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A NOVEL POWER MANAGEMENT TECHNIQUE FOR BI-DIRECTIONAL INVERTER INTEGRATED WITH BUCK-BOOST CONVERTER

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ABSTRACT

A single-phase bi-directional inverter with two buck/boost maximum power point trackers (MPPTs) for dc-distribution applications. In a dc-distribution system, a bi-directional inverter is essential to control the power flow between dc bus and ac grid, and to regulate the dc bus to a certain range of voltages. Since the photovoltaic (PV) array voltage can vary from 0 to 600 V, especially with thin-film PV panels, the MPPT topology is formed with buck and boost converters to operate at the dc-bus voltage around 120 V, reducing the voltage stress of its followed inverter. In the proposed system battery back-up can be employed for PV for better stabilization. The system can be tested with the help of MATLAB software using Simulink.

Keywords— Maximum Power Point Trackers (MPPT), BUCK/BOOST converter, Bi-directional inverter.

I. INTRODUCTION

Power electronics is the field of electrical engineering related to the use of semiconductor devices to convert power from the form available from a source to that required by a load. The load may be AC or DC, single-phase or three-phase, and may or may not need isolation from the power source. The power source can be a DC source or an AC source (single-phase or three-phase with line frequency of 50 or 60 Hz), an electric battery, a solar panel, an electric generator or a commercial power supply. A power converter takes the power provided by the source and converts it to the form required by the load. The power converter can be an AC-DC converter, a DC-DC converter, a DC-AC inverter or an AC-AC converter depending on the application.

There are some renewable energy resources that have attracted the researches over many years [1]-[3] such as photovoltaic, wind, tidal and geothermal energy. Many transformerless inverter topologies were proposed [5]-[7] to avoid leakage ground current running through PV arrays and ground. Recently a conventional two-stage configuration is usually adopted in the PV inverter systems [4].

Renewable energy sources are becoming increasingly important recently with focus turning towards clean electricity generation. In particular, photovoltaic (PV) or solar power systems are one of the most promising and attractive renewable energy sources due to their low operational and maintenance costs, pollution free power generation, long life cycles, and noise free operation. Prior to installation, performance and efficiency of solar power conditioning systems have to be evaluated. Moreover, experimental validation and verification of solar power conditioning systems under a wide range of different environmental and load conditions have to be done.

Solar or PV cells are used to directly convert sunlight into dc power. PV cells exhibit nonlinear output current-voltage characteristic. This current-voltage curve is characterized with a unique maximum power point (MPP) and depends on environmental conditions (solar irradiance, cell temperature, wind speed, etc…) and PV cell fabrication material. Accordingly, a maximum power point tracking (MPPT) algorithm is required in solar power conditioning systems in order to maximize the generated output power.

In addition battery backup is also employed for PV array for better stabilization. So in this project it is proposed a MPPT based power management system for parallel connected PV arrays by integrating buck-boost dc-dc converter with single phase inverter. Recently a new control strategy of limiting the dc-link voltage fluctuation was developed [8] for a back-to-back pulsewidth modulation converter in a doubly fed induction generator (DFIG) for wind turbine systems.

For dc-microgrid applications, the grid connection and rectification has to be fulfilled by the bidirectional inverter to regulate the dc bus to a certain range of

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voltages. There is some wide inductance variation during the operation of the inverter. This will be normalized by designing controller and selecting key components to make inverter normal operation. This approach was proposed by Tsai-Fu Wu [9].

Recently a dc-bus voltage control with a three-phase bidirectional inverter was proposed [10] which includes one line-cycle regulation approach (OLCRA) and one-sixth line-cycle regulation approach (OSLCRA) which take into account dc-bus capacitance and control dc-bus voltage to track a linear relationship between the dc-bus voltage and inverter inductor current. There is a detailed operation analysis, controller design, and realization of a high-power bidirectional quasi-Z-source inverter (BQ-ZSI) for electric vehicle applications was proposed recently [11]. A dedicated voltage controller with feed-forward compensation was designed to reject the disturbance and stabilize the dc-link voltage during a non-shoot-through state. Recently a hybrid electric vehicle (HEV) based on a bidirectional z-source nine-switch inverter [12] was proposed to allow bidirectional power flow.

A bidirectional buck-boost cascade inverter was proposed by Honglin Zhou [13]. This proposed inverter has the features like bidirectional operation with bipolar buck-boost output voltage, reduced output distortion, reduced size and weight with only one main energy storage component, decoupled linear controller design and a good steady-state with dynamic performance including wide operation range, strong robustness to load and input voltage variations, fast dynamic response, and good overload protection.

