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PV Based Hybrid Boost DC-DC Converter for Induction Motor Applications

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ABSTRACT

Due to the increasing need for the electrical energy and due to the depletion of conventional sources of energy along with the rising cost of those, renewable energy resources are getting more importance. When solar energy is considered, electricity production from it, is very eco-friendly and available in plenty in nature. The high cost of PV panels and its low efficiency limited its use earlier but with the increase in technology the efficiency of solar cells are also getting increased which encourages the use of PV system in present days In this paper a new Hybrid DC-DC converter with PV input is presented, this converter has high voltage gain where the input is 50V and the output is 600V. This converter is designed based on the topology of neutral clamped Inverter. This DC-DC converter mainly solves the problem of voltage mismatch between PV source and grid. This converter uses one inductor and two capacitors connected in series are the cause for obtaining High voltage gain. PWM method is used to ON and OFF the Power Electronic Switches of the converter. The output of the proposed DC-DC converter is inverted and then fed to Induction Motor Drive.

Index Terms- DC-DC converter, PV panels, voltage gain, PWM method, Hybrid DC-DC converter

I. INTRODUCTION

Demand for electrical energy has remarkably increased during the recent years with growing population and industrial progress. Since long time ago, fossil fuels have served as the major source of generating electrical energy, exceeding decline and also environmental consequences of these resources have made it necessary to benefit from new energy sources such as nuclear and renewable energies. On the other hand, generation, transmission and distribution of electrical energy in the current manner cannot meet energy supply requirements of consumers. Transmission line losses, adjustment of improper voltage, and low power quality are among the problems of electrical energy consumers in the conventional methods. Photovoltaic systems (PV) and fuel cells (FC) and wind turbines (WT) could act as suitable choices for alleviating the aforementioned problems regarding provision of the local electrical energy load for consumers, thanks to their low current expenditure and absence of transmission losses. Individual energy provision from these resources is not very cost-effective owing to low reliability (dependence of produced energy to different atmospheric conditions) and high initial costs. Due to the rising costs and limited amount of nonrenewable energy sources, there is an increasing demand for the utilization of renewable energy sources such as photovoltaic (PV) modules. Integrating the power from the PV module into the existing power distribution infrastructure can be achieved through power conditioning systems (PCS). The dc–dc conversion stage of the PCS requires a high efficiency, high boost ratio dc–dc converter

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to increase the low dc input voltage from the PV panel to a higher dc voltage. This voltage has to be higher than the peak output voltage of the dc–ac inverter, nominally in the 380–400V range. The double-stage design can also suppress ac line double frequency by utilizing the active ripple cancellation technique [1]. The high boost ratio dc–dc converter for such systems can be isolated or non isolated [1]; however, transformer-isolated converters tend to be less efficient and more expensive due to the increased manufacturing costs. A non isolated dc–dc converter with a high boost ratio would be advantageous for a two-stage PCS [1] because it can be easily integrated with current PV systems while reducing the cost and maintaining a high system efficiency. Due to the different output voltages from the PV panel, it would be beneficial to have a system with a high efficiency over the entire PV voltage range to maximize the useof the PV during different operating conditions.

