Three Phase RV-Multilevel Inverter Fed Induction Motor for PV systems

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Abstract— **A multilevel inverter can provide near sinusoidal output waveform compared with two-level inverter. Though the multilevel inverters hold attractive features, usage of more switches in the conventional configuration poses a limitation to its wide range application. Therefore a symmetric multilevel inverter structure, Reversing Voltage Multilevel Inverter(RVMLI) is introduced incorporating the least number of unidirectional switches and gate trigger circuitry, thereby compensating the disadvantages such as increased number of components, complex pulse width modulation control method,switching losses, size of inverter and installation cost.**

This topology is well suited for drives and renewable energy applications, hence PV based RVMLI is designed. The performance quality in terms of THD of 9-level MLI is compared with conventional cascaded MLI using carrier-based PWM (PD-PWM) technique. Finally in this paper the results of PV based 3-Phase RVMLI fed induction motor are validated using MATLAB/SIMULINK.

Keywords: **Multi-Level Inverters, RVMLI, THD, PD-PWM.**

Introduction ***(Heading 1)***

I. INTRODUCTION

A multilevel inverter not only achieves high power ratings, but also enables the use of renewable energy. In recent years, there has been a substantial increase in interest to multilevel power conversion. The term multilevel began with the three-level converter. The advantages of three-level Inverter topology over conventional two-level topology are:

1. The voltage across the switches is only one half of the DC source voltage;

2. The switching frequency can be reduced for the same switching losses;

3. The higher output current harmonics are reduced by the same switching frequency.

Recent research has involved the introduction of novel converter topologies and unique modulation strategies. However, the most recently used inverter topologies, which are mainly addressed as applicable multilevel inverters, are cascade converter, neutral-point clamped (NPC) inverter, and flying capacitor inverter. There are also some combinations of the mentioned topologies as series combination of a two-level converter with a three-level NPC converter which is named cascade 3/2 multilevel inverter [3]. There is also a series combination of a three-level cascade converter with a five-level NPC converter which is named cascade 5/3 multilevel inverter [4]. The proposed topology is a symmetrical topology since all the values of all voltage sources are equal. However, there are asymmetrical topologies [5] which require different voltage sources. This criterion needs to arrange dc power supplies according to a specific relation between the supplies. Difference in ratings of the switches in the topology is also a major drawback of the topology. This problem also happens in similar topologies [6]–[8], while some of the high-frequency switches should approximately withstand the maximum overall voltage which makes its application limited for high-voltage products. In recent years demand for electrical energy is increasing at rapid pace. In such a contrast standalone systems with photovoltaic cells (PV cells) are gaining importance. Standalone systems with PV cells are gaining demand due to their convenience in installation; ease in maintenance and in economic issues. The drawback of PV cells is that voltage available across their terminals is low. If such systems are to be installed for domestic applications they require dc-dc Converters with high conversion gains or an inverter circuit with a step up transformer. For a system that required is to supply 3 phase voltages require a step up transformer, usage of a transformer makes the entire system bulk. Here an attempt is made to eliminate the use of transformer.

In practical implementation, reducing the number of switches and gate driver circuits is very important. RV (Reversing-Voltage) multilevel inverter will obtain a nearly sinusoidal voltage with a lower switch count [1]. Also this topology can be easily implemented for three phase system due to less number of switches and hence less complexity of controlling them.

II. CIRCUIT TOPOLOGY

The power circuit of the inverter consists of the power semiconductor switches which are combined to produce a high-frequency waveform in positive and negative polarities. However, there is no need to utilize all the switches for generating bipolar levels. This idea has been put into practice by the new topology [1]. This topology is a hybrid multilevel topology which separates the output voltage into two parts. One part is named *level generation* part and is responsible for