A circuit configuration, a circuit topological family, a buck-mode active clamped circuit, and an instantaneous output voltage feedback control strategy of combined bidirectional buck–boost dc–dc chopper-mode inverter with high-frequency (HF) link (HFL) were proposed [14] recently. The circuit configuration is composed of two identical isolated bidirectional buck-boost dc-dc choppers with the same input and output filters.

The dc capacitors voltage unbalancing is the main technical drawback of a diode-clamped multilevelinverter (DCMLI), with more than three levels. A voltage-balancing circuit based on buck-boost chopper connected to the dc link of DCMLI is a reliable and robust solution to this problem. A recent study was presented [15] with four different schemes for controlling the chopper circuit to achieve the capacitor voltages equalisation. These can be broadly categorised as single-pulse, multi-pulse and hysteresis band current control schemes.

II. SOLAR POWER

The solar cell is the basic unit of a PV system. An individual solar cell produces direct current and power typically between 1 and 2 W, hardly enough to power most applications. Solar Cell or Photovoltaic (PV) cell is a device that is made up of semiconductor materials such as silicon, gallium arsenide and cadmium telluride, etc. that converts sunlight directly into electricity. The voltage of a solar cell does not depend strongly on the solar irradiance but depends primarily on the cell temperature. PV modules can be designed to operate at different voltages by connecting solar cells in series. When solar cells absorb sunlight, free electrons and holes are created at positive/negative junctions. If the positive and negative junctions of solar cell are connected to DC electrical equipment, current is delivered to operate the electrical equipment.

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III. MPPT ALGORITHM

The nonlinear current-voltage characteristic of PV cells is characterized with a unique MPP, which is highly dependent on weather and load conditions. An MPPT algorithm is an analog or digital based technique allows the PV cell to operate at the MPP at any given environmental conditions. MPPT controllers or algorithms are integrated with solar power conditioning systems to maximize the output power extracted from PV generator. Various MPPT techniques have been proposed including, perturbation and observation (P&O), incremental conductance, fractional open-circuit voltage, fractional short-circuit current, fuzzy logic controller, neural network, ripple correlation control, and dc link capacitor droop control.

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The perturbation and observation method is the most commonly implemented technique among other algorithms although oscillations around the MPP can occur. In this technique, the controller adjusts the output voltage of the PV cell based on its instantaneous output power. The incremental conductance algorithm uses the slope of the power-voltage curve of the PV cell to determine the voltage reference. The derivative of the cell output power with respect to the cell output voltage at the MPP is zero. This method requires more computations relative to the P&O but may reach the MPP faster.

MPPT or Maximum Power Point Tracking is an algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. The voltage at which PV module can produce maximum power is called 'maximum power point' (or peak power voltage).Maximum power varies with solar radiation, ambient temperature and solar cell temperature. The MPPT system is shown in Fig. 1

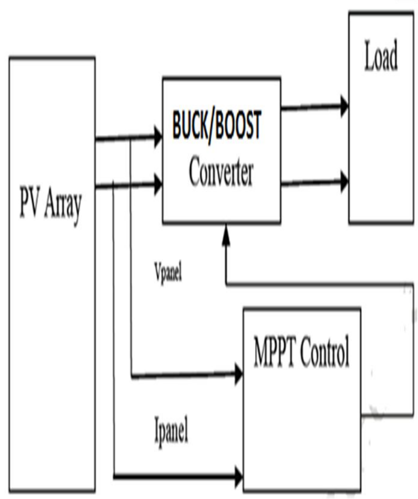

Fig. 1 MPPT system

The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the boost converter which steps up the voltage to required magnitude. The main aim will be to track the maximum power point of the photovoltaic module so that the maximum possible power can be extracted from the photovoltaic module. The incremental conductance algorithms utilized for MPPT to increase the efficiency of the system. The MPPT configuration check is shown in Fig. 2.

