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OPTIMIZING POWER OUTPUT IN GRID-CONNECTED PV SYSTEMS: NOVEL CONTROL APPROACH FOR TWO PV ARRAYS IN MISMATCHED ENVIRONMENTAL CONDITIONS

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ABSTRACT: This article covers a transformer-less photovoltaic (PV) inverter that is connected to the grid via a single phase and does not have a transformer. It can function in either buck or boost mode, drawing the most power from two serially connected subarrays at the same time, regardless of weather conditions. The inverter's flexibility to work in both buck and boost modes greatly decreases the number of solar PV modules that must be linked in series to produce a subarray. Each subarray's power output rises in response to a certain set of environmental parameters. The inverter's structure and control approach are specifically designed to eliminate the presence of high frequency components in the common mode voltage. This ensures a constant leakage current from the PV arrays. Furthermore, it performs effectively and efficiently throughout its operational range. A mathematical model is built as a result of the full system analysis. Extensive modeling studies are carried out to ensure the plan's practicality. To test the concept's viability, a 1.5 kW lab prototype is built and subjected to a series of experiments. Connectivity to the grid, single phase, no transformer, boost and buck solar inverters, maximum power point, bad weather, and modules connected in series.

Keywords: PV modules, PV inverter, boost, sub array, PV arrays

1.INTRODUCTION

The primary goal of a photovoltaic (PV) system is to guarantee that individual PV modules within an array function optimally in the face of varying external circumstances caused by fluctuations in operating temperature and/or insolation. Misaligned PV module working conditions result in a significant loss in power generation. Mismatched environmental conditions (MEC) are aggravated by connecting a high number of modules in series on a PV array.

To attain the desired amplitude of the inverter's input dc link voltage in a grid-connected transformer-less PV system, a larger number of series-linked modules are required. As a result, MEC has a substantial impact on the power output of grid-connected transformer-less (GCT) PV systems, such as single phase GCT (SPGCT) inverter-based systems developed from Hbridge and neutral point clamp (NPC) inverters.

The literature describes several techniques to resolving the difficulty created by MEC in a PV system. A thorough analysis of various methodologies has been offered. Power extraction during MEC can be increased by using a sophisticated MPP tracking (MPPT) algorithm to monitor the PV array's global maximum power point (MPP) or by connecting the PV modules correctly. These strategies, however, are useless when used with low-power SPGCT PV systems. Similarly, altering the electrical connections of PV modules inside a PV array is considered unsuccessful for SPGCT PV systems because to the significant increase in component count and operational complexity.

An effort has been made to regulate individual PV modules within a PV array by implementing power electronic equalization (PEE) or connecting a dc to dc converter. The goal is to get the most power out of each PV module while managing MEC. The installation of power electronic equalization techniques necessitates a large number of components, increasing operating complexity and costs.

The proposal describes a method for regulating power variations between PV modules at their respective MPPs using a generation control circuit (GCC), which is the only device used for this purpose. In addition to shunt current compensation for each module, the technique proposed here uses series voltage compensation for each PV string in a PV array to boost power production during MEC. Using module integrated converters, each PV module's scheme includes a separate DC-to-DC converter. However, because of the large number of components and converter stages used in these systems, their efficiency is low, and they face the same restrictions as the power electronic equalization base system. Instead of ensuring that each module works properly under MPP, a string is created by successively connecting a set number of modules. The strings are then adjusted to run www.jespublication.com using MPP. However, neither the total number of components nor the complexity of the control system have been greatly reduced. Strategies that divide each PV module into two subarrays and then configure each subarray to operate at its own maximum power point (MPP) streamline control configurations while reducing the number of components.

Despite this, the claimed total efficacy of both techniques is poor. The SPGCT PV inverter can extract more power during MEC thanks to its surge and buck stages. The intermediate boost stage reduces the number of series-connected PV modules required for a PV array. The operational efficiency of the offered schemes is greatly enhanced by incorporating high frequency switches into the inverter stage and/or dc to dc converter stage, resulting in a significant reduction in the number of passive elements. Furthermore, the stated efficacy increases by 1-2 percent when compared to previous results.

