ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

Simulation of Locomotive Control of Traction Motor Using a New Bidirectional DC-DC-AC Converter

S. Durga Priya[1], S.Senthil[2]

[1]PG Student, Dept of Power Electronics and Electrical Drives, S.V.C.E.T, Chittoor, Andhra Pradesh, India
[2]Associate professor, Dept of Electrical& Electronics Engg, , S.V.C.E.T, Chittoor, Andhra Pradesh, India

Abstract: **This project mainly concentrates on a simulation of locomotive control of traction motors with a new bidirectional DC-DC-AC converter using Renewable Energy Sources. The existing system is developed with four quadrant operation of dc series motor or induction motor fed voltage and frequency control using power electronic controllers. But in this system the efficiency is low and speed control is not synchronized with other motors. Therefore there is jerking of compartments, uniform braking is not possible in the traction system. The DC motors have been utilized for traction for over one hundred years and were originally chosen because of their inherent compatibility with traction power supplies and ease of mounting within locomotive bogies. The proposed system is designed with fuel cell based bidirectional DC-DC-AC dual inverter for traction motor to optimize third harmonic distortion, switching pattern losses, voltage fluctuations, reducing of switches, cost and also increasing efficiency and feasible operation of traction motors. The Fuel cell based system is powered to the traction motor to run forward, reverse and regenerative braking operation with the help of bidirectional control. So that the kinematic operation of traction motor is control the voltage, speed, torque levels using the ZVS DC-DC-AC converters. The proposed multilevel inverter minimizes the THD with the implementation of Z-source inverter. It is useful in boosting the voltage and additionally reducing the voltage fluctuations in the nine switch Z-source inverter. In a fuel cell powered to traction system the bidirectional dc-dc converter and inverter are essential for efficient performance of the traction motor. The simulation of dual converters is developed using MATLAB/SIMULINK and rotor current, stator current, stator voltage, rotor speed, electromagnetic torque and rotor angle is obtained for the traction motor. The multilevel inverters are developed to reduce the total third harmonic distortions (THD) in the converters. The multilevel converters are used to reduce the switching pattern losses. The performance of the traction system is compatible and running of motors is continuous without any disturbances. The most advantageous of the system is the multistep boost ZVS converter is implemented to maintain the constant power output**.

Keywords: **Bidirectional Dc-Dc Converter, Traction Motor, Nine Switch Inverter, Fuel Cell.**

I. INTRODUCTION

This project is mainly concentrates on a Simulation of Locomotive Control of Traction Motor Using a New Bidirectional DC-DC-AC Converter. For the fuel cell based traction motor both bidirectional dc-dc converter and inverter are necessary. Bidirectional dc-dc converters became prominent because of the requirements of fuel cell applications. The bidirectional dc-dc converter for this application has simple circuit topology, soft switching implementation without no additional devices, high efficiency and simple control. The Speed Control of 3-Phase Motors Using Nine-Switch Z-Source VSI from CSI is can be done here. The multi-level inverters are developed to cut back the entire third harmonic

ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

distortions (THD) within the converters. The multi level converters are used to scale back the losses in switching pattern; however the THD increases with the increasing levels. The projected multilevel inverter minimizes the THD with the implementation of z-source Inverter. It is used to boosting up the voltage and reducing the voltage fluctuations in the nine-switch z-source inverter.

Nine switches - z-source inverter with sinusoidal PWM techniques are enforced to reduce the switching patterns and acquire 3 phase output voltages which are connected to three-phase motors.

Actually the inverter model includes 6 pulse PWM control for switching the devices and control output voltage. The power quality, power factor are less and THD is more. The Z-source CSI model is intended for the speed control of three phase motors by changing in terms of current switches. The speed is adjustable by varying the SPWM and its controls the output current. The similar model is additionally projected to VSI and varies the output voltage by SPWM control. Therefore the speed at three-phase motors is controlled.

