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A NOVEL ISOLATED MODULAR MULTILEVEL HIGH VOLTAGE GAIN DC-DC CONVERTER FOR INDUCTION MOTOR DRIVES

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Abstract- The proposed concept gives the analysis and design of a line interactive uninterruptible power supply (UPS) connected to a Microgrid through a high step-up/down (bidirectional) dc-dc isolated modular multilevel converter with a high input to output voltage ratio for Induction motor drive application is presented. Resonant switching is used on the MMC to improve overall efficiency of the converter. The input source for this converter is a set of series and parallel batteries and the output of the converter is connected to a Microgrid. The proposed converter steps up the input voltage with a 1:15 conversion ratio, and steps down the input voltage with a 15:1 conversion ratio. A transformer is used to both isolate the converter and to further increase the step-up/down ratio. This type of systems is very much useful in renewable energy source applications for better efficiency and high voltage gain. The multilevel inverter is fed to a induction motor drive and the performance of the motor is analyzed by using MATLAB/SIMULINK software.

Key words: uninterruptible power supply (UPS), Induction Motor

I.INTRODUCTION

Recently, there has been increased use of Microgrid systems that can supply the load from renewable energy to the load with high quality [1]. The power from renewable energy can be supplied to the load, or it could be saved depending on the power flow situation. Some renewable energy systems have limitations related to low voltage. For instance, the battery energy storage system, supercapacitor, and photovoltaic cells generate low voltage levels, and they cannot be connected directly to the load bus. To solve this connection problem, power electronics can be employed to connect the renewable energy to the load. Therefore, a converter could be used to boost the input voltage to meet the load bus or transmission line requirements. For these typical low-voltage problems, a high step-up/down converter becomes one of the most important and significant solutions for interfacing microgrid systems [2].Battery energy storage systems are a good solution to increase grid reliability. The energy can be stored for later use during grid-connection mode, and energy storage systems can supply the power to the grid when a fault occurs in the grid. To connect energy storage systems to the grid, dc-dc buck-boost converters are normally used [3]. With medium and high voltage grids, bidirectional dcdc transformer converters could be used to step up and step down the voltages. Researchers have been working on and improving modular multilevel converters (MMCs) for more than 30 years. This technology has been successfully used in the industry for years and is considered a trusted technology [4]. The significance of MMCs has been increasing among the other types of multilevel converters. This is because MMCs are proven to be more appropriate for utilization in medium-voltage and high-voltage applications, which are at variance with low-power applications, where topologies that include transformers are found to be more effective in terms of conversion ratios [4]-[12].This paper discusses a high step-up/down isolated modular multilevel converter for an uninterruptible power supply (UPS) system. For the UPS, there are two modes: grid-connection mode and stand-alone mode. In grid connection mode, power from the grid can charge batteries. In this grid-connection mode, the isolated MMC also works as a step-down converter with a 15:1 voltage conversion ratio. In the second mode, stand-alone mode, power can flow from the batteries to the grid. During this mode, the converter steps up the input voltage with a 1:15 voltage conversion ratio. In stand-alone mode power flow is also controlled by using a voltage and frequency drooping method. This ensures seamless transfer between the two conversion modes. Detailed MATLAB-Simulink simulations are presented and indicate the benefits of the proposed converter.

II.SYSTEM CONFIGARATION

The overall system is shown in Fig. 1. It has a set of parallel- and series-connected batteries as an input, a bidirectional high step-up/down isolated MMC converter, and a three phase bidirectional dc-ac inverter. Depending on the load condition, the high step-up/down can boost, or buck the voltage. In other words, the MMC can charge the batteries in battery charging mode, and it can operate as a step-up converter during discharging mode. The UPS is controlled based on the droop method.