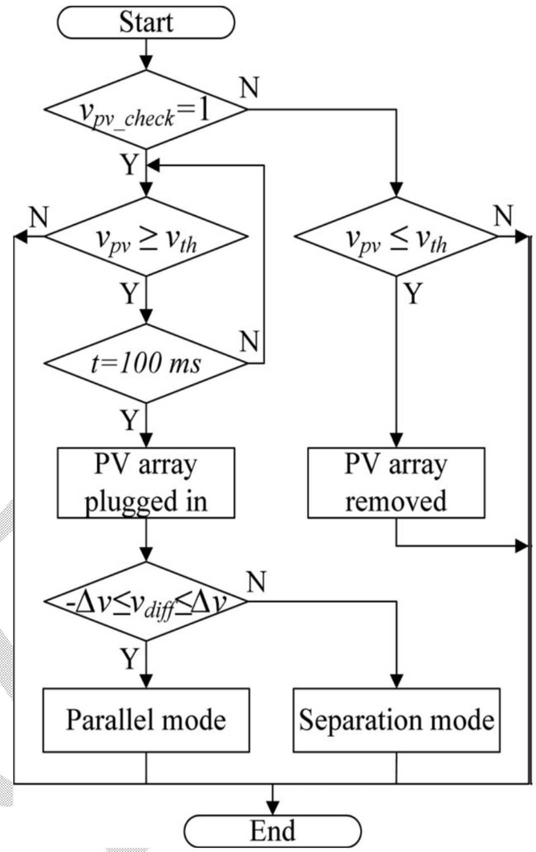

Fig. 2 Flowchart of online MPPT configuration check

IV. P & O METHOD

The MPPT controller tracks the maximum output power of a PV array based on the perturbation and observation tracking method. At the beginning, the controller will determine the operation mode of the proposed MPPT. When the MPPT is operated in boost mode, inductor current iLm is equal to output current iPV of the PV array; thus, the output power of the PV array can be expressed as follows:

$$PPV\ boost(n) = vPV(n) \times iLm(n)$$

On the other hand, when the proposed MPPT is operated in buck mode, inductor current iLm is equal to output current io ; thus, the output power of the PV array can be expressed as follows:

$$PPV\ buck(n) = vdc(n) \times iLm(n)$$

With this control algorithm, the controller tracks the peak power by increasing or decreasing the duty ratio periodically. In this studied PV inverter system, there is a shared auxiliary power supply for the MPPTs and the inverter. Because the switching frequencies of the MPPT (25 kHz) and the inverter (20

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kHz) are different, their switching noises might affect the accuracy of voltage and current sampling, especially under high-power condition. To avoid noise interference, the MPPTs are synchronized with the inverter, and the controller will update the duty ratio of the MPPT power stage every ten line cycles at the zero crossing of the line voltage. Additionally, since the single-phase PV inverter system has a twice line-frequency ripple voltage on the dc bus, this synchronization approach can also eliminate the ripple voltage effect and determine accurate output power of the PV arrays. When the output power of the PV arrays can be determined accurately, the proposed controller can track the maximum power point precisely.

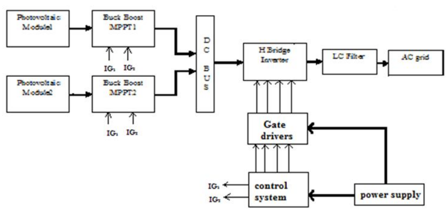

Fig. 3 Functional block diagram of proposed system

Here the solar cell is represented by a block named 'Photovoltaic cell'. The MPPT and gating signal generator are shown in a single unit called 'MPPT with Gating Signal'

During boost operation, a LC-circuit with high quality factor (Q-factor) is employed to amplify the dc input voltage to required high voltage level. Here, a MOSFET power switch is employed to make and break a high current pulse through the inductance. When current is made to flow through inductance, energy is stored in inductance and when this current is cut the stored energy in inductance is transferred to capacitance, which results in a high voltage across capacitor and this high voltage is filtered and fed to dc-bus. During buck operation, the high dc voltage is chopped by using a MOSFET power switch in series with a source and then the resultant pulsating dc is filtered and fed to dc-bus. A bidirectional inverter is also interfaced to dc bus which is used for energy transfer from dc bus to ac grid and vice versa. When the dc power is excess, the inverter is used to convert excess dc power to ac power and inject to grid, and when there is efficiency in dc power the inverter is used to convert ac power to dc power and supply to dc bus. Pulse generators are employed to produce switching pulses and pwm. The Simulation is done with the help of MATLAB Software using Simulink. The Voltage Measurement block measures the instantaneous voltage between two electric nodes. The output provides a Simulink signal that can be used by other Simulink blocks. The output of the system can be viewed through the scope.

