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A Power Management Scheme for Grid connected PV Integrated with Hybrid Energy Storage System

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Abstract: *This paper presents a hybrid system comprise of Photovoltaic (PV), Battery, Super-capacitor (SC), Grid to meet isolated DC load demand. The PV is the primary energy source, whereas battery and SC both are considered for their different power density to supply transient and steady load respectively. in this paper for a grid-united PV system combined with hybrid storage of super-capacitor and battery. The combined battery and super-capacitor storage system grips the average and transient power changes, which provides a quick control for the DC link voltage, The current controller in the control module is replaced with P&O MPPT technique for maximum power extraction from the PV module. A comparative analysis is done with current control and MPPT control and the results are presented using MATLAB software.*

Keywords: *Photovoltaic (PV), Battery, Super-capacitor, Hybrid Storage, State of Charge, P&O MPPT technique.*

1. Introduction

Today's power system stresses the rising use of green technology due to the concern about energy conservation and the quick penetration of renewable sources. The most often utilized environmental technologies presently are wind turbines and PV. In terms of dependability and sustainability, the best option is PV owing to the benefits like cheap cost, high efficiency, minimal maintenance and high consistency. But the stability and production of the PV are greatly impacted by the fluctuating ambient operating circumstances including temperature, irradiance, impacts of partial shade, and humidity. Energy storage systems (ESSs) are used in microgrids to provide uninterrupted power from an intermittent source like PV, reduce the power mismatch between the produced and required power, i.e., the smoothing output power mode, and improve the system's quality and stability. The battery is the most common kind of energy storage due to its low cost and simplicity of usage.

Batteries, on the other hand, have a low charging/discharging rate due to their high energy density and low power density. Unlike batteries, which provide rapid charging and discharging, supercapacitors (SC) have a limited energy density and high-power density. To reap the advantages of both batteries and capacitors, hybrid energy storage systems (HESS) are developed. By diverting the transient current from the batteries to the super capacitors, HESS may extend the battery life.

1.1 Renewable Energy

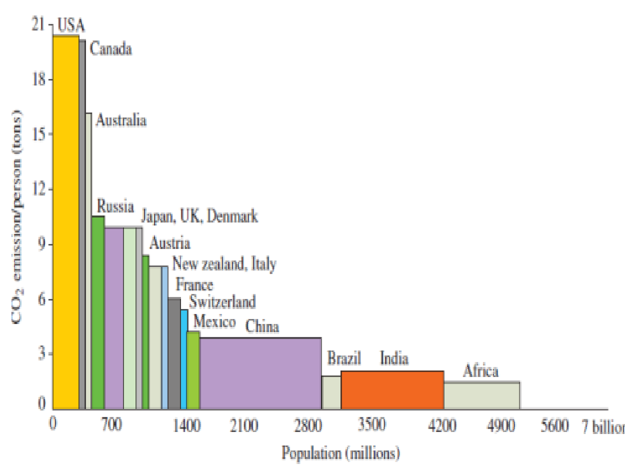

Figure 1. Per capita CO_2 emissions versus the population of selected countries

Today, most electricity in the globe comes from coal, oil, gas, and other nonrenewable sources. Polluting gases (SO2, CO, NOX, HC, and CO2) are produced when fossil fuels are burned. Climate change and global warming are the most noticeable consequences of using fossil fuels.
An estimated 80% of CO2 in the atmosphere comes from the combustion of fossil fuels for energy, with half of that coming from the creation of electricity. The population of each country is shown along the horizontal axis, while CO2 emissions per person are shown in tonnes per year along the vertical axis in Fig. 1.1. The United States and Canada are competing against one another for maximum per capita emission in the world. Following the United States, we find Australia, European countries, Russia, and Japan, all of which normally emit less than half as much as the United States. The global warming issue is significantly impacted by a country's overall emission, which is represented by the rectangle area. The global price of these non-renewable energy is rising as well.[1]
Using renewable energy sources has become more common on the grid in recent years. A rise is anticipated for the near future.