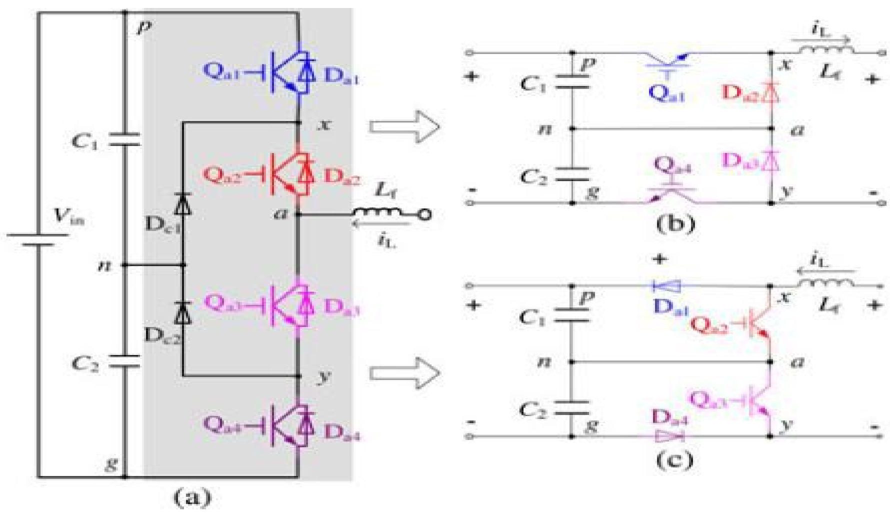

Fig.1 Single-phase diode-clamped three-level inverter and two classical three-level dc–dc converters

In grid-connected PV generation systems, a single- PV array can only supply lower dc voltage, but higher voltage level is demanded for the grid connected side [3]. Therefore, the mode of PV arrays in series has been adopted to offset the differential voltage levels between dc bus and grid side. Unfortunately, low-voltage PV arrays are always subjected to inevitable cloud, dust, shadow, and so on, which will limit the output current of the total PV arrays, and then the efficiency of the entire PV generation system will be degraded [4], [5]. Naturally, the other mode of PV arrays in parallel has also been proposed, and the power generation level can be improved by extending the parallel-connected PV arrays flexibly [6]. As to the parallel-connected PV configuration, one of the most important problems is that the low dc-bus voltage has to be boosted with high step-up gain. Therefore, high-step-up dc–dc converters are introduced to fulfill the voltage conversion between low-voltage parallel-connected PV arrays and the demanded high-voltage grid-connected side [7], as well as the maximum power point tracking (MPPT). When converters operate with high step-up gains, the power switches in conventional boost two-level converters would sustain high output voltage completely. While the classical boost three-level converters shown in Fig. 1(c) could reduce half of the voltage stress [8], but the extreme duty cycles of power switches limit its voltage gains and switching frequency because of the shorter turn-OFF time of the power switches in each switching period.

II. PHOTOVOLTAIC SYSTEM

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A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices.

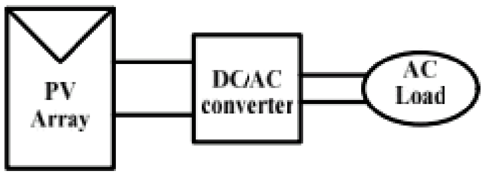

Fig.2. Block diagram representation of Photovoltaic system

This photovoltaic system consists of three main parts which are PV module, balance of system and load.

The major balance of system components in this systems are charger, battery and inverter. The Block

diagram of the PV system is shown in Fig.3. A. Photovoltaic cell A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates

charge carriers that originate an electric current if the cell is short circuited1

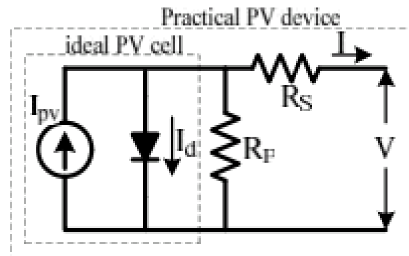

Fig.3. Practical PV device

The equivalent circuit of PV cell is shown in the fig.3. In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.4. The net cell current I is composed of the light generated current IPV and the diode current ID.

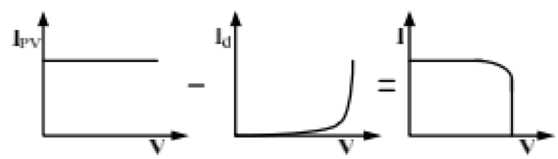

Fig.4. Characteristics I-V curve of the PV cell

III. ANALYSIS OF TOPOLOGY SYNTHESIS

The conventional single-phase diode-clamped threelevel inverter is shown in Fig. 1(a), and there are four power switches$Qa1 - Qa4$ with corresponding antiparallel diodes $Da1 - Da4$ .Based on this topology, two classical three-level dc–dc converters (buck and boost converters) are deduced, as shown in Fig. 1(b) and (c)

