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COORDINATION CONTROL OF MICROGRID USING SLIDING MODE CONTROLLER

T.Geetha [1*], S. Chitra[2]

[1]PG Scholar, Department of EEE, Government College of Technology, Coimbatore, TN, India
[2] Associate Professor, Department of EEE, Government College of Technology, Coimbatore, TN, India
**Corresponding author E-Mail ID: geethudhanya13@gmail.com, Mobile: +91 7708256300.*

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ABSTRACT

Traditional power generation and consumption are undergoing major transformation. One of the tendencies is to integrate microgrid into the distribution network with high penetration of renewable energy resources. A synchronous generator and a PV farm supply power to the system's AC and DC sides, respectively. A DC/DC boost converter with a maximum power point tracking (MPPT) function is implemented to maximize the energy generation from the PV farm. In the existing system a model predictive power and voltage control (MPPVC) method is developed for the AC/DC interlinking converter this has a drawback in smooth grid synchronization. But in the proposed system a sliding mode controller is used to link the AC bus with the DC bus while regulating the system voltage and frequency and it ensures smooth power transfer between the DC and AC sub grids. Meanwhile, smooth grid synchronization and connection can be achieved. Proposed constant frequency sliding mode control retains the advantages of good dynamic response as in hysteresis control, better reference tracking switching frequency and less sensitivity to parameter variations and non liner loads. From the Simulation results it is verified that the proposed topology is coordinated for power management in both AC and DC sides under critical loads with high efficiency, reliability, and robustness under both grid-connected and islanding modes.

Keywords— permanent magnet synchronous generator (PMSG), sliding mode controller (SMC), Renewable Energy Sources (RES), Power Quality (PQ), Pulse Width Modulation (PWM)

1. INTRODUCTION

Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth. The sun and wind energy are the alternative energy sources. Previously, they were used to supply local loads in remote areas, outside the national grid. Later, they have become some of main sources.

Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power quality (PQ) issues. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network. With the advancement in power electronics and digital control technology, the DG systems can now be actively controlled to enhance the system operation with improved PQ at PCC. However, the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may deteriorate the quality of power. The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters (APF) are extensively used to compensate the load current harmonics and load unbalance at distribution level. This results in an additional hardware cost. However, in this paper authors have incorporated the features of APF in the, conventional inverter interfacing renewable with the grid, without any additional hardware cost.

2. BLOCK DIAGRAM

The microgrid offers decentralized operation and control which helps to reduce the transmission burden on power utility systems. The block diagram of Coordination Control of Microgrid using Sliding Mode Controller is shown in Figure.1.The AC voltage obtained from the solar and wind are combined and Stored in battery. The excess power is then sent to the inverter for conversion (DC). The output of the inverter is taken as feedback and given to the sliding mode controller. This controller reduces the harmonics and to stabilize the voltage between AC and DC sub grids. The output is supplied to the grid and load .

