Design of Intelligent Controller for Hybrid PV/ Wind Energy Based Smart Grid for Energy Management Applications

D Sarathkumar1*, M Srinivasan2, Albert Alexander Stonier3, Ravi Samikannu4 and D Vijay Anand5
1,2Assistant Professor (Senior Grade), Department of Electrical and Electronics Engineering, Kongu Engineering College, Erode district-638 060, Tamilnadu, India.
3Associate Professor, Department of Electrical and Electronics Engineering, Kongu Engineering College, Erode district-638 060, Tamilnadu, India.
4Associate Professor, Electrical Engineering, Botswana International University of Science and Technology, Palapye, Botswana
5Assistant Professor (Senior Grade), Department of Information Technology, Kongu Engineering College, Erode district-638 060, Tamilnadu, India.
Corresponding author e-mail address: dsarthkumaee@gmail.com

Abstract. This article deals in the modelling of intelligent controller for the Hybrid photovoltaic (PV)/Wind based smart grid system. With the development of solid state electronics also power systems intelligent techniques like neural networks, fuzzy logic, expert systems take part an essential contribution in design of controller for the smart grid. The above techniques give potential tools for design and development of fault detection controller in the advanced smart grid (SG). The intelligent techniques attained in rapid evolution during previous decades and their utilization now increased rapidly in current industrial environment. Renewable energy integration, participation of customers, performance optimization is important key features of digital grid power systems. In this article presents in new method of digital grid for hybrid photovoltaic/Wind based smart grid system were developed. It consists of solar PV array systems, wind power systems, asynchronous generator, converters, MPPT systems, fuzzy logic controllers (FLC). The model was performed through MATLAB/SIMULINK environment. The dynamic performance in presented model was tested in various operating conditions. Sunlight Irradiation, heat and rate of wind statistics was collected in a power grid combined solar PV model placed in main system. In this proposed simulation model also in supervision scheme give an appropriate tool for optimization of smart grid performance.

Keywords— Hybrid system, Photovoltaic (PV), renewable energy systems (RES), Smart grid, Wind energy system, Energy management, MATLAB/SIMULINK

1. Introduction
The traditional power resources like charcoal, petroleum, diesel, nuclear radiations are polluting in environment on day by day. It is prompt activity and very essential in identify best methods of producing substitute resources to match the supply and demand. Hence, a definite pathway is needed to balance the demand and supply. Smart grid integration of PV/Wind energy scheme was the preeminent solution to match the power demand and source of supply. Power systems structure it applies data transmission topology was identify also respond in localized variations in control was called intelligent power system. Smart grid gives an astute system it allows bidirectional connection.
among load and producing stations. This mechanization rescues the power, increased the system reliability also sustains security. In essential features in smart power grid network involves demand side management, optimization of grid, and smart meters along with distributed power production. This article deals combination of photovoltaic/Wind integration based smart grid fault diagnosis.

Over the previous decade many research is executed in the experts over the global in integration of smart grid to combination of power sources such as solar and wind. In paper [1], presents the combination of PV and wind system its operates Maximum power point tracking control supporting background of artificial neural network to drop out of maximal energy from PV and wind energy system. In paper [2]-[8], illustrated hybrid renewable sources in distant places and also conferred the benefits of diversified hybrid power system structure. In paper [9], examined PV-Wind combination of renewable source to regulate also enhance final voltage from supply to load also given in rest of power is saved through turn on actions of energy saving devices. In paper [9, 10], executed the problems related to power quality in hybrid solar photovoltaic-Wind power system was implemented by using adaptive fuzzy controller

In paper [11], issues related to economic dispatch of photovoltaic-wind electrical network was executed by using chaos particle swarm optimization (CPSO) algorithm. Along with above, extensive research performances have been performed on hybrid energy generation scheme. This paper [12], performed as solar PV model interconnected to power system was employing Power System Computer Aided Design software to analyze the electromagnetic transient analysis. In paper [16], presented the combination of photovoltaic–wind power scheme adopting simulink toolbox to analyze the performance investigation. In paper [17], given the simulation design of 15MW integrated solar network by applying PV system – Logiciel Photovoltaique programs. In paper [18]-[20], given the grid integration of solar and wind system by applying the simulink toolbox to analyze the Total Harmonic Distortion (THD). In paper [21], author suggested fixed supply Maximum power point tracking optimization approach to PV/wind scheme was employing the charging the battery charging controller. In paper [22], author developed solar photovoltaic grid-integration with isolating basis. In this principle conveys if any abnormal condition occurs the power grid was separated, the load was compensated through power generation also distribution systems. In paper [23], author recommended the appropriate energy flow regulator designed for electrical hybrid energy scheme involves solar, ultra capacitor and wind. In paper [24], author valuated collection of maximal energy through with particle swarm optimization based PV MPPT system supporting diverse category of variations in sunlight irradiation.