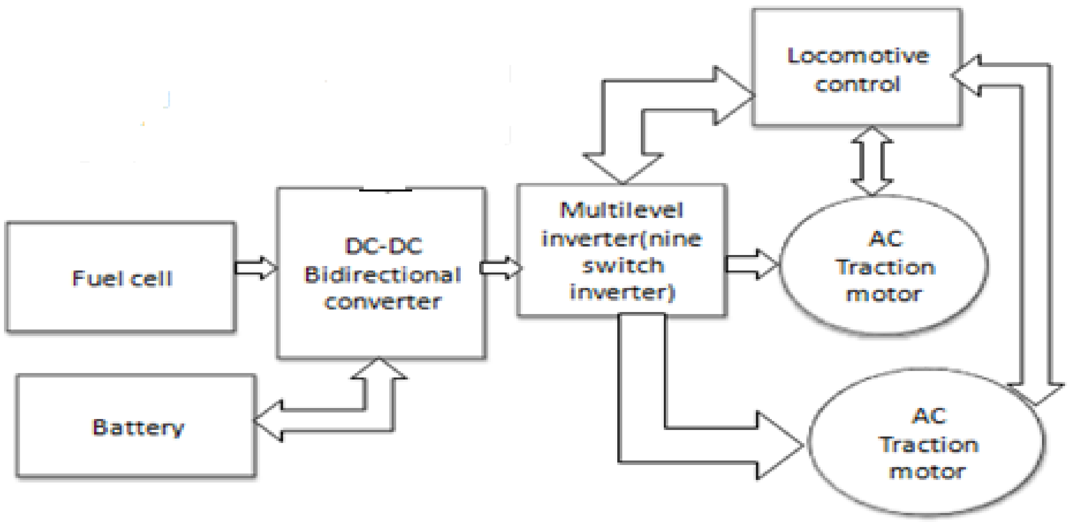

Fig 1: block diagram of the proposed system

II. BIDIRECTIONAL DC-DC CONVERTER

The bidirectional dc–dc converter for fuel cell powered systems is shown in Fig. 2.

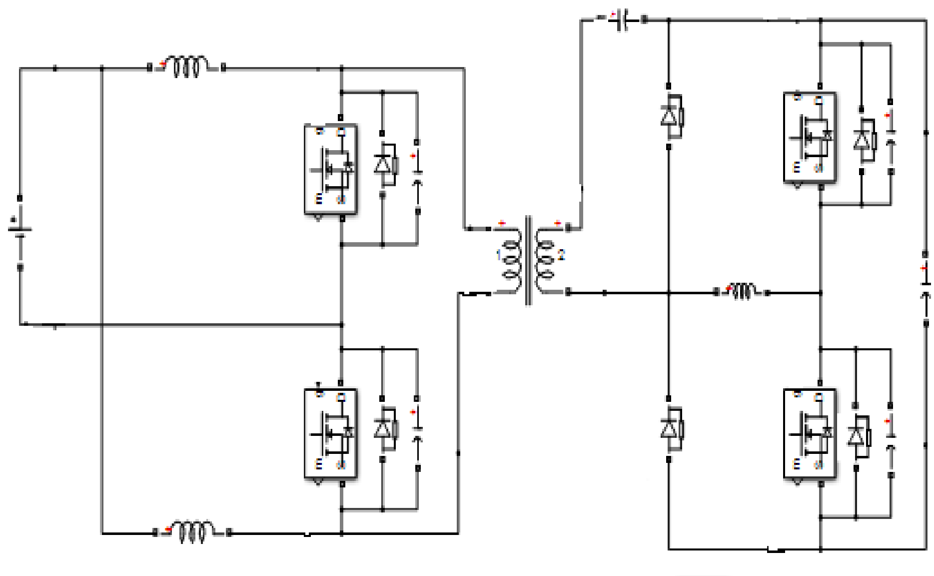

Fig 2: Bidirectional dc-dc converter

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

The circuit has an inductor on the battery side and two half-bridges on either side of the main transformer. A parallel capacitor is present across each switching device for soft switching. The circuit works in boost mode when power flows from the low voltage side (LVS) to the high voltage side (HVS), to keep the HVS voltage at a desired high value. In the reverse the circuit works in buck mode to recharge the battery from the fuel cell or from absorbing regenerated energy in the other direction of power flow. The unique arrangement here is of the inductor and the LVS half bridge. The LVS half bridge here performs two functions:

1) It acts a boost converter to step up voltage;

2) Also as an inverter to produce high frequency ac voltage.

The boost function is obtained by the inductor and the LVS half bridge. The LVS boost converter is capable of drawing much smoother current from the load voltage source than full bridge voltage source inverter. This incorporated dual function provided by the LVS half bridge is main advantage over other topologies, because the initial current rating of the transformer and current stress of the LVS devices are minimized. Here the capacitor across each switch is a lossless snubber (or resonant capacitor) used for soft switching. The transformer here provides isolation and voltage matching. The leakage inductance of the transformer present acts as a interface and an element which transfers energy between the two voltage-source half bridge inverters: LVS and HVS half bridges.