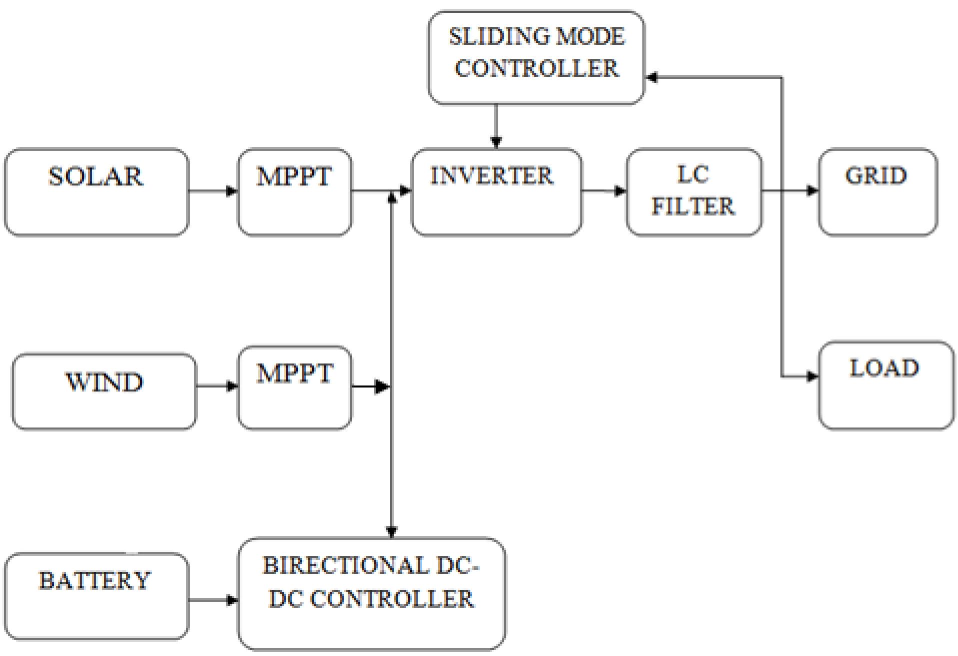


Fig.1 Block Diagram Of Coordination Control Of Microgrid Using Sliding Mode Controller

Hybrid power system improves the quality and availability of power. Hybrid power generation system also leads to reduction in required generating capacity of basic individual system such as solar and wind energy system as total load is shared. The boost converter combined with the MPPT block is capable of effectively extracting maximum power from the given solar data and thus better control is obtained. The generated power from the renewable energy sources is generally fluctuating in nature due to the environmental and seasonal changes.

In case of wind energy conversion system; apart from variable load there is a wind variation at the input also. Therefore, under such conditions bidirectional active and reactive power control is required to maintain the voltage and frequency.

When the PWM signal is given to the IGBT's gate terminal, the inverter is either switched ON or OFF depending on the width of the pulse. When the converter is ON, the diode which is connected with it and is reverse biased. Since the circuit is now open, the inductor is charged and the maximum rate of change of output voltage is limited or in other words controlled. The ripples in the voltage are reduced by the capacitor which acts as a filter. On the other hand, if the converter is in OFF position, the diode is forward biased, therefore, a path is established for the current to be discharged by the inductor. Also the capacitor now forces the PV output voltage to follow the reference voltage in order to work at the maximum power point. This also enables the PV voltage to effectively track the reference even under varying irradiance and temperature. Since the output obtained from the PV resource is DC, it needs to be converted into three phase AC such that it can be facilitated to tie up with the utility grid. Therefore, an inverter is necessary and also a crucial part of the system. The battery is capable of storing a huge amount of energy according to the defined capacity and can release the same when necessary. in the microgrid the intermittent resources like wind and solar energy need an energy storage system to produce best results with enhanced power quality. The equation 2.1 expresses the turbine power output,

$$P_{WT} = (1/2)\rho C_p \qquad \textbf{(2.1)}$$

Here ρ is the air density (kg/m3);

A is the rotor swept area (m2);

Cp is the power coefficient (based on the angle of attack and tip speed ratio);

V is the wind velocity (m/s).

The state of charge at the moment t can be obtained using the equation (2.2),

$$SOC(t)=SOC(t-1)+((N_{wind}P_{wind}(t)+N_{PV}P_{PV}(t)-P_{load})/(V_b) \qquad \textbf{(2.2)}$$

where $P(t)$ is the electric power demand at time t (W),

Vb is the battery voltage (V),

Nwind is the number of wind turbines,

Npv is the number of PV panels in the array.