1.2 Advantages and Disadvantages of Renewable Energy

Advantages of Renewable Energy

- Renewable energy is well renewable: We will never exhaust its supply because of its infinity of sustainability. Coal, oil, and natural gas are finite resources that eventually be depleted.
- Environmental Benefits: Greenhouse gas and net carbon dioxide emissions are greatly reduced or eliminated. Because it doesn't produce waste products like carbon dioxide (CO2) and other, more hazardous byproducts of burning fossil fuels or using other forms of energy, it won't deplete our natural resources and will have little, if any, negative effects on the environment.
- Reliable Energy Source
- Economic Benefits: In addition to being environmentally and fiscally preferable, renewable energy is less expensive.
- Stabilize Energy Prices

Disadvantages of Renewable Energy

- Reliability of Supply: A disadvantage of renewable energy is that it is highly dependent on the elements for its supply, such as rain, wind, and sunlight. Climate conditions necessary for the generation of electricity from renewable sources are not always present, and in such cases, the capacity of these sources is reduced.
- Difficult to Generate in Large Quantity
- Large Capital Cost
- Large Tracts of Land Required

1.3 Photovoltaic

Filtering photovoltaic systems by power output, system setup, or grid connection is possible. The photovoltaic array, power conditioner, energy storage, and PV inverter are the four main components of a typical PV system. After that, with or without local load, the system is hooked up to the utility grid. Please also Fig. 1.2, which depicts a simplified PV system connected to the grid and serving a local load. [2].
PV modules are assembled from solar cells wired in series to turn sunlight into electricity. Depending on the electric power need, PV modules may be connected in series or in parallel to create a PV array.

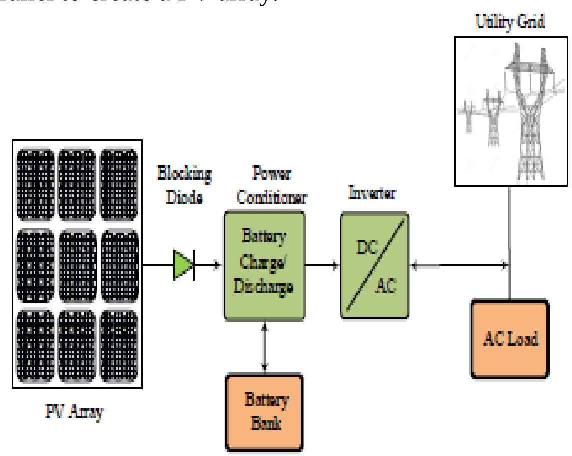

Figure 2 Block diagram of basic PV

An array is a collection of photovoltaic modules connected electrically and installed in the same plane to generate enough electricity to run a certain device or set of devices. The power output of arrays may be anything from a few hundred watts to several hundred kilowatts. Similar to how individual cells in a module are connected, so too are modules in an array. Connecting modules in series raises the voltage while connecting them in parallel boosts the current. Matching is crucial to the array's overall efficiency, therefore it's worth stressing again. Figure 1.3 illustrates the basic layout of an array, with four parallel connections of four module strings linked in series.[3] [4].

2. Methodology

Grid-coupled photovoltaic systems that include energy storage are seen in Fig. 4.1. With a high enough output voltage, a DC-DC converter can integrate a low-voltage PV system into the distribution grid. Because of this, a quadratic boost converter is used in conjunction with a PV system to achieve a high con version ratio while maintaining high efficiency throughout a broad voltage range.

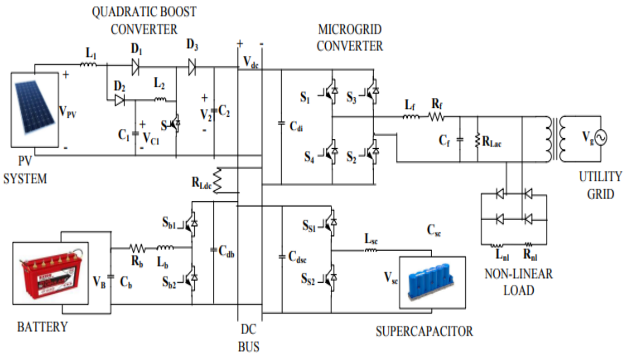

Figure 3 Suggested power management arrangement for grid-connected system

The bidirectional boost DC-DC converter (BDDC) is used to regulate power flow between the grid and the ESSs, while supercapacitors and batteries are used for energy storage. A voltage source converter (VSC) connects the DC microgrid to the AC utility grid; this device may function as an inverter or a rectifier, respectively. At the VSC's output, the LC filter is employed to reduce the AC side voltages and currents. In order to test how well the suggested method works under varying circumstances of use, this system includes both linear and nonlinear loads.

