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MODULAR MULTILEVEL CONVERTER BASED INDUCTION MOTOR DRIVE

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ABSTRACT

Nowadays, for drives working on medium voltage, the Modular Multilevel Converters (MMCs) are the preferable choice. Because from both as inverter point of view or motor point of view, the MMCs have the advantages like output quantities having less distortion, semiconductor devices having low average switching frequencies, low harmonic content because of which these can be used for high power motor applications without derating. But the main disadvantage is the complexity in triggering the power semiconductor switches by proper pulse width modulation techniques, as it consists of a greater number of switches and capacitors and extra care need to be taken during the control of MMCs at low frequency operations. This is required because the low frequency operation will lead to unbalance in the capacitor voltages of submodule and further may lead to tripping of MMC. In this paper, open loop control of MMC fed induction motor is described, and the performance of the drive is verified for different load conditions and variable speed operation. In order to balance the DC capacitor voltages, phase shift sinusoidal pulse width modulation technique, which is suitable for any number of H-bridge converters, is applied. The paper is examined on 21 level cascaded multilevel inverter induction motor drive by using MATLab/Simulink and also validation of MMC output voltage is done using Real-Time Typhoon HIL 402 Simulator.

I. INTRODUCTION

With the rapid development of the high-voltage power applications, a newer kind of VSC, modular multilevel converter (MMC) has been applied in HVDC systems. Till now, MMC is used more and more widely in industrial area. In the renewable energy market, MMC can replace a two level or three-level VSC to drive a wind machine. Study on motor drive with MMC in this paper can be applied to wind farms. Compared with the traditional two-level VSC, the MMC contains more than one sub-module (SM) in cascaded connection on each arm. The structure of a three-phase dc-to-ac MMC with a detailed sub-module is shown in Fig.1.The sub-module is a simple buck converter with two IGBT and a dc capacitor, Csm. MMC has two main advantages due to its special structure. First, the cascaded connection of sub-modules makes the MMC intended for any voltage power level requirement, especially for the medium and high voltage power applications. Second, the high-level number of the submodules can reduce the effect of the harmonic distortion and the switching frequency. For simulation-based studies, MMC has a drawback on simulation time. The huge number of submodules corresponds to the huge effort of computation. Therefore, for simulation studies, the range of the number of sub-modules in many experiments is from 2 to 8. One of the most promising converter families in this context is the MMC family.

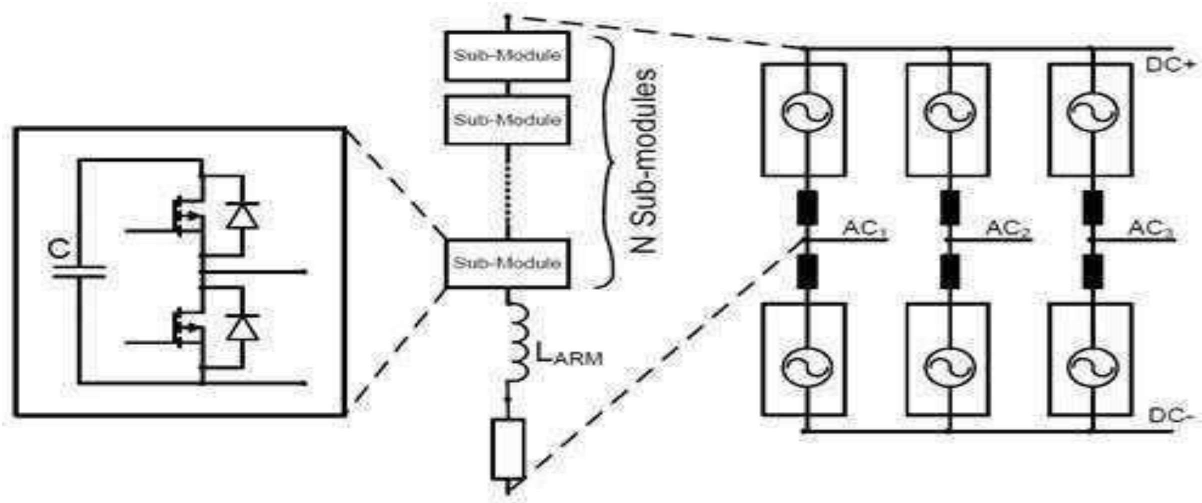

Fig. 1. Modular multilevel converter based on half-bridges - 3-phase schematic.