A battery management system ensures that the state of charge (SOC) of the EV is monitored continuously and depending upon the input power from the PV array the battery charges or discharges accordingly. For this purpose a detailed description of the battery model is mandatory. In this work a Nickel Metal Hydride (Ni-MH) battery is used. The components of the Ni-MH battery are harmless to the environment and the batteries can be recycled. Once the battery reaches the full charge the voltage decreases slowly depending on the amplitude of current. The Battery Management system has to be efficient in order to estimate the state-of-charge and enable V2G or G2V transactions of power depending upon the solar irradiation.

$$\left.\begin{matrix}Charging\ time\ of\\ a\ battery\end{matrix}\right\} = \left[Battery\ (\text{Ah})/Charging\ Current\right]$$

Control of microgrids with various distributed generations (DGs) and loads has always been challenging. Unlike the conventional power plant, the renewable power generation does not provide continual electricity output. Take the solar PV for example, usually maximum solar irradiation occurs at midday while the demand is not high for residential loads. On the other hand, the peak demand occurs at evening when there is no generation from PV systems. With high level penetration of renewable energy, the usual peak production time and peak consumption time do not coincide. This characteristic will affect the system stability and degrade the overall system performance.

3. SLIDING MODE CONTROLLER

Sliding Mode Control is a typical non linear control technique that modifies the system performance by continuous switching of the controlled variable according to the current status of the known system state and thereby causes the trajectory to move on a pre defined sliding surface. This control signal, forces the system to reach, and then subsequently remain on, a predefined surface (called the sliding surface). The dynamical behavior of the system, when confined to the surface is called sliding mode. The beauty of this SMC is model parameters need not to be exactly known only their bounds is needed to be known and controlled system is insensitive to the parameter variation of the system hence it is highly robust.

The Sliding mode design involves two major tasks:

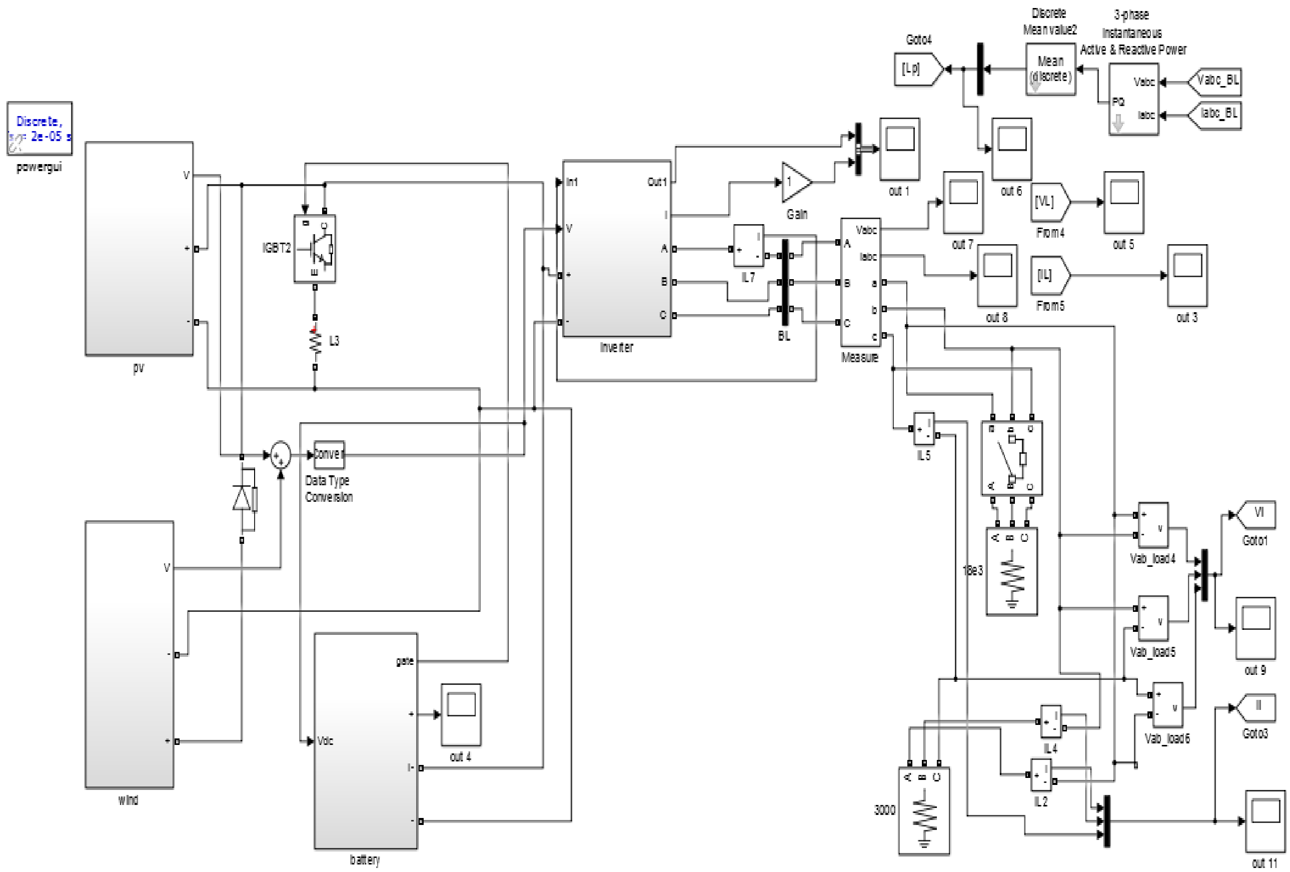
(i) The selection of a stable sliding surface in state space on which the state trajectory must ultimately lie in.

