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Simulation of Multilevel Inverter Fed Induction Motor Drive

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Abstract:
The ruggedness, dependability, and economy of induction motors make them a popular choice in the industrial sector. Induction motor drive necessitates the use of appropriate converters in order to achieve the required speed and torque with minimal or no ripples. Multilevel inverter technology has recently emerged as a very important alternative in the areas of high power medium-voltage control as well as for improving total harmonic distortion by reducing the harmonics, both of which are important considerations. Most of the time, the poor quality of voltage and current produced by a conventional inverter fed induction machine is due to the presence of harmonics, which results in a significant amount of energy being wasted. In MATLAB, the simulation results of the proposed topology three phase 33-level multilevel inverter fed induction motor drive are verified against the real-world results.

Introduction :

DC motors have been used during the last century in industries for variable speed control applications, because its flux and torque can be controlled easily changing the field and armature currents respectively. Furthermore, four quadrant operation of induction motor was also achieved. Induction motor is popularly used in industries due to ruggedness and robustness. The induction motors were mainly used for essentially constant speed applications because of the unavailability of the variable-frequency voltage supply. The advancement of power electronics has made it possible to vary the frequency of the voltage. Thus, it has extended the use of induction motor in variable speed drive applications. The concept of multilevel inverter control has opened a new possibility that induction motors can be controlled to achieve dynamic performance equally as that of DC motors. It has been found that the dynamic model equations developed on a rotating reference frame is a better way to describe the characteristics of induction motor. Variable speed induction motor drives are widely spread in electromechanical systems for a large spectrum of industrial applications. When high dynamic performance and high precision control in a wide speed range are required, vector control based induction motor drive can be used with speed sensor (D. Hadiouche, H. Razik, and A. Rezzoug, 2000). On the other hand, for medium and low performance applications, sensor-less control of induction motor is becoming an industrial standard. The recent advancement in power electronics has been initiated to improve the level of inverter rather than increasing the filter size. Using multilevel inverters, it is better to reduce the harmonics. In this paper, space vector modulation technique that uses to reduce the harmonics. For redundant switching, a space vector modulation is required due to vector selection in dq stationary reference frame. The space vector modulation technique is used for multilevel inverter system. However, space vector modulation has more advantages due to low harmonic production (K. Yamanaka et al., 2002). The performance of the multilevel inverter is better than a classical inverter. The total harmonic distortion of the classical inverter is very high. In other words the total harmonic distortion for multilevel inverter is low. The diode clamped inverter provides multiple voltage levels from a series bank of capacitors. The voltage across the switches is only half of the DC bus voltage. These features effectively double the power rating of voltage source inverter for a given semiconductor device. A normal neutral point potential stabilization technique using the information of output current polarity is proposed by K. Yamanaka et al. (2002). The neutral point potential balancing algorithm for three level neutral point clamped inverters using analytically injected zero sequence voltage is developed by Q. Song (2003). Modulation schemes to eliminate common mode voltage in multilevel inverter topology is suggested by H. Zhang (2000). A generalized multilevel inverter topology with self voltage balancing is suggested by F Zeng Peng (2001). Survey of topologies, control and applications of multilevel inverters was done by J. Rodriguez (2002). Digital modulation technique for dual three phase a.c machines has been presented by R Bojoi (2002). Space vector PWM technique for dual three phase a.c machine and its DSP implementation has been presented by Hadiouche (2006). Practical medium voltage converter topologies for high power applications is presented by Steimer (2001). In the above mentioned literature, implementation of multilevel inverter using embedded controller is not presented. The present work deals with implementation of embedded controlled multilevel inverter fed induction motor drive. The details of simulation, control circuit and hardware are presented in this paper.

Multilevel inverter fed induction motor:

AC input is rectified using a diode rectifier. It is filtered using a capacitor filter. DC is applied to the multilevel inverter. The output of the inverter is fed to the induction motor. This system is simulated using Matlab Simulink. The Simulink model for multilevel inverter fed system is depicted in Figure 2. Input pulses to the MOSFETs are generated by the sources V1 to V6. The phase voltage and line to line voltages are measured by the scopes connected at the output. The scope is connected to measure parameters like voltage, rotor speed and torque. The pulses are generated using SVM method. The speed loop ensures that the actual speed of the motor is equal to set speed. The current loop provides protection for the devices in the inverter.