Here, the main circuit can be designed without complex high voltage solutions for interconnection of different clamping elements that are necessary in diode or capacitor clamped multilevel topologies, and contrary to other cascaded-bridge technologies, the MMC can be fed from a common direct voltage source instead of individual supplies for each level. An outline of an MMC based on cascaded half-bridges is given in Fig. 1. However, there are also features of the topology that will need extra effort to be taken care of. It can immediately be observed that the output current flows through the capacitors in the submodules and accordingly will cause significant ripple in the capacitor voltages at low operating frequency. In order then to ensure stable operation, the converter control should be designed such that it not only regulates the total capacitor voltage per phase leg, but also the voltage balance between the arms as wellas the voltage sharing among the submodule capacitors.

Many current and future designs will incorporate the use of induction motors as the primary source for traction in electric vehicles. Designs for heavy duty trucks and many military combat vehicles that have large electric drives will require advanced power electronic inverters to meet the high-power demands (>250 kW). Development of electric drive trains for these large vehicles will result in increased fuel efficiency, lower emissions, and likely better vehicle performance (acceleration and braking). Multilevel inverters are uniquely suited for these applications because of the high VA ratings possible with these inverters.

II. MODELLING AND DESIGN

The MMC control system provides instantaneous reference values for the voltages to be insertedin each arm. These voltage references are converted into insertion indices (0 to bypass all submodules, 1 to insert all submodules) that are given to the modulator, which determines anyincremental insert/bypass commands to be carried out. A sorting algorithm finally selects, in runtime, the appropriate submodule to execute the commanded switching. It has been shown that, if the insertion indices are being calculated without considering the ripple of the capacitorvoltages, unintended current harmonics will occur in the converter arms. Below are thesimulation results that are being performed.

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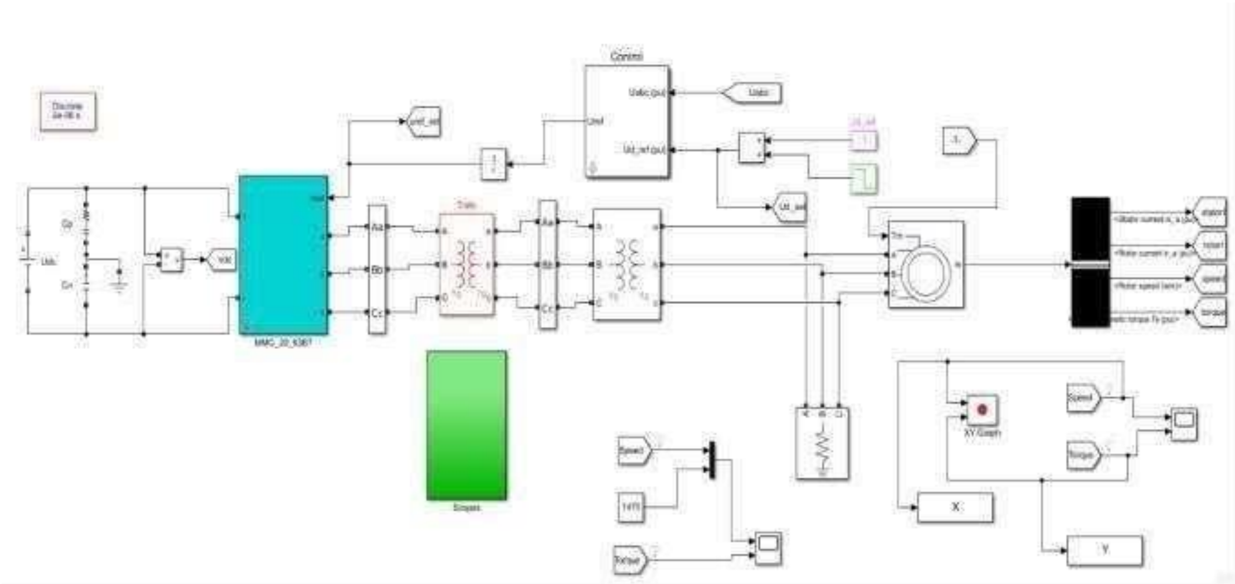
III. SIMULATION CIRCUIT

Below is the circuit of Modular-Multilevel converter which is simulated in MATLab/ Simulink. The main objective of the paper is to compare the output results in two scenarios. And there is a smooth variation in the output.