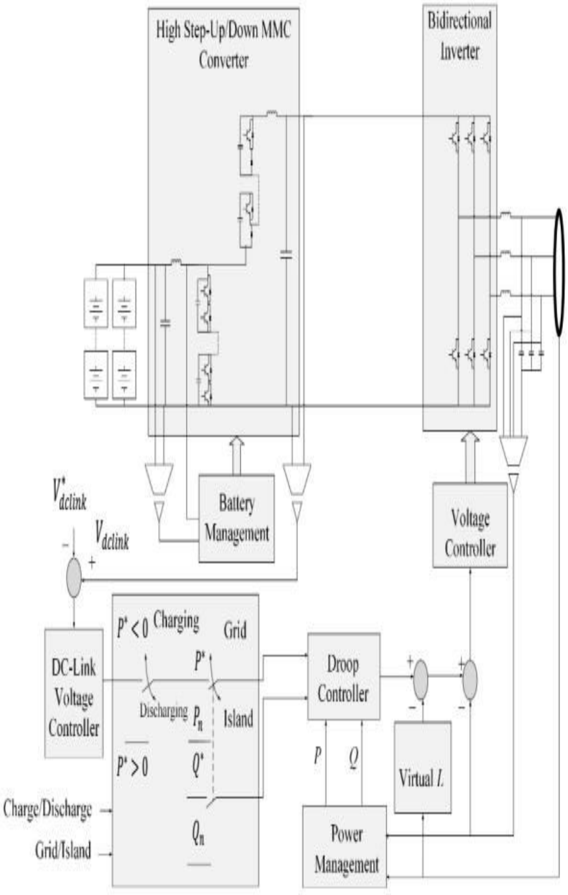

Fig.1.The overall control system with proposed converter

III.CONVERTER DESIGN

The topology that is described in [15] is for a transformer less modular multilevel converter where the transformer less MMC circuit system consists of an upper and lower set of capacitor-transistor cells, where the number of upper capacitor-transistor cells is N and the number of the lower capacitor-transistor cells is M [15], as shown in Fig. 2. Phase shift pulse width modulation (PSPWM) with a high duty cycle is used with the proposed MMC. This high duty cycle ensures that all except one of the capacitors are connected at any given time. This means that at any instance the pulse-width modulation method ensures all of the upper and lower capacitors (except one of them) are in series with the high side inductor and capacitor. However, for isolation purposes, a transformer is placed between the upper and lower cells. The transformer ensures that there is no direct connection between the input and the output. In addition, the transformer can provide some additional voltage increase on the output. Fig. 3 shows an isolated high step-up modular multilevel converter.

For a transformer less MMC, the voltage and current conversion ratio equations are written in [15] as:

$$\frac{v_H}{v_L} = \frac{N}{1-d} \tag{1}$$

The current for this converter design is then derived [16]

$$I_L = \frac{v_H}{v_L} I_o \tag{2}$$

where v_H is the output voltage, v_L is the input voltage, d is the duty cycle, I_L is the input current, and I_O is the output current. From (2), the voltage conversion ratio depends on both the number of the upper cells, N, and the duty cycle d. To have a 1:10 conversion ratio, the number of the upper cells sets to be 4, and the duty cycle 0.6. Both equations (1) and (2) have the same expression for an isolated MMC. The only difference is that the turns ratio for the transformer should be included in the voltage and current conversion ratio equations. In other words, the voltage and current conversion ratio for an isolated topology can be written as:

$$\frac{v_H}{v_L} = \left(\frac{N_s}{N_p}\right)\frac{N}{1-d} \tag{3}$$

$$I_L = \left(\frac{N_p}{N_s}\right)\frac{N}{1-d} I_o \tag{4}$$

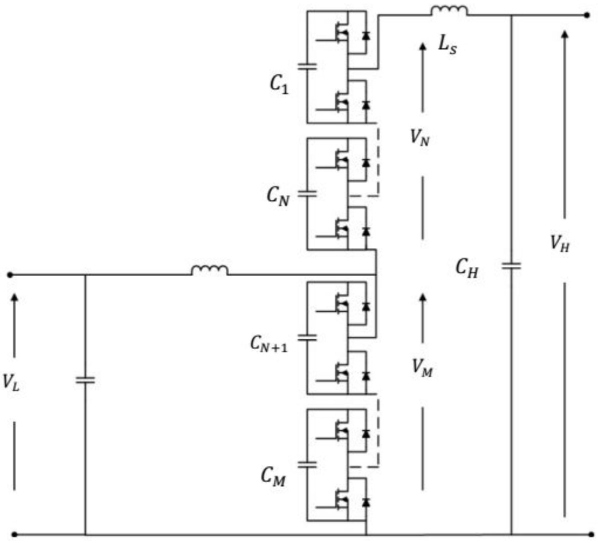

Fig.2. A high step-up modular multilevel converter [15].

