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Grid Connected Photovoltaic Battery Energy Storage System with Active and Reactive Power Control at Distribution System



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Abstract:

Photovoltaic (PV) star farms manufacture power throughout the day and area unit utterly idle within the nights. Thus, the whole high-priced quality of star farms remains extremely unutilized. So to outcome from this issue battery energy storage (BES) is critical to assist so as to urge stable and reliable output from the PV star farm systems even in dark. during this work PV array with most power pursuit (MPPT) and BES is connected to the common dc bus and so it's connected to a distribution network via common DC/AC device (G-VSC). Here perturb & observe MPPT algorithm planned that helps PV array to get the most power to the given dc bus or batteries.

At day time, PV array can provide power through the G-VSC to the grid and if the excess power is accessible than charges the batteries. at the hours of darkness time, Battery energy storage can supply power through the grid aspect voltage supply device to the grid that indicates that a photovoltaic energy storage system maintains constant dc bus voltage even once the PV-SF is not manufacturing any power chiefly in dark. In distribution system, these area units handle massive load fluctuations, therefore these area unit wide variations within the voltage levels. Therefore this work deals with G-VSC works as STATCOM, which is able to provideflexible voltage management at the purpose of coupling (PCC) to the distribution network for maintain the constant voltage inside an appropriate vary by exchanging the reactive power. A comprehensive controller is going to be developed that utilizing the whole capability of the prevailing GVSC.

This planned system can modify to will increase the connections of voltage fluctuating load to the grid and show abundant superior performance to the distribution networks. This work deals with STATCOM, which has been sculptured with a hundred kilowatt electrical phenomenon Energy Storage System in MATLAB/SIMULINK. Simulation results can describes the effectiveness of the indirect distribution network voltage regulation by utilizing the PV star farm and storage batteries and additionally shows the up the ability quality of distribution systems.

1. INTRODUCTION:

In the future, the demand for electric energy is expected to increase rapidly due to the global population growth and industrialization. This increase in the energy demand requireselectric utilities to increase their generation. Recent studies predict that the world's net electricity generation is expected to rise from 24.4 trillion kilowatt-hours (an increase of 41% compare to 2005) in 2015 and 33.3 trillion kilowatt-hours (an increase of 92.5%) in 2030 [10]. Currently, a large share of electricity is generated from fossil fuels, especiallycoal due to its low prices. However, the increasing use of fossil fuels accounts for a significant portion of environmental pollution and greenhouse gas emissions, which are considered the main reason behind the global warming. For example, the emissions of carbon dioxide and mercury are expected to increase by 35% and 8%, respectively, by the year 2020 due to the expected increase in electricity generation. Moreover, possible depletion of fossil fuel reserves and unstable price of oil are two main concerns for industrialized countries.

To overcome the problems associated with generation of electricity from fossil fuels, renewable energy sources can be participated in the energy mix. One of the renewable energy sources that can be used for this purpose is the light received from the sun. Solar energy is the most widely use source of renewable and sustainable energy that can play a leading role in the program of reducing greenhouse gas emissions. Renewable energy sources currently supply somewhere between 15% and 20% of the total world energy demand [1]. Photovoltaic generation is the technique which uses photovoltaic cell to convert solar energy to electric energy using 'photovoltaic effect'. Due to solar intermittency by reason of the variations in weather and grid power interruptions, energy storages being used as a backup in present PV systems. Therefore, to have an economical PV system, it is desirable to have properly sized energy storage. Grid-Connected PV system with an energy storage system is similar to stand-alone systems except for the connection of the system to the utility grid. Due to the interconnection with the utility grid, a system can reap several benefits like selling the excess PV electricityinteractive UPS [3]-[6] at the expense of lower potency and further size and value because of the employment of additional electrical converter and hulking electrical device. However, this topology remains a lot of economical than classical on-line double conversion UPS as a result of the complementary electrical converter has solely to produce 100 percent to twenty of the UPS nominal power [7].There are variety of publications on the management of line interactive UPS systems [8]-[15].