IV. RESULTS AND DISCUSSION

Speed and Torque characteristics of the Induction Motor at different loads are analyzed here, and also terminal voltage and current of the motor, output voltage and current of converter, stator and rotor currents of induction motor are observed.

No load characteristics:

Fig 1. Speed and torque characteristics of Induction Motor at no-load

Above figure 1 shows the no-load N-T characteristics of IM. Upper graph represents the reference speed of 1460 rpm, which is the rated speed of induction motor and lower graph represents no-load torque of motor. There are slight disturbances during initial stages due to moment of inertia of rotor.

Characteristics at 10 N-m load:

Figure 2 shows the N-T characteristics of IM at 10 N-m. When load is applied to the motor the speed is decreased from rated speed (1460 rpm) to 1420 rpm.

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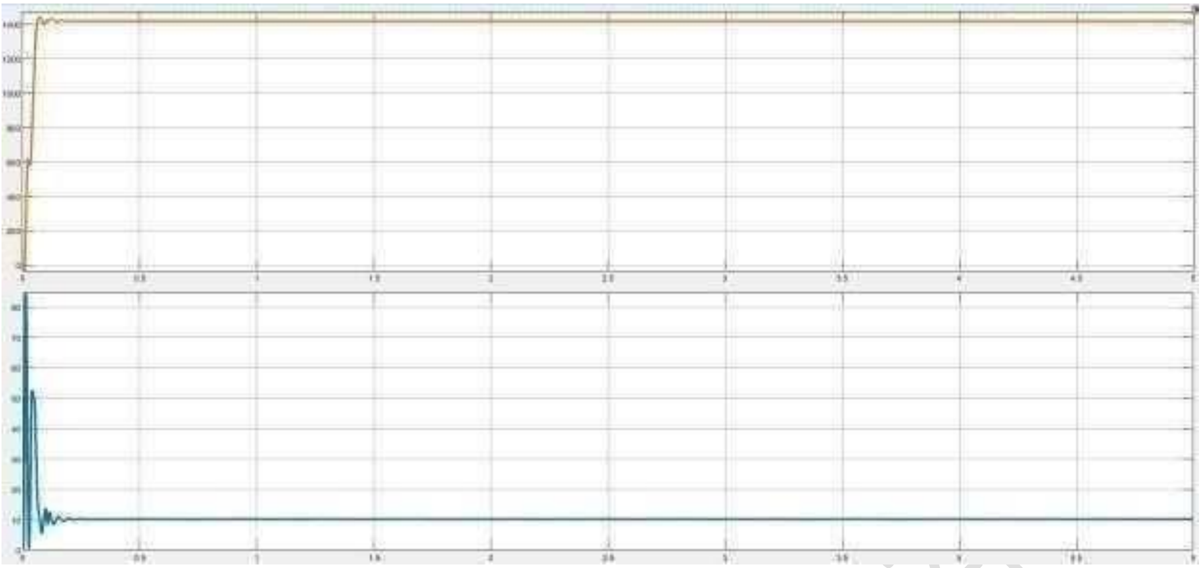

Fig 2 Speed and torque characteristics of Induction Motor at 10 N-m load

Characteristics at 20 N-m load:

As shown in figure 3, when the load is further increased to 20 N-m, the speed is further decreased below 1400 rpm.