1. Quadratic Boost Converter

A single-switch quadratic boost converter is shown in Fig. 4.2, where E represents the input voltage, VC2 represents the output voltage, and S represents the switching frequency. For a three-terminal network to emerge, this model requires pairs of active and passive switches. The quadratic boost converter with a single switch consists of an active switch and three passive switches, however this analytical approach may be extended to include both types of switches. Therefore, voltage sources replace diodes D1 and D3, while current sources replace diodes D2 and transistor switch S.

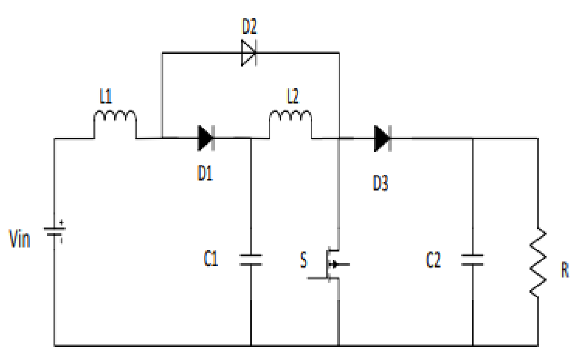

Figure 4 Quadratic Boost Converter

Mode 1: It is considered that switch S operates perfectly and that C1 and C2 are of sufficiently great magnitude that the voltage across C1 and C2 remains practically constant across the switching time. Switch S to forward bias D2, and you'll see that D1 and D3 are now reverse biased. Vin and C1 are the current sources for both L1 and L2. Below, in Fig. 4.3, is the circuit of a quadratic boost converter operating in mode 1.

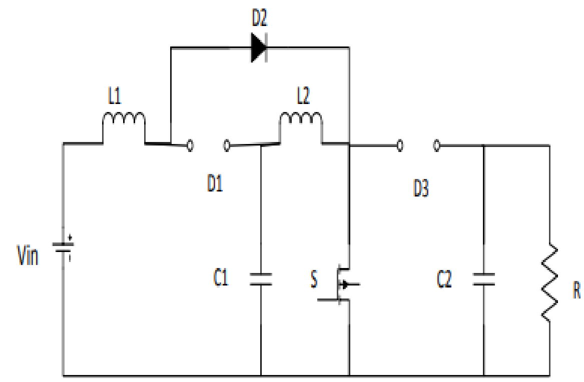

Figure 5 Circuit Diagram for Mode 1 Operation of Quadratic Boost Converter

Mode 2: Under these circumstances, diodes D1 and D3 are forward-biased, whereas diode D2 is reverse-biased. Each of the two accumulators, C1 and C2, is being charged by load level 1, L1. Both iL1 and iL2 are at their lowest during this phase. The circuit of a quadratic boost converter in mode 2 is shown in Fig. 4.4.

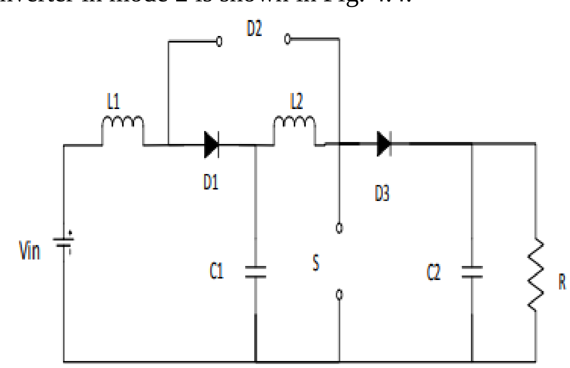

Figure 6 Circuit operation for Mode 2 of Quadratic Boost converter

3. Simulation Results and Discussion

The architecture of the grid coupled PV system with storage devices is presented in Fig. 7 To get the required DC link voltage, the output voltage of DC-DC converter should be sufficiently high for the integration of a low-voltage PV system with the distribution system. The AC utility grid is linked to the DC micro-grid via a voltage source converter (VSC), which can operate as an inverter or a rectifier according to the mode of operation. The LC

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filter is used at the output of VSC to smooth the voltages and currents at the AC side.

