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INTELLIGENT CONTROL OF SOLAR MICRO-GRID WITH ENERGY STORAGE SYSTEMS

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Abstract:

With the population growth, depletion of fossil fuels and evolution of electrical Vehicles, the demand for the electrical energy by using renewable energy resources have been increased. Here the solar renewable energy is used. A solar based microgrid can be operated in standalone mode or can be connected to main grid using Point of Common Coupling (PCC). Synchronisation and power quality becomes main concern when connected to main grid. Here Intelligent control techniques are proposed for the efficient operation of solar based Microgrid. Maximum Power Point Tracking (MPPT) technique is used to obtain the maximum power from PV array due to solar irradiation problem. Generally, Perturb and Observation (P&O) Technique is used but by using this MPPT technique the power at maximum power point has more oscillations. To overcome the above problem Particle Swarm Optimisation (PSO) technique is proposed for maximum power tracking. By using this PSO based MPPT the oscillations at MPP are reduced. To obtain the efficient operation of microgrid different controllers are used in PQ control mode. Generally, PI controller is used but the voltages and frequencies of inverter and grid are getting unbalanced. So, to maintain the balance between grid and inverter voltages and frequencies, Adaptive Neuro Interface System (ANFIS) controller is proposed. Also, the energy storage system is used along with solar system as the solar energy is not available all the day. This model is simulated in Simulink / MATLAB.

keywords: Solar based Microgrid, Particle Swarm Optimisation (PSO) MPPT technique, Adaptive Neuro interface System (ANFIS) controller, energy storage system.

1. Introduction

With the depletion of fossil fuels and to reduce the environmental pollution, the electrical power generation using the renewable energy sources have been increased [1]. Among all renewable energy resources solar energy and wind energy-based power generations gained more popularity due to easily available in nature. Generally power generation using renewable energy resources are referred as Microgrid [2]. These microgrids can be operated in isolated or grid connected mode. Due to the variation in solar Irradiation the power output from PV System is also varied. So, to obtain the maximum power from the PV system Maximum Power Point Tracking (MPPT) technique is used. So many researches have been worked on Maximum Power Point Tracking system among them Salman, Xin Ali and Zhouyang mu [3]

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performed Perturb and Observation (P&O) method. Srushti R. Chafle , Uttam B. Vaidya [4]performed Incremental Conductance (IC) MPPT technique.

For the power flow balancing in the solar based microgrid PQ control mode is used. Adhikari and Li [7] have performed coordinated V-f and P-Q control of solar based microgrid using PI Controller. Saiedi et al. [8] have designed PQ control of solar based microgrid with self-tuning of controller using PSO. Taoufik laagoubi, Mustafa Bouzi, Mohamed Benchagra [9] have proposed fuzzy logic controller of grid connected pv systems.

By using Perturb and Observation (P&O) and Incremental Conductance (IC) MPPT techniques the output voltage from the PV array output power has oscillations around the MPP. There is complexity of implementing Incremental Conductance method (IC), to overcome these problems here the MPPT based on optimisation technique is proposed that is Particle Swarm Optimisation (PSO) technique.

Due to the intermittent nature of solar energy and by using manual tuning controllers at grid side poses a problem in stable microgrid operation and produce severe frequency deviations and eventually leads to loss of synchronisation [5]. To avoid this problem Auto tuning of controller is proposed with the combination of two intelligent techniques that is Fuzzy Logic (FLC)and Artificial Neural Network (ANN) known as Adaptive Neuro Interface System (ANFIS) controller is proposed.

2. Proposed method

PV arrays designed by manufactures are operated for low output voltages and the maximum output power is obtained at Standard Temperature Conditions (STC) i.e at temperature of 25^{o} C and solar irradiation of 1000W/m^{2}. But due to the variation in solar irradiation the output power of pv array varies continuously and the output voltage obtained is low, which is not sufficient to supply the load. So, DC-DC converter is connected at the output of solar pv panel to boost-up the voltage and is controlled by gating signal obtained from MPPT [6].

In general, Perturb and Observation (P&O) MPPT is used to control gate signal of boost converter along with PI controller and battery storage system to balance any mismatch in generation and supply to load and it is shown in fig.1

