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Hardware Implementation of PV and Synchronous Generator based Micro Grid with Power Quality Controller

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ABSTRACT: Non-conventional - Solar Energy, sources are very important and have become an integral part of our power system, once energy is generated from such a source proper work needs to be done in grid synchronization. The System Presented here consists of solar panel, DC-DC boost converter which is boosting the input voltage, voltage source inverter and PCC (Point of common coupling). The solar panel is the primary source and synchronous generator acts as a backup source. The demand is fulfilled through the primary source. If the primary source is not able to provide adequate power to system. Then the controller robotically shifts the whole load to synchronous generator. If the system has excess power then the power is robotically transfer to utility grid, the shifting from one source to another source and providing excess power to the utility grid is automatically done through the controller. Here the synchronization between two different sources and controlling technique is attempted in micro-grid. PV and synchronous generator based Micro-grid with power quality controller to supply balanced power for nonlinear load by reconnecting utility grid has been proposed here. Because of the effective controlling strategy, the system is running without any interruption.

Keywords: Controller, Energy, PCC, PV Micro Grid, Synchronous generator,

Abbreviations: ADC, CT, PCC, PQ, PV.

I. INTRODUCTION

Renewable energy is energy from sources that are naturally replenishing but flow-limited, provision of another provider is enforced. It could be synchronous generator, utility grid which is with assurance provider. Synchronization between different sources is very difficult task. To establish an efficient energy management strategy, a central controller takes the decision based on the status of the loads and sources. Effective controlling strategy is required for the synchronization. Renewable energy sources like wind, solar, biomass etc. are used for the production of the electricity. But the renewable sources are depends on the environmental conditions, so the secondary energy source is essential. Primarily, the load will be fulfilled through the renewable energy source, when the renewable energy source will not able to generate the electricity then the load will be directly shifted to the utility grid. The maximum limit and minimum limit will be decided for the control strategy. If primary energy source have less energy than its minimum limit then the load automatically shifted to utility grid. If the primary source has greater power than its maximum limit then the power will be transferred to the utility grid. For those operations, effective controlling strategy has introduced here. Solar energy is used as a primary source and utility grid is used as a secondary source.

Solar energy is selected from the renewable energy sources because the solar energy is one of the sources of clean and abundant energy. Solar panel is act as primary source and utility grid is act as secondary source for this system. Battery current is sensed through the current transformer and it converts into voltage. The converted voltage is given to the ADC. ADC is converting the analog signal to digital signal and the signal is given to the microcontroller. The conditions have been written in the microcontroller as per the battery voltage. For these conditions the maximum limit and minimum limit of the battery voltage have been decided. If the battery voltage is greater than the maximum limit then the energy will be transferred to the utility grid. When the battery voltage is decreasing and comes down below its minimum limit then the load automatically shifted to the synchronous generator. Because of the controlling strategy, the system will not be shut down and effectively fulfilled the consumers demand. If the battery voltage is in between the maximum limit and minimum limit then to stop the transferring power to the utility grid. As per earlier mentioned conditions, the system is running.

The solar panel is connected to the boost converter. Boost converter is providing the step up voltage and to store in the battery storage.

Microcontroller (AT89S52) is generating signal as per the earlier mentioned conditions and providing the signal to switching unit. Switching unit contains two relay which acting as a switch. One relay is working as an ON/OFF switch for supplying energy to the utility grid and another relay is working as an ON/OFF switch for triggering the PCC (point of common coupling) unit.
Combining the strategy involved, the synchronization between the utility grid, source and load needs to be addressed.

