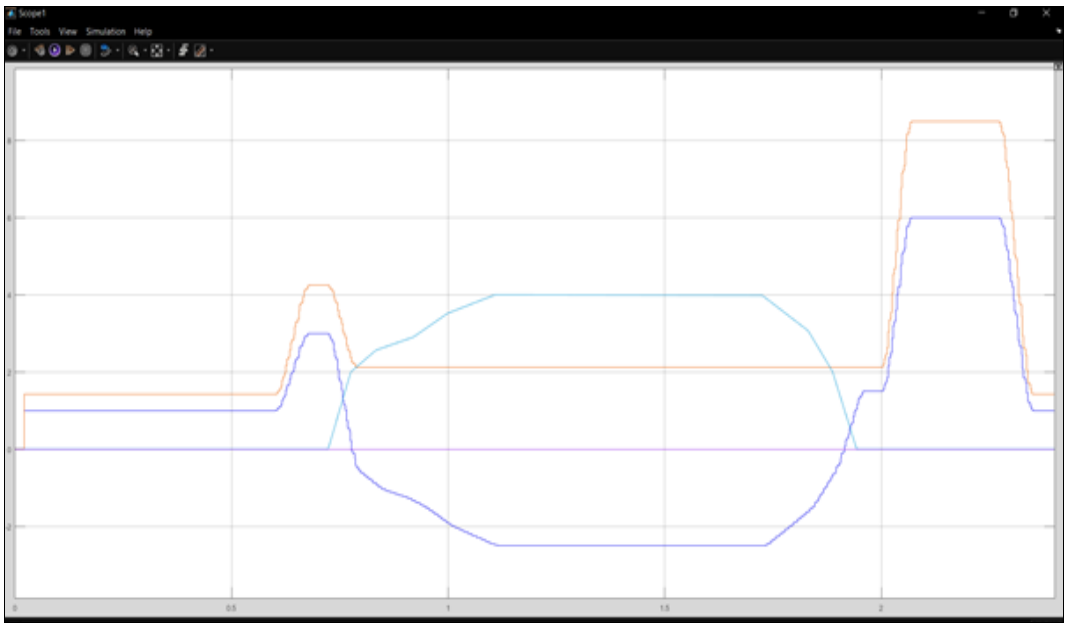

**Fig 9:** Power Utilization of House 2

The House 2 load curve bend is portrayed by accompanying appropriation: between 00h00 to 7h00 it devours a steady energy of 4KW given by solar. The primary consumption of house is 1KW that lasts for 5:00h. The peak of 2KW is observed for which solar intervenes to realize the requirement. The last hours when solar discharges and consumption increases to 6KW the GEN perform the necessary need till night.

Contrasting Houses, Industries are significant poles of production and consumption. The fig 10 shows 5MW of energy is supplied by wind turbine from 7:00 in the morning then workers starts entering the industry and switch on heavy machines, after the arrival load curve observe its 1st peak of 7MW which will be remunerated by GEN till 10:00. The load is reduced to 5MW as certain machines are shut down again turbine provides the requirements for the same from 10:00 to 1:00 in evening. The consumption of 6MW observed will be repaid by the GEN till the end.