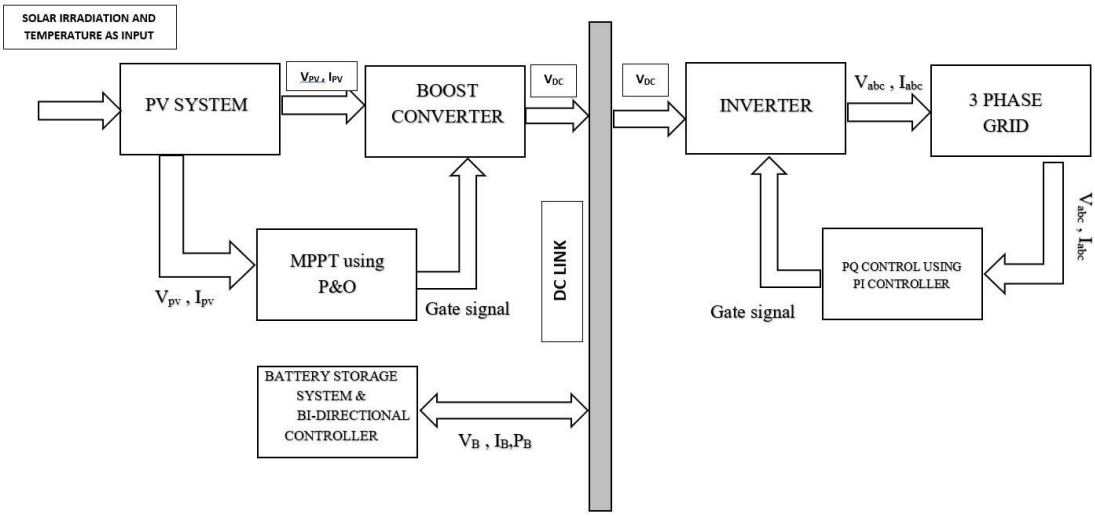

Fig.1 Block diagram of microgrid with P&O MPPT and PI controller at grid side

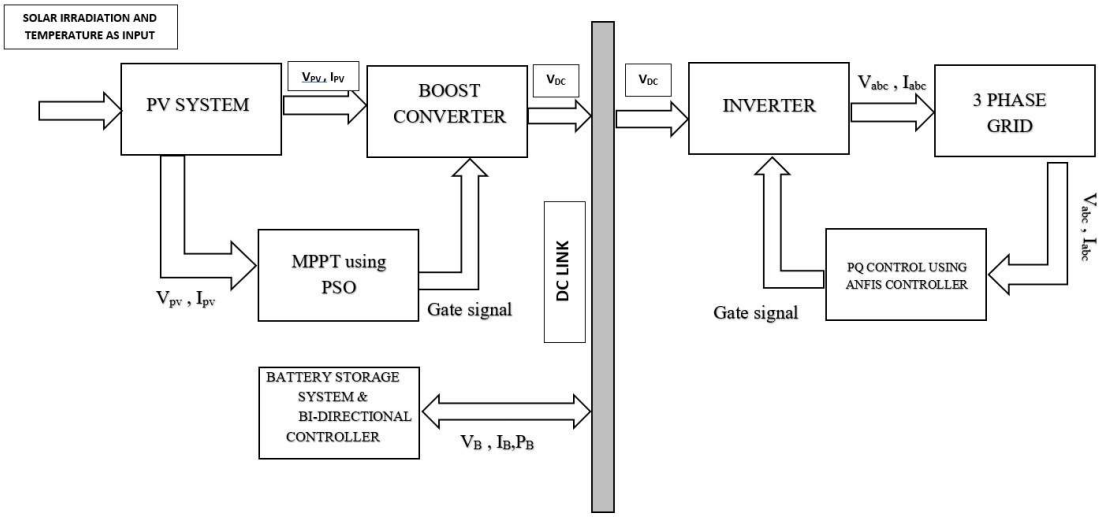

Fig.2 Block diagram of microgrid with PSO MPPT and ANFIS controller at grid side

In this proposed work, to obtain better gating signal, the P&O MPPT is replaced Particle Swarm Optimisation MPPT technique is used to control gate signal and ANFIS controller is used and shown in fig.2

To maintain the synchronisation of grid frequency and voltages with inverter frequency and voltages PQ control mode of grid is used [10]. Generally, in PQ control mode at grid, PI controller is used to maintain the balance between grid and inverter. But due to the intermittent availability of solar energy, variable loads, the manual tuning problem of PI controller causes the unbalance between the grid and inverter voltages and frequencies. So, in the place of conventional PI controller Adaptive Neuro Interface System (ANFIS) controller is proposed in the system. According to the variation of frequency and voltage at grid, the auto tuning controller tunes the parameters by using Adaptive Neuro Interface System (ANFIS).

To obtain the desired output power, the solar cells are connected in series and parallel combination [11-12]. In this work the irradiation is varied from 100 to 1200W/m^2 and temperature of 25^o C. the parameter vales considered for PV array are tabulated in Table1.

Table1: Parameters of PV panel

Parameters of PV Array	**value**
Number of cells per module	60
Open circuit voltage of the module	36.3 V
Short-circuit current of the module	7.84 A
MPP Voltage of the module	29 V
MPP Current of the module	7.35 A
Number of parallel strings (N_{pvst})	2
Number of series strings (N_{pvs})	28
Phase to phase voltage (RMS) of grid	230 v
Grid frequency	50 Hz
Grid configuration	Y-g
Phase angle of phase A	0 degrees
Phase to phase base voltage (RMS)	380 V
X/R ratio of the grid model	7

3. Methodology

3.1 Particle Swarm Optimisation (PSO) based MPPT technique

The major drawback of the Perturb and Observation (P&O) Mppt technique is presence of more oscillations in the output around the Maximum Power Point, this is due to increment or decrement of constant duty cycle value irrespective of the voltage error value that is difference between PV array output voltage and reference voltage, thus operating voltage of PV system is varied only at some particular time instants. This leads to the slow convergence of MPP and oscillations around MPP point. To avoid this problem in conventional P&O MPPT it is going to replace with PSO based MPPT optimisation technique.