II. LITERATURE SURVEY

Mane *et al*., (2018) have discussed a simulation result of synchronous generator based micro grid with power quality controller. The simulation result of the SG based PV micro grid shows the satisfactory performance. Perturb and observation is extracted maximum power at any environmental condition. Adaptive filter strategy with voltage source converter is improving the power quality at PCC [1].
Thankachan *et al.,* (2017) have the idea of photovoltaic system connected to the utility grid with an energy management scheme. The energy management scheme is incorporated with the grid connected PV system to maintain the power balance in the system [2].
Deepak *et al.,* (2013) have the idea of hardware implementation of grid connected PV system with energy management scheme making us think in direction of, in case of excess energy generation from the PV panel, the excess energy can be transferred to grid in order to supply the loads at grid side [3].
Olivares *et al.,* (2014) have discussed Trends in microgrid control and invoking an idea in our mind that If the energy generated from the PV system is not sufficient to meet the local load demand, additional power is taken from the grid. This system allows the bidirectional flow of power between the grid and PV system [4].
Shatakshi *et al.,* (2017) have represented a synchronous generator based diesel-PV hybrid micro-grid with power quality controller also generating in our mind the idea to connect as how to hardware prototype of the grid connected PV system with energy management system using batteries. PV systems use photovoltaic cells for converting solar energy to electrical energy [5].
Sharma *et al.,* (2017) have presented an idea of sun tracking solar panel using 8051 microcontroller which may be used with the micro-grid. The main aim is to enhance the existing solar panel output. The output of the proposed solar tracking panel is found to be 32.17% higher as compared to the static Flat solar panel [6].
Zavody *et al.,* (2014) have discussed the grid challenges for renewable energy thus generating in our mind the idea to some challenges for a micro-grid. For the urban or rural areas, the renewable energy based micro-grids are becoming very popular and which systems may be operated with or without grid [7].
Ibrahim *et al.,* (2015) have discussed on Matlab/Simulink model of solar PV array with perturb and observe MPPT for maximizing PV array efficiency thus providing an idea for us in our mind to PCC (point of common coupling), two different energy sources are connected [8].
Shafiullah *et al.,* (2012) have discussed, Now a day's whole world is facing the problem of the global warming. Production of electricity using fuels has been playing an important role of the global warming. The growing population has not only increased the electricity demand rather than damages to the climate in many ways. In this study, a feasibility study has been carried out to explore the potential for deployment of both small-scale and large-scale renewable energy in the Capricorn Coast region to meet the growing energy demand and reduce global warming [9].
Pathak *et al.,* (2014) have discussed Permanent magnet synchronous generator based wind energy and DG hybrid system thus making us think about methods to regulate the voltage, current and frequency of the system in case of presence/absence of grid or linear/nonlinear load or unbalance in the three-phase systems is very critical part[10].
Pathak *et al.,* (2014) have discussed Isolated microgrid employing PMBLDCG for wind power generation and synchronous reluctance generator for DG system thus making us get the idea of the importance of simulation results of the problem that needs to be verified through hardware set up. Hence implementing and verifying the hardware set up in this research, thereby solving the grid synchronization problem [11].

III. PROBLEM STATEMENT

The variable and fluctuating nature of renewable energy makes the task of integrating them a real challenge. Due to this disadvantage of renewable source, backup source is necessary to avoid the interruption of the system. Synchronization between two sources is very critical job which is made through a controlling strategy.

IV. OBJECTIVE OF THE SYSTEM

The system designed should synchronize between two sources, utility grid and load; by using voltage source converter with power quality controller. An effective controlling strategy system is needed for running without any interruption. This can be achieved by automatic shifting of load on the synchronous generator.

V. SYSTEM OVERVIEW

Synchronization between two different sources is very difficult task. Synchronization is done through the controlling strategy. The sun radiation depends on the environmental condition so the secondary source is necessary to avoid interruption while system is running. Battery current is given for deciding the control strategy. Current transformer is sensing the battery current and converts it into voltage. The converted voltage is used for writing the program into the microcontroller. For the program, the maximum and minimum valued of the converted voltage are fixed. These conditions are when the battery voltage is greater than the maximum set value then the energy will be transferred to the utility grid. If the battery voltage is less than the minimum set value then the load will be shifted to the synchronous generator. If the battery voltage is in between the maximum limit and minimum limit then to stop the transferring power to the utility grid. Due to the earlier mentioned conditions, the system is running without any interruption. For the system solar panel, boost

converter, current transformer, microcontroller, voltage source inverter, relays are used.
When the battery voltage is greater than the maximum set value then the microcontroller generates signal and provide the signal to switching unit. The relay which is assigned for the utility grid turned ON and to start the transfer power to the utility grid. The transferring power to the utility grid is continue till the battery voltage comes down its maximum set value. The relay for providing the power is transferring to utility grid. When the battery voltage is coming down the maximum set value, the relay is OFF and to stop the transferring the power to utility grid. When the battery voltage is decreasing and comes below its minimum limit then the load automatically shifted to synchronous generator. Because of the controlling strategy, the system will not be shut down and effectively fulfilled the consumers demand.

Block Diagram of Synchronous Generator based Solar Panel Micro-Grid with Power Quality Controller. Fig. 1 shows the block diagram. Solar system can be used with or without utility grid. Solar panel is a main source and utility grid is secondary source for this system. The boost converter is connected in between solar panel and battery. Boost converter is boosting the input voltage and gives as per the demanded output voltage. Battery current is sensed through the current transformer and it converts into voltage. The converted voltage is given to the ADC. ADC is converting the analog signal to digital signal and the signal is given to the microcontroller. For the microcontroller working the maximum and minimum limit is decided and as per those values the conditions have been written in the microcontroller. These conditions are, if the battery voltage is greater than the maximum se value then the power will be transferred to the utility grid. If the battery voltage is less than the minimum set value then the load will be shifted to the utility grid. If the battery voltage is in between the maximum set value and minimum set value then to stop the transferring power to the utility grid. As per earlier mentioned conditions, the microcontroller generates signal and the system is running.

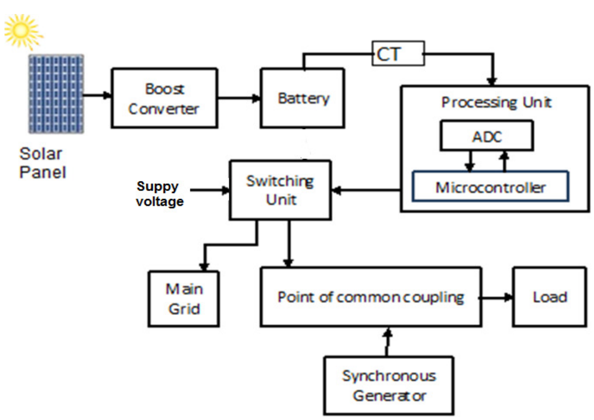

Fig. 1. Block diagram of the synchronous generator based PV micro-grid with power quality controller.