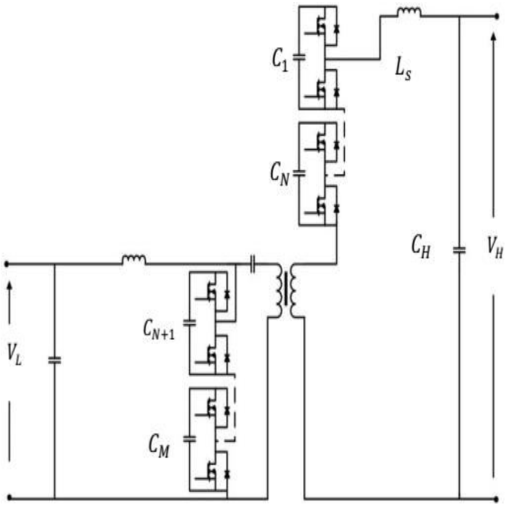

Fig.3. The proposed isolated modular multilevel converter

Where N_p and N_s are the number of the turns in the primary and secondary winding of the transformer, respectively. As mentioned earlier, the transformer less MMC can achieve 1:10 conversion ratio. However, the conversion ratio could be increased to 1:15 by using a transformer.

IV. INDUCTION MOTOR

An asynchronous motor type of an induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor as are found in universal, DC and synchronous motors. An asynchronous motor's rotor can be either wound type or squirrel-cage type.Three-phase squirrel-cage asynchronous motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications. Variable voltage and variable frequency drives are also used in variable-speed service.In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance. The rotating magnetic flux induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary winding(s). The currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The difference, or "slip," between actual and synchronous speed varies from about 0.5 to 5.0% for standard Design B torque curve induction motors. The induction machine's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent magnet motors.For rotor currents to be induced the speed of the physical rotor must be lower than that of the stator's rotating magnetic field (n_s); otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called slip. Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load.

Synchronous Speed:

The rotational speed of the rotating magnetic field is called as synchronous speed.

$$Ns = \frac{120 \text{ x } f}{P} \quad (RPM) \qquad (5)$$

Where,

f = frequency of the supply
P = number of poles

Slip:

Rotor tries to catch up the synchronous speed of the stator field, and hence it rotates. But in practice, rotor never succeeds in catching up. If rotor catches up the stator speed, there won’t be any relative speed between the stator flux and the rotor, hence no induced rotor current and no torque production to maintain the rotation. However, this won't stop the motor, the rotor will slow down due to lost of torque, and the torque will again be exerted due to relative speed. That is why the rotor rotates at speed which is always less the synchronous speed.The difference between the synchronous speed (Ns) and actual speed (N) of the rotor is called as slip.