(ii) Designing a suitable control law that makes this sliding surface attractive for the state trajectory to reach it in finite time.

Sliding mode control thus can be broadly divided into two phases, the Reaching Phase and the Sliding Phase. The reaching phase the trajectory reaches the sliding mode and in the sliding phase the trajectory stays on the sliding mode for all further time.

4. SIMULATION DESCRIPTION

The simulation module of the proposed system is shown in Figure.2. It consists of solar, wind, battery, inverter, LC filter, load and grid. For a hybrid ac/dc microgrid, the common dc-bus voltage and ac-bus voltage must be well maintained within a limited variation. This requires advanced control strategies. To be specifically, the main tasks to be fulfilled in this work can be described as follows. At the local level, the power converters as the electronic interfaces between the energy resources and the common voltage buses should be controlled properly to inject power into the microgrid system. This will be achieved essentially by controlling the voltages and currents of the power converters. At the system level, the power within the microgrid with various generation and loads should be balanced so that stable operation of the system can be achieved. With this goal, an EMS on top will be designed, based on which the operation modes of each power converter will be determined in a coordinated manner. In light of these, this work aims to fill the above technical gaps. A coordinated control strategy is developed to control the distributed power converters in microgrid applications. It aims to ensure stable operation with high voltage quality under different operation modes and various generation and consumption conditions.



5. RESULT AND DISCUSSION

The figure.3 shows the output AC voltage waveform after the LC filter using sliding mode controller. This controller is to stabilize the voltage between AC and DC sub grids. Thus the harmonics are reduced in the proposed system.

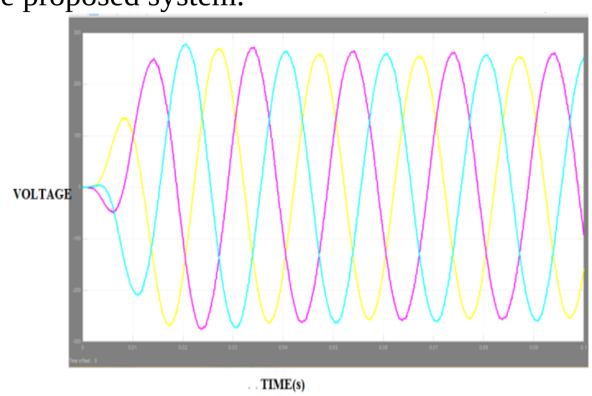


Fig 3: Proposed System Voltage Waveform

The figure.4 shows the output AC voltage waveform after the LC filter using pi controller. Thus the harmonics are more in the existing system. The voltage is not stabilized .