The current transformer is sensing the batter current and it converts into voltage. The converted voltage gives to ADC which converts the analog signal to digital signal. The given digital value passed to Microcontroller (AT89S52). When the voltage is greater than the maximum set value then the power is transferred to the main grid till the voltage comes down its maximum set value. When the battery voltage is in between maximum set value and minimum set value, then stop to transfer the power to main grid. When the voltage is comes down its minimum set value and then the load shifts to the synchronous generator.

Flow diagram. The flow diagram of the PV micro-grid with power quality controller to supply balanced power for nonlinear load by reconnecting utility grid is shown in Fig. 2. The battery is a storage unit which stores the energy coming from the solar panel. The current transformer senses the current and converts into voltage. The converted voltage gives to the ADC which converts analog signal to digital signal. The digital value gives to the microcontroller.

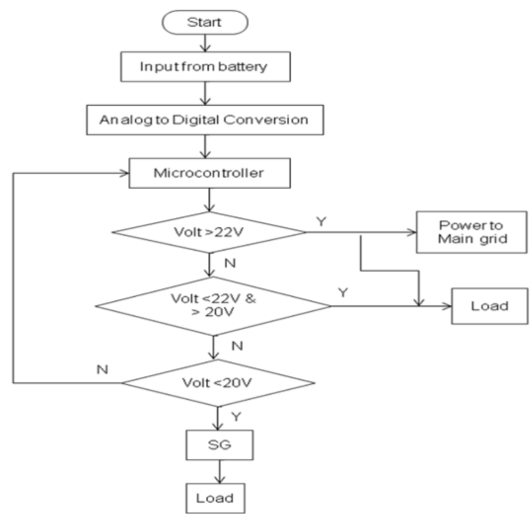

Fig. 2. Flow diagram of the synchronous generator based PV micro-grid with power quality controller.

If the getting value is greater than the maximum set value (22V) then the microcontroller generates signal and passed to the switching unit. Switching unit starts to transfer the power to utility grid. If the getting value is less than its minimum set value (20V) then the microcontroller provides the signal to switching unit. Switching unit triggers the PCC and load shifts to the synchronous generator. If the getting value is in between maximum set value and minimum set value then the microcontroller generates signal and passed to the switching unit. Switching unit stops the transferring power to the utility grid. Earlier mentioned conditions have written in the microcontroller. As per these conditions the system is running without any interruption. As per this data, microcontroller generates signal and sends to the switching unit.

VI. HARDWARE DESCRIPTION

The hardware of the PV micro-grid with power quality controller to supply balanced power for nonlinear load by reconnecting utility grid is consist of solar panel, boost converter, battery, current transformer, ADC, microcontroller, switching unit, PCC (point of common coupling) and voltage source inverter.

Circuit diagram of the synchronous generator based PV micro- grid with power quality controller