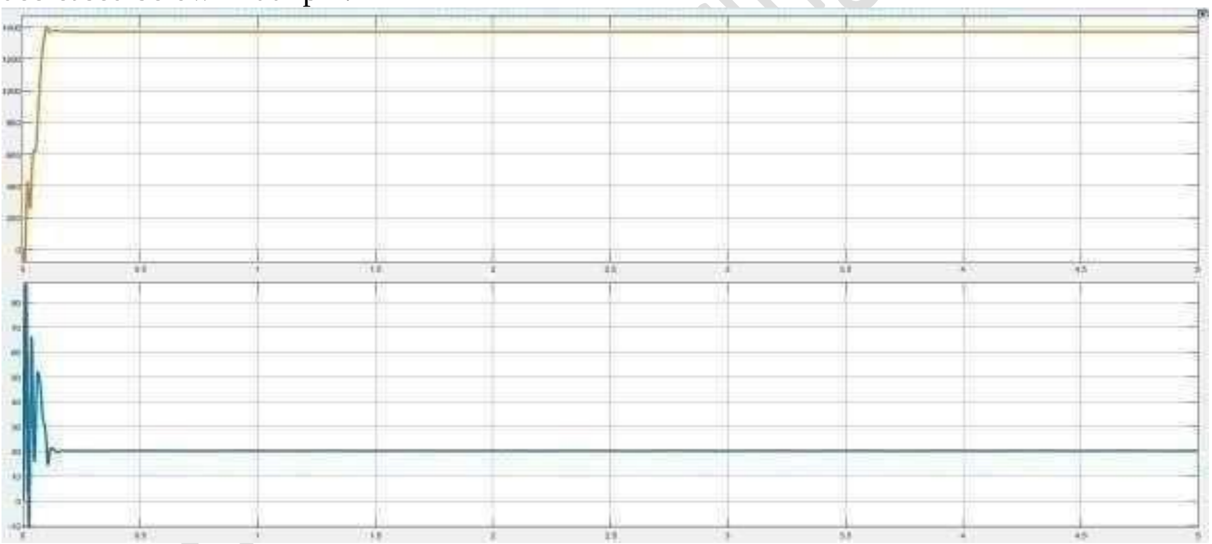

Fig 3 Speed and torque characteristics of induction motor at 20 N-m load

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Characteristics at step change in load:

The characteristics of induction motor for step change in the load is observed. The speed is correspondingly decreasing with change in load as shown in figure 4.

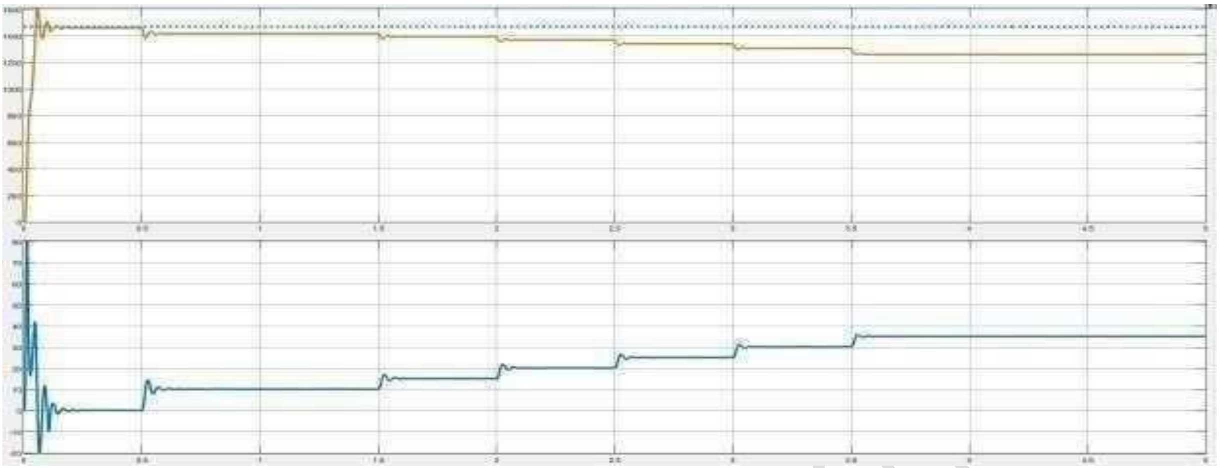
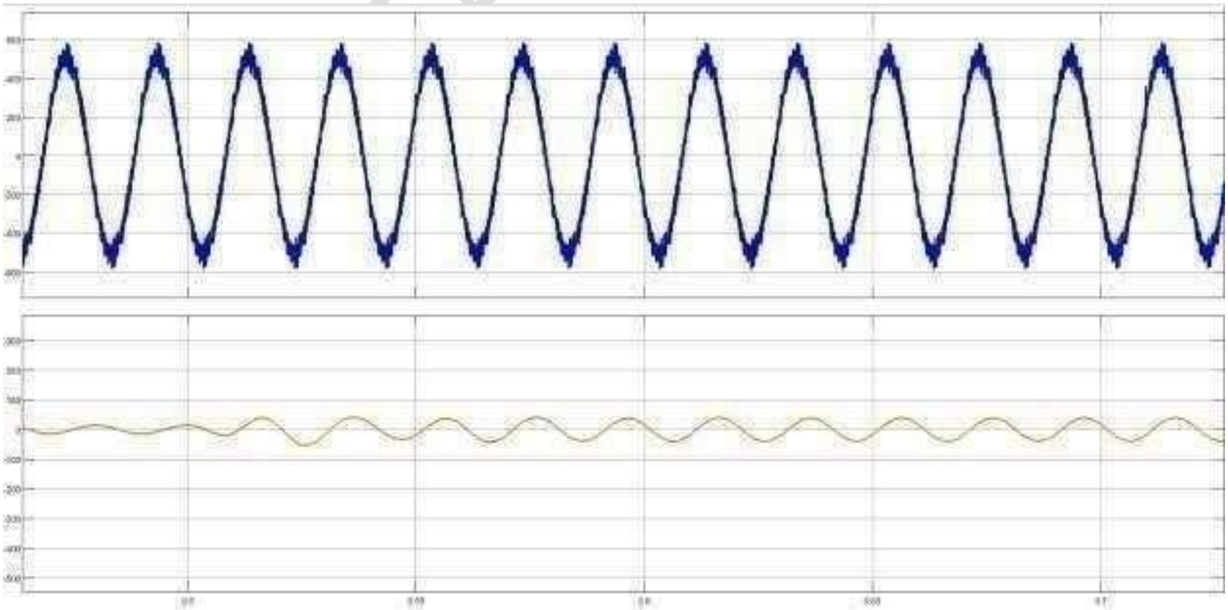