Tirumala et al. [8] planned a bearing algorithmic rule for grid production to the grid, battery system charging at off peak hours and buying powerwhenever the PV and battery power are deficient to feed the loads. Even though there is an extra investment cost for the battery system, by scheduling the battery operation in a smart way, the overall benefits of the system can get increased. It is desirable to comprise with suitable energy storage devices, the local consumption of PV produced energy could be boosted by storing surplus energy at times of peak production and using this energy when and it is not enough or not exist. Batteries are frequently used in PV systems for compensating the power during outages and in the intention of storing the excess energy generated by the PV modules during the day time.

Then the stored power in batteries can deliver it to electrical loads as and when it is needed (during the night and intermittent weather conditions). Battery energy storage (BES) system can be integrated into PV generation system to form a hybrid PV-Battery generation system. In the grid connected mode, hybrid system connected to the common dc bus to deliver the constant input dc voltage to the grid side voltage source converter (G-VSC) in both day and night time. When distribution system load demand changes, there is voltage fluctuation in distribution grid. To maintain distribution grid voltage constant grid side voltage source converter (G-VSC) work as STATCOM. So, in this case there must need to maintain input DC voltage to converter is constant by proper utilizing BES system and PV system [6].

2. PROPOSED SYSETM CONFIGURATION:

In the system,the renewable solar power is taken as the primary source while battery energy storage system is used as a backup and storage system. This system can be considered as a complete "green" power generation system due to the main energy sources and storage system are completely environmentally friendly. This hybrid system can be stand-alone or grid-connected. In the grid connected mode, the operation of PV system can be enhanced by utilizing the battery energy storage to properly manage the output of PV system so as to improve the efficiency. This hybrid, PV-BES system connected in parallel to dc bus. These dc bus voltages maintain constant by properly optimizing the hybrid system parameters in both day and night time.

A voltage source converter is practically used to interface the hybrid system to grid, which is connected to point of common coupling. With a input dc voltage source, the converter can produce a balanced set of three quasi square voltage waveforms at given frequency by connecting the dc source sequentially to the three output terminals via the appropriate converter switches and supplying to grid or ac load. The exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage. So, by compensation of reactive power we can improve the voltage level in voltage variation conditions distribution system.

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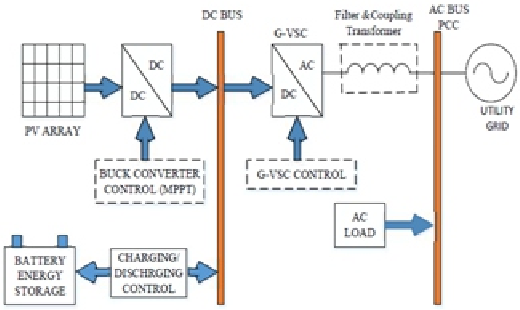

Fig-1: Block Diagram of the Proposed System

Figure shows the system layout for the considered PV/BES hybrid system consisting a PV array interfaced to the DC bus through a buck DC/DC converter with MPPT. BES systemis connected to the DC bus via charging and discharging controller. While the grid side voltage source converter is used for grid interfacing. An equivalent inductor represents the total inductances of system filter and coupling transformer which ensures the injected harmonics follow the required standard. Here we consider two parts, first is dc bus and second is ac bus. First we consider dc bus part. The main aim in this part is maintain the dc bus voltage stable and reliable in both days when PV power is available and night, when PV power is unavailable.

We have considered the PV array system; its output power is also depend on the weather condition i.e. solar insolation and temperature. If we directly connected PV array to the load or system, it's operates at the intersection of current–voltage curves. This operating point may be far from the maximum power point (MPP) of the generator wasting a significant proportion of the available solar power. By maximum power transfer theorem, a source will deliver its maximum power when the source impedance matches the load impedance. The PV system can deliver the maximum power when the load impedance matches with the source impedance under a givenInsolation level. A number of different MPPT algorithms have been proposed to operate the PV system at MPP of V-I curves, in which we utilize the P&O algorithm. Since the load and Irradiance are varying dynamically, the maximum power point tracking (MPPT) becomes more complex with the use of MPPT functions. A simple dc–dc converter controlled by an MPPT algorithm can be used as a controller to match the PV generator to the load or system.