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level generating in positive polarity. This part requires high-frequency switches to generate the required levels. The switches in this part should have high-switching-frequency capability. The other part is called *polarity generation* part and is responsible for generating the polarity of the output voltage, which is the low-frequency part operating at line frequency. The topology combines the two parts (high frequency and low frequency) to generate the multilevel voltage output. In order to generate a complete multilevel output, the positive levels are generated by the high-frequency part (level generation), and then, this part is fed to a full-bridge inverter (polarity generation), which will generate the required polarity for the output. This will eliminate many of the semiconductor switches which were responsible to generate the output voltage levels in positive and negative polarities. The RV topology in seven levels is shown in Fig. 1. As can be seen, it requires ten switches and three isolated sources. The principal idea of this topology as a multilevel inverter is that the left stage in Fig. 1 generates the required output levels (without polarity) and the right circuit (full-bridge converter) decides about the polarity of the output voltage. This part, which is named polarity generation, transfers the required output level to the output with the same direction or opposite direction according to the required output polarity. It reverses the voltage direction when the voltage polarity requires to be changed for negative polarity.

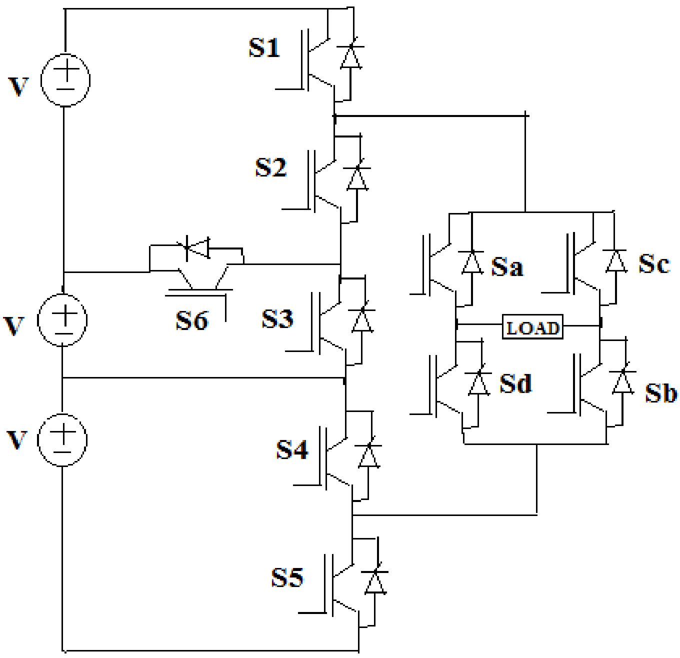

Fig.1. Seven level structure of RVMLI.

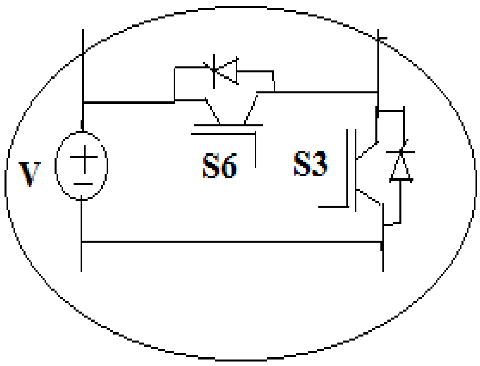

Fig.2. RVMLI duplicate stage for higher levels.

This topology easily extends to higher voltage levels by duplicating the middle stage as shown in Fig. 1. Therefore, this topology is modular and can be easily increased to higher voltage levels by adding the middle stage in Fig. 2. Hence the higher levels are obtained easily and with fewer components.

Switching sequences in this converter are easier than its counter parts. According to its inherent advantages, it does not need to generate negative pulses for negative cycle control. Thus, there is no need for extra conditions for controlling the negative voltage. Instead, the reversing full-bridge converter performs this task, and the required level is produced by the high-switching-frequency component of the inverter. Then, this level is translated to negative or positive according to output voltage requirements. This topology is redundant and flexible in the switching sequence. In this paper, IPD SPWM is adopted for its simplicity. Carriers in this method do not have any coincidence, and they have definite offset from each other. They are also in phase with each other. The modulator and three carriers for SPWM are shown below.