Fig 4 Speed and torque characteristics of induction motor for step change in load

Terminal voltage and current of motor:

Below figure 5 shows the motor terminal voltage and current and the validation of MMC output phase-to-phase voltage in Typhoon HIL 402 Real Time Simulation is also shown. These are considered for period of time. It can be observed that there is increase in current as load changes.



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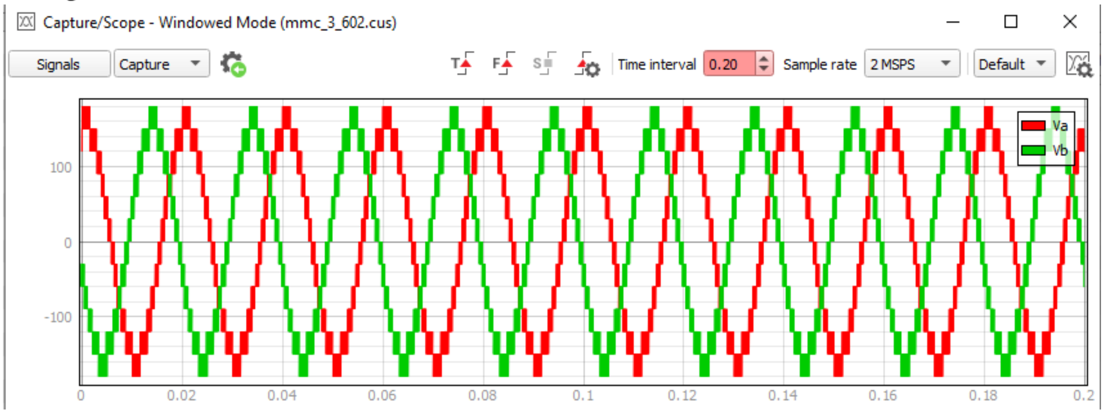

Fig 5 Terminal voltage, current of motor, and Real -Time Simulator Typhoon HIL 402 MMC Output Voltage

Output voltage and current of Converter:

Below figure 6, depicts the output voltage and current of the converter.