Also the PV energy is drained by the DC-DC converter from the photovoltaic array and fed to the DC link capacitor for different solar irradiance. In our system, when excess output power is available from the PV system, so it supplies both dc bus and charge the battery. In night time unavailability of power from the PV system, the battery energy storage system is used to supply power to dc bus voltage. And maintain the dc bus voltage constant. For the BES system a control algorithm is developed to ensure safe and optimal operation of battery while providing additional support for dc bus voltage regulation. The control for charge/discharge of battery is to compensate the dc bus voltage deviations. The controller utilizes logic circuits for the decision of operation modes of BES including charge/discharge or stopping mode. Now consider the second part is ac bus, at ac bus we have to maintain the optimal voltage level in any voltage disturbance condition. These voltage regulation or alleviation of the voltage sag is done by voltage source converter work as STATCOM. By doing so supplying or absorbing reactive power, we can alleviate the voltage variation at distribution system. Which work we are already done in previous work.

3. BLOCK DIAGRAM FOR WORK COMPLETED:

In this section we consider the block diagram of the work which i have done after the phase-1.Here we consider the photovoltaic system with battery energy storage system. By proper controlling of the hybrid system we get the constant dc link voltage. It is done with taking different mode of operation i.e. at different hour solar irradiation is changes and also the output power is change. So by taking different output power level from the PV system, we understand the present system.Figure shows that PV MPPT system output is supply to the dc-dc boost converter toenhance the output voltage. The BES system is connected to PV system with charging/discharging controller.

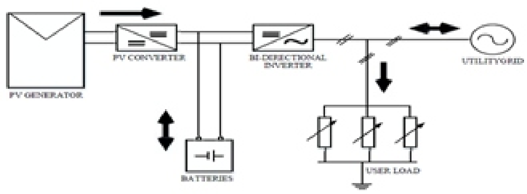

Fig-2: Block Diagram of the Work Completed.

The dc bus voltage is converted to ac and supply to grid or loadthrough the bi-directional inverter.

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4. FLOWCHART FOR PERTURB & OBSERVE ALGORITHM:

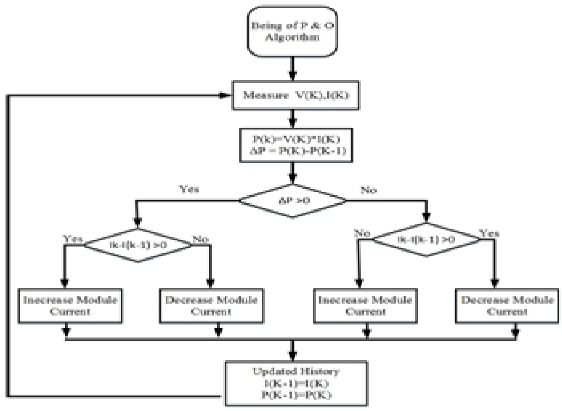

Fig-4:Flowchart for perturb & observe algorithm

4. MODES OF OPERATION OF PRESENT SYSTEM:

The operation of the present system has been divided into three modes. The modes are

(i)Day time excess power mode,
(ii)Day time mode,
(iii)Night time mode.

1. Day time excess power mode:

In this mode, the output voltage of the PV system matches the dc bus voltage and also charge battery. In this mode battery is in charging mode.

2. Day time mode:

if the PV output voltage is equal to the dc bus voltage. In this mode, the battery is not come in to operation.

3. Night time mode:

In this mode, PV output is absent and only the battery matches the dc bus voltage and supply the voltage source converter. In this mode battery is in discharging mode.

5. SHEMATIC DIAGRAM OF HYBRID SYSTEM TO SYCHRONAZATIONWITH GRID:

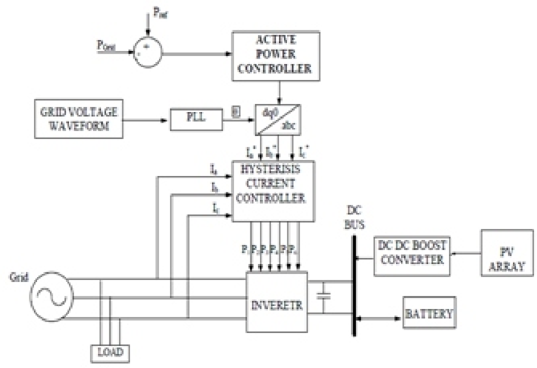

Fig-5:Shematic diagram of hybrid system to synchronization with grid

Block diagram of proposed system is shown in figure. Interfacing of hybrid system to grid is done using VSC. Hybrid system connected to dc bus to continue the flow of power. Inverter is convert dc voltage to ac voltage and feeding power to the grid. There are loads connected to the grid. It is very important to create appropriate gate pulse for inverter. For this purpose, control scheme is used. Active power controller block is used in control scheme.

