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INVESTIGATION ON GSS BASED MPPT FOR PV APPLICATION

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ABSTRACT

In many photovoltaic (PV) energy conversion systems, nonisolated DC-DC converters with high voltage gain are desired.The PV exhibits a nonlinear power characteristicwhich greatly depends on the environmental conditions.Hence in order to drawmaximum available power various algorithms are used with PV voltage/current or both as an input for the maximum power point tracking (MPPT) controller. In this paper, golden section search (GSS) based MPPT control and its application with three-level DC-DC boost converter for MPPT are demonstrated. The nonlinear power characteristic of PV greatly depends on the environmental conditions. Hence in order to draw maximum available power, various algorithms are used with PV voltage/current or both as an input for the maximum power point tracking (MPPT) controller. Non-isolated DC-DC converters with high voltage gain are desired in all photovoltaic (PV) energy conversion systems. The three-level boost converter provides the high voltage transfer which enables the high power PV system to work with low size inductors with high efficiency. The balancing of the voltage across the two capacitors of the converter and MPPT is achieved using a simple duty cycle based voltage controller. Detailed simulation of three-level DC-DC converter topology with GSS algorithm is carried out in MATLAB/SIMULINK platform. The validation of the proposed system is done by the experiments carried out on hardware prototype of 100 W converter with low cost AT'mega328 controller as a core controller. The proposed system will suit as one of the solutions for PV based generation system and will show high performance, such as a conversion efficiency of up to 94%.

1. INTRODUCTION

The world's energy consumption is increasing by about 3.5% annually and is expected to rise further because of population growth and demanding modern lifestyles. The increased energy demand results in rapid depletion of conventional fossil fuels and adds to the existing consequences of the environmental pollution. Solar energy—for all practical purposes as a source of energy, is inexhaustible, absolutely free (in terms of its availability), quiet, and environmentally friendly. In order to reduce the overall cost of PV systems, therefore, these are utilized effectively with interface to the existing systems through DC-DC converters. The major challenge is to extract the power under varying operating conditions which influence the output voltage extraction of the maximum power from a solar cell turns out to be a vital consideration for optimal system design. Under fluctuation of climatic conditions, MPP changes and MPPT must adjust the converter duty cycle to track the new MPP. Therefore, the DC-DC converter must be chosen to be able to match the MPP under different atmospheric conditions. When the duty cycle changes as a result of changed climatic conditions, the boundary of the converter design parameters will change. Isolated converter structures with cascaded configuration enables to achieve high voltage gain. Three level boost converters have significant advantage as compared to conventional boost converter. The size of the inductor is reduced and switch voltage rating is half of the output voltage. This reduces the overall size and improves the efficiency in three-level DC-DC converters.The photovoltaic systems are major contributors in the electrical power.These are utilized effectivelywith interface to the existing systems through DC-DC converters. The major challenge is to extract the power under varying operating conditions which

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influence the output voltage [1, 2]. Isolated converter structures with cascaded configuration enables to achieve high voltage gain [3]. However, these are used up to several kW applications [4, 5]. The multilevel buck converters proposed are widely used in high frequency DC/DC power conversion [6, 7]. In the conventional boost converters, high voltage ratio is feasible without multistage cascading.The voltage ratios in these are limited by the parasitic elements and switching control used. Threelevel boost converters have significant advantage as compared to conventional boost converter. The size of the inductor is reduced and switch voltage rating is half of the output voltage. This reduces the overall size and improves the efficiency in three-level DC-DC converters. However, the voltage balancing across the DC bus capacitors is required due to nonidealities in the components. This is feasible by sensing the voltages across them with corrective feedback through controllers. The current sensing of inductor by dispensing the voltage measurements is feasible to balance the voltages

across the DC bus capacitors.

PV array in solar power conversion system operates at a point havingmaximumpower transfer. It is necessary to track this operating point by using the MPPT control algorithms to maximize the utilization efficiency. Various algorithms for MPPT are reported in the literature and used for the efficient energy conversion process. These methods are derivative basedandnoise sensitive. A computational easewith inherent robust MPPT using golden section search (GSS) based algorithmis proposed in this paper.This is having noise and signal fluctuation immunity with fast convergence as compared to many reported MPPT methods. This GSS based MPPT method is easy to implement on the low cost hardware