The reason behind the usage of the dual half-bridge topology instead of a dual full-bridge configuration is due the comparison of total device rating in full bridge and half bridge. The full bridge produces a high-frequency square-wave voltage. The switching devices in the full bridge will be subjected to a voltage stress equal to the dc-input voltage, and the current stress which may be equal to that of the load current. The total device rating of the full bridge can be calculated as 4 times the output power for 4 devices. The LVS half bridge is shown in the proposed converter Fig. 2 which has the capability to boost the dc-rail voltage two times that of the dc-input voltage and also it can generate same level of high-frequency, square-wave voltage with when being operated at 50% duty cycle. Hence, for half bridge every switching device's voltage stress is two times the dc input voltage, and the current stress will still be same as the load current. Likewise, the total device rating of the half-bridge will also be calculated as 4 times output power for 2 devices. From the above discussion the conclusions made are as follows.

1) For the dual half bridge topology and the dual full bridge the total device rating is the same for the similar output power.

2) The devices of the half-bridge being subjected to twice the dc input voltage in this case is an advantage for EV/HEV and fuel cell applications because the dc input voltage is very low.

3) Obviously the dual half bridge topology uses half the number of devices that the full-bridge topology uses.

The most important downside of the half bridge is the split dc capacitors which will have to handle the full load current. For the projected application, high current electrolytic capacitors in a combination with high frequency polypropylene capacitors are used. The other merits of the circuit for bidirectional dc-dc converter are

1) A relatively ripple-free dc current that is advantageous and pleasant to the low-voltage source (fuel cell or battery) is produced by the LVS half bridge.

2) Stresses are minimized for the LVS switching devices and transformer

3) Without additional switching devices the unified soft-switching capabilities in either direction of power flow is achieved.

The ZVS in either direction of power flow is achieved with no involvement of lossy components and without any additional active switch. The double functions (simultaneous boost conversion and inversion) is provided by the low voltage side half bridge, current stresses on the switching devices and transformer are kept least amount. The advantages of this circuit includes ZVS with full load range, decreased device count, high efficiency and less cost and also less control and accessory power needs which makes the converter very promising for medium power applications with high power density.

ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

III. TRACTION MOTOR

The operation of a traction motor is to propel (drive) a vehicle at variable speed in the traction duty cycle loading constraints. Electrical machines that are being used for traction should respect:

- limits on area for physical installation
- economy in operation is a requirement
- machine insulation's dielectric stress should be restricted
- maximal thermal loading of conducting and insulation materials
- harsh surroundings -including vibration, shock, temperature and wetness
- Restrictions on weight for axle/wheel loading.

Over the time continuous improvement of machines resulted in effective machine designs being made while not the requirement for importance over dimensioning.

The appropriate motors for traction:

- DC series commutator motor
- separately-excited commutator motor
- low-frequency AC commutator motor
- Three-phase AC synchronous motor
- Three-phase AC asynchronous (induction) motor.

Although massive numbers of traction vehicles are still working with low-frequency commutator motors and DC series motors, the separately-excited commutator motor and the three-phase cage induction motor are considered the best for the purpose of traction. The synchronous machine is being used in high-speed train drives.

DC motors are utilized for traction for over one hundred years and were originally chosen thanks to their inherent compatibility with traction power supplies and easy mounting in locomotive. Their operation voltage, current, speed and torque levels are dependable with the dynamic and kinematic traction duty cycle necessities.

Series motor ideal for traction as the machine develops a high starting torque; the actual advantage of the series motor is that control of just one variable, the armature current, is needed.

The separately-excited motor is apt for traction as a result of it is going to be controlled to make high torque at low speeds, and nonetheless totally utilize its rated power at high speeds.

Three-phase cage induction (asynchronous) motors were being used for traction over the years, and it is again with the influence of power electronic devices within variable-frequency converters it was made possible. Induction motors are the simplest when considered mechanically among all traction machine types which has no electrical connections needed for the rotating field winding. The induction motor's torque-speed characteristic is given by the basic equation of torque from which speed control variables are obtained and they are the stator field frequency, terminal voltage, number of poles and rotor circuit resistance. Of which number of poles and rotor circuit resistance are not used in inverter-fed drives where traction control is done by variation of the terminal voltage or current and the stator frequency. The motor is controlled within four regions of operation.

IV. STRUCTURE OF THE NINE-SWITCH INVERTER

Basic Concept:

Below figure shows the structure of the projected nine-switch inverter that consists of two three-phase inverters combined with three common switches (UM, VM, and WM). The upper portion in Fig 3 is termed Inv1, and also the lower part is termed Inv2. Inv1 consists of switches UH, VH, WH, UM, VM, and WM, and Inv2 consists of the switches UM, VM, WM, UL, VL, and WL. A pulse-width modulator (PWM) generates gate signals for Inv1 and Inv2, as shown in Fig 3. This PWM modulator contains a unique carrier waveform. For the PWM modulation for Inv1 a reference for Inv2 is lower than carrier2 is calculated from the waveform.