$$\% \text{ slip} \quad s = \frac{Ns - N}{Ns} \text{ x } 100 \qquad (6)$$

IV.MATLAB/SIMULINK RESULTS

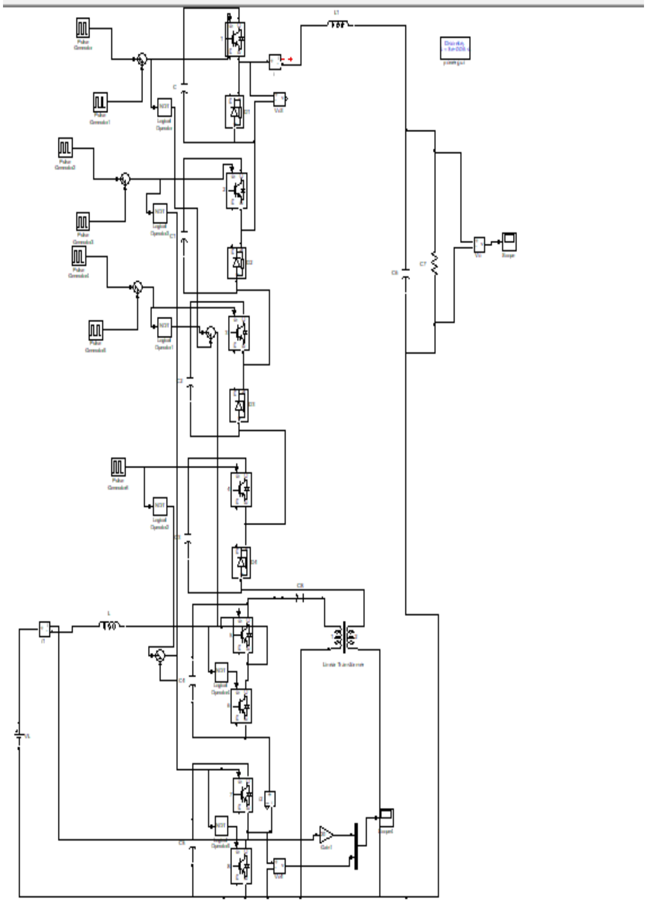

Fig.4: Simulation model of A high step-up modular multilevel converter

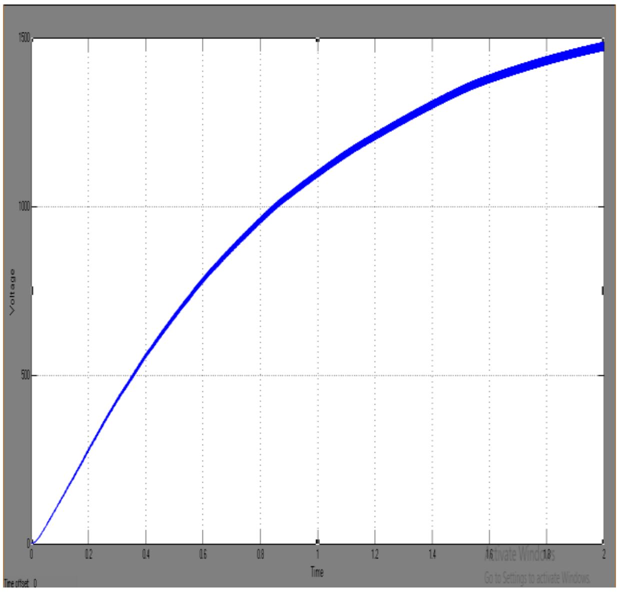

Fig5.Simulation waveform of output voltage

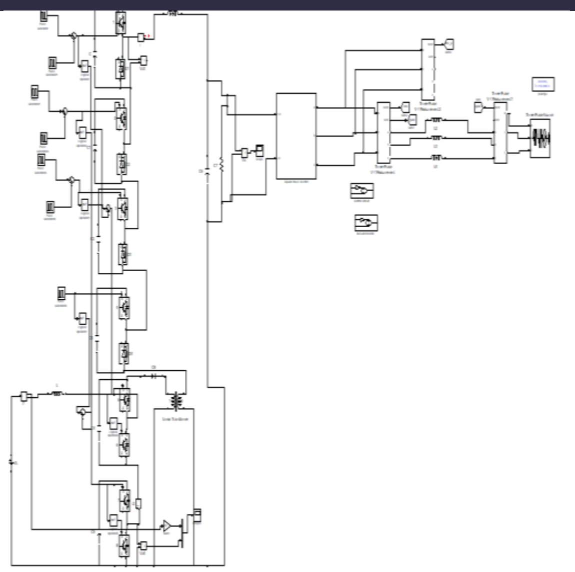

Fig.6: Simulation modelling of A high step-up modular multilevel converter