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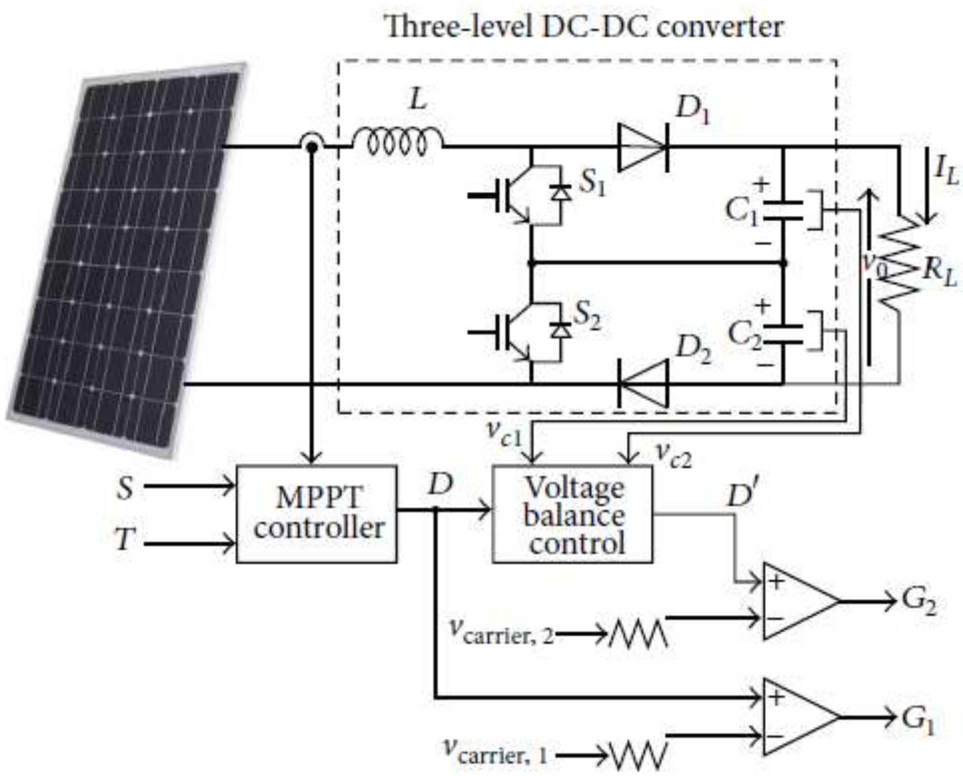

Figure 1: Proposed scheme with PV-fed three-level boost converter.

with single current sensor. The PV connected system with three-level converter using GSS based MPPT is presented in Figure 1. In this paper, GSSMPPT based three-level DC-DC boost converter for PV energy conversion system is presented. A simple duty cycle based pulse width modulation (PWM) and capacitor voltage controller are suggested.The switching and reverse recovery losses are less in the three-level boost converter. A hardware prototype of 100W converter is built and the control is made cost effective using AT'mega based low cost controller.The steady state and dynamic behavior of the system are presented. Both the simulation and hardware results are seen to have clear agreement with inherent robustness built using new MPPT algorithm.

2. THREE-LEVEL NONISOLATED DC-DC CONVERTER

To maintain DC bus voltage constant, in high power rating PV systems with high voltage gain requires boost converter with controller.Interfacing PV with boost converter having three-level with wider range of voltage level is preferred due to reduce input filter size and current ripple cancellation. Three-level boost converter have increased power density, efficiency, and reduction in cost as the switching device's voltage rating is half of the output voltage. As the capacitors $C1$ and $C2$ are equal, voltage of the center point is $Vo/2$. This alsoreduces the voltage stress across the switching devices in these converters.

2.1Operating Principle In three-level boost converter V$c1$, V$c2$are the voltage across the capacitors$C1$, $C2$, respectively.The switch $S1$ is upper switch and $S2$ islower switch and switching frequency is fs. In this converter,carrier signals Vcarrier,1 and

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Vcarrier,2 for PWM generation are triangular for both switches but those are in 180º phase shiftto each other.With these carrier signals both switches can beturning ON and OFF at the same time. Therefore, the converter operates in four distinct modes as shown in Figure 2.