Hybrid grid integration of PV-Wind supply scheme was famous emerging research area in recent times. Wind power was economic model of sustainable power source and solar energy provides extra benefits, compare to remaining non-conventional energy resources and integration in wind and PV energy system gives reasonable pattern of energy production. Primary aim of the article was to draw highest energy and to sustain quality of power to an acceptable limit in fluctuating actions of solar PV with various irradiations and wind. An arrest maximal energy in solar power scheme, maximum power point tracking controller was used also this designed system gives enhanced performance and stability of power system. Control approach and performance in designed system was evaluated through simulink toolboxes.

2. Description and Methodology of proposed System

Methodology of the proposed system is to design of Intelligent Controller for Hybrid PV/ Wind energy based smart grid for Energy Management Applications. General system of presented hybrid non-conventional electrical supply structure was shown as Figure 1. In this scheme comprises as solar photovoltaic systems, wind electrical generation systems also the utility grid in more than one power resources. All the generation systems were coupled to a steady state power pool accomplished in necessary controllers. The alternate battery unit was coupled in solar photovoltaic system for the purpose of save the excessive produced sunlight power in all produced energy through solar photovoltaic was not supplied to the systems load.

Different types of utility systems was examined the proposed system also coupled with utility bus bar, as feed through typical steady state energy pond. Details gathered in supply and load was transmitted in a laptop to be assessed in choice producing action of energy regulation structure. Energy
management optimization was designed for handle solar PV also wind source as optimum power produce under several environmental circumstances whereas sustaining energy demand of distribution side in necessary level. Hence the energy control comprises high intensity detection of solar PV also wind source system, storage of energies, grid interconnection, switching of load. Moreover, distribution side problems like mitigation of harmonics, dipping of voltage, variations in voltage, oscillations of frequency, voltage amplitude was incorporated with in controlling scheme. In observable as numerous inputs quantities and variables in power control determination systems. The fuzzy logic controller determination design was designed also applied in several-input, numerous objective structures.

\[ \text{Figure 1 Energy Managements for Hybrid Renewable Energy System} \]

2.1. Modeling of proposed system

**Photo voltaic System:** PVES was formed utilizing the common equation in solar photovoltaic cell. In VI expression in solar photovoltaic cell was depending the electric current of a P-N junction solid state conductor. Electric current is an operation of solar radiation also varies in the solar light intensity. Voltage between junction terminals of P-N element changes in an operation of electric current. If the direction in between ends of positive-negative semiconductor, PVarray, and outer current runs over in these directions, the system varied using this load. In noticed as in cell voltage was raised, PV arrays was hooted leads to a reduced in voltage at terminal. Also, taking into account of abatement in voltage and opposite overload current of P-N semiconductor. The equivalent circuit of a solar cell is shown in Figure 2. From the equivalent circuit of solar cell the current produced by the solar cell is equal to that produced by the current source, minus that which flows through the diode, minus that which flows through the shunt resistor

\[ \text{Figure 2 The equivalent circuit of a solar cell} \]
\[ I = I_l - I_d - I_{sh} \]  

Where:
- \( I \) = output current (ampere)
- \( I_l \) = photo generated current (ampere)
- \( I_d \) = diode current (ampere)
- \( I_{sh} \) = shunt current (ampere).

The current through these elements is governed by the voltage across them:
\[ V_j = V + IR_S \]  

Where:
- \( V_j \) = voltage across both diode and resistor RSH (volt)
- \( V \) = voltage across the output terminals (volt)
- \( I \) = output current (ampere)
- \( R_S \) = series resistance (\( \Omega \)).

The total power produced from the solar cell is given in the following expression:
\[ \text{Power generated from the solar cell} = P = V \times I \]  

**Wind energy system:** Mechanical energy in the wind turbines transforms i.e. generated in the wind in to electricity power. To utilizing this power can able to control the frequency and current wherever required. In design of wind systems was evolved in basis of normal performance of wind generator. An induction generators computation is entirely in frame of direct-quarture axis.

2.2 **Modelling Topology for Proposed Hybrid Renewable Energy System**

MATLAB simulation for smart grid integration of solar photovoltaic and wind system was shown in this part. This system was comprises PV array, wind power systems, induction generator, step up chopper, integrated energy controller and load. Maximum power point tracking optimization was employed to obtain maximal energy from photovoltaic also wind energy. Representational diagram of proposed hybrid renewable energy system structure was shown as Figure 3.