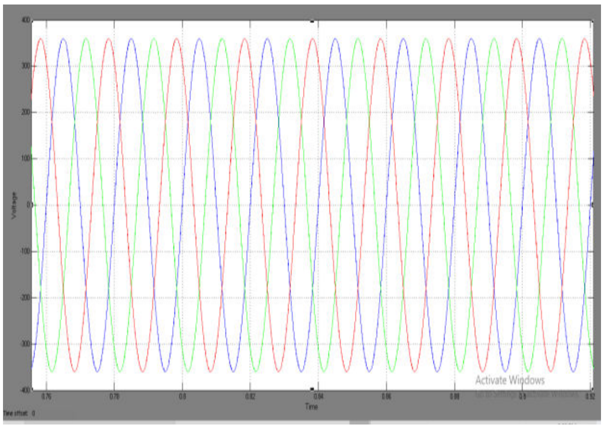

Fig7:Simulation waveform of gain voltage discharging to charging mode.

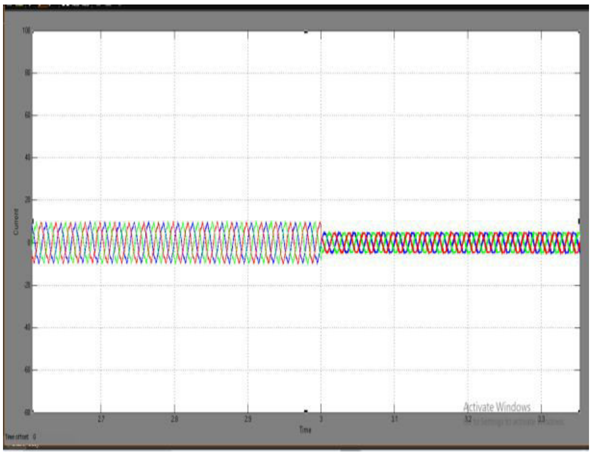

Fig8: Simulation waveform of gain current discharging to charging mode.

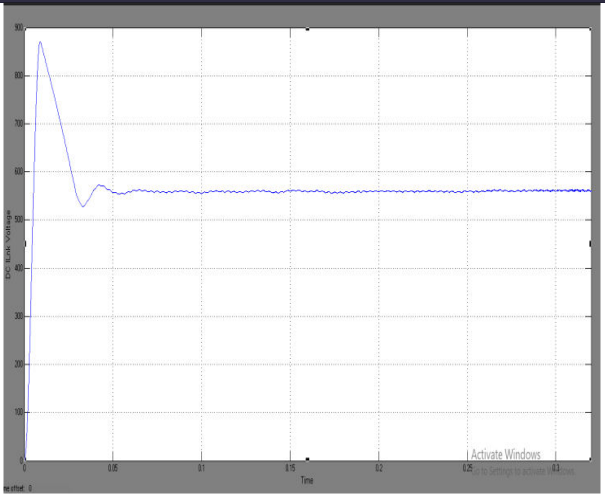

Fig9: Simulation waveform of inverse voltage discharging to charging mode.