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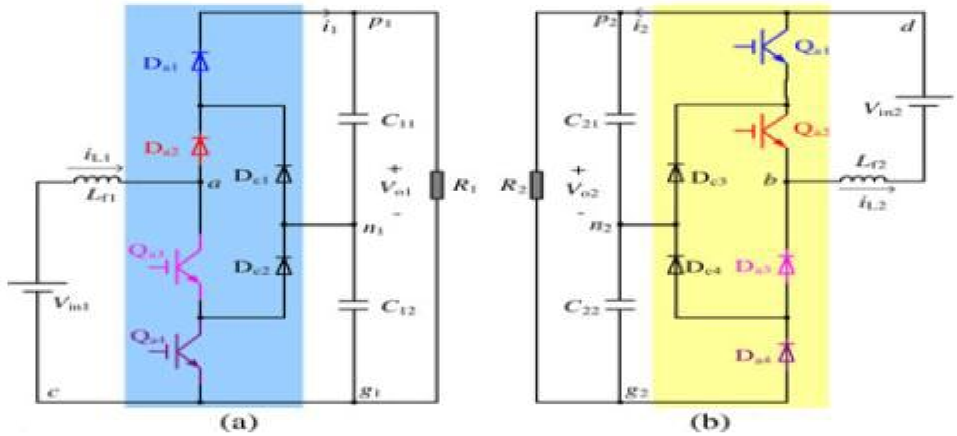

Fig.5 Two deduced boost three-level dc–dc converters

In fact, there are still two other boost three level converters shown in Fig. 5 which can also be deduced from the inverter in Fig. 1(a). However, these two boost three level converters cannot operate separately, due to the unbalanced capacitor voltages across (C_{11}, C_{12}) or (C_{21}, C_{22}). In order to not only improve the dc-bus voltage and power level of PV generation systems, but also obtain narrower pulse voltages from the difference between wider ones through the idea based on the topology of a single-phase diode-clamped inverter with two threelevel legs, a novel hybrid boost three- level converter can be synthesized by the two boost three-level Converters I and II in Fig. 5 naturally. V_{in1}, V_{in2} and L_{f1}, L_{f2} are the input dc voltages and filtering inductors of Converters I and II, respectively. Then, the input power level of the hybrid converter can be improved by means of two converters' input sides in series, namely (V_{in1} + V_{in2}), and the output power level of the hybrid converter can also be increased by the parallel connected outputs of Converters I and II, namely (i_1 + i_2) as shown in Fig. 5.

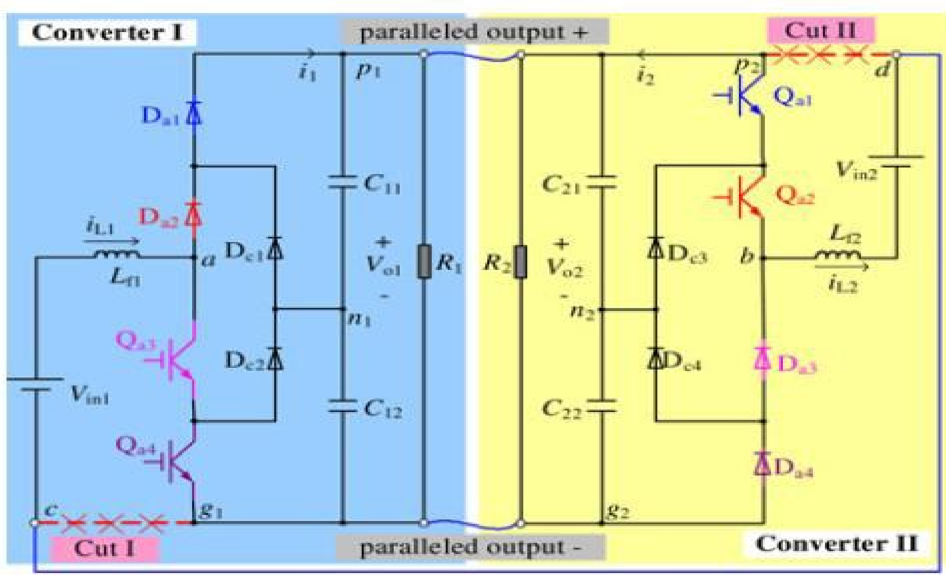

Fig. 6 Synthesized process of the hybrid boost three-level dc–dc converter by the mode of inputs in series and outputs in parallel