![Figure 3 Modelling Topology for Hybrid Renewable Energy System](image-url)

3. **Modelling of Fuzzy Logic Controller (FLC) Based Intelligent Hybrid System**

Fuzzy logic system was chosen in the proposed simulation. It is easier algorithm technique and addition of many systems of output and input variables are feasible in future also. This offers best triggering depend in if-else conditions. Increased amount in membership function variables and the systems provides better output result.

The proposed method avail a learning tool depends on inference design that transforms variables input to an output resultant. Mamdani and Sugeno type employed for the proposed fuzzy system. The systems have a frequent procedure of inputs fuzzyfying and employing inference operators. Actual variations among these methods are generates the output; sugeno method produces constant or varying
the output and Mamdani method produces output variables [21, 22]. The price factor of micro grids is shown in equation 4.

Micro grids price factor = Savings (t) = Income (t) – Outgoing (t)  
(4)

Where t was indicates total unit of time steps of scheduled time period, actual energy production of microgrid is not acceptable the maximum demand of power or more costly in supply to output, power generation Pg (t) was purchased in micro grid.

Efficacy of fuzzy logic method was completely depends on chosen in input variables. Commonly the modelling of fuzzy comprises of variables inputs such as photovoltaic, wind energy also voltages of microgrid. PV and wind resources are considered due to power output variation because of atmosphere circumstances. Grid parameters changed based on types of loads interconnected to network. Digression configuration parameters from the rated systems were employed to opted for completing rules. In any case voltage factor must be uniform in the electrical network. Fuzzification operations of variables were transformed as variables.

This presented method the change in voltage parameters was applied for generating in membership operation. Variable criterions were utilized in inputs as arithmetic parameters into fuzzy operations. Usual statement of Mamdani based type was that voltages $V_w$, $V_s$ are maximum compared to $V_{mg}$ was probably 1. The operation rules were bring out of in the fixed parameters through defuzzification operations transforms of fuzzy levels was add-on accurate crispy generation rate.

3.1. PV and wind based system simulation design

This part of basic idea beyond in numerous-agent smart controller system was executed to exhibit in the projected method assist data transmission, effectual regulation also supervising of electrical system. PV, wind based simulation system was executed as 1 & 2 system was interconnected with microgrid. Fuzzy logic controller were designed for network 4, transmission among the network was simulated through TCP/IP standards.
3.2. Operation of the proposed circuit simulation

PV power production systems comprises of photovoltaic array of 36 cells. Simulation in proposed method was executed in the test bed system modelled through simulink tool box. In course of additional energy production of batteries was employed for keep in energy of PV plant. Internet protocol activated protective breaker was employed for coupling of photovoltaic energy to the grid. Figure 5 exhibits of PV plant simulation design. Maintaining of stable electrical systems, generator was connected in series of capacitor circuits banks. Self supported wind energy production approach was applied this circuit design. Additional meters were employed for compute voltage, electric current and several other parameters. Design of the wind energy system was indicated in Figure 7. Parameters appeared in transforming of output from PV, wind, micro grid were connected in fuzzy logic controller. This controller produces parameters output of stable between the range of 1 and 5. Fuzzy logic controller was interconnected in internet protocol based protective breakers to regulate arrival and discharge of power through microgrid. Condition of the circuit breaker varied based on the formation of fuzzy rules.
The MATLAB design of PV, wind electrical model was indicated as Figure 5 and 7. Figure 5 was employed to make photovoltaic design and Figure 7 was employed in wind design. Output power in connection with wave forms of PV was indicated as Figure 8. System 4 and 6 was employed in fuzzy logic controller design along the functions. Controller output to control protective circuit breakers. Control variables were transformed through excels sheets via fuzzy logic algorithm. The excel sheets values was send to the database systems applying MATLAB algorithm also interfaced in notepad prior to simulates in software. Controller determines on the decision depends on system parameters obtained as input variables. Output steady parameters in the controller were employed for control in protection breakers interconnecting PV with wind electrical system in powergrid. Circuit breakers were enabled via input triggering. Fuzzy controller was managed in energy control center instructions. Energy control center responsible for supervising and regulating amplitude of wind, PV generation was uniform interval also determines PV, wind power into power grid as cost evaluation via transmission of data applying structure of TCP/IP.