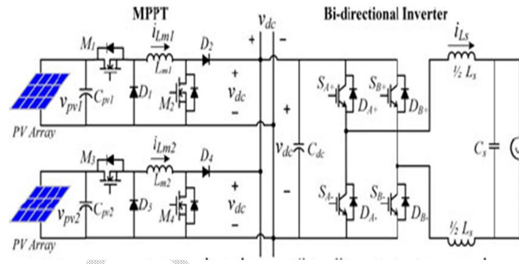

Fig. 4 Circuit Diagram for Proposed System

V. CIRCUIT DESCRIPTION

When the PV voltage is greater than the DC bus output voltage the MPPT will operate as a buck converter. During this buck mode M1 is on and the current flow is from M1 to Lm so the inductor is continuously charging here and the inductor current will increase.When M1 is turned off then the inductor will discharge and the current will flow through the diode D1 and D2. During this buck mode iLm=ipv. When the PV voltage is lesser than output dc voltage then MPPT will operate as a boost converter.Now M1 and M2 gets turn ON. Now the current flow is from M1-Lm-M2.So the inductor Lm continuously gets charging. When M2 gets off then the inductor Lm will start to discharge and the current flows through the diode D2.During this boost mode iLm=Io

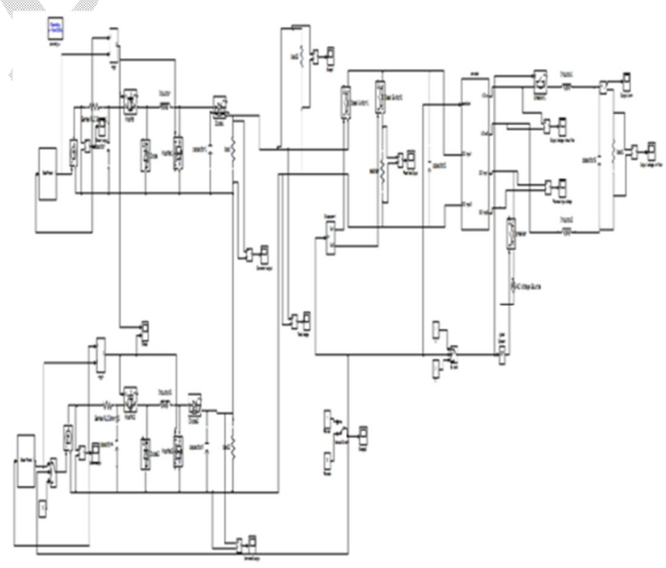

Fig. 5 Simulation Circuit

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VI. SIMULATION RESULTS

The Simulation results for this work are shown in the following figures.