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Therefore, the synthesized process of the hybrid converter by the mode of inputs in series and outputs
in parallel is depicted in Fig.6. The input node *c* is cutoff from node *g*1 in Converter I, which is denoted "Cut I." In addition, the other input node *d* is also cutoff from node *p*2 in Converter II, which is shown as "Cut II." Then, the two input nodes *c* and *d* can be connected in series, namely both of the input dc voltage supplies *V*in1 and *V*in2 are in series. While the output structures of Converters I and II are identical, nodes *p*1 and *p*2, as well as *g*1 and *g*2 can be connected in parallel, leading to the "paralleled output +" and "paralleled output –" for the hybrid converter as shown in Fig. 6. The synthesized hybrid boost three-level converter is shown in Fig. 7, the equivalent input dc voltage *V*in and inductor *Lf* can be obtained linearly due to the input sides of Converters I and II in series. In addition, the parallel-connected capacitors (*C*11*, C*12) and (*C*21*, C*22) as shown in Fig. 6, can be equivalent to *Cf* 1and *Cf* 2 in Fig. 6, as well as the parallel-connected load resistors *R*1 and *R*2 which are equivalent to *RL* . However, the neutral points *n*1 and *n*2 in Fig. 3 have to be connected together, leading to the neutral point *n* that may keep the blocking voltages across power switches as the corresponding capacitors' voltages in Fig. 7. Therefore, the proposed hybrid converter, which is synthesized by Converters I and II in Fig. 4, comprises Half-Bridges I and II, as shown in Fig. 7