In PSO based MPPT it contains search space with N particles each providing the optimal solution to the MPPT problem [13]. Here the particles refer to the duty cycle of power converter. The fitness value refers to the error value of PV array output power and represented in Eqn. (1). The best particle of each individual group is denoted as P_{best} and best Particle among the whole populations is denoted as g_{best}. The duty cycle associated with g_{best} is given to the boost converter.

$$\text{Fitness value} = P_{pv\ new} - P_{pv\ old} \quad \ldots\ldots(1)$$

The steps involved in measuring power using PSO based MPPT is given in flow chart of fig.3

$$\text{Convergence criteria } P_{best} = g_{best} \ldots.(2)$$

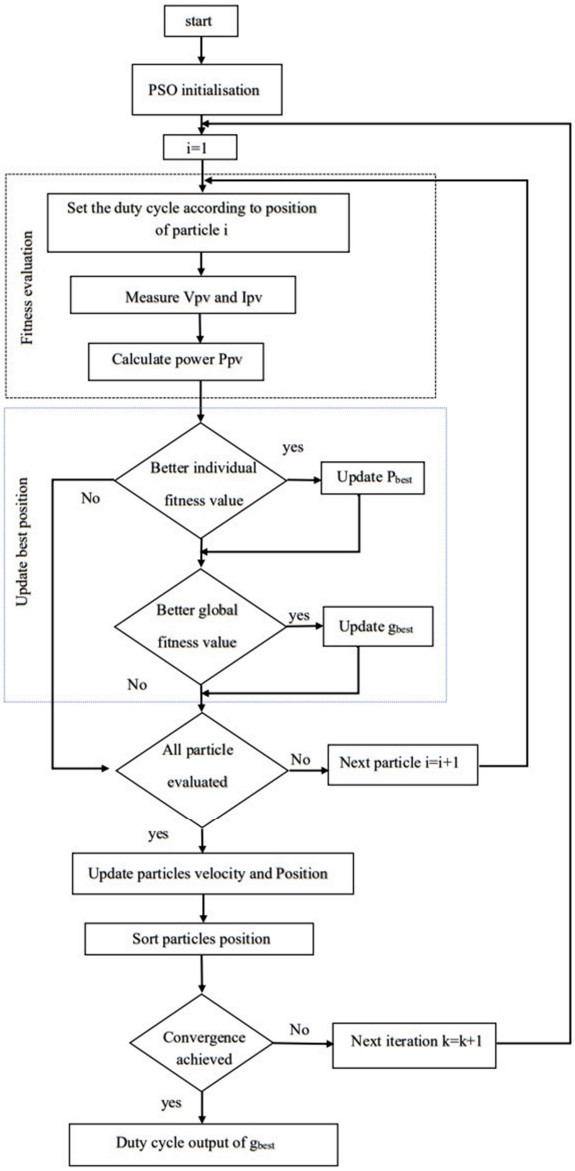

Fig3. flow chart for PSO MPPT technique

3.2 Adaptive Neuro Fuzzy Interface System (ANFIS) Controller

By using the PI controller in PQ control mode at grid side converter, the voltages and frequency are getting unbalanced. Error is calculated between the grid and inverter voltages. This is due to the manual tuning problem, error obtained is not precise, the gains of the PI controller are need to change manually according to error produced. But in ANFIS controller, there will be set of rules for finding the accurate error then according to error the control signal is given and obtains the required grid voltage and frequency [14]. So, here it is replaced with Adaptive Neuro Fuzzy Interface System (ANFIS) controller. The flow chart for ANFIS controller is shown in fig.4.