4. Discussion of Results

Investigation of outputs obtained in design of PV, wind energy systems applying simulink tools are shown in waveforms as figures 9, 10. When wind unit, velocity of wind was considered as constant. Outputs obtained this simulation was saved in command box and transformed into excel file applying MATLAB program command. Fuzzy logic controller obtains the input waveforms, generates outputs, this output parameters depends on MATLAB command created this topology. Depend on parameters of output, condition of protective breakers 1 and 2 was altered. Demand response-depend on load estimation method was used to determine power demand of micro grid context through evaluating the grid and distributed power sources.

The excel data sheet was given Figure 8 indicates parameters saved should indicated in playing a supervising drive to analysis the simulation outputs also it provides grid visualization. In this task executed in present interval cost system enhances consumer benefits, decreases demand of peak power also increases the efficiency of system.

Tabulation 1 represents real time tariff rates for Industrial HT Consumer of customer depend on peak duration interval and tariffs is applicable of the tamilnadu state in India. Output results are executed in long interval of maximal durations. This provides best behaviour in demand part control due to the more loads should be deviated as enhanced. Energy generation of non-conventional power sources is determined depend on speed of wind and photo voltaic radiation forecasted consider in MNRE website portal. Tabulation 2 indicates hourly predicting energy production in non-conventional resources. Tabulation 3 indicates controllable components of HT side customers also operation time is minimizes cost of customer to carry out the method.
The Indian state of TamilNadu the HT side customers the per unit charges of power was Rs 5.75. Consumer gets profited after implementing of this tariff system. Figure 11 represents daily based energy demand curve later consideration of proposed approaches; power demands were approximately sustained as stable. Best efficiency, minimizing of pollution of CO2 and minimizing the customer charges was achieved through applying this approach.

**Tabulation 1** Charge Applicable for State of Tamil Nadu

| Time Period     | Tariff for Industrial HT Consumer | Charges Applicable          |
|-----------------|-----------------------------------|-----------------------------|
| Peak Period     | 05 AM-08 AM 05 PM-08 PM            | + 25% on the total energy charges |
| Off-peak Period | 09 PM-04 AM                          | - 10% of total energy charges |

**Tabulation 2** Hourly Forecasted PV and wind power production in Renewable Energy Sources

| Time period in Hours | Wind Energy Generation | Solar Energy Generation | Time period in Hours | Wind Energy Generation | Solar Energy Generation |
|----------------------|------------------------|-------------------------|----------------------|------------------------|-------------------------|
| 1                    | 0.0980                 | 0                       | 13                   | 0.0986                 | 0.8500                  |
| 2                    | 0.1365                 | 0                       | 14                   | 0.0526                 | 0.8448                  |
| 3                    | 0.2559                 | 0                       | 15                   | 0.0162                 | 0.6879                  |
| 4                    | 0.1928                 | 0.0024                  | 16                   | 0.0153                 | 0.5832                  |
| 5                    | 0.3880                 | 0.0838                  | 17                   | 0                      | 0.3547                  |
| 6                    | 0.6522                 | 0.2263                  | 18                   | 0.0052                 | 0.3124                  |
| 7                    | 0.9936                 | 0.3647                  | 19                   | 0                      | 0.2526                  |
| 8                    | 0.6472                 | 0.5666                  | 20                   | 0                      | 0.0780                  |
| 9                    | 0.5650                 | 0.6058                  | 21                   | 0.0164                 | 0.0525                  |
| 10                   | 0.4821                 | 0.7980                  | 22                   | 0.0120                 | 0.0234                  |
| 11                   | 0.2874                 | 0.8131                  | 23                   | 0.0160                 | 0.01067                 |
| 12                   | 0.1628                 | 0.8969                  | 24                   | 0.0544                 | 0.0025                  |

**Tabulation 3** Statistical analysis of controllable gadgets of High Tension side users

| Device Type         | Hourly utilization of the gadget |
|---------------------|----------------------------------|
| Electric Water Heater| 14.5 13.5 12.5 11.5 0 0         |
| Lathe Machine       | 28 27 27 27 27 0                 |
| Fan                 | 32 33 33 33 33 0                 |
| Induction Motor     | 125 120 120 120 120 120          |
5. Conclusion
The articles, solar photovoltaic/wind hybrid electrical system was modelled, simulated in smart power grid. This design have been executed through the MATLAB and implemented in a simulink blocks employed MATLAB tool libraries. Generation of energy from solar photovoltaic was mainly based in sunlight intensity. Conquer these drawbacks of solar photovoltaic systems, interconnected in a wind energy system. Transient characteristics of presented system are checked under various operating circumstances. Solar irradiation, wind density statistics and temperature was designed in a 36.6kW integrated PV, the designed system and its control scheme gives best behaviour of this design for an entire day. This presented method gives best techniques for energy management and detection of faults in smart grid.

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