PLL is used to extract phase angle θ from the grid. dq-to-abcreference frame transformation is necessary. It transformed direct and quadrature axis current to three phase abc quantity. It uses phase angle of grid voltage, which is obtained by PLL. The active power by the load and active power supply by the inverter is compared and output is given to hysteresis current controller. Hysteresis current controller is used to create gate pulses for the inverter.

6. SIMULATION AND RESULTS ANALYSIS:

This section will describe the modeling and simulation results of the grid connected hybrid system in the MATLAB/SIMULINK. Figure 5.4 shows the schematic diagram of synchronization of hybrid system used to carry out the modeling and analysis. This studied system compromises of a 440 V three- phase distribution system, at which 50 KW load is connected supplied by the two level voltage source converter based STATCOM. The needed input dc voltage of the VSC is provides by PV-BES hybrid system. Both PV and BES system is connect to common 800V dc bus. The aim of the PV-BES system is to provide proper voltage regulation at the dc bus by properly optimizing the control parameter.

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In case of the low output from the PV system battery energy storage system is supplied remaining voltage to maintain the dc bus voltage. And in case of the output voltage is higher, than it is charge the batteries and maintain the dc bus voltage. The stable dc input voltage to VSC is necessary to the distribution system subject to disturbance. Because in this case of the system disturbance cause hybrid system to disconnected. It is important to maintain dc bus voltage helps in efficient power conversion and improves stability while protecting the DC bus capacitor and the VSC valves against overvoltage stress.

In this chapter consider the mathematical modeling of the 100 KW photovoltaic systems. This photovoltaic array used the BP SX 150S PV module, because it has a maximum power output 150 W. And also these PV module rating is easily available and also match with our system requirement. Perturb & observe algorithm is considered in the maximum power point tracking because of less complexity than other method. The Nickel MetalHydride battery energy storage system with 50KWh capacity and 50% state of charge is modeled. The three phase voltage source converter is interface between the grid and dc bus. The VSC synchronization with grid done with synchronous reference frame control method in which require grid voltage waveform phase angle θobtain from the phase locked loop circuit. By comparing current signals Id and Idref with hysteresis current control technique which gives the switching pattern for VSC.

7. SIMULATIONS FOR SYNCHRONIZATION OF PV-BES SYSTEM WITH GRID:

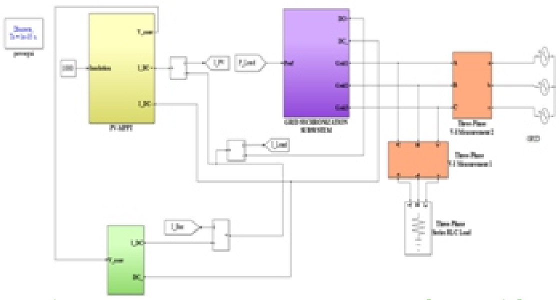

Fig-6: PV-BES system connected to grid

Figure show the subsystem of photovoltaic system with maximum power point tracking, subsystem of battery energy storage system and subsystem for grid synchronization of this hybrid system. Here we consider only the active power control so the load is 50KW. The 440 V three phase distribution system is doesn't supply power to load or to the dc bus. Theac load is totally supplied by the hybrid system. So the power management of this hybrid system such that dc bus voltage should constant in any situations.

8. SIMULATION FOR PV MPPT SUBSYTEM:

Figure shows this subsystem consist the PVarray subsystem, subsystem of the MPPT programming and dc-dc boost converter sub system. Here we consider the mathematical modeling of the photovoltaic system. The output of the PV system is totally depend on the solar irradiation.