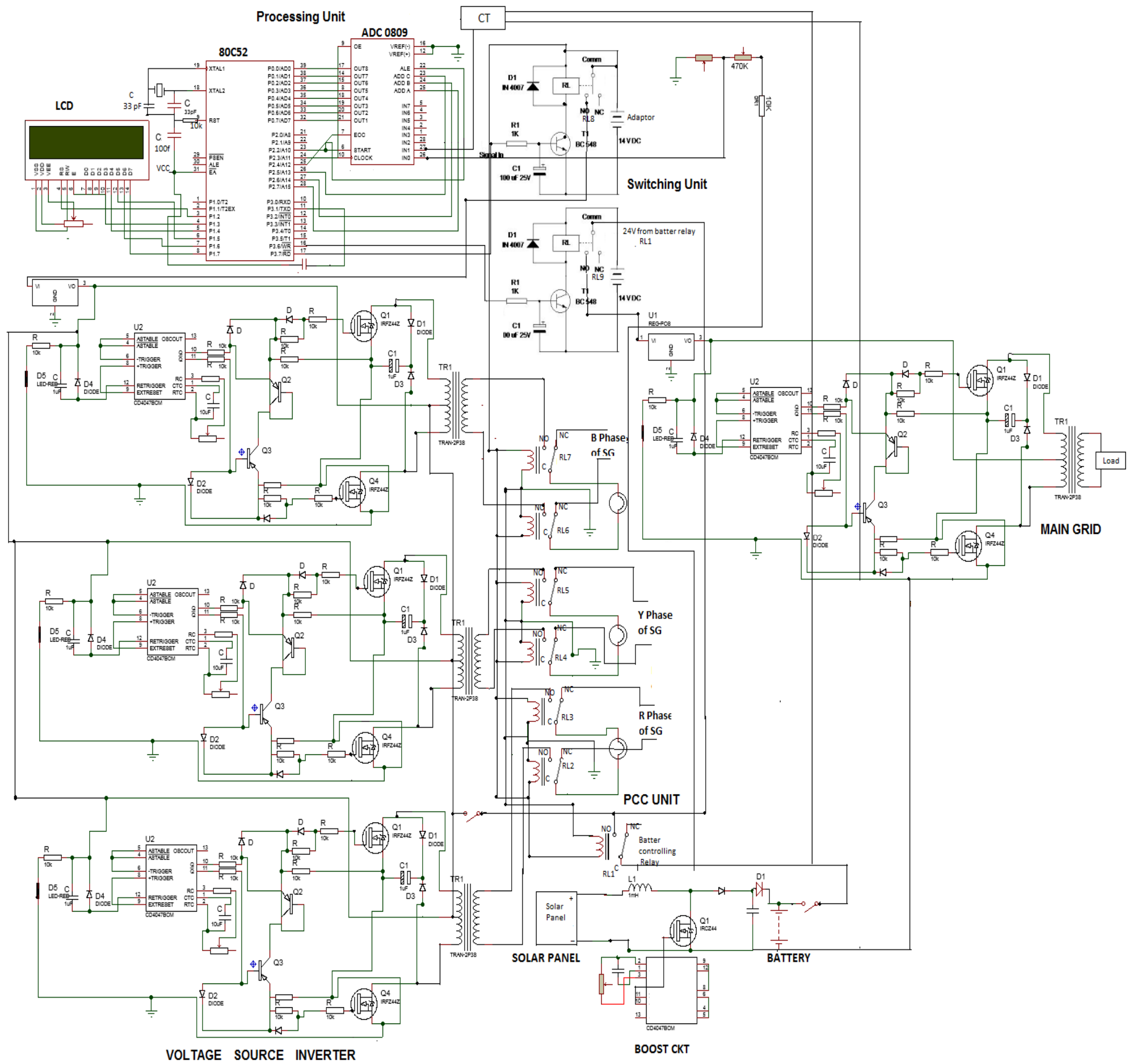

Fig. 3. The Circuit diagram of synchronous generator based PV Micro-grid with power quality controller.

The system is operating through the controlling strategy which has written in the microcontroller. The circuit diagram of the system is shown in the Fig. 3, which shows the connection of the components of the system.

The circuit diagram of the synchronous generator based PV micro-grid with power quality controller is shown in Fig. 3. The most important blocks of the system are the processing unit, switching unit, point of common coupling and voltage source inverter. The switching unit and processing unit are the back bone of the system. Voltage source inverter is also important; it converts DC power into AC power. Point of common coupling is playing key role of switching the load from one source to another source. 18V, 1A solar panel is used in the system which generates electricity during the day time. Boost converter is the DC-DC converter which is also called as step up converter. The capacity of the solar panel is 12V which is the input of boost converter. It steps up the 24V which is the requirement of the battery storage. One relay is connected in between battery and the current transformer. The relay is used to provide the input voltage to the PWM IC and transformer and excess power.

The current transformer senses the current of the battery and converts it into voltage. This value is given to the pin IN1 of ADC. The ADC is converting the analog signal into digital signal which is given to the port PO of microcontroller. Port P0 is reserved for the ADC. The 8 bit digital data is passing to the port P0 of the microcontroller. Microcontroller checks the given data and generates signal as high or low and PCC and another for excess power. If the sends to the switching unit through the pin number P3.6 and P3.7. Switching unit contains two relay.

One battery voltage is greater than the 22V; microcontroller generates high signal and send to pin P3. 6 and P3.7. Pin P3.7 is connected to relay of switching unit.

When the coil of the relay is energized, it triggers the PCC and load runs on battery. As well as the high signal from the controller is given to the pin P3.6, this turns on the relay of switching unit which is for the excess power. This relay gives the input voltage to voltage regulator of the excess powercircuit and it starts to transfer the excess power to the main grid. If the battery voltage is decreased and comes down below 22V, controller sends the low signal to pin P3.6. Relay coil is de-energized, to stop the input of voltage regulator of the excess power circuit. Automatically to stop the excess power but the load is running on the battery voltage. When the battery voltage comes down below 20V, the controller generates low signal for the pin P3.7. Switching unit passed away the low signal to the PCC.

PCC contains six relay, the NO (normally open) point of relay is connected to the secondary side of the transformer and NC (normally close) point of relay is connected to the utility load. Two relays are using for the one phase; common point of relay is connected to the load. When the low signal passes to the relay of switching unit, the relays of PCC are de-energized. Automatically the NC point and the common point of the PCC relays are short circuited and whole load shifts to the synchronous generator. LCD is used to display the message while load on solar or load on synchronous generator. LCD is connected to port P1. Controller sends the data to LCD display via port P1.

VII. EXPERIMENTAL SETUP

The system is fulfilled the demand of the consumers without any interruption due to the effective controlling strategy. The demand is fulfilled by the solar panel but when the solar panel is not able to providing the energy then the load is shifted to the utility grid.