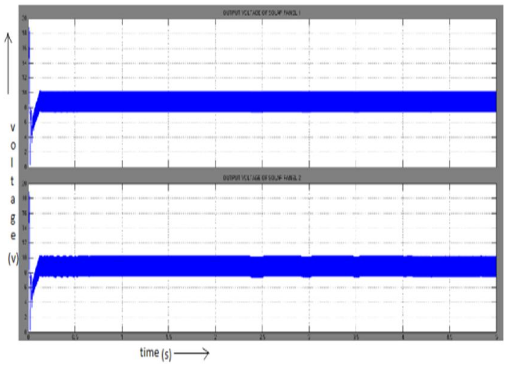

Fig. 6 Output Voltages from Solar Panel 1&2

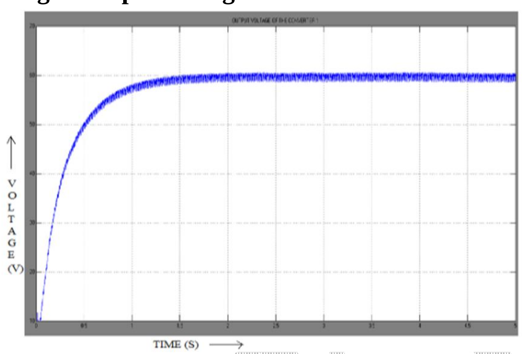

Fig. 7 Output Voltage of Converter 1

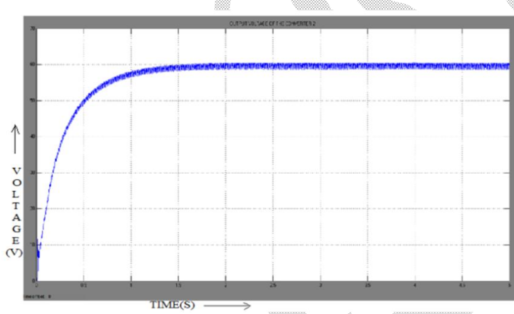

Fig. 8 Output Voltage Of Converter 2

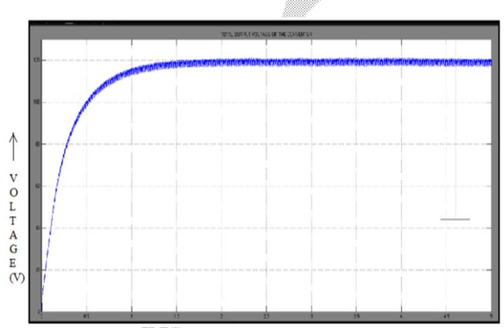

Fig. 9 Total Output Voltage of the Converter

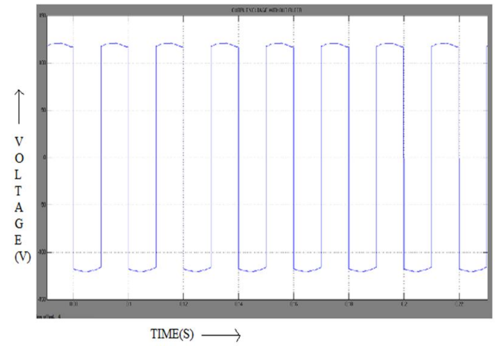

Fig. 10 AC Output Voltage without Filter

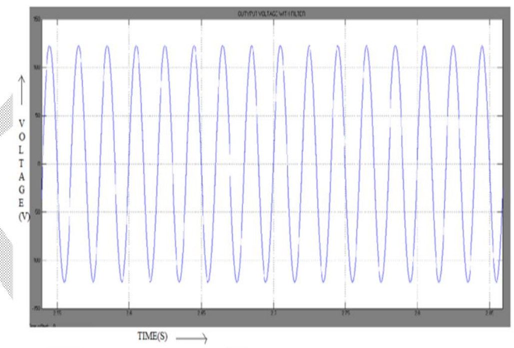

Fig. 11 AC Output Voltage with Filter

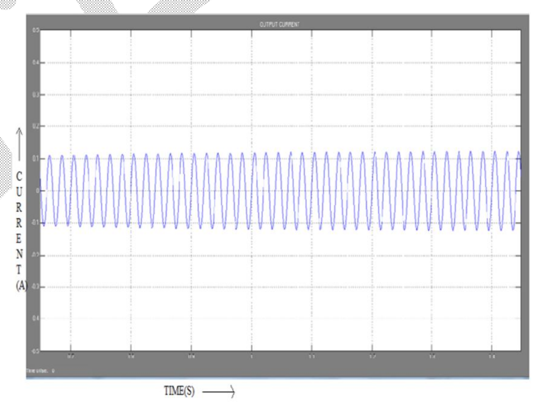

Fig.12 Ac Output Current

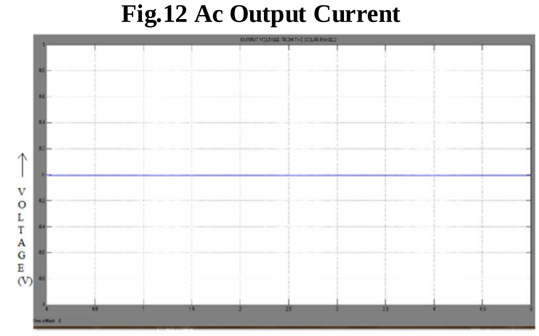

Fig. 13 Output Voltages from the Panel2 at the Time of Fault

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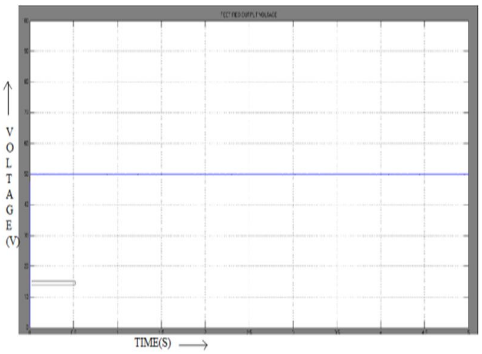

Fig. 14 Rectified Voltages at the Time of Fault

VII. CONCLUSIONS

A single-phase bidirectional inverter with two buck/boost MPPTs has been designed and implemented. The inverter controls the power flow between dc bus and ac grid, and regulates the dc bus to a certain range of voltages. A droop regulation mechanism according to the inductor current levels has been proposed to balance the power flow and accommodate load variation. Integration and operation of the overall inverter system contributes to dc-distribution applications significantly. The simulation is done with the help of MATLAB software.

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