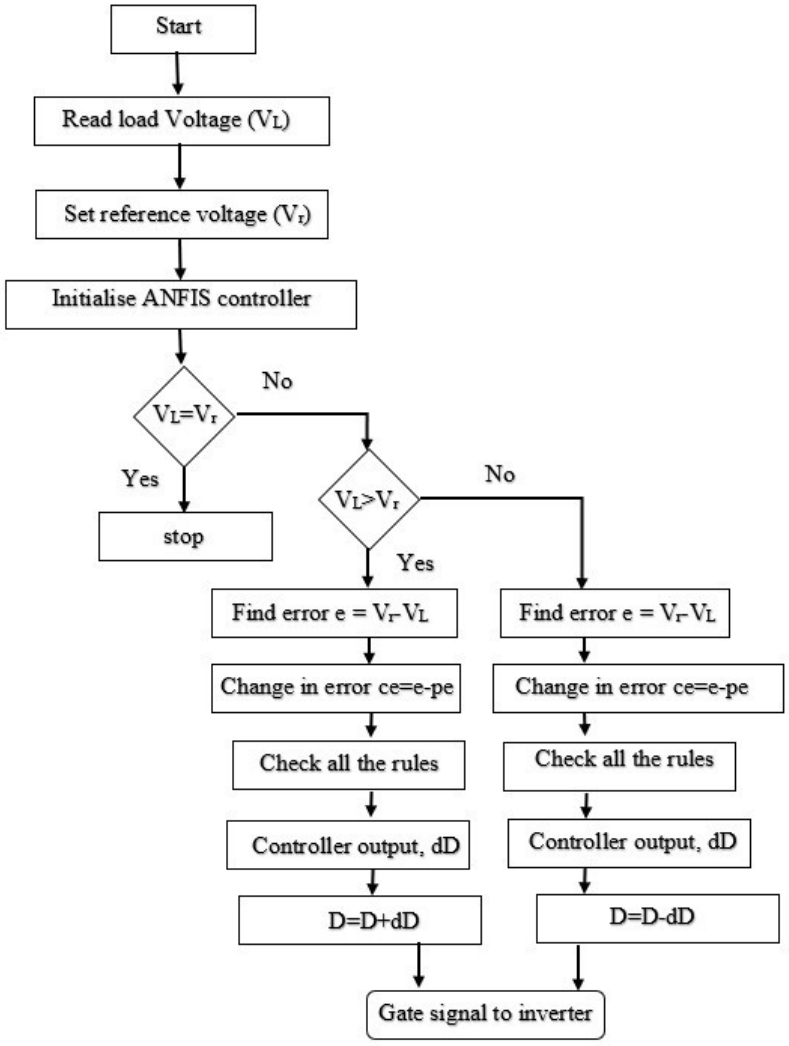

Fig. 4. Flow chart for ANFIS controller

voltage from grid is measured and the compares with the inverter reference voltage. If both reference and grid voltages are equal there is no change made for duty cycle of inverter. But when both reference and load voltages are not equal then it goes for calculating the error and gives accurate gate signal using ANFIS controller. The block diagram of ANFIS controller is shown below in fig.5. The two inputs to the ANFIS controller is error, change in error and the output is control gate signal for the system. The two inputs are crisp values and converted into triangular membership values ranging from [NB,NS,Z,PS,PB] by fuzzification and the inputs undergoes through fuzzy rules according to that output membership function is produced. The output membership function is converted in to the crisp value by the Deffuzication. All the fuzzy rules are framed in a FLC system which output is tuned automatically by using artificial neural networks methods that is least square recursive method

and back propagation algorithm. The output obtained by ANFIS is the control gate signal. The architecture of ANFIS controller is shown in fig.6.

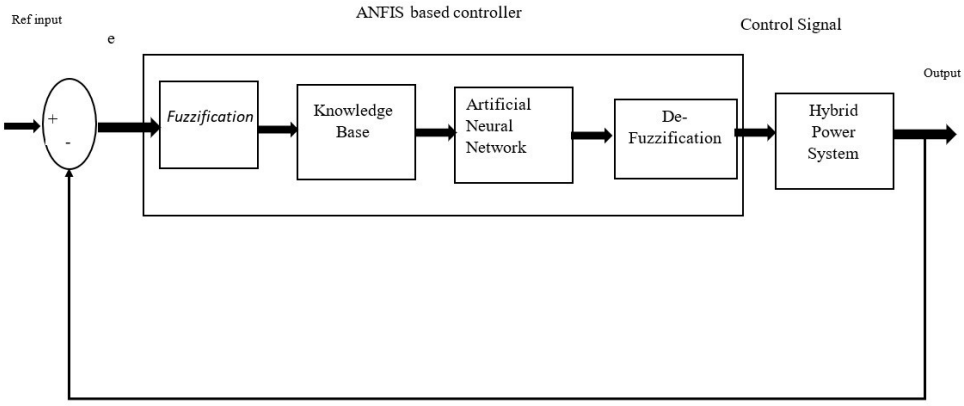

Fig.5: Block diagram of ANFIS controller

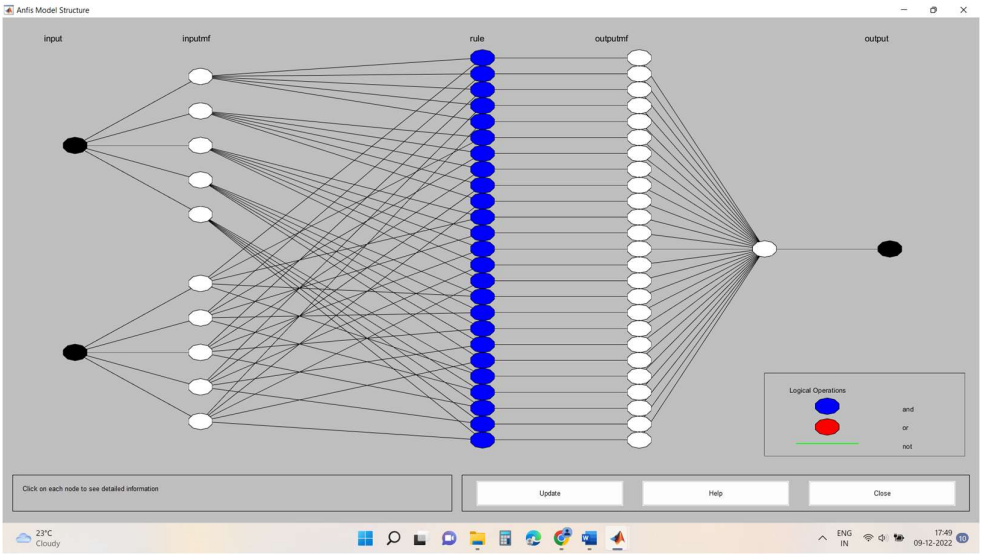

Fig.6: Architecture of ANFIS

The control gate signal from ANFIS controller given to the Inverter gate. Thus, the voltages and frequencies of grid and inverter comes under synchronisation.

4. Simulation block diagram and results

The simulation of Intelligent control of solar micro-grid with energy storage system with PSO based MPPT technique at PV system and ANFIS controller at grid side converter has been simulated in MATLAB. The Simulink diagram of solar microgrid is shown in fig.7.