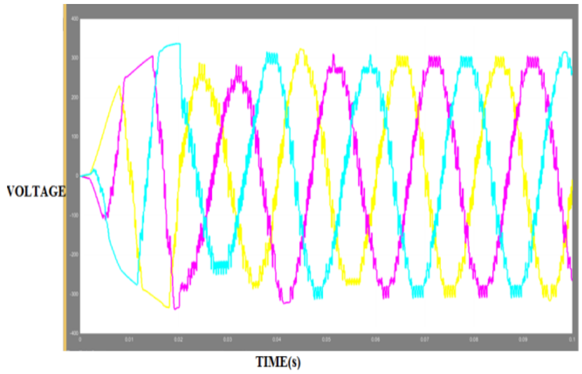


Fig 4: Existing System Voltage Waveform

The figure.5 shows the wind power output using MPPT.

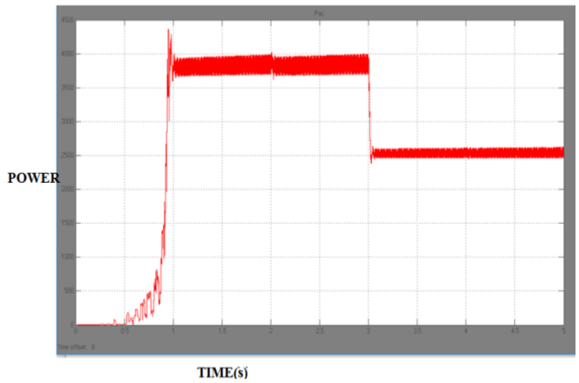


Fig 5: wind output Waveform

The figure.6 shows the solar power output using MPPT.

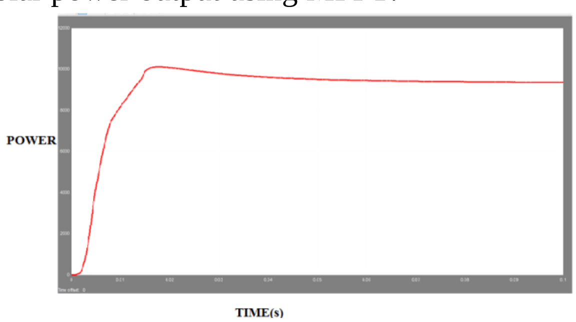


Fig 6: solar power Waveform

The figure.7 shows the battery power output.

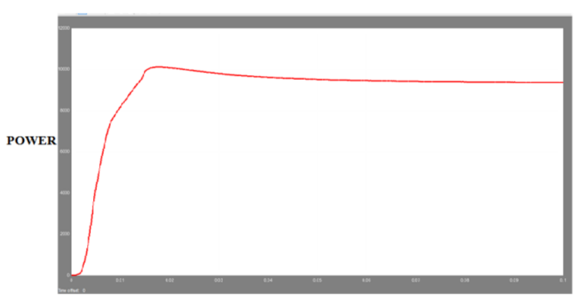


Fig 7: Battery power Waveform

6. CONCLUSION

In this paper, coordination control of microgrid using sliding mode controller is proposed for a hybrid AC/DC microgrid operated in grid-connected mode. The microgrid has a PV, wind and a battery that supply energy to its DC and AC side. Battery banks are connected to the DC bus through bi-directional DC/DC converter. The AC side and DC side are linked by the bi-directional AC/DC inverter. The proposed design is capable of supplying continuous power to loads, and ensures the evacuation of surplus PV and wind power into the grid. Thus the smooth grid synchronization and stable operation under variable power generation and consumption conditions. From the simulation results show that the proposed microgrid with the SMC controller can greatly increase the system stability and robustness.

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Conflict of Interest

None of the authors have any conflicts of interest to declare.

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