Operation of the synchronous generator based PV micro-grid with power quality controller: The prototype model of the PV micro-grid with power quality controller to supply balanced power for nonlinear load by reconnecting utility grid is shown in the Fig. 4. The solar panel is connected to the boost converter. PWM IC (CD4047) is used to generate PWM signal and provides this signal to the gate of MOSFET of the boost converter. Due to this process the output voltage is given up to the 24V. The capacity of the battery is 24V. The current transformer is sensed the current of the battery and converted voltage.

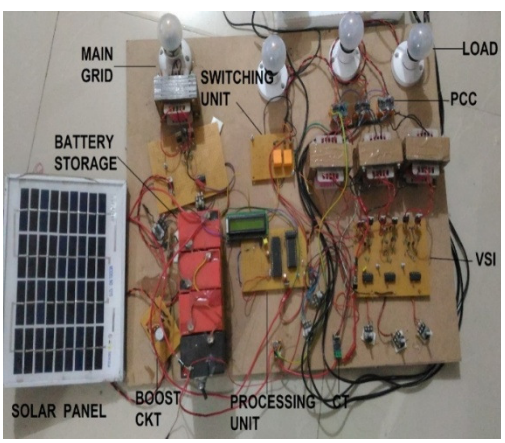

Fig. 4. Photograph of hardware setup of the synchronous generator based PV micro-grid with power quality controller.

When the incoming value of current transformer is greater than the maximum set value then the microcontroller gave the signal to switching unit and switching unit started transfer the power to main. When the incoming value is comes down then microcontroller generates signal and passed to switching unit. Switching unit is stopped the transferring power to the utility grid which is shown in Fig. 5. When the battery voltage is comes down below its minimum set value then the microcontroller is generated signal as per the program logic and shifted the load to the synchronous generator which is shown in Fig. 6.

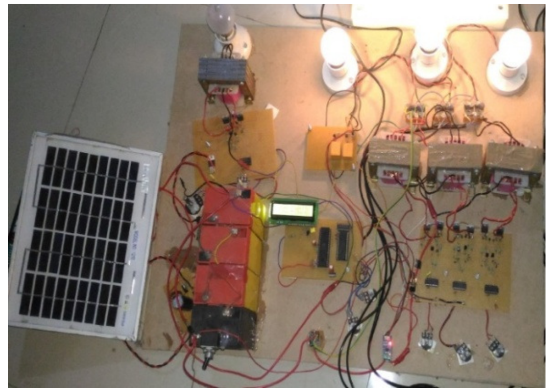

Fig. 5. Photograph of transferred the power to utility grid and load is running on solar panel.

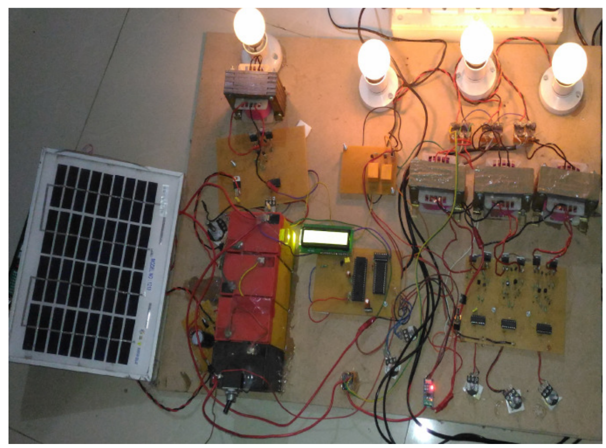

Fig. 6. Photograph of load shift to synchronous generator.

VIII. RESULTS AND DISCUSSION

Solar panel output analysis: The voltage, current and power is measured of the solar panel on different times on the day. Open circuit voltage is getting through the voltmeter which is connecting in between positive and negative point of the solar panel. Load current is obtained when the ammeter connected between positive wire of solar panel and the one point of load. Power is getting through the multiplication of voltage and current.

Table 1 shows the reading of voltage (Voc) and current (IL) of the solar panel from 9 am to 5 pm for a day. Sun rays (solar radiation) intensity is maximum during the peak hours as compared to the morning and evening. As per the table 1, the maximum voltage 17.69V is obtained at 2.00 pm and the maximum power is obtained at 2.00 pm which is 19.56W. Fig. 7 shows the graph of voltage current reading of the day 1. Upper side line shows the voltage of day 1 and lower side line shows the current of the day 1. The power graph of the day 1 is shown in the Fig. 8.

Table 1: Solar panel output analysis of day 1.

S. No.	Time	Voltage (Voc) (Volt)	Current (IL) (Amp)	Power (Watt)
1.	9.00 am	8	0.3	2.4
2.	10.00 am	10.2	0.8	8.16
3.	11.00 am	13.5	0.89	12.015
4.	12.00 noon	15.75	1	15.75
5.	1.00 pm	16.2	1	16.2
6.	2.00 pm	17.69	1.10	19.459
7.	3.00 pm	16	0.9	14.4
8.	4.00 pm	14.7	0.8	11.76
9.	5.00 pm	7	0.4	2.8

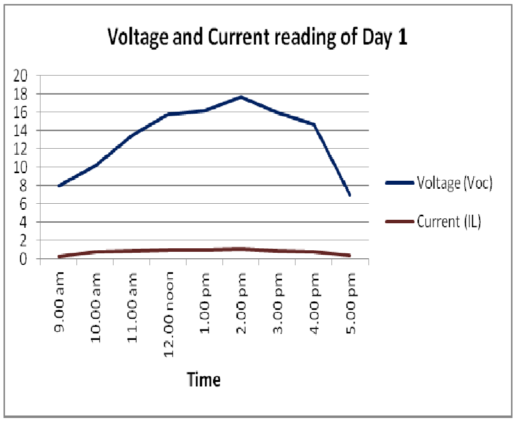

Fig. 7. Graph of voltage and current of day 1.