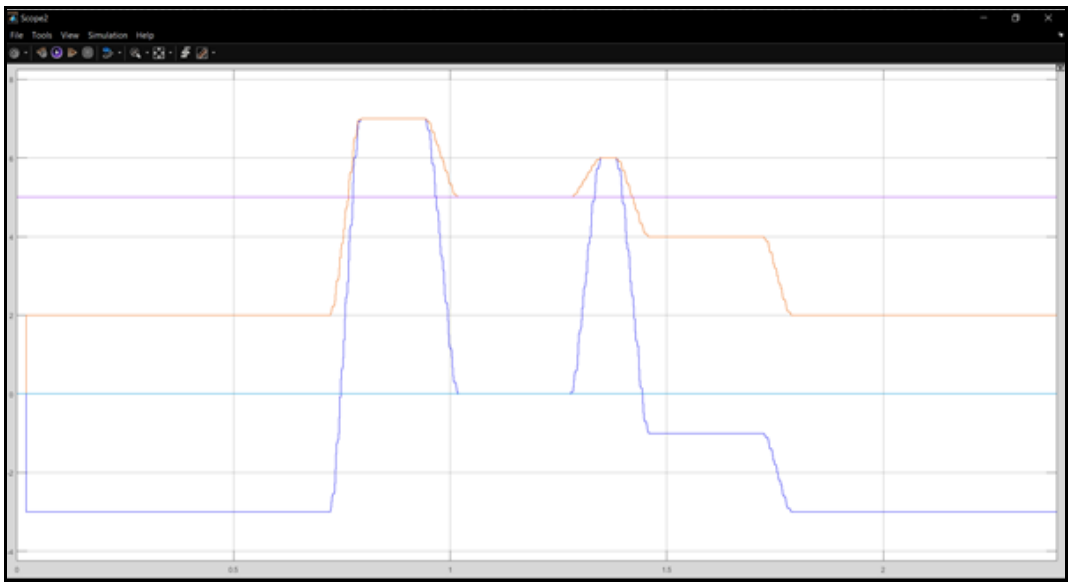

**Fig 10:** Power Utilization industry 1

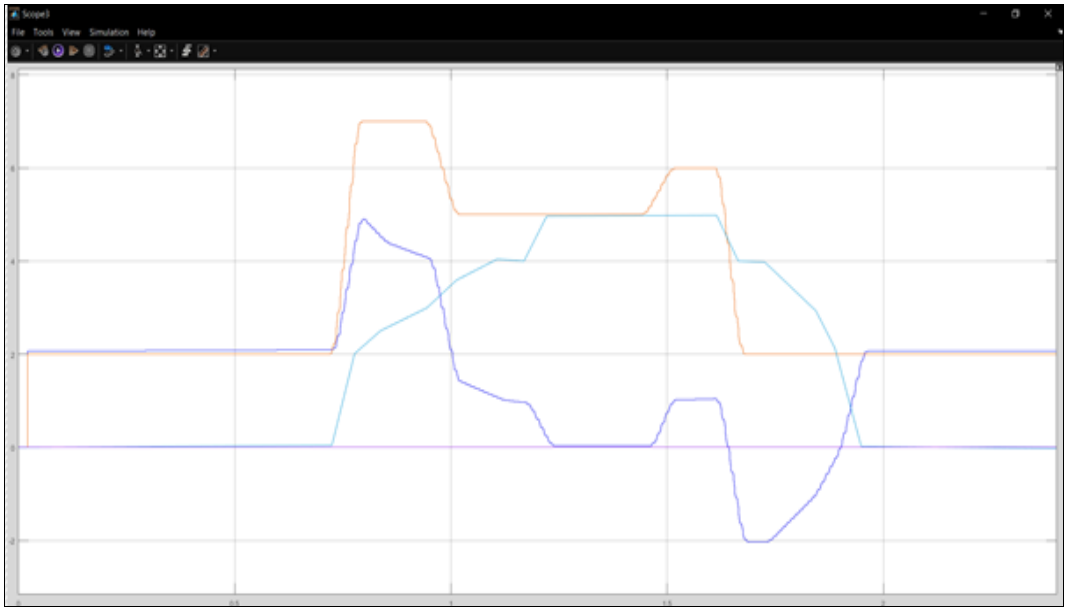

**Fig 11:** Power Utilization of industry 2

Industry 2 load curve, appeared through Figure 11, 5MW is associated with GEN that contains a solar park with a capacity, that's why this is powered by both energy origin. A power of 2MW given by GEN and start-up of machines of business and entry of laborers, a pinnacle of 7MW energy is observed and just GEN deals with it. A moment pinnacle of 6MW is seen at 15:00 and proceeds until at 5 pm, then At 8:00 am the place the energy of solar shows up as the consumption is 5MW reimbursed by solar itself. However solar energy alone cannot nourish plant. The second peak of 6MW compensated by solar as its providing curve of 7MW it is utilized till the end of day at 7:00, now the sun starts to set so the load again runs on GEN with the nightfall.

## Conclusion

This paper presents the Fuzzy control for smart grid integration using solar/wind energy conversion system. The effective performance of smart grid using fuzzy controller is achieved. The solar and wind energy is acting in typical working condition. The benefit of this framework is that the purchasers can take the energy at lower expensive rates. Adjustment in estimation of Active-Power with fluctuating loads like the household and the modern loads for the instances of House 1 and House 2 with industry 1 and Industry 2. The cutting-edge power grid, utilizes two-route stream of power and data by sing the smart metering frameworks utilized in the re-enactment and the essential circuit with controlling MPPT is incorporated inside the load circuits. The active power examination for solar, wind and grid frameworks is clearly visible in results. This tremendously increasing technology has given immense pleasure to everyone to lead a easy life with full access to cheaper power which is generated through renewable sources of energy.

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