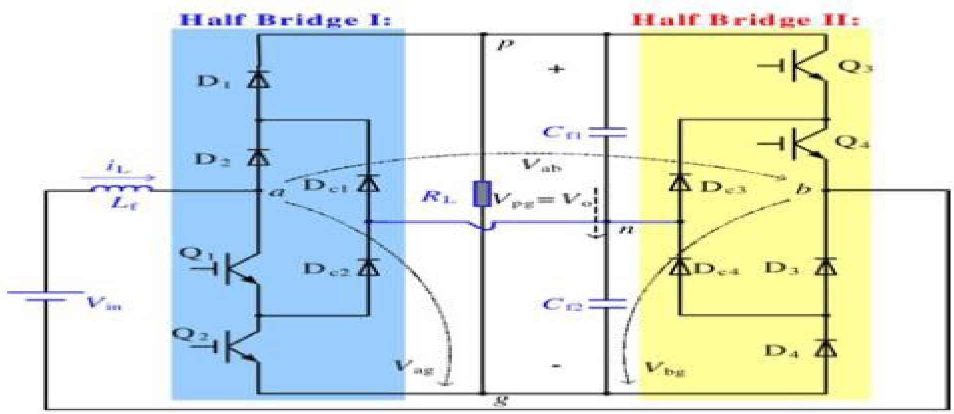

Fig.7 Proposed hybrid boost three-level dc–dc converter

A. Operation States of Topology

According to Fig. 7, the output pulse voltages of two half bridges are *Vag* and *Vbg* , and then the output pulse voltage *Vab* of the hybrid converter can be described as As a result, the output dc voltage *Vpg* = *Vo* can be obtained from *Vab* , filtering by capacitors *Cf* 1 and *Cf* 2 . The corresponding states of power components for instantaneous *Vab* of the hybrid converter are listed in Table I, and it is also assumed that the voltages across capacitors *Cf* 1 and *Cf* 2 are equal, namely *VCf* 1 = *VCf* 2 .When the power switches *Q*1− *Q*4 are turned OFF, the capacitors *Cf* 1 and *Cf* 2 in series are charged together by both the dc voltage source *V*in and the energy stored in *Lf* through diodes *D*1 − *D*4 . Then, the instantaneous *Vab* of the hybrid converter is *Vo* . While *Cf* 1 is charged by *V*in , as well as the energy stored in*Lf* through diodes*D*2*,D*1 , and *Dc*3 when only *Q*4 is turned ON. At the same time, *Cf* 2 is discharged for the load, and the instantaneous *Vab* is *Vo* /2, which is the voltage across *Cf* 1. In addition, the redundant state for the instantaneous *Vab* = *Vo* /2 is that *Cf* 2 is charged by *V*in and the energy stored in *Lf* through diodes *Dc*2*,D*4 , and *D*3 when only *Q*1 is turned ON. Meanwhile, *Cf* 1 is discharged for the load, and *Vab* is the voltage across *Cf* 2 . When the power switches *Q*1 and *Q*2 are turned ON, the energy is stored in *Lf* through diodes *D*4 and *D*3, while *Cf* 1 and *Cf* 2 are discharged together for the load. Then, the instantaneous *Vab* is zero. Moreover, the other two redundant

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states for *Vab* = 0 is that power switch pairs (*Q*1,*Q*4), or (*Q*3,*Q*4) are turned ON, respectively, the energy is stored in *Lf* by *V*in through the corresponding diodes, while *Cf* 1 and *Cf* 2 are discharged together for the load.

IV. SIMULATION RESULTS

The simulink model of hybrid boost dc-dc three level converter is shown below.

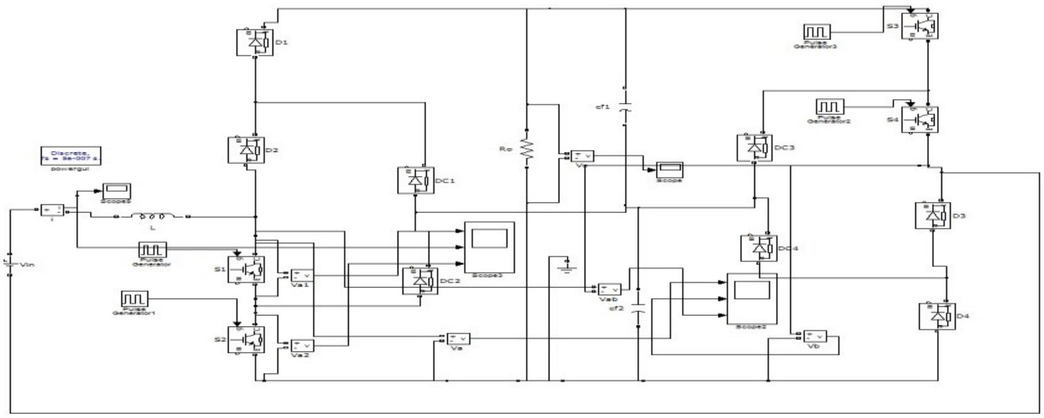

Fig.8 simulink model of hybrid boost dc-dc three level converter

Steady state output voltage of the proposed system is shown below.