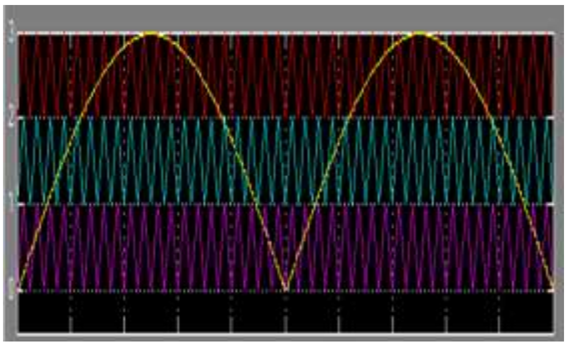

Fig.3. IPD PWM structure of RVMLI

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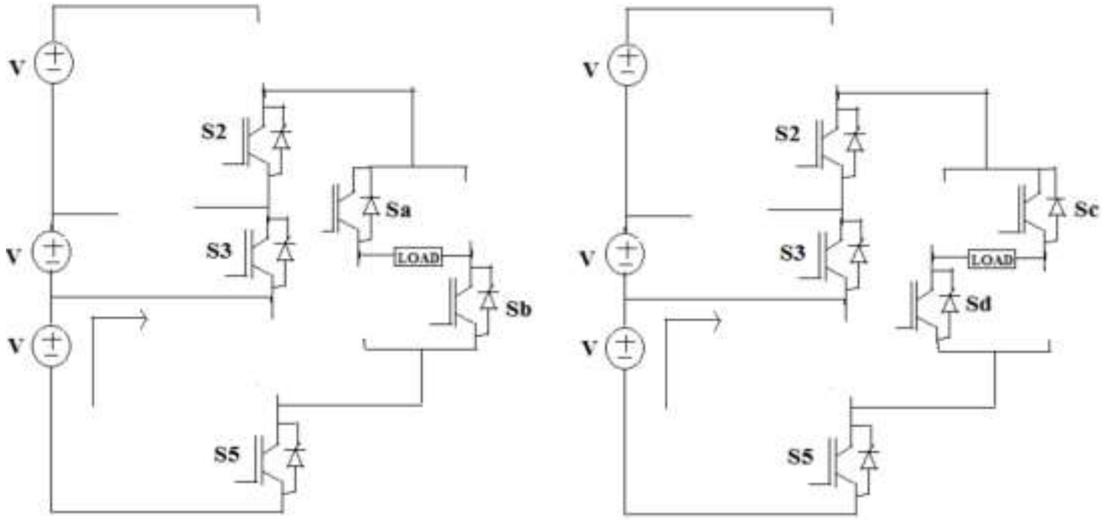

Fig.4. RVMLI operating mode-level 1(±116 V).