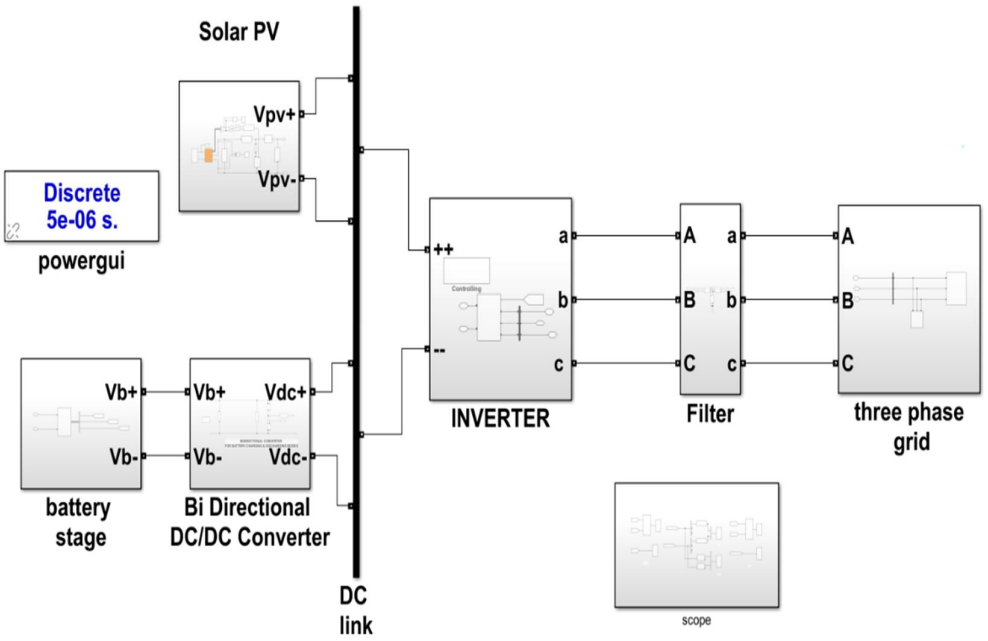

Fig.7: Simulink diagram for solar microgrid

To analyse P&O and PSO based MPPT, the solar irradiation input is varied from 100-1200W/m^2 and is shown in fig.8.

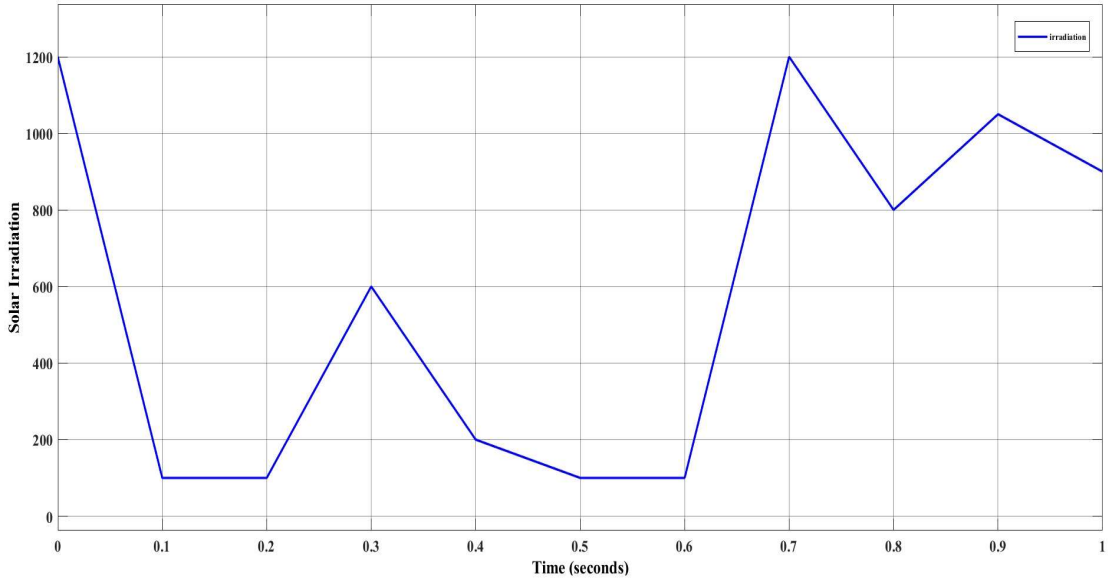

Fig.8: Solar irradiation of pv array 100 W/m2 to 1200 W/m2.

Case1 :P&O MPPT with PI controller at grid side

With the application of P&O MPPT and with PI controller at grid side for solar microgrid, the results obtained are shown in fig.9,10,11.