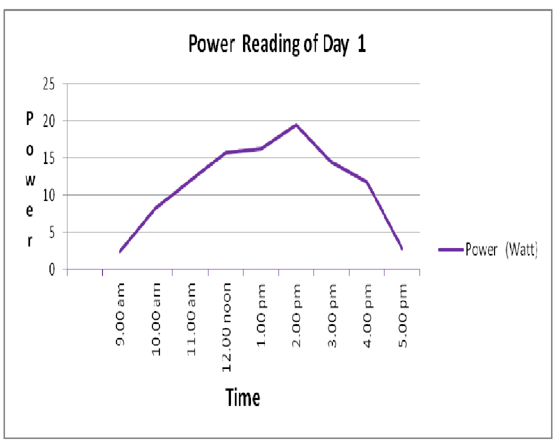

Fig. 8. Power graph of day 1.

In the day 1 reading, peak value of voltage (17.69V) is given at 2 pm. The day 2 is some cloudy atmospheric condition, given voltage is little bit less than the day1 reading. The peak value of voltage is 15.8V which gets at 12 noon. Day 3 is sunny day, so the reading is very good as compared to day 1 and day 2. The peak value of voltage is 17.96V, which gets at 2pm.

The voltage and current of solar panel is measured on the day 2 and mentioned it in the Table 2. The maximum voltage 15.8V is obtained at 12.00 pm. The obtained current and voltage is shown in the graph which is shown in Fig. 9. The power graph of the day 2 is shown in the Fig. 10.

Table 2: Solar panel output analysis of day 2.

S. No.	Time	Voltage (Voc) (Volt)	Current (IL) (Amp)	Power (Watt)
1.	9.00 am	12	0.4	4.8
2.	10.00 am	13	0.48	6.24
3.	11.00 am	14.2	0.52	7.384
4.	12.00 noon	15.8	0.8	12.64
5.	1.00 pm	10.2	0.73	7.446
6.	2.00 pm	9.6	0.5	4.8
7.	3.00 pm	8.2	0.48	3.936
8.	4.00 pm	7	0.45	3.15
9.	5.00 pm	6	0.4	2.4

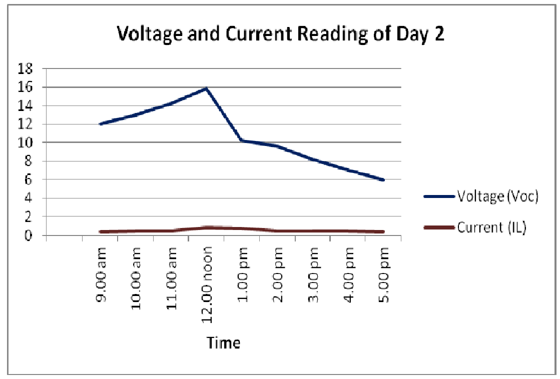

Fig. 9. Graph of the voltage and current of day 2.

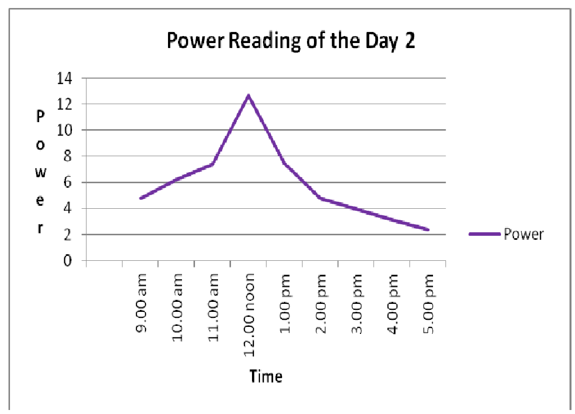

Fig. 10. Power graph of the day 2.

Table 3: Solar panel output analysis of day 3.