Description of the Proposed Structure:

The proposed multilevel inverter topology is depicted in Fig.1. When generating a staircase waveform, a simple variation of a diode clamped multilevel inverter is used, as shown here. In order to obtain an alternating signal with both positive and negative polarities, an H-bridge is employed. Capacitors are used to divide the DC link voltage into k distinct levels, with each level represented by a different colour. Following that, the voltages of the capacitors are added and subtracted by operating the power switches, resulting in a 2k+ level staircase voltage waveform generated. Each power switch is equipped with a diode that operates in reverse blocking mode. The working principle of the proposed topology is illustrated in Fig. 2, where Vbus denotes the DC bus voltage, Vac denotes the alternating current output voltage, and Vac 1 denotes the fundamental component of Vac. The gating signals of the switches are represented by the numbers S1 - Sk. Similarly, the gating signals of the H-bridge are represented by the numbers Q1 - Q4. Each of the four switches in an H-bridge operates at a frequency equal to the fundamental frequency of the output voltage.

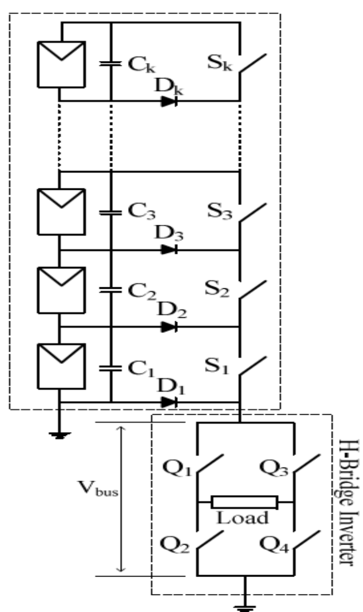

Fig. 1: Our proposed topology of multilevel inverter

The proposed topology necessitates the use of k power switches in order to generate the k levels staircase waveform Vbus. In order to obtain a staircase ac waveform Vac with 2k+ levels, four additional switches of an H-bridge inverter are used. Effectively, only k + 4 power switches, k capacitors, and k diodes are required to generate a 2k+ level staircase voltage ac waveform, resulting in a lower overall device count than an existing multilevel topology, to the best of our knowledge.

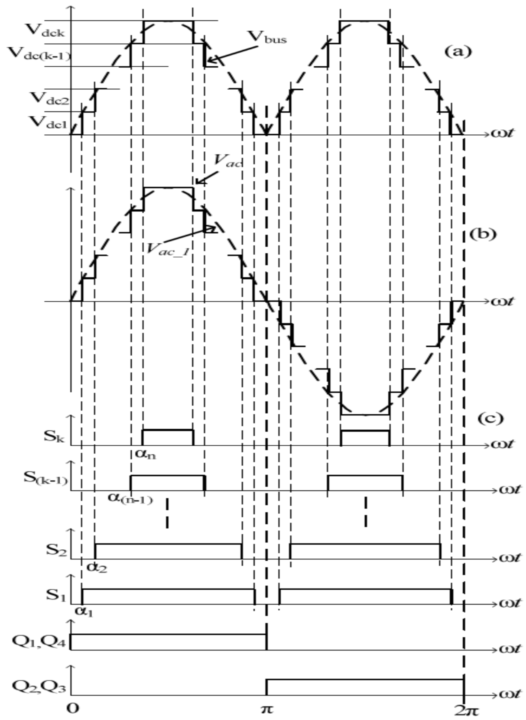

Fig. 2: Output waveform and states of various switches

Simulation Results:

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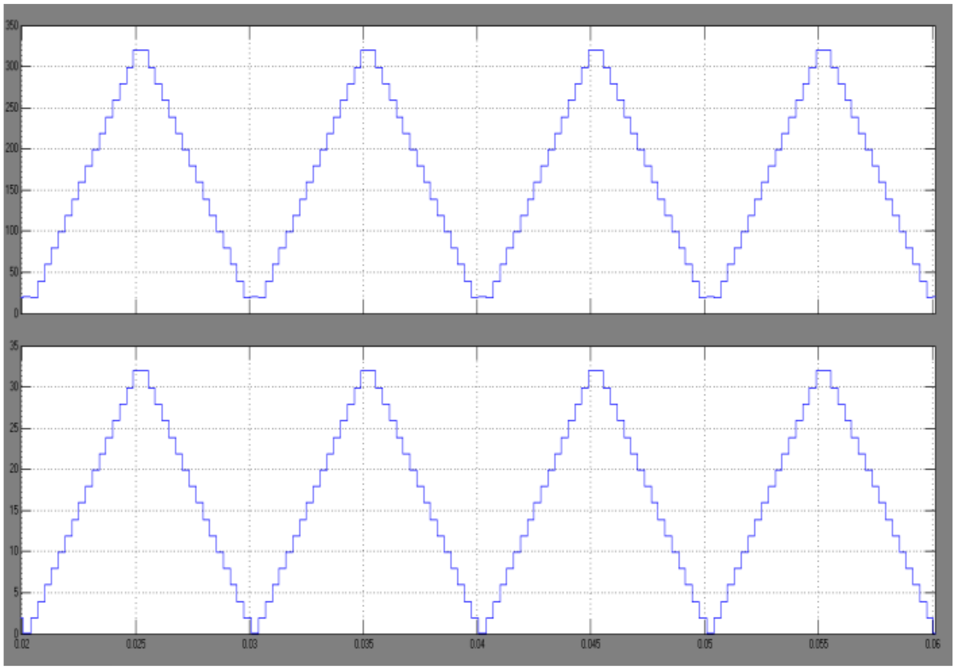

Fig. 3 Simulated waveforms of DC bus voltage and current of a 33 level multilevel inverter

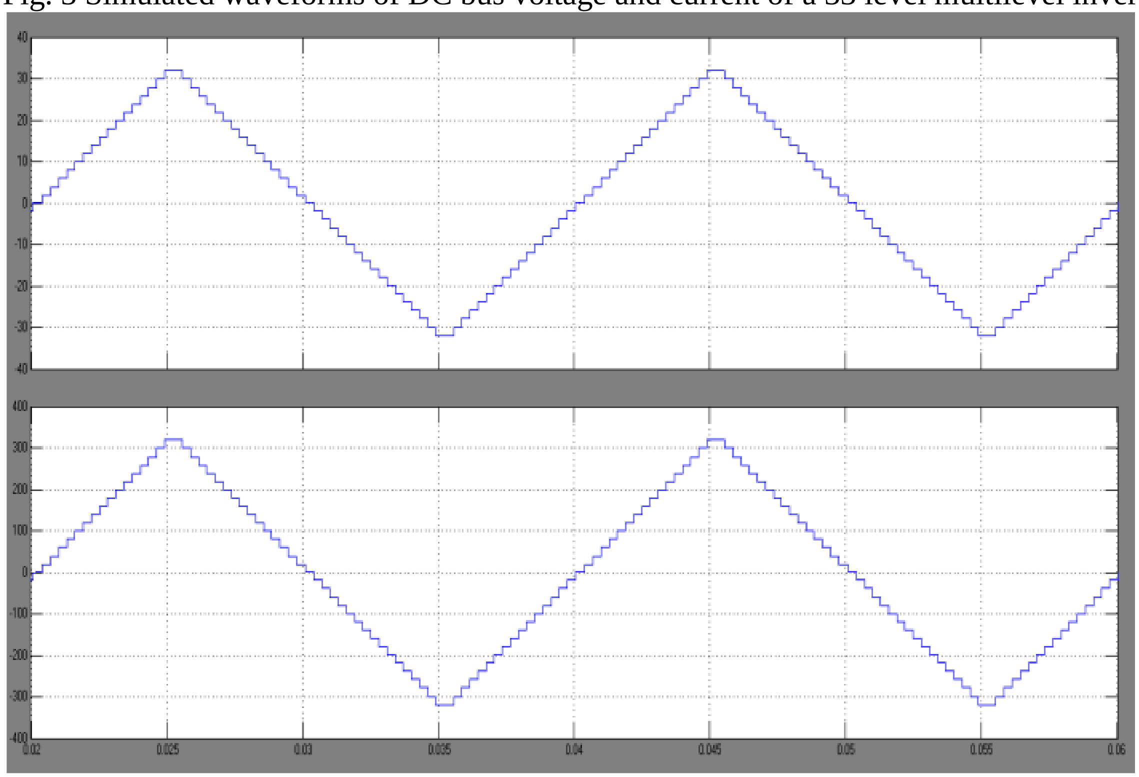

Fig.:4 Simulated waveforms of AC output voltage and current of a 33 level multilevel inverter