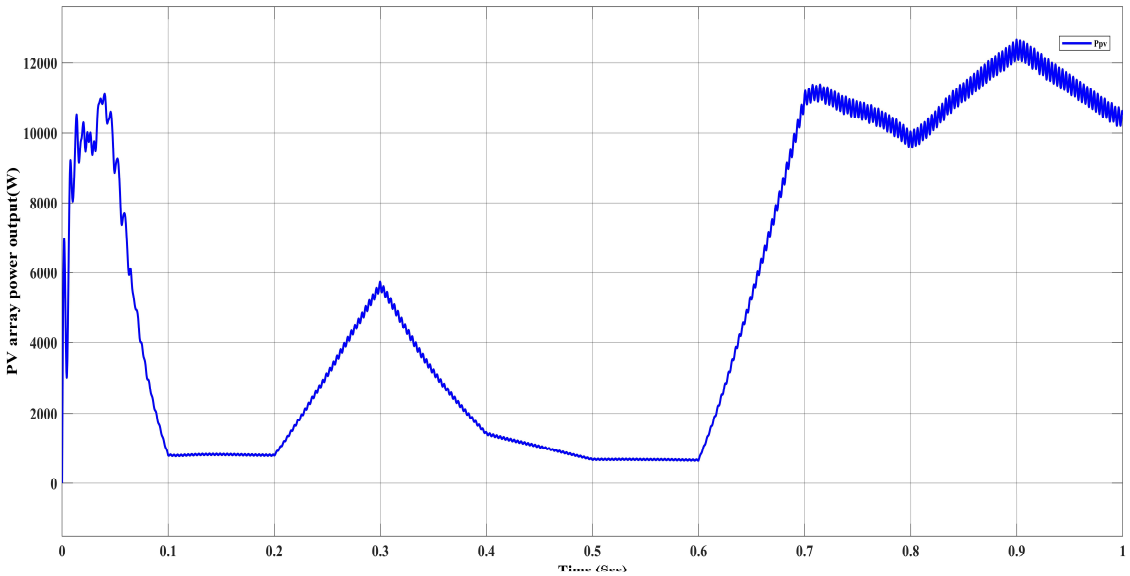

Fig.9: PV Array output power (KW) corresponding to solar irradiation for P&O MPPT technique.

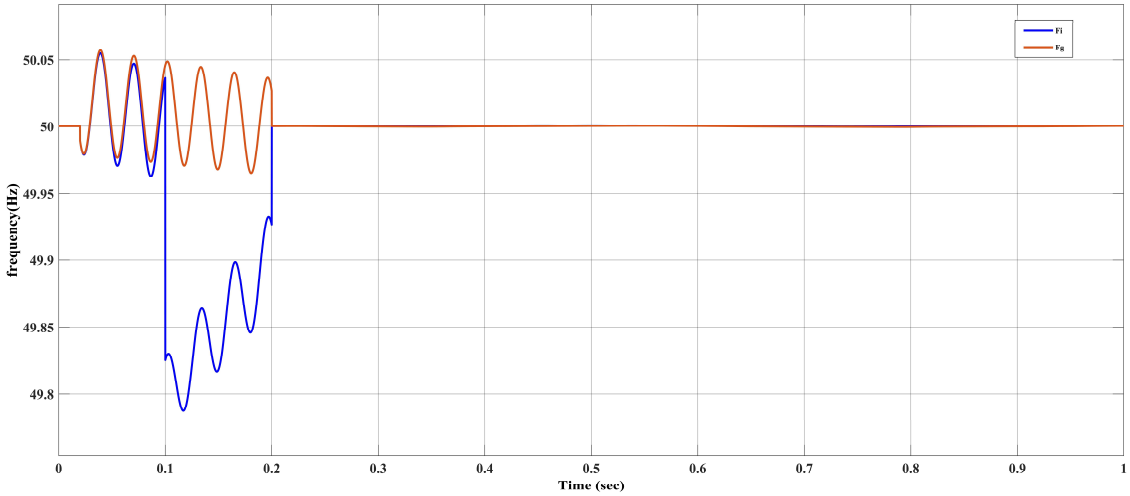

Fig.10: frequency of grid and inverter for PI controller

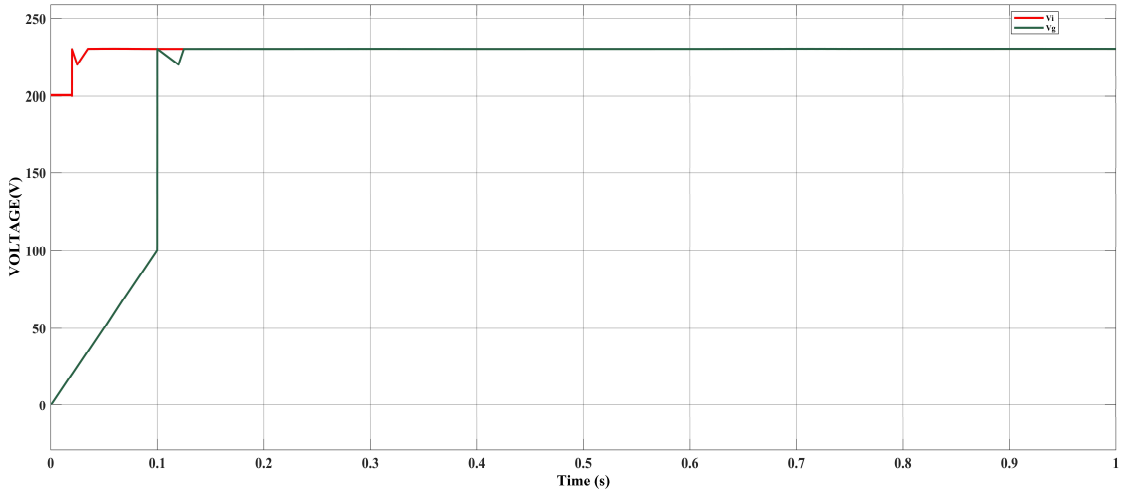

Fig.11: Voltages of grid and inverter for PI controller

From fig.9 it is observed that output power is initially having more oscillations and magnitude of 9600W for input solar irradiation 1000W/m^2 and power generated is varied from 800W to 12300W with more distortions in output power,

From fig.10 it is shown that grid frequency is initiated at 50Hz then varies from 50.06 to 49.96 Hz and stabilises at 50Hz at 0.2 sec and the inverter frequency is initiated at 50Hz then varies from 50.06 to 49.78 Hz at stabilises to 50Hz at 0.2 sec.