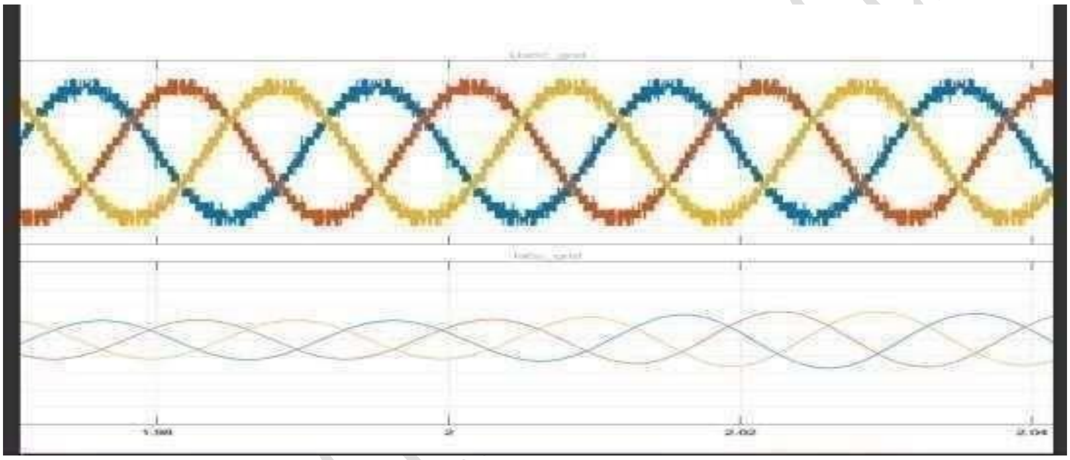

Fig 6 Output voltage and current of converter

Stator and rotor currents:

Below figure 7, shows the stator and rotor currents of the motor. The outputs are recorded for increase in load. Upper graph is stator current and lower graph is rotor current.

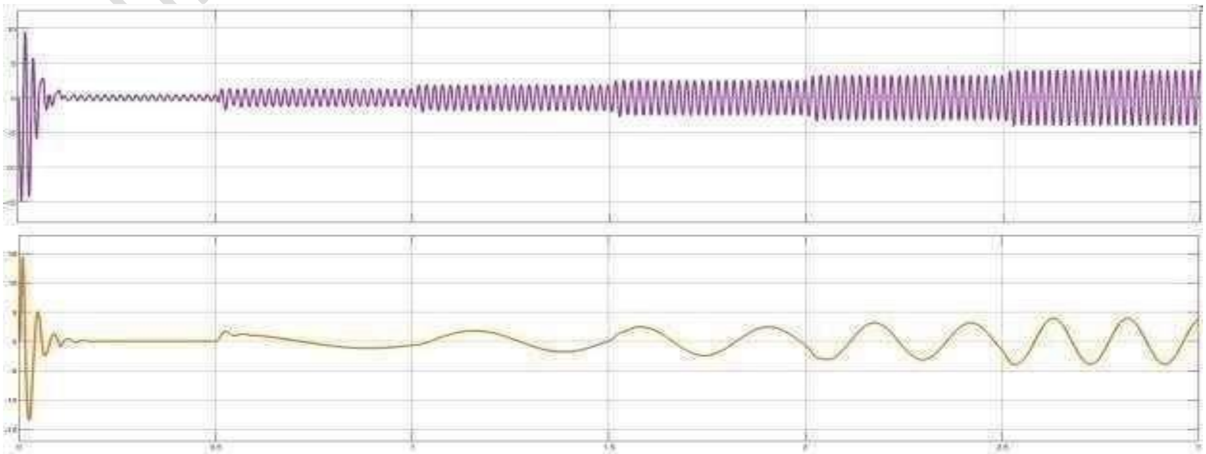

Fig 7 Stator and rotor currents

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CONCLUSION

In this paper, the performance of 21-level Modular Multilevel Converter fed Induction Motor Drive controlled by phase shift modulation technique is analyzed for no-load condition, half load condition, full load condition and step change in load conditions. Accordingly, the speed parameter is noted for the different torque conditions. As a result, the MMC family can become a highly competitive alternative for medium and high-power motor drives, as it is capable of running constant torque loads from zero up to the nominal speed, with the implementation of the appropriate control technique. With increasing the level of the converter (increasing the number of sub-modules) the output voltage waveform is achieved nearly to the sine wave. And also, from the stator and rotor current waveforms, it can be clearly seen that the harmonic content is reduced which implies that the performance of the drive is improved and there is reduction in losses of the drive system.

Hence the speed control of induction motor drive is achieved smoothly from zero to nominal speed under different loading conditions with the help of 21-level modular multilevel converter.

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