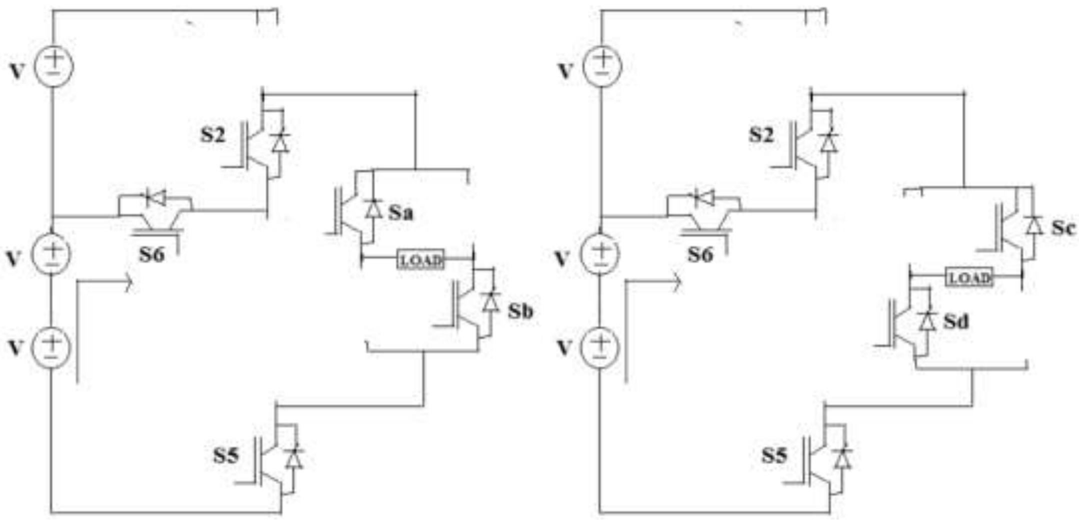

Fig.5. RVMLI operating mode-level 2(±232 V).

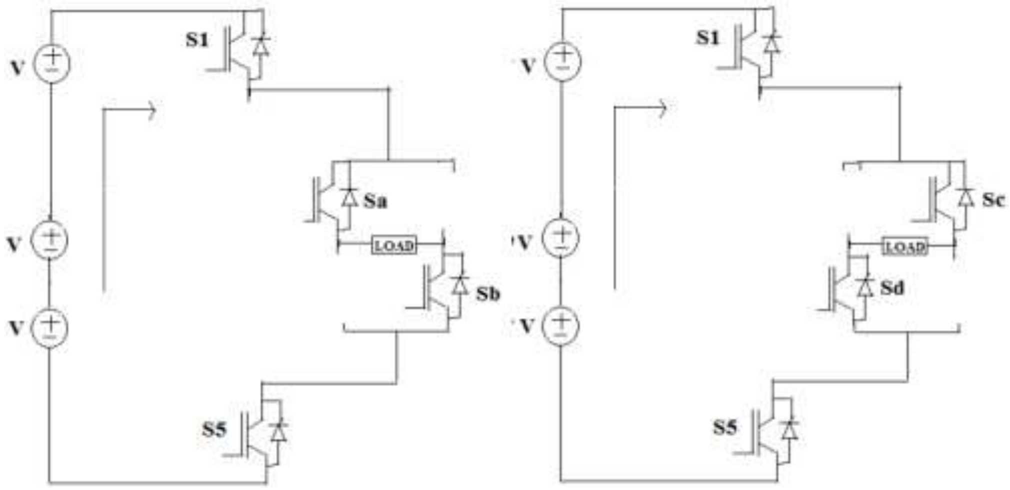

Fig.6. RVMLI operating mode-level 3(±350 V).

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III. SIMULATION RESULTS

The 7-level RVMLI has been implemented and simulated using MATLAB for Resistance & Inductive loads. The %THD of output voltage is 3.55% for seven level topology with filter has been obtained for resistive load of 124 Ω and shown in fig.12.