From fig. 11 it is observed that the inverter and grid voltage contain ripples at 0.02 sec. and 0.12 sec respectively with voltage deviation upto 220V and stabilises at 0.125 sec with voltage of 230V.

To analyse the performance of solar microgrid the irradiation value is considered is 1000W/m2 and the grid rated frequency is considered as 50Hz and rated voltage as 230V.

The summarised results for P&O MPPT with PI controller at grid side is tabulated in table 2

Table 2: Performance analysis for P&O MPPT with PI controller at grid side

Parameters	Irradiation (W/m^2)	Power (W)	Frequency (Hz)		Voltage (V)	
			Deviation value	Steady state (sec)	Deviation value	Steady state (sec)
Grid	-	-	50.06 to 49.96	0.2	220	0.125
Inverter	-	-	50.06 to 49.76	0.2	220	0.04
PV array	1000	9600	-	-	-	-

Case2: PSO based MPPT with ANFIS controller at grid side

With the application of PSO based MPPT and with ANFIS controller at grid side for the solar microgrid, the results obtained are shown in fig. 12,13,14.

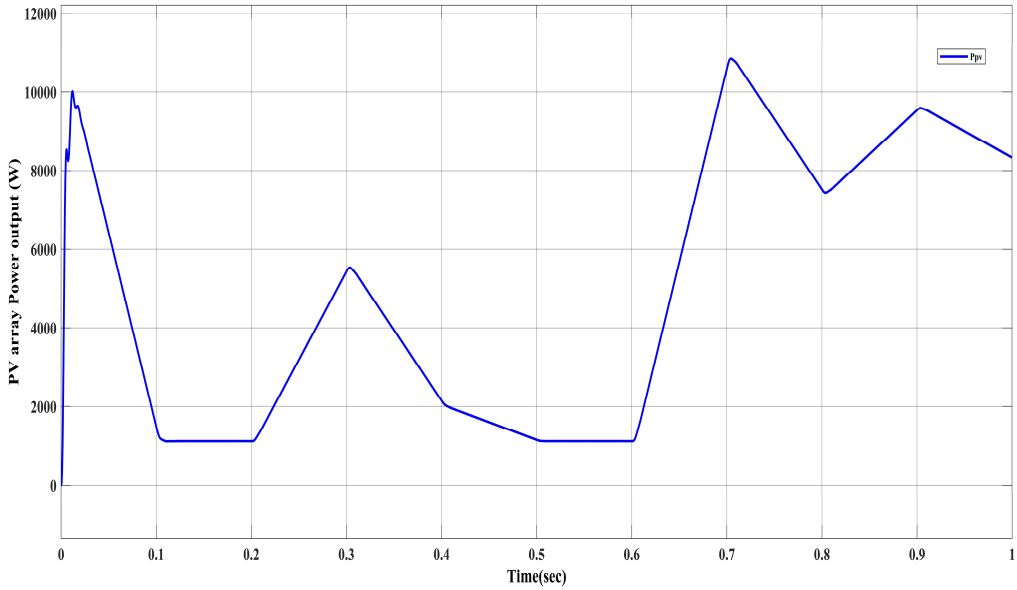

Fig.12: PV Array output power (KW) corresponding to solar irradiation for PSO mppt technique.