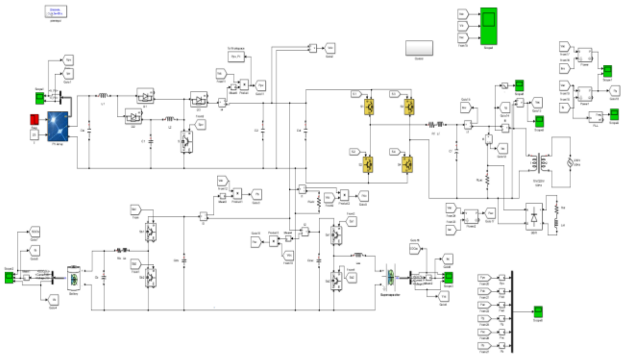

Figure 7 Modeling of proposed test system

In this system, both linear and nonlinear loads are connected to check the performance of the proposed scheme under different operating conditions. The PV power generation is varied at t=2 s by changing the irradiance of the system from 1000 W/m2 to 700 W/m2. The reduction in PV generation at 2 s is noticeable. Irrespective of the change in PV power, the DC bus voltage regains its constant voltage value at 100V.

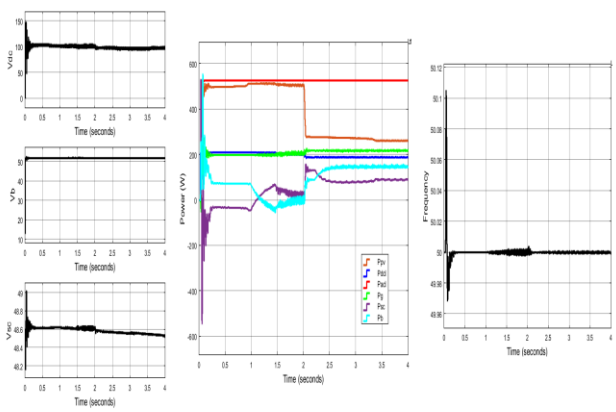

Figure 8 Vdc, Vb, Vsc, powers of all modules PV, DC load, AC load, Grid, SC, battery

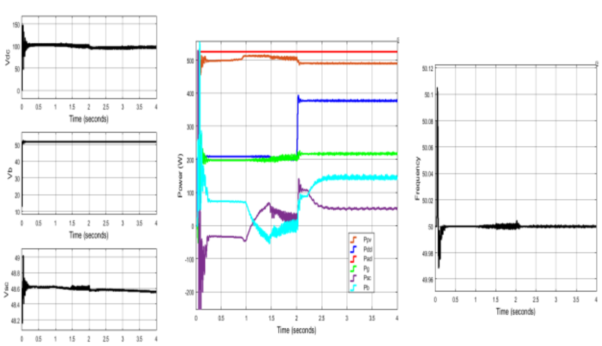

Figure 9 Vdc, Vb, Vsc, powers of all modules PV, DC load, AC load, Grid, SC, battery and frequency of grid during DC load power variation at 2sec.

The proposed controller is updated with P&O MPPT replacing the conventional current PI controller for maximum power extraction.

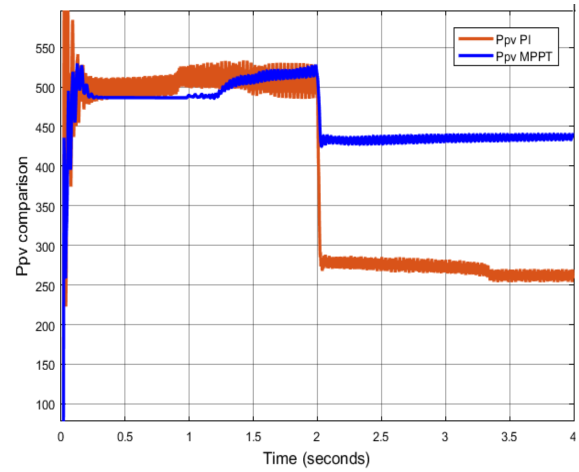

Figure 10 PV power comparison with PI and MPPT controllers

As it can be seen that the power from PV extracted during drop in irradiation is higher when operated with MPPT control.

4. Conclusion

The objectives of the proposed scheme, e.g., faster DC volt- age regulation, voltage and frequency regulation, maintenance of power quality issues, and limiting the SOC of storage systems within their limits, are justified through simulation results. The potency of the discussed control technique is conveyed by comparing the power quality features like settling time, overshoot/undershoot, and THD with other different methods

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