To determine the optimal power evacuation from the subarrays during MEC, this article divides the PV modules into two serially connected subarrays and uses a buck and boost inverter to manage each subarray.

In comparison to the indicated approaches, partitioning an input PV array into two subarrays reduces the number of series-connected modules in each subarray significantly. The control mechanism and topological design of the proposed inverter ensure that the leakage current linked to the PV arrays remains below acceptable limits. Furthermore, the voltage stress across the active devices is virtually halved when compared to the supplied systems, allowing for extremely high frequency operation while minimizing switching loss.

The size of the passive components decreases as the frequency of operation increases. The proposed design delivers a high level of operational effectiveness. The planned project has a measured peak efficiency of 97.65% and a European efficiency of 97.02%.

2.PHOTOVOLTAIC INVERTER

The essential block diagram of a grid-connected solar power generation system is shown in Figure. 2.1. The key components of the PV power generation system are listed below: 1. A photovoltaic (PV) unit is made up of numerous PV cells that use the photovoltaic effect to convert light energy directly into direct current (DC). An inverter converts a photovoltaic system's DC output to alternating current (AC) power. 3. Grid: The inverter's output power is routed to the local electrical grid for power generating. To optimize the use of the electricity generated by the PV modules, the power conversion apparatus must include a maximum power point tracking (MPPT) device. An MPPT is a system that continuously monitors the voltage at which the most power is utilized.

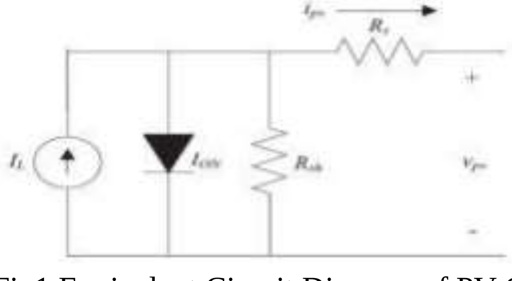


Fig1.Equivalent Circuit Diagram of PV Cell

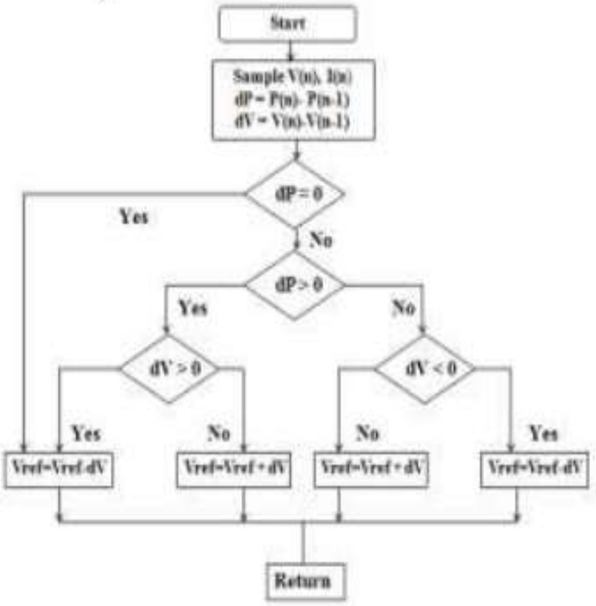
$$i_{pv} = I_L - I_s[\exp[\alpha(v_{pv} + R_s i_{pv})] - 1] - \frac{v_{pv} + R_s i_{pv}}{R_{sh}}$$

MPPT:(MaximumPowerPointTracking)

The use of maximum power point monitoring, or MPPT, is one method for optimizing energy output across all normal operational scenarios. The installation of MPPT saves energy costs by improving system efficiency. The difficulty raised by MPPT techniques is the automatic determination of the voltage or current () at which a solar array works at its maximum power point under certain temperature and irradiation circumstances. The MPPT can be implemented using a variety of approaches. While some approaches only respond to temperature variations, the great majority of solutions are responsive to both irradiance and temperature fluctuations.