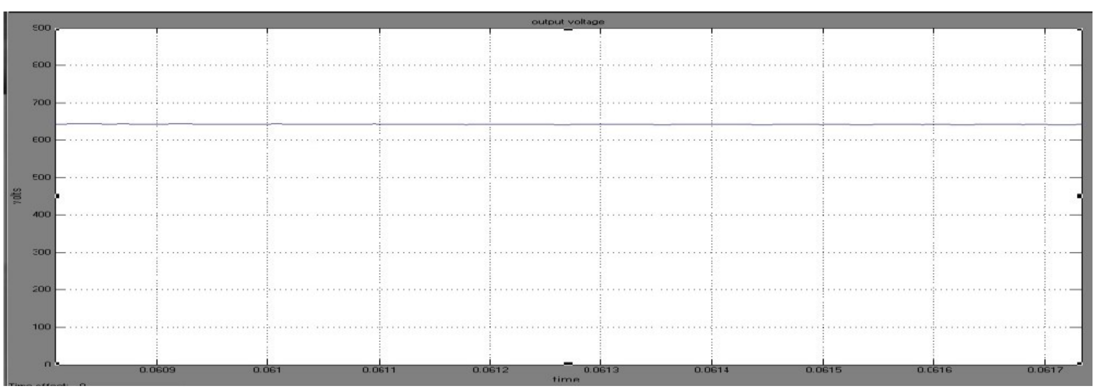

Fig 9 output voltage of the existing system

Blocking voltages of S1, S2 and inductor current is shown below

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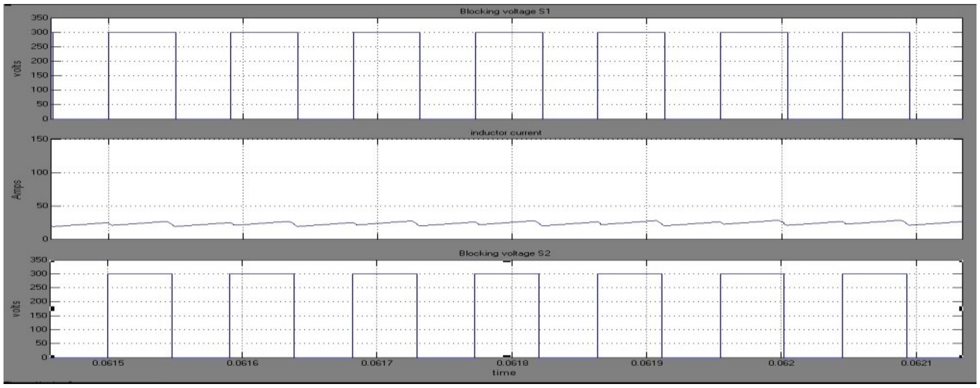

Fig 10 Blocking voltages across S1, S2, and the inductor current.

Output voltages of three level converter is shown below

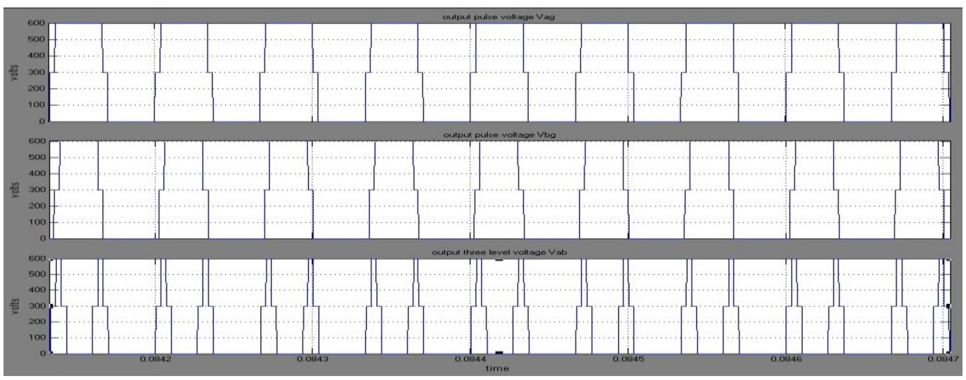

Fig11 output voltages of three level converters

Simulink model of extension system is shown below.