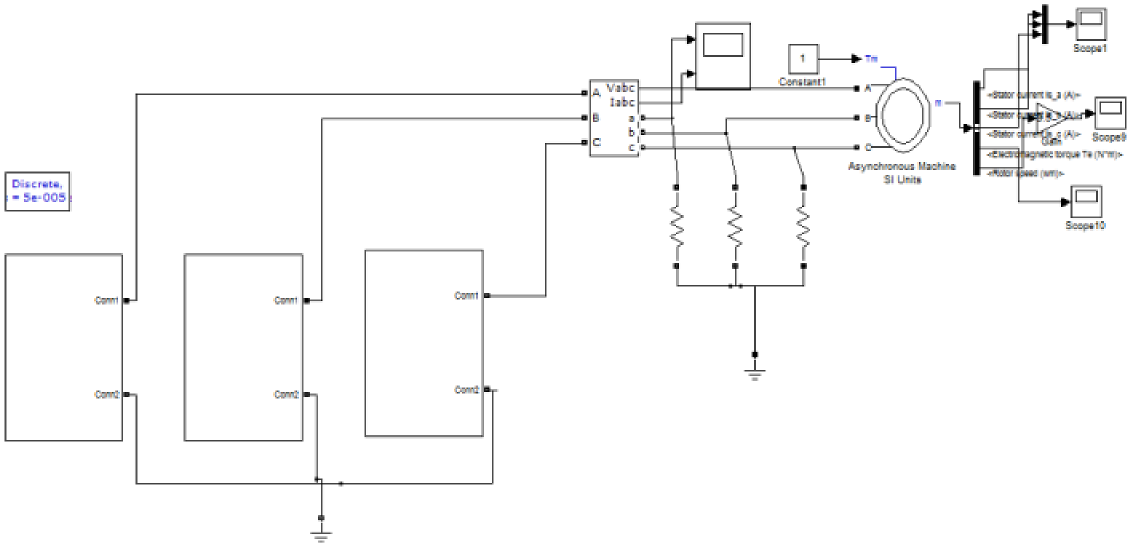

Fig.: 5 Simulink model of proposed multilevel inverter with induction motor drive

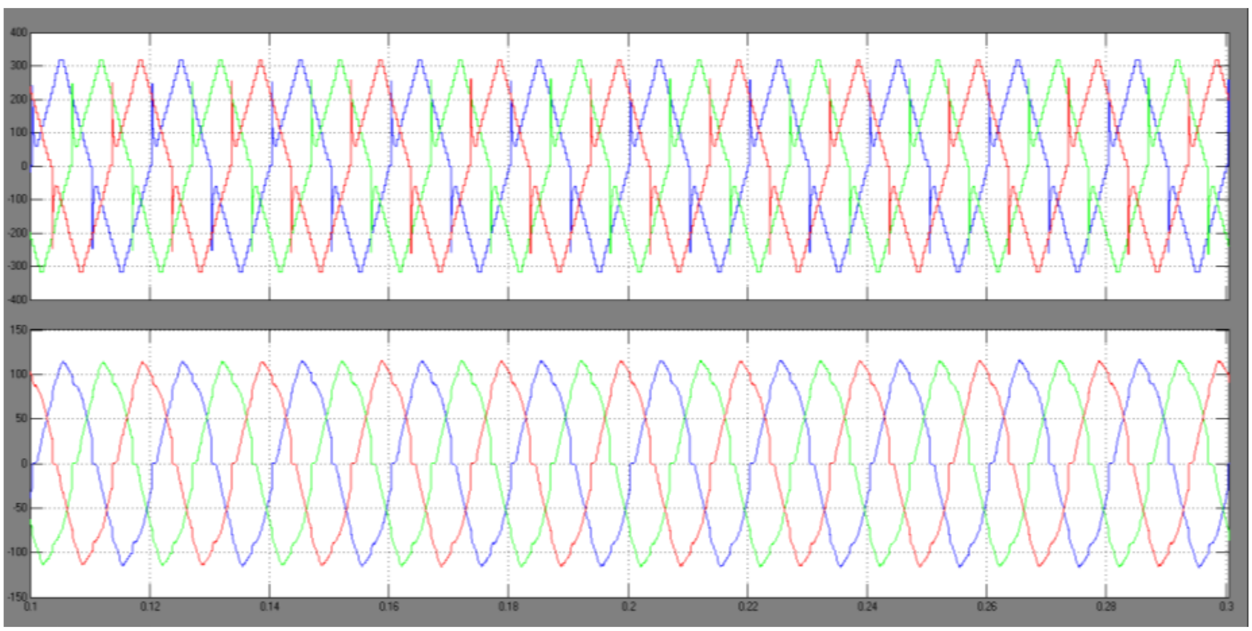

Fig.:6 Simulated waveforms of three-phase output voltage and current of a 33 level multilevel Inverter