S. No.	Time	Voltage (Voc) (Volt)	Current (IL) (Amp)	Power (Watt)
1.	9.00 am	16.3	0.39	6.357
2.	10.00 am	16.9	0.6	10.14
3.	11.00 am	17.3	0.64	11.072
4.	12.00 noon	17.6	0.8	14.08
5.	1.00 pm	17.77	0.9	15.993
6.	2.00 pm	17.96	0.95	17.062
7.	3.00 pm	17.9	0.5	8.95
8.	4.00 pm	15.3	0.4	6.12
9.	5.00 pm	12	0.2	2.4

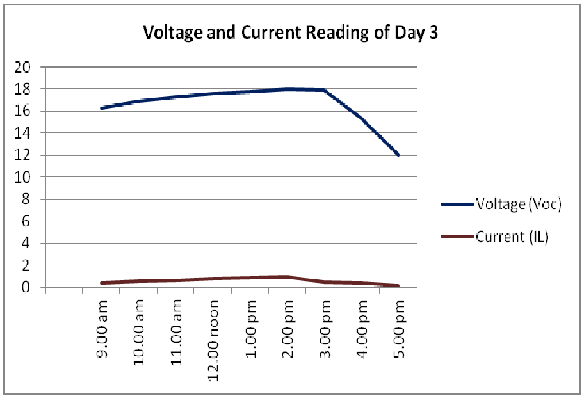

Fig. 11. Graph of the voltage and current of day 3.

The voltage and current of solar panel is measured on the day 3 and mentioned it in the Table 3. The maximum voltage 17.96V is obtained at 2.00 pm. The obtained current and voltage is shown in the graph which is shown in Fig. 11.

The maximum power is obtained at 2.00 pm which is 17.06 W. The power graph of the day 3 is shown in the Fig. 12.

Transferred power measured in no-load condition: When the load is not running on the solar panel, total transferred power is measured and mentioned it in the Table 4. When the 10W power is given to the utility grid per day then the total 15.39W power is transferred to the utility grid per year. When the 25W power is given to the utility grid per day then the total 33.61W power is transferred to the utility grid per year.

When the 40W power is given to the utility grid per day then the total 39.42W power is transferred to the utility grid per year. When the 60W power is given to the utility grid per day then the total 46.36W power is transferred to the utility grid per year. When the 100W power is given to the utility grid per day then the total 57.83W power is transferred to the utility grid per year.

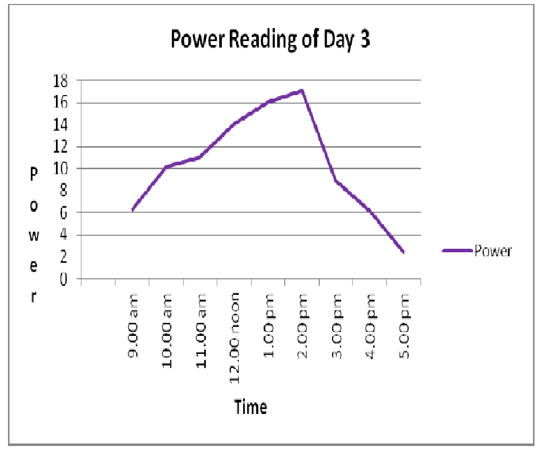

Fig. 12. Power graph of the day 3.

Table 4: Power transferred to main grid when the no load is running on the solar panel.

S. No.	Power given to the main grid per hour	Excess power transferred to main grid. (Time in hours)	Total energy given to the main grid per day Energy= Power*Time (kWh)	Total energy given to the main grid per year (kWh)
1.	10	4.13	0.0195	15.39
2.	25	3.41	0.092	33.61
3.	40	2.42	0.108	39.42
4.	60	2.07	0.127	46.355
5.	100	1.34	1.57	57.183

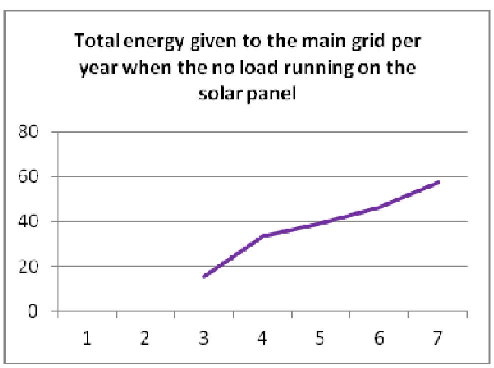

Fig. 13. Graph of power transferred to main grid per year in no load on solar panel condition.

Fig. 13 shows the graphical representation of the power transferred to the utility grid per year when the not load is running on the solar panel.

Balanced load on the three phase: Transferred power to the utility grid is measured when the balanced load is running on the three phase. The measured readings are mentioned in the Table 5.

The transferred energy is calculated as per using the following formula:

$$\text{Energy} = \text{Power} \times \text{Time} \quad (1)$$

When the load is 10 watt on the three phases and the excess power is transferred to main grid using 10 watt bulbs. The energy is transferred to main grid 0.00023kWh which is given through the following equation:

$$0.01 \text{ kW} \times (117/60)\text{h} = 0.0195 \text{ kWh} \quad (2)$$

For a year,

$0.0195 \times 365 = 7.1175$ kWh power is given to the main grid.

When the load is 25 watt on the three phases and the excess power is transferred to main grid using 10watt bulbs. The energy is transferred to main grid 0.00015kWh which is given through the following equation:

$$0.01 \text{ kW} \times (83/60)\text{h} = 0.0138 \text{ kWh} \quad (3)$$

For a year,

$0.0138 \times 365 = 5.037$ kWh power is given to the main grid.

When the load is 40 watt on the three phases and the excess power is transferred to main grid using 10watt bulbs.