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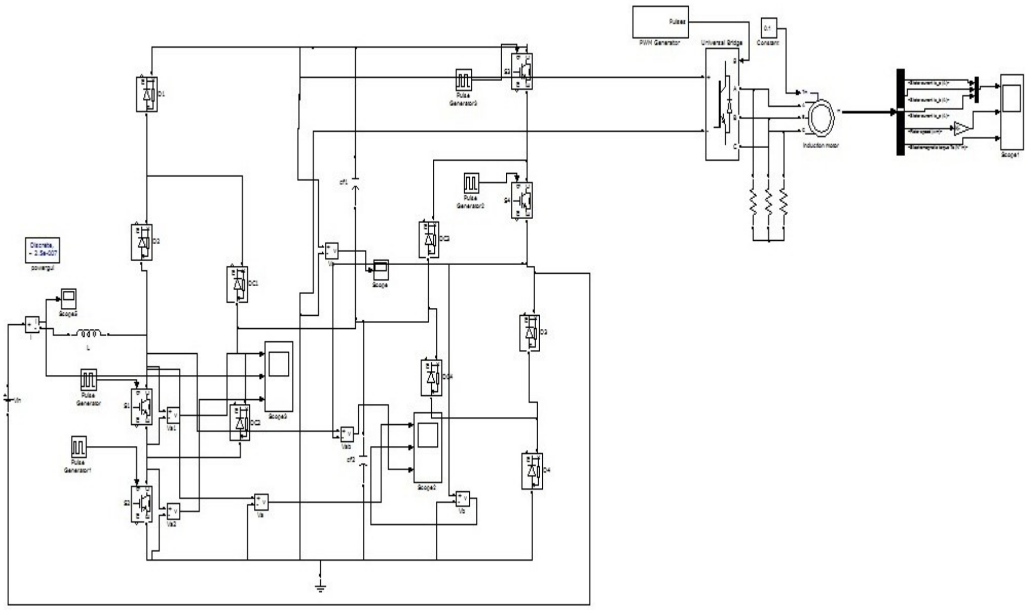

Fig 12 simulink model of proposed system

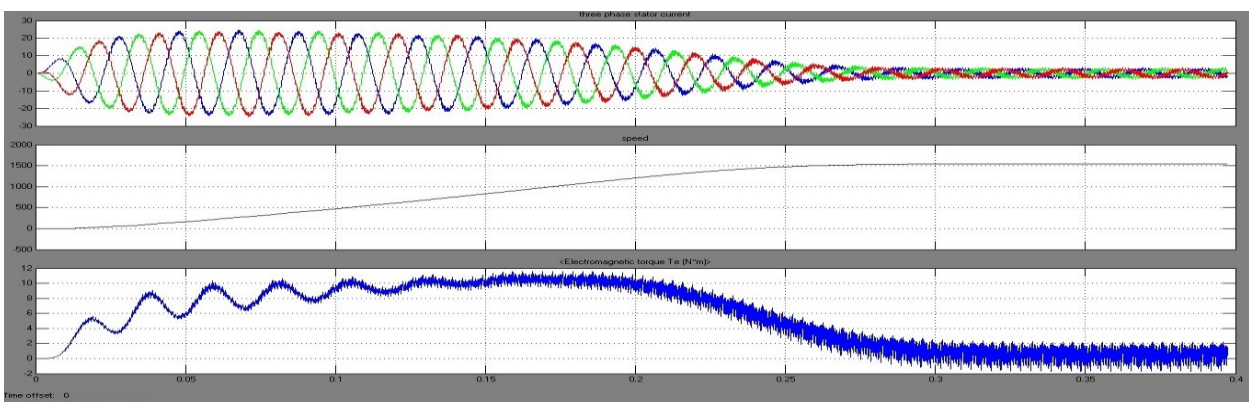

Fig 13 output waveforms stator current, speed &electromagnetic torque of induction motor

CONCLUSION & SCOPE OF FUTURE WORK

The hybrid boost three-level dc–dc converter is proposed in this letter, based on the conventional single-phase diode clamped three-level inverter. It cannot only operate with transformer less high voltage gain, but also make the duty cycles of the power switches closer to 0.5 with the increasing voltage gain, instead of the extreme duty cycles. Moreover, the capacitor voltages can be balanced both in dynamic and steady states by the proposed PWM control method and the blocking voltages of the power switches are half of the output dc voltage. The measured maximum efficiency of the hybrid converter is about 93.1%. Therefore, the proposed converter is suitable for PV generation systems connected to the grid with parallel-connected low-voltage PV arrays. Naturally, the MPPT of PV arrays will be studied further based on this hybrid converter in the future.

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