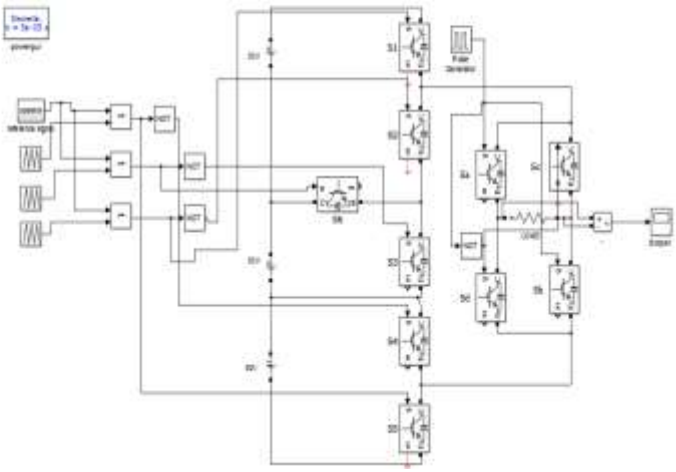

Fig.7 Simulation Circuit for 7-level RVMLI using PD-PWM

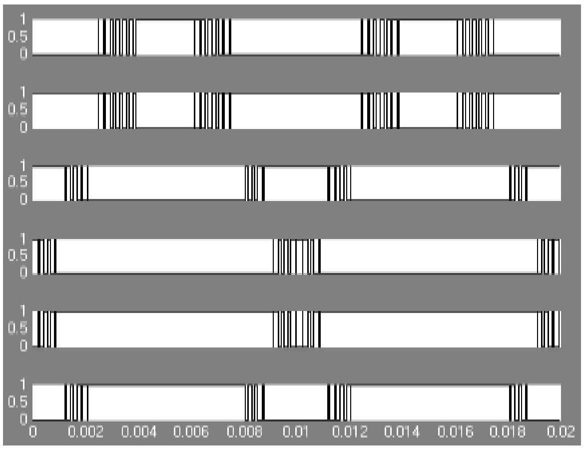

Fig. 8. Complete gate signals for Switches S1-S6

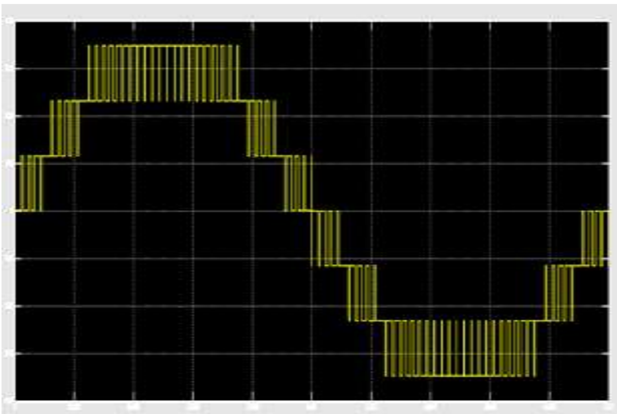

Fig. 9.output voltage waveform of RVMLI with R-load without filter

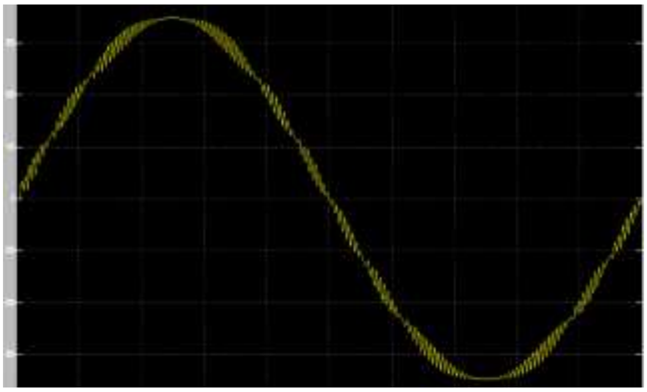

Fig.10. output voltage waveform of RVMLI with RL-load with filter

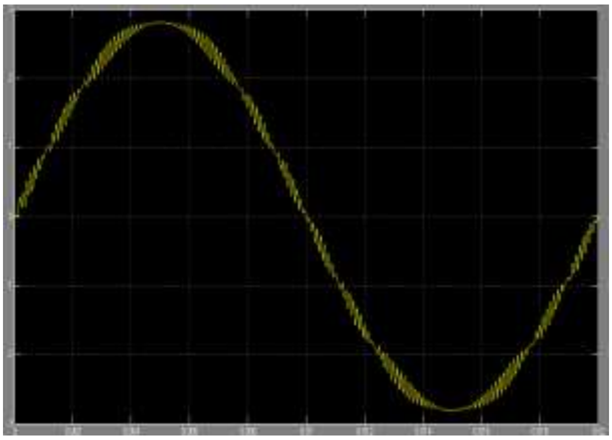

Fig.11. output current waveform of RVMLI with RL-load with filter

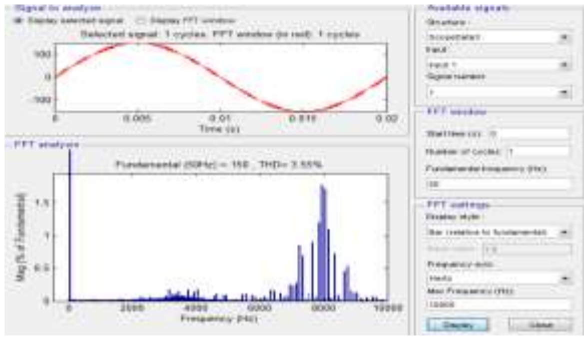

Fig. 12.FFT Analysis

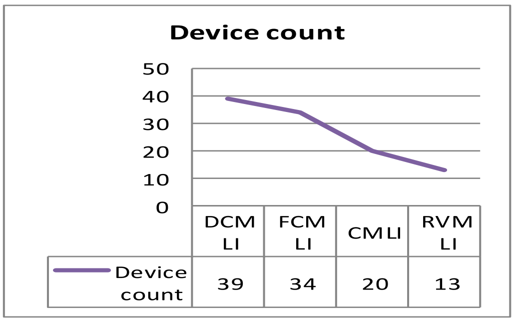

Fig.13. Comparison of device count between different 7 level Multi-level structures

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9-level structure	CHBMLI	RVMLI
No. of switches	16	12
No. of PWM drivers	8	4
T.H.D	***14.06%***	***13.90%***
Design part (in higher levels)	Difficult	Easy