So the input to the PV module is irradiation and the current Ipvbecausewe assume here the voltage is constant for different irradiation. So the output of the PV module is voltageVpv. By using this Vpvand Ipv calculate the Ppv. which is the input of MPPT subsystem. The output of this MPPT subsystem is input of the boost converter with M.E. Power System Parul Institute of Technology Page 45.

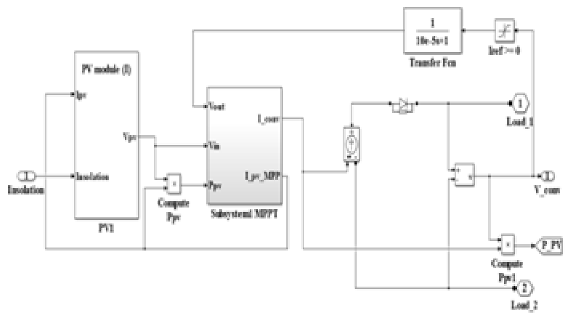

Fig-7:Simulation of PV MPPT system

theVpv& the output volatge is feedback. Boost converter switching loss consider 0.03 and the internal resistance is 0.5ohms. The boost converter output is current is applied to the contrlled current souce by which we measure the total voltage and current of the PV MPPT system and calculate the PV system output power.

9. SIMULATION FOR MATHEMATICAL MODELLING OF PV ARRAY:

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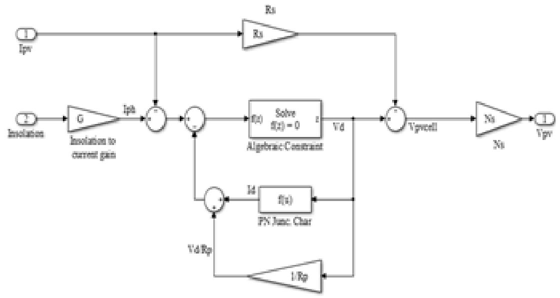


Fig-8:Subsystem of PV array

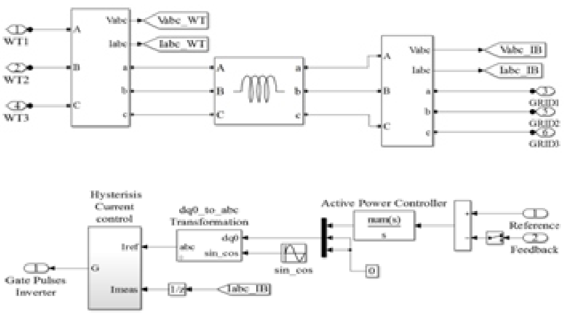


Figure shows the mathematical model of the PV system. It is similar to electrical equivalentmodel as we discussed in previous chapter. It consist the current source with the anti-parallel diode. The internal source impedance is shown as the series resistance Rs and the shunt is very small for oppose the recombination effect but we neglected the Rsh. Here BP SX 150S PV module electrical parameter is use to develop this PV array.

9.1 ELECTRICAL SPECIFICATION OF PV:

PV MODULE SPECIFICATION	
Maximum Power (P_{max})	150W
Voltage at P_{max} (V_{max})	50
Current at P_{max} (I_{max})	4.35A
Open- circuit voltage (V_{OC})	43.5A
Short- circuit current (I_{SC})	4.75A
Temperature co-efficient of I_{SC}	0.065±0.015 % /℃
Temperature co-efficient of V_{OC}	-160±20mv /℃
Temperature co-efficient of power	0.5±0.05 % /℃

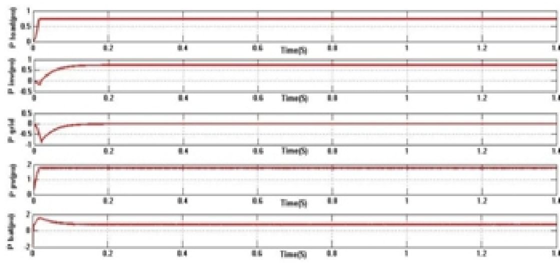
Table-1: Specifications of Electrical PV.