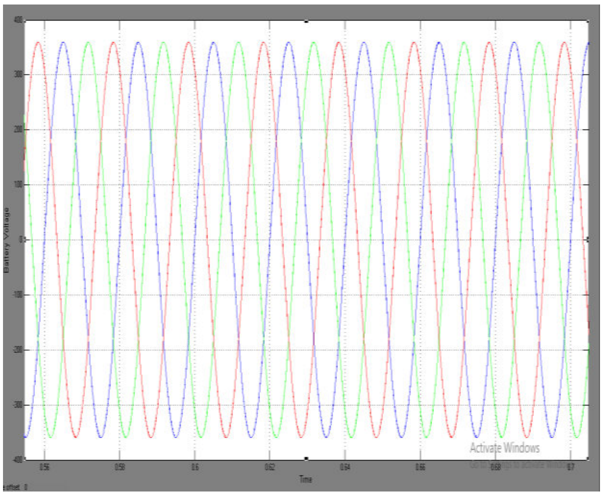

Fig10: Simulation waveform of gain voltage charging to discharging mode

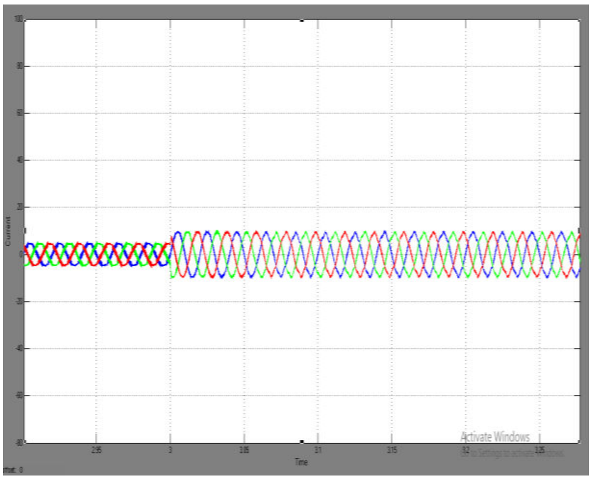

Fig 11: Simulation waveform of gain current charging to discharging mode.

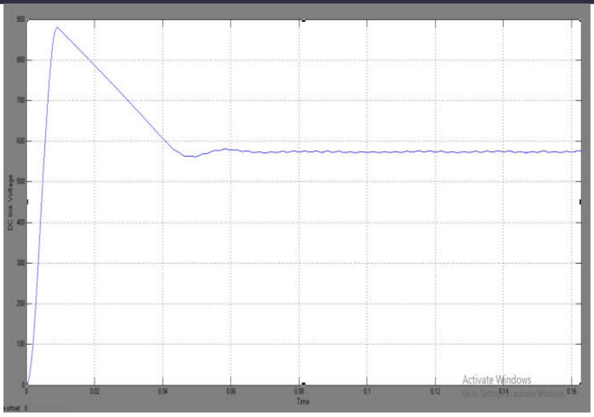

Fig:12 Simulation waveform of inverse voltage charging to discharging mode

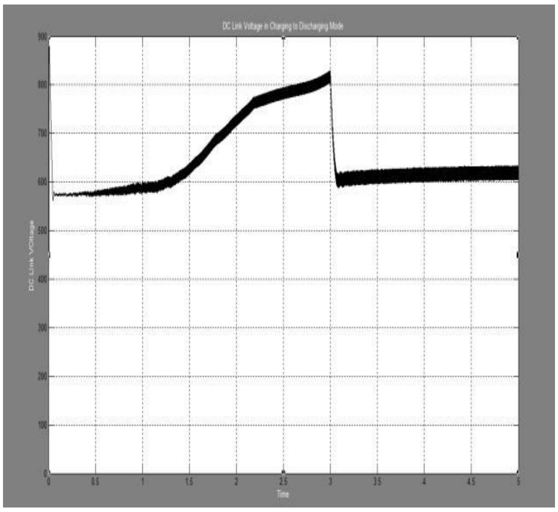

fig 13 Simulation waveform of inverse voltage discharging to charging mode.