Pertur band Observe algorithm

At this time, the perturb and observe MPPT approach is the most common in PV systems. Before beginning with this procedure, the system is subjected to a minor perturbation. If the output power increases, the system will get a perturbation in the same direction; if the output power falls, the system will receive a perturbation in the opposite direction. The Perturb and Observe algorithm works by varying the array terminal voltage on a periodic basis and then comparing the PV output power to the value recorded in the previous perturbation cycle. If the operating point of the PV array does not change in line with the operating voltage and power, the control system adjusts it in the other direction. The technique remains unaltered over the next perturbation cycle. Flow chat 2.1 illustrates the algorithm's rationale. The array terminal voltage varies with each MPPT cycle, which is a recurring disadvantage of the perturb and observe technique. As a result, power loss occurs in the PV system when the output power oscillates near the maximum power point, which is attained.



FlowChart1:PerturbandObserve

3.DC-DCCONVERTERBASICS

A DC-to-DC converter is a type of electrical power converter that generates a DC yield voltage after detecting a DC input voltage. An electrical circuit or electromechanical apparatus is used to control the voltage of a direct current (DC) source. Extremely low (small batteries) and extremely high (high-voltage power transmission) power levels are reported. Typically, the supplied yield has a different voltage level than the information. In addition to these applications, DC-to-DC converters are used to reduce noise and regulate force transfer. The following is a summary of several common topologies seen in DC-to-DC converters.

3.1Boost Converter

Figure 3.6 shows the schematic for the basic boost converter. When the needed output voltage exceeds the input voltage, this circuit is used.

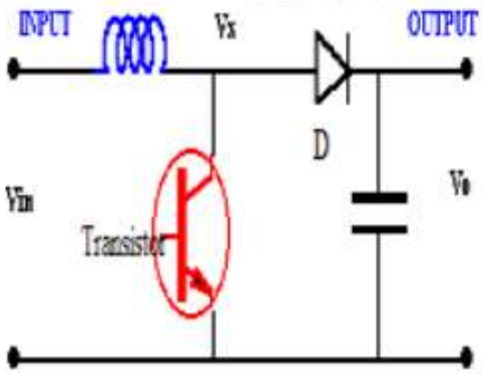
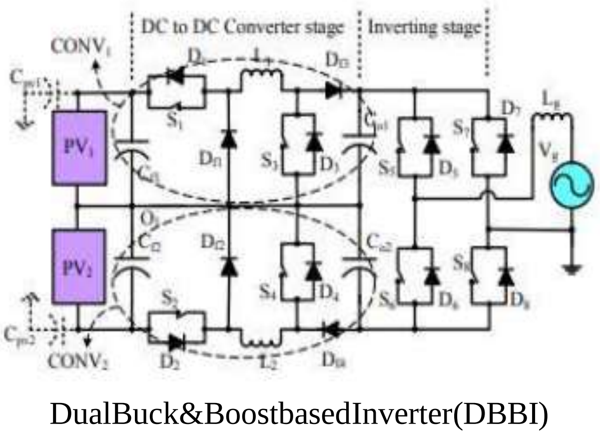


Fig BoostConverterCircuit

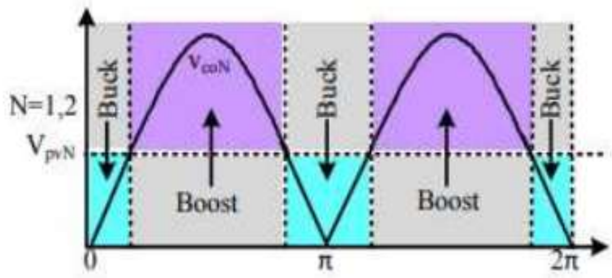
The inductor current passing through the diode determines the value of Vx = Vin when the transistor is ON and Vx = Vo when it is OFF. Continuous conduction (CC) refers to the assumption that the inductor current flows continuously for the purposes of this study. As shown in Figure 3.7, the average voltage across the inductor must be zero in order for the average current to stay continuous.