PV ARRAY SPECIFICATION	
Number of module in a string series N_{ss}	18
Number of module in a string parallel N_{pp}	40
Maximum Power (P_{max})	540000W
Voltage at P_{max} (V_{max})	591.36
Current at P_{max} (I_{max})	175
Open- circuit voltage (V_{OC})	745.2
Short- circuit current (I_{SC})	192

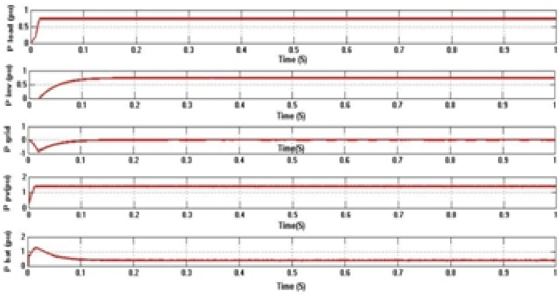
Table-2: Specifications of ARRAY PV.

10. SIMULATION RESULT:

* FOR 1000 SOLAR INSOLATION



* FOR 750 SOLAR INSOLATION



* FOR 500 SOLAR INSOLATION

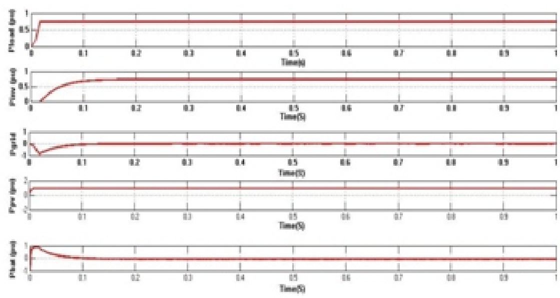


Fig-10: Results of Solar Insolation

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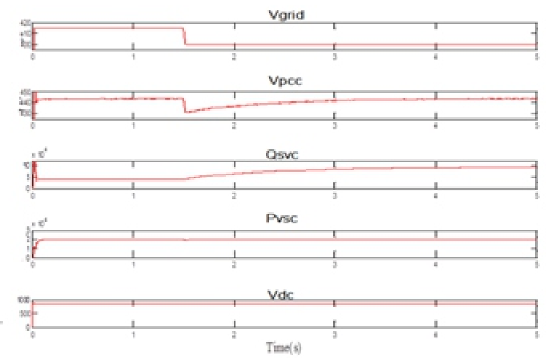
From the above waveform we conclude that with increase in the solar irradiation the anyone electrical quantity either voltages or current is increase. Here in this case we consider the Vpv is constant , so with the irradiation there is slide changes in the voltages but the we can easily show that the PV output current is increase with the irradiations and vice versa. Due to the increase in the current with irradiation the output power of the PV is alsoincrease.

Case:1Grid Voltage fall from 415V to 400V.



Case-2Grid Voltage Rise from 415V to 440V.

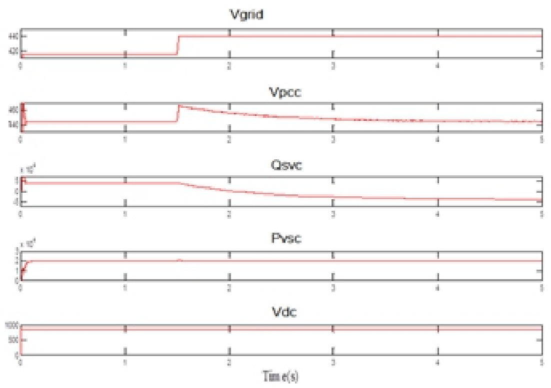


Fig-11: Waveform of Grid Voltage

CONCLUSION:

To utilizing the photovoltaic systems in day and night time the BES system put parallel with PV system in order to compensate active and reactive power. In this paper a simple and effective control method is proposed using the p-q theory so as the PV-BES to compensate the reactive power of the load throughout the day and night.

In fact, the application of such a PV-BES system in the household and in industry in order to compensate reactive power to maintain the voltage stability at distribution system by utilizing grid side voltage source converter as STATCOM. The Dc bus voltage is also maintain by properly controlling the charging / discharging process of BES in the no sunshine and sunshine time would greatly improve the power system stability. Future prospects of the present proposal include a more realistic modeling of PV, use accurate MPPT method and also the modification of the control method so that the system works, even if the source voltage is not ideal and the load current contains harmonic components.

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