Fig.14. Comparison of 9-level Cascaded MLI & RVMLI without Filter

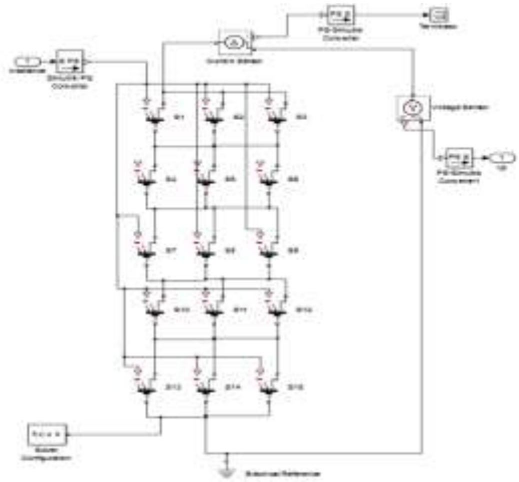

Fig.15 PV cell Mat lab Circuit design

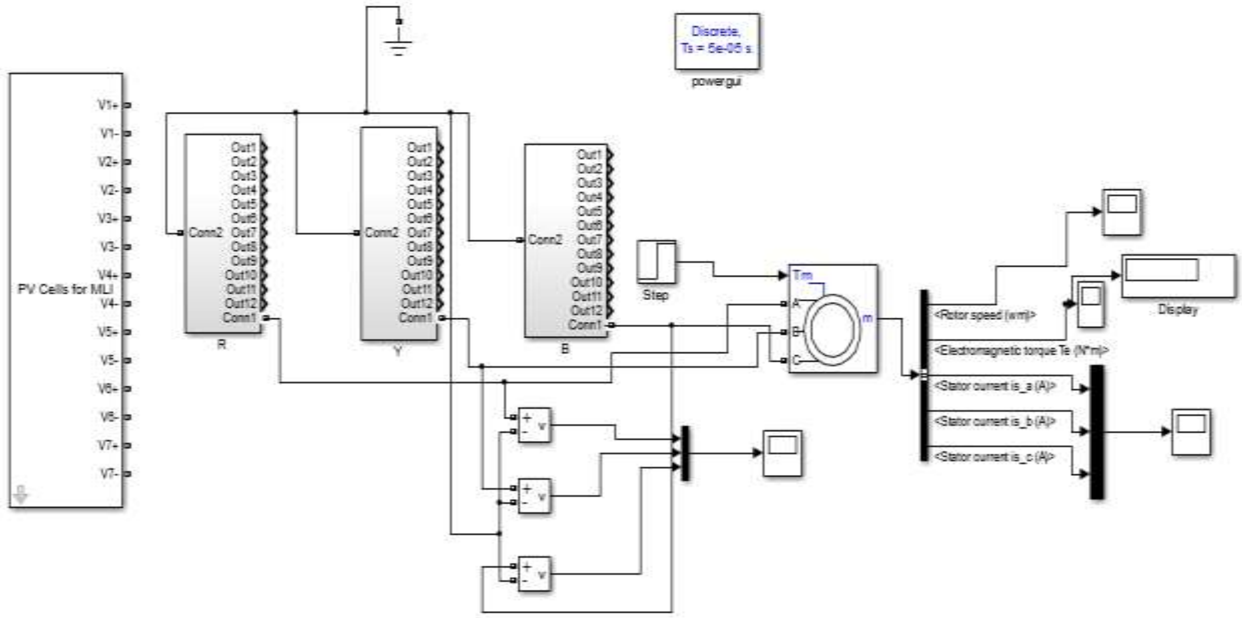

Fig.16 Simulation Circuit for PV based RVMLI fed induction motor using PD-PWM

The resulting current THD was 3.85%, which complies with the IEEE 519 harmonic standard. Figs. 9,10 and 11 clearly show the performance of the proposed inverter for resistive and inductive loads. Therefore, this RVMLI topology is proven to work with different kinds of loads as shown in Figs. 9,10 and 11. The output waveform with an inductive load of 182 mH, which is equal to 115 Ω, is also shown in Fig. 11. The resulting THD for current was 2.3%, which is in compliance with the IEEE 519 harmonic standard. The PD-SPWM control method is used to drive the inverter. The PWM for this topology has fewer complexities since it only generates positive carriers for PWM control, but less carrier signals are sufficient. This RVMLI is implemented for PV systems. The simulation circuit and results of three phase Induction motor are presented in fig. 16 and 17.