4. PROPOSED INVERTER AND ITS CONTROL

Fig. 2 depicts the proposed Dual Buck & Boost Based Inverter (DBBI) circuit, which includes a dc-dc converter stage and a rectifying stage. The dc-to-dc converter stage is made up of two segments, CONV1 and CONV2, which deliver power to the solar PV array's P V1 and P V2 subarrays, respectively. Sequence CONV1 consists of self-commutating switches S1 and D1, S3 and D3, free-wheeling diodes Df1 and Df3, filter inductors and capacitors L1, Cf1, and Co1, and antiparallel body diodes D1 and D3, respectively. Similarly, the CONV2 section has the following components: free-wheeling diodes Df2, Df4, filter inductors and capacitors L2, Cf2, and Co2, self-commutating switches S2, and an anti-parallel body diode, D2. The inverting stage is made up of self-commutated switches (S5, S6, S7, and S8) and their matching body diodes. Lg, the filter inductor, serves as the link between the grid and the inverter stage. Cpv1 and Cpv2 capacitors simulate the parasitic capacitance that flows from the solar array to ground.

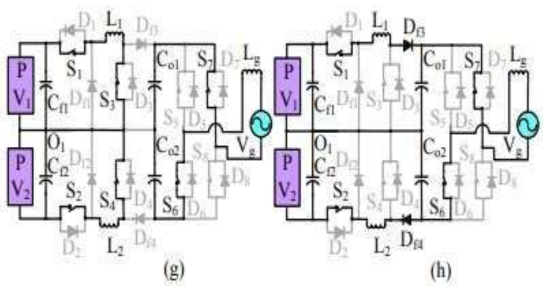


DualBuck&BoostbasedInverter(DBBI)



Buck stage and Boost stage of the proposed inverter

Considering Figure. 2. When Vpv2 exceeds vco2, CONV2 functions in buck mode. Conversely, when Vpv1 >= vco1, CONV1 operates in buck mode. Vpv1 and Vpv2 represent the MPP voltages of P V1 and P V2, while Vco1 and Vco2 indicate the output voltages of CONV1 and CONV2, respectively. S1 and S2 remain constant to ensure sinusoidal grid current (ig) throughout the switches' buck mode duty ratios. CONV1 runs in boost mode when Vpv1 is less than vco1, and CONV2 when Vpv2 is more than vco2. While S1 and S2 stay active during the boost mode, S3 and S4 are modulated sinusoidally to ensure sinusoidal IG. The sinusoidal switching pulses of the CONV1 and CONV2 switches are coordinated with the grid voltage, vg, to achieve unity power factor functioning. Throughout the positive half cycle (PHC), the switches S5 and S8 stay lighted, whereas the switches S6 and S7 are always turned off. During the negative half cycle (NHC), the switches S6 and S7 stay lighted, while S5 and S8 are permanently disengaged. Figure depicts each step of operation for the proposed inverter. 2.1. In circumstances when the insolation level and ambient temperature of subarray P V1 differ from those of P V2, the MPP parameters