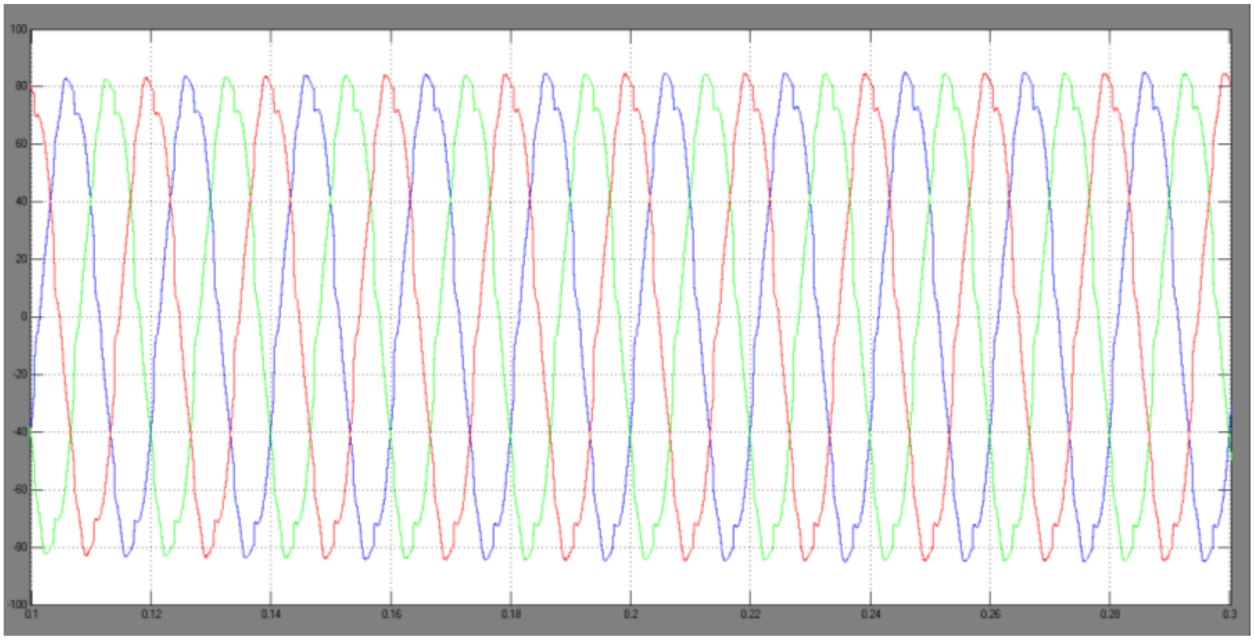

Fig.: 7 Stator current

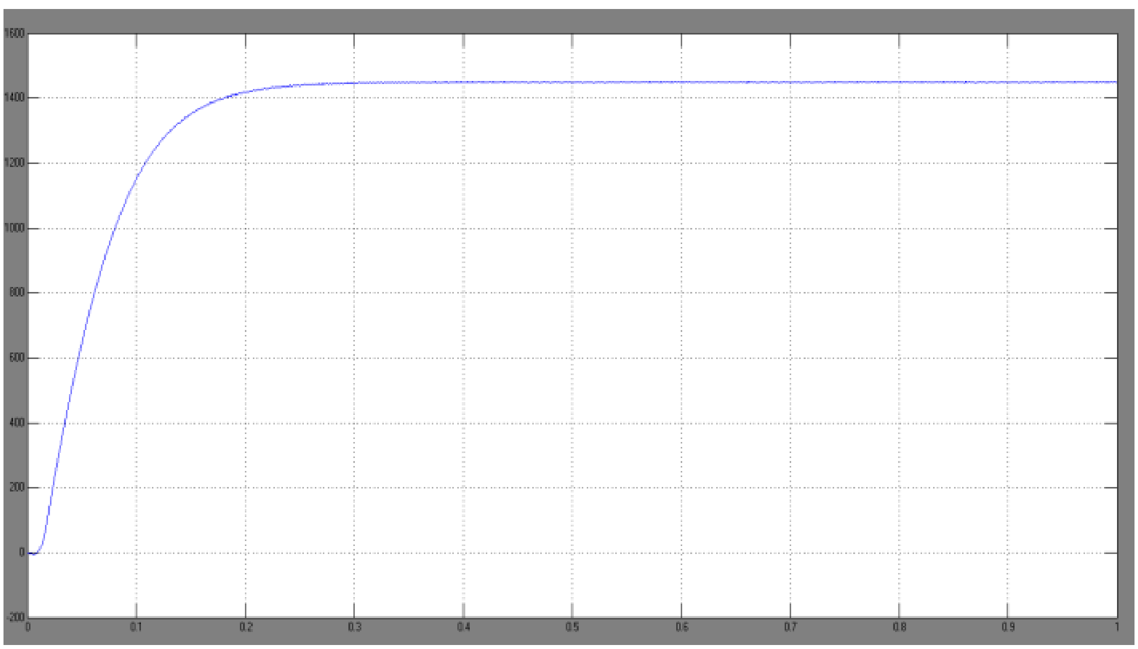

Fig.: 8 Speed of the induction motor

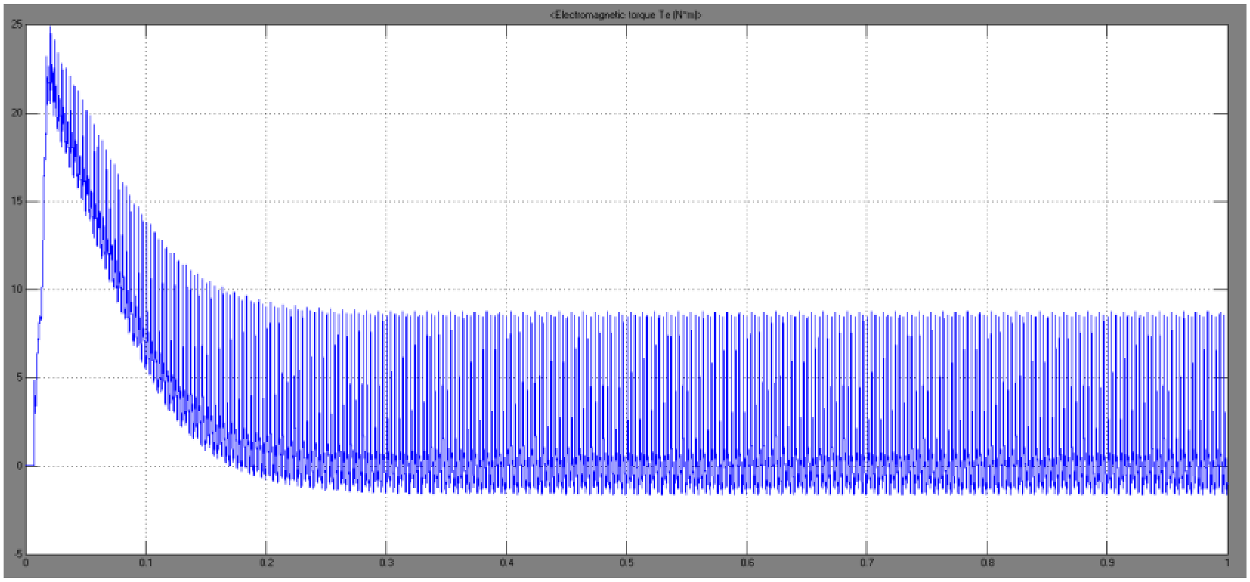

Fig.: 9 Torque characteristics of the induction motor

Conclusion

It has been proposed to use a new multilevel inverter topology. The proposed topology is a hybrid of conventional diode clamped and H-bridge converters, with the former serving as the basis for the latter. Photovoltaic applications in which multiple separate DC sources are available may be a good fit for this type of system. It has been shown in this paper that the proposed topology's concept and operating principles are sound. To fully verify the advantages of this new circuit, a detailed analysis of its efficiency as well as its practical implementation is still required. The proposed system is then implemented with a Three Phase Induction Motor, and the performance of the system is evaluated in terms of Stator Current (I), Speed (V), and Torque.

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