Table 5: Result table for the balance condition.

Load			Excess power transferred to main grid. in Hours	Load on solar panel Time in Hours	Total energy given to the main grid per day Energy= Power*Time (kWh)	Total energy given to the main grid per year (kWh)
R in W	Y in W	B in W				
10	10	10	1.57	2.33	0.0195	7.1175
25	25	25	1.23	2.05	0.0138	5.037
40	40	40	1.02	1.35	0.0103	3.7595

Table 6: Result table for the unbalance condition.

Load		Excess power transferred to main grid. (Hours)	Load on solar panel (Hours)	Total energy given to the main grid per day Energy= Power*Time (kWh)		Total energy given to the main grid per year
R (W)	Y (W)	B (W)				
10	10	25	1.42	2.07	0.017	6.205
40	25	25	1.17	1.45	0.0128	4.672
40	25	40	1.00	1.32	0.01	3.65

The energy is transferred to main grid 0.00011kWh which is given through the following equation:

$$0.01 \text{ kW} \times (62/60)\text{h} = 0.0103 \text{ kWh} \quad (4)$$

For a year,
0.0103 × 365= 3.7595 kWh power is given to the main grid.

Unbalance load on three phases: Transferred power to the utility grid is measured when the unbalanced load is running on the three phase. The given readings are mentioned in the Table 6.

For the first reading, to keep the 10 watt bulb on phase R and Y and 25 watt on B phase. Here we are getting 0.00020kWh power transferred to maid grid and the system is run 28 minutes on battery. The excess power transferred to main grid is given through the following equation:

$$0.01 \text{ kW} \times (102/60)\text{h} = 0.017 \text{ kWh} \quad (5)$$

For a year,
0.017 × 365= 6.205 kWh power is given to the main grid.

For the second reading, to keep the 40 watt bulb on R phase and 25 watt on Y and B phase. Here we are getting 0.00016kWh power transferred to maid grid and the system is run 22 minutes on the battery. The system is transferring the excess power to main grid around 10 minutes which is measured through the 10 watt bulb. The excess power transferred to main grid is given through the following equation:

$$0.01 \text{ kW} \times (77/60)\text{h} = 0.0128 \text{ kWh} \quad (6)$$

For a year,
0.0128 × 365= 4.672 kWh power is given to the main grid.

For the third reading, to keep the 40 watt bulb on phase R and B and 25 watt on Y phase. Here we are getting 0.00013kWh power transferred to maid grid and the system is run 18 minutes on the battery. The excess power transferred to main grid is given through the following equation:

$$0.01 \text{ kW} \times (60/60)\text{h} = 0.01 \text{ kWh} \quad (7)$$

For a year,
0.01 × 365= 3.65 kWh power is given to the main grid.

As per the above process getting the result, how much excess power is given to the main grid in a year.

To summarize the results obtained we can say that, the system has transferred more power in no load condition than the load is in running condition. The simulation results as per the literature studied is verified from the hardware setup created and experimented, i.e.

In no load condition, 10W power is transferred to the utility grid per day then the total 15.39kWh energy transferred to the utility grid per year. When the 25W power is transferred to the utility grid per day then the total 33.61kWh energy transferred to the utility grid per year. When the 40W power is transferred to the utility grid per day then the total 39.42kWh energy transferred to the utility grid per year. When the 60W power is transferred to the utility grid per day then the total 46.36kWh energy transferred to the utility grid per year. When the 100W power is transferred to the utility grid per day then the total 57.18kWh energy transferred to the utility grid per year. When the load is running on the solar panel, the transferring power is reduced. When the 30W load is running on the solar panel and 100W power is transferred to the main grid per day then the 7.118kWh energy is transferred to the main grid. When the 45W load is running on the solar panel and 100W power is transferred to the utility grid per day then the 6.205kWh energy is transferred to utility grid.

An effective controlling strategy is realized for running without any interruption; synchronization between the utility grid, source and load is achieved.

IX. CONCLUSION

PV and synchronous generator based Micro-Grid with power quality controller to supply balanced power for nonlinear load by reconnecting utility grid has been verified here. At PCC point, PV and Synchronous generator are connected. Through this PCC point, power is transferred to load and utility grid. By using voltage source converter with power quality controller synchronization is done between two sources, utility grid and load. Due to this effective controlling strategy system is running without any interruption. The hardware result of the proposed system shows satisfactory performance.

X. FUTURE SCOPE

The future scope of the micro-grid system will be developed a model for the small offices, colleges, societies. As well as the system will be establish to fulfill the load requirement of the consumer in rural areas or urban area where the requirement of electricity is not more. Renewable energy sources depend on the environmental condition so that the backup system is used in the form of non-conventional source. The non-conventional source with renewable source will fulfills the power demand of consumer without fail. Fixed solar panel is generating power but the dual axis panel will be generating more power than the fixed solar panel. In future the dual solar panel will be used with the system for generating more power. Different renewable will be combined and used for the generation of electricity. Also, we can reduce the pollution and fulfill the power demand in the future.

Conflict of Interest: The authors confirm that there are no known conflicts of interest associated with the publication of this paper.

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