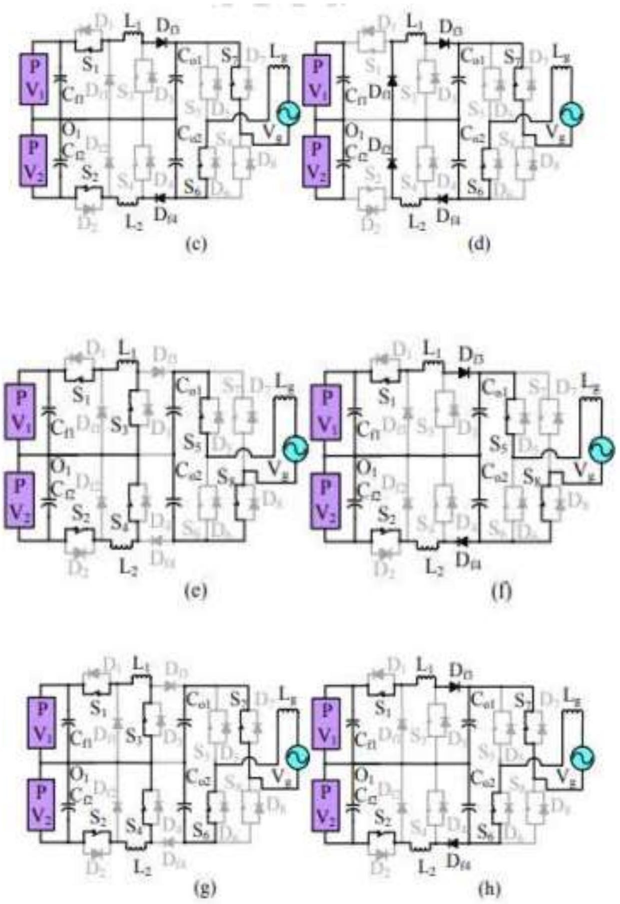


Figure 3 depicts the operational states of DBBI, which are (a) active and (b) freewheeling in the buck mode of PHC, (c) active and (d) freewheeling in the buck mode of PHC, (e) active and (f) freewheeling in the boost mode of PHC, and (g) active and (h) freewheeling in the boost mode of NHC. The power levels at MPP, designated as Ppv1 and Ppv2, which correspond to P V1 and P V2, are distinct. Assuming power processing stage losses are ignored and each subarray runs at its maximum power point (MPP), it is possible to conclude that the average power consumed by Co1 and Co2, Pco1 and Pco2, throughout a half-cycle is comparable to the power extracted from P V1 and P V2. As a result,

$$P_{co1}=P_{pv1} \& P_{co2}=P_{pv2} \quad (1)$$

Pg represents the average power provided into the grid during the period of a half cycle.

$$P_g=P_{pv1}+P_{pv2} \quad (2)$$

5. CONTROL STRATEGYOF THE PROPOSED SCHEME

Figure shows the control technique for the proposed method. 5. The controller is developed with the following goals in mind: i) ig is sinusoidal and in phase with vg throughout the operating range; ii) output voltage sensing eliminates the need for vco1 and vco2; and iii) both subarrays function simultaneously at their respective MPPs.

To compute Ppv1 and Ppv2, which are required for the estimation of Vco1m and Vco2m, two proportional integral (PI) controllers and two separate MPP trackers are used. Vco1m and Vco2m are calculated using equation (12), with Vm derived from the phase locked loop (PLL). The same PLL generates a rectified version of a unity sinusoidal function, denoted by R, from a synchronized unity sinusoidal function, X, and vg. By multiplying R by Vco1m and Vco2m, we may approximate vco1 and vco2.

As a result, the two voltage sensors required for identifying vco1 and vco2 are removed from the equation. CONV1's mode of operation (boost or buck mode) is identified by comparing Vpv1 and Vco1, whereas CONV2's mode of operation is determined by comparing Vpv2 and Vco2. By dividing the squared approximate RMS values of vco1 and vco2 by Ppv1 and Ppv2, the emulated effective resistances of the two component converters, Rpco1 and Rpco2, can be calculated. In the buck mode, the reference currents iL1ref of L1 and iL2ref of L2 are created by applying (28) to the following stages.