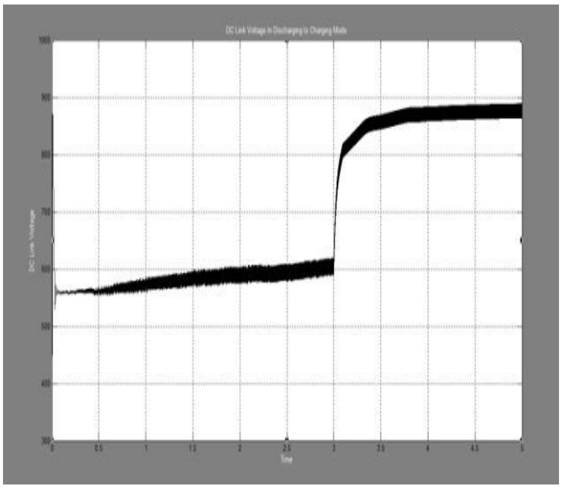

Fig:14 Simulation waveform of inverse voltage charging to discharging mode

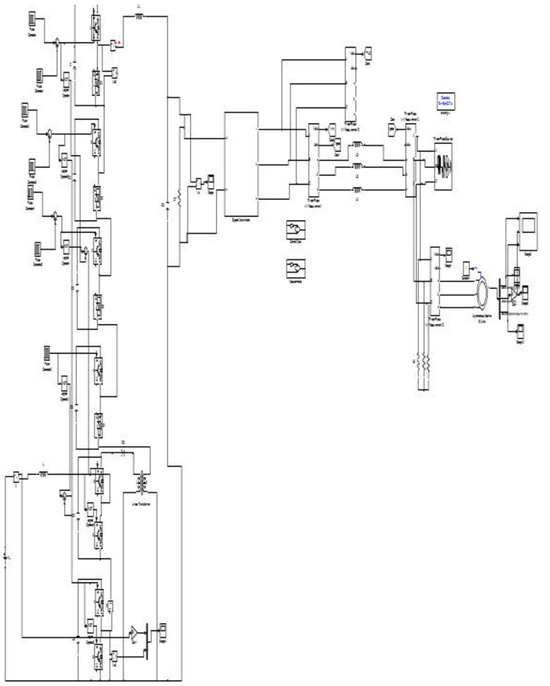

Fig.15: Simulation model of A high step-up modular multilevel converter with induction motor drive

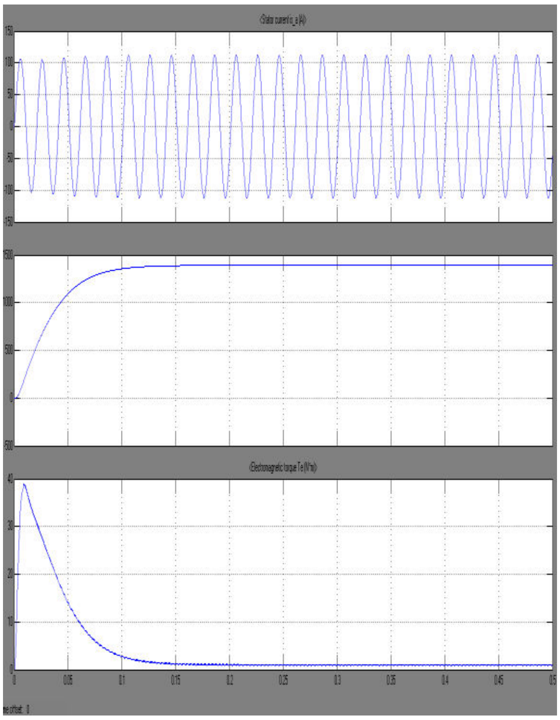

Figure 16 characteristics of stator current Stator current, speed, torque Induction motor

CONCLUSION

A high step-up/down converter with Induction motor drive was integrated with a line uninterruptible power supply system and evaluated through simulation for stability, response and efficiency. With the appropriate control, the proposed MMC can make use of low-voltage input voltage sources, such as batteries and photovoltaic devices, and connect them to a medium/high voltage microgrid. The system can generate power flow from ac to dc or from dc to ac in either direction depending on the power flow situation. The voltage amplification ratio up to 1:10 can be achieved without the need for a transformer, and an even higher voltage step-up (1:15 ratio) is possible with a transformer. The use of a transformer would also provide galvanic isolation. This isolation would prevent (1) current flow between the circuits, (2) circulating currents if the ground potentials of both sides may differ and (3) dangerous passing of current through someone who comes in contact with the circuit.

This MMC therefore is practical and flexible for inexpensive low-voltage Microgrid connections. The MMC requires relatively simple cascaded control to achieve a response that is not far too slow for a better controller to correct. However, the response would be improved if it were made to be faster. The transient response is just under half a cycle (less than 25 ms), but a response of 7 ms or less is preferred, as typical faults and surges can become very problematic if they last more than about a quarter of the operating frequency on an ac line [17]. Future investigation into this MMC setup would include faster and more robust control to reduce the correction response time.

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