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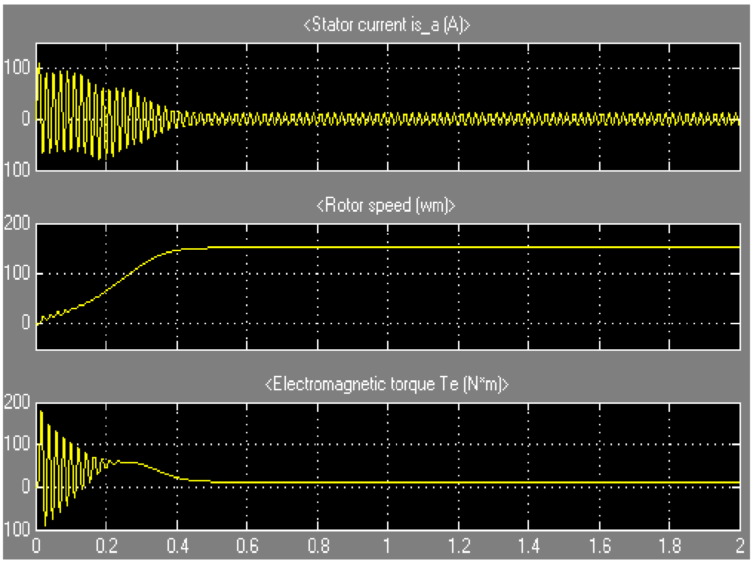

Fig.17 speed waveform of RVMLI fed single phase induction motor.

IV. CONCLUSION

A RVMLI topology provides the better sinusoidal output voltage with low THD and also requirement of gate drivers, protection circuits, installation area and converter cost is reduced compared with existing MLI topologies.

In RV (Reversing-Voltage) multilevel inverter topology, the switching operation is separated into high- and low-frequency parts. This will add up to the efficiency of the converter as well as reducing the size and cost. This topology can be a good candidate for converters used in power applications such as FACTS, HVDC, PV systems, UPS, etc. finally in this paper PV based three phase RVMLI fed induction motor is implemented and the results are presented.

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