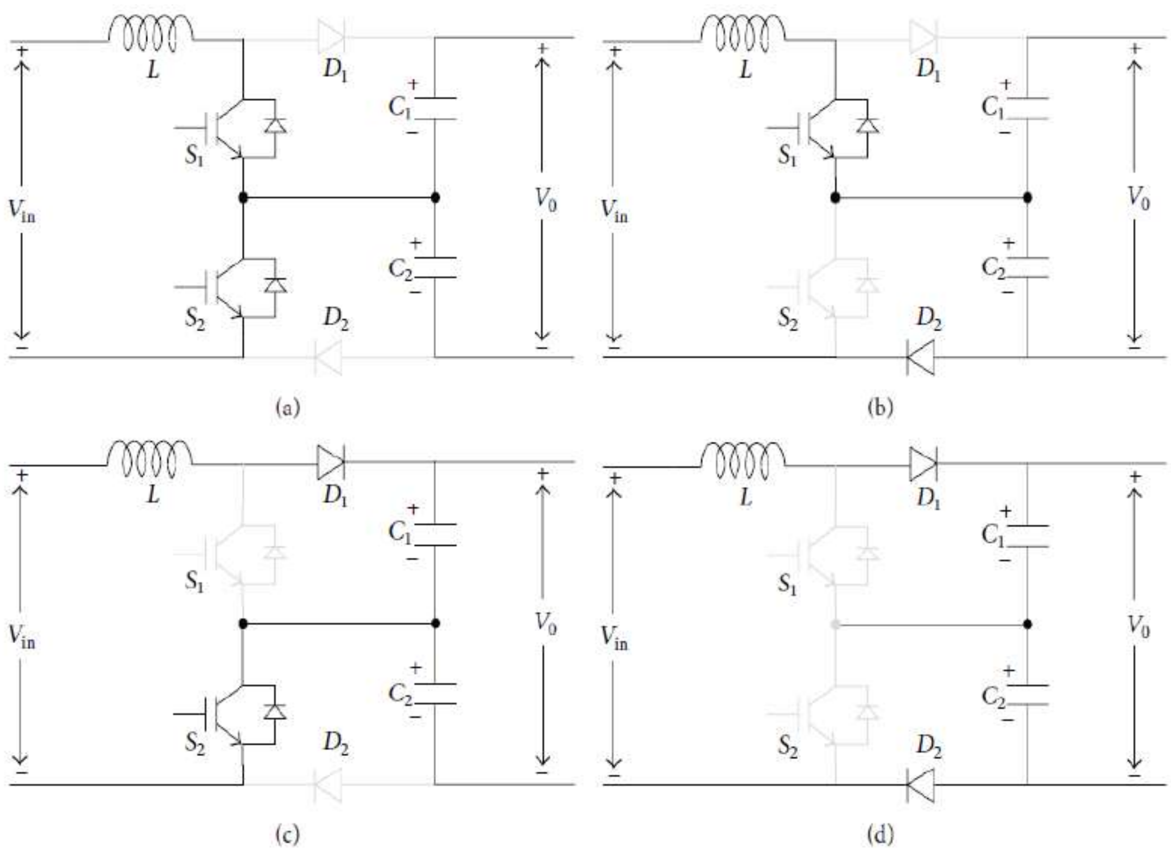

Figure.2 Operating modes of three-level DC-DC converter (1) Mode 1: both switches are turn ON as shown inFigure 2(a) and the voltage across inductor is (V..) =input voltage (Vin > 0).

In this mode the inductoris always in charging mode and charged capacitorssupply the current to the load. (2) Mode 2: in thismode ..1 isONand ..2 isOFF as shownin Figure 2(b) and voltage across the inductor is V..=Vin . V..2. In this mode inductor may be in chargingmode or discharging mode and charged capacitor ..1 supplies the current to the loadwhile ..2 is in chargingmode. (3) Mode 3: in this mode, ..1 is OFF and switch ..2 isON as shown in Figure 2(c) and voltage across the inductor is V..= Vin.V..1. In thismode inductormaybein charging mode or discharging mode and chargedcapacitor ..2 supplies the current to the load while ..1is in charging mode. (4) Mode 4: both switches are turned OFF as shown inFigure 2(d) and inductor voltage is V..= Vin . V..2< 0.Due to boosting operation V..1+ V..2> Vin, so inthis mode inductor always is in discharging modeand both capacitors are in charging mode and inputsupplies the current to the load. In modes 1 and 4 inductor is in charging mode anddischargingmode, respectively, but inmodes 2 and 3 inductorcurrents raising polarity depend on the voltages V..1 and V..2,depending upon the relation between Vin and half of the output

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voltage (V0/2); there exist two operating regions. (1) Region 1: Vin > V0/2 (2) Region 2: Vin < V0/2 In region 1, Vin > V0/2; hence V..= Vin . V0/2 > 0 soinductor current raising polarity is positive in modes 3 and 2as shown in Figure 3(a).Thiswill occur onlywhen duty ratiosof upper switch (..1) and of lower switch (..2) are less than0.5; in this region both switches must not be ON at the sametime. In region 2, ..1= ..2> 0.5; input voltage is Vin < V0/2;then, inductor current raising polarity is negative V..= Vin .V0/2 < 0 in modes 2 and 3 as shown in Figure 3(b). In thisregion both switches must not be OFF at the same time.

3. CURRENT RIPPLE AND EFFICIENCY

In boost converter,maximum inductor current ripple (Δimax) occurs when duty ratio (D) is 0.5; at this duty ratioVin = 0.5Vo. The inductor current ripple is given by

$$\Delta i_{\max} = \frac{v_{\text{in}}}{L} D T_s = \frac{V_0 T_s}{L}. \qquad (1)$$

In three-level boost converter, equivalent switching frequency is twice the switching frequency of conventional
boost converter. In region 1 maximum ripple occurs at Vin = 0.25Vo and is given by

$$\Delta i_{\max} = \frac{v_{\text{in}}}{L} D T_s \frac{1}{2} = \frac{V_0 T_s}{16L}. \qquad (2)$$

From (1) and (2), it is observed that the inductor current ripple is less for three-level boost converter for the same
inductor value and inductor value is four times less than conventional boost converter. The inductor loss due to the resistance is a major design parameter. The selection of the L/R ratio and switching devices losses are the major contributors in the efficient operation of the converter.

CONCLUSION

The three-level boost converter is used to interface the PV system for maximization of the power extraction. Various maximum power point tracking algorithms- P&O, InCond and Golden Section Search were compared in the simulation and found that GSS algorithm shows the better dynamic response with the faster convergence without any oscillations while tracking. So the hardware was implemented using GSS algorithm. The voltagebalancing of the DC bus is executed through the PI controller and performance is observed to be satisfactory.

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