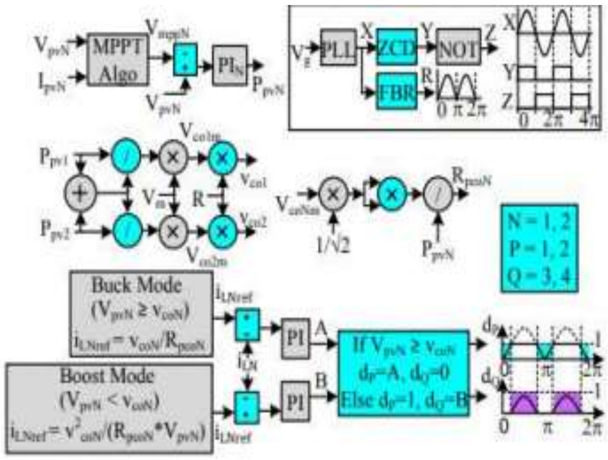


Fig. Control configuration of the proposed inverter

6.SIMULATION RESULTS

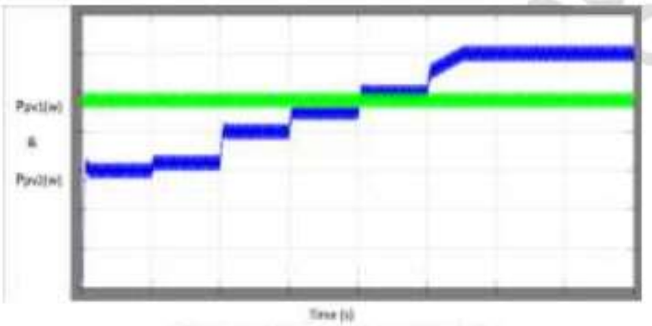


Fig. 6.a. Simulated Waveform: Variation in Ppv1 and Ppv2

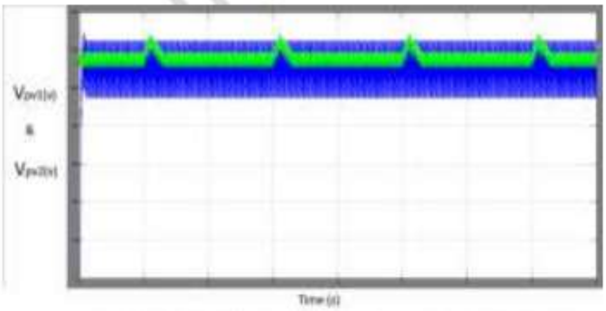


Fig. 6.b. Simulated Waveform: Variation in Vpv1 and Vpv2 during entire range of operation

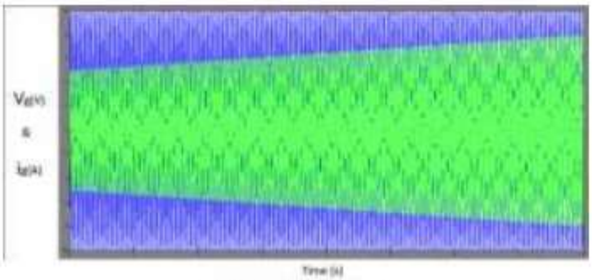


Fig. 7. Simulated Waveform: Vg and Ig

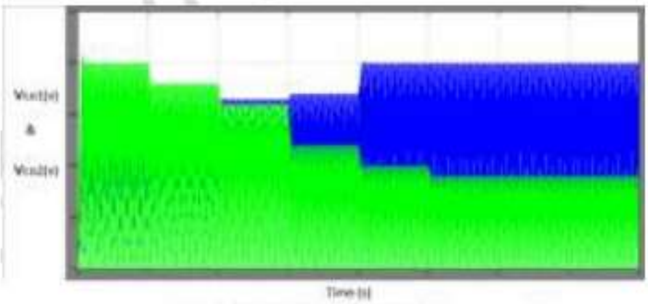


Fig. 9. Simulated Waveform: Vcs1 and Vcs2

7.CONCLUSION

This study proposes a transformerless buck and boost solar inverter connected to a single phase grid and capable of powering two subarrays at their respective MPPs. The inverter had several desirable characteristics, including managing adverse environmental conditions, achieving a high operating efficiency of ηeuro = 97.02%, enabling decoupled component converter control, ensuring MPP operation for the component converters through a straightforward MPPT algorithm, and ensuring leakage current associated with the PV arrays remained below the VDE 0126-1-1. A mathematical analysis of the proposed inverter resulted in the development of its small signal model. The selection process for the output filter's component parts was discussed. After undertaking extensive modeling study to evaluate the proposal, its practicality was confirmed by rigorous testing on a prototype inverter with a power output of 1.5 kW constructed expressly for that purpose.

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