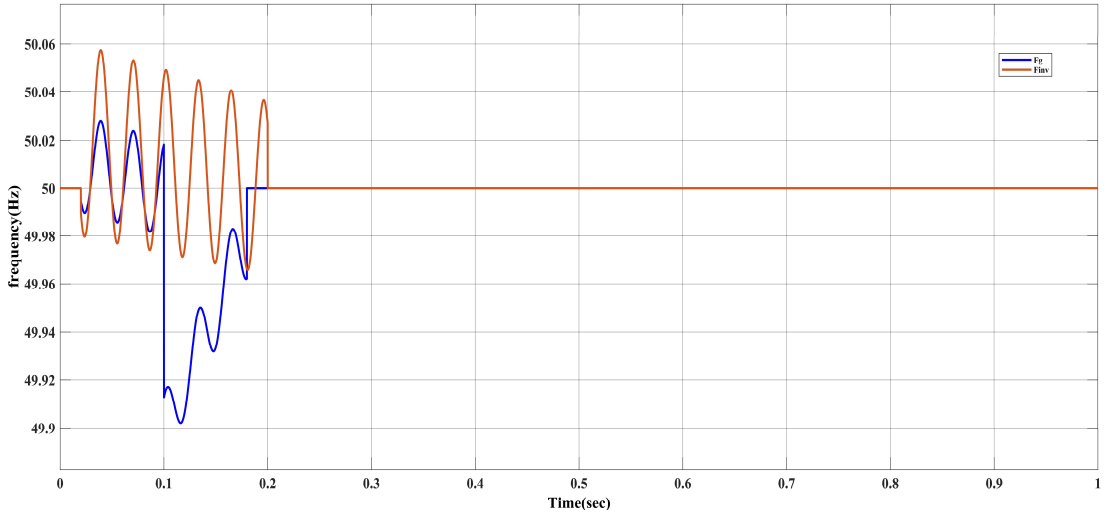

Fig13: frequency of grid and inverter for ANFIS controller

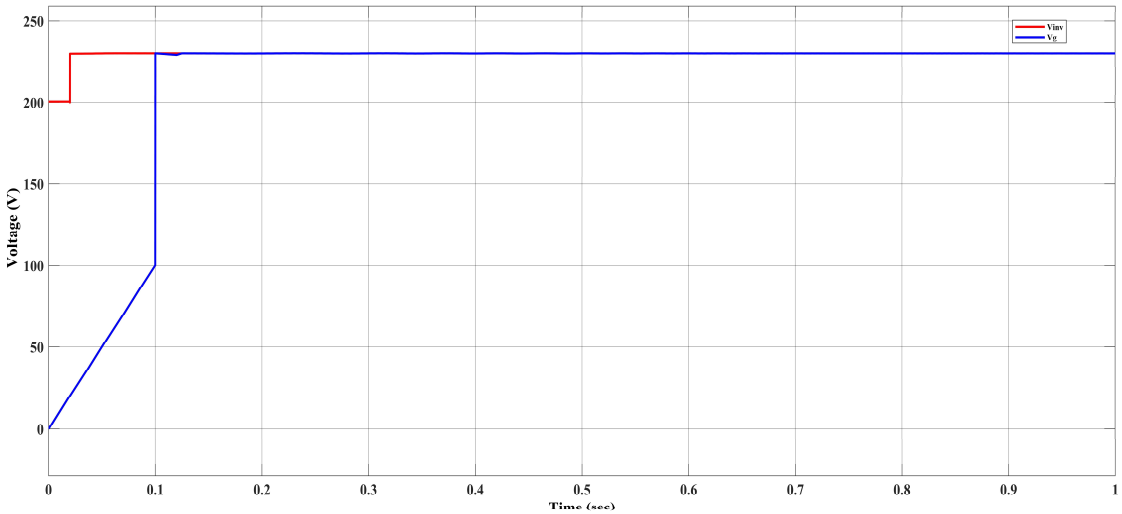

Fig 14: Voltages of grid and inverter for ANFIS controller

From fig.12 it is observed that output power is initially having less oscillations at initial stage of waveform for input solar irradiation 1000W/m2 and power generated is vary from 1200W/m^2 to 10800W/m^2

From fig.13 it is shown that grid frequency is initiated at 50Hz and varying from 50.06 to 49.97 Hz and stabilises at 50Hz at 0.2 sec and the inverter frequency is initiated at 50Hz, varying from 50.02 to 49.9 Hz at stabilises to 50Hz at 0.18 sec.

From fig. 14 it is observed that the inverter ripples are eliminated and grid voltages are reduced to 228V and stabilises at 0.1sec with voltage of 230V. The summarised results for PSO based MPPT with ANFIS controller at grid side is tabulated in Table 3.

To analyse the performance of solar microgrid the irradiation value is considered is 1000W/m2 and the grid rated frequency is considered as 50Hz and rated voltage as 230V.

Table 3: Performance analysis for PSO MPPT with ANFIS controller at grid side

Parameters	Irradiation (W/m^2)	Power (W)	Frequency (Hz)		Voltage (V)	
			Deviation value	Steady state (sec)	Deviation value	Steady state (sec)
Grid	-	-	50.05 to 49.97	0.2	230	0.125
Inverter	-	-	50.02 to 49.9	0.18	228	0.02
PV array	1000	10000	-	-	-	-

The summarised results for solar microgrid tabulated in table 4.

Table 4: Comparison of Conventional and Intelligent control techniques.

Parameters		PV array	Frequency (Hz)	Voltage (V)

	Irradiation (W/m^2)	Power (W)	Deviation value	Steady state (sec)	Deviation value	Steady state (sec)
P&O with PI controller	1000	9600	50.06 to 49.76	0.2	220	0.125
P&O with PI controller	1000	10000	50.02 to 49.9	0.18	228	0.1

5. CONCLUSION

In this work the Intelligent control of solar based microgrid with energy storage systems is presented and is analysed for different MPPT techniques and controllers. Due to the solar irradiance MPPT techniques are used to obtain maximum power from PV array. Generally, Perturb and Observation (P&O) MPPT technique is used but it produces the oscillations around maximum power point. So, these problems are eliminated by using the Particle Swarm Optimisation (PSO) based MPPT technique. Due to intermittent nature of solar energy and variable load effects the microgrid operation. At grid side, inverter control by using PI controller the voltages of inverter and grid contains the ripples and the frequencies of inverter and grid gets deviated from synchronisation. These synchronisation problems are eliminated by using the ANFIS controller in place of PI controller and at the microgrid the ripples in voltages are eliminated and the frequency is maintained constant. From this study it is concluded that by using Intelligent control techniques (PSO and ANFIS techniques), microgrid operation is efficient rather than the conventional methods (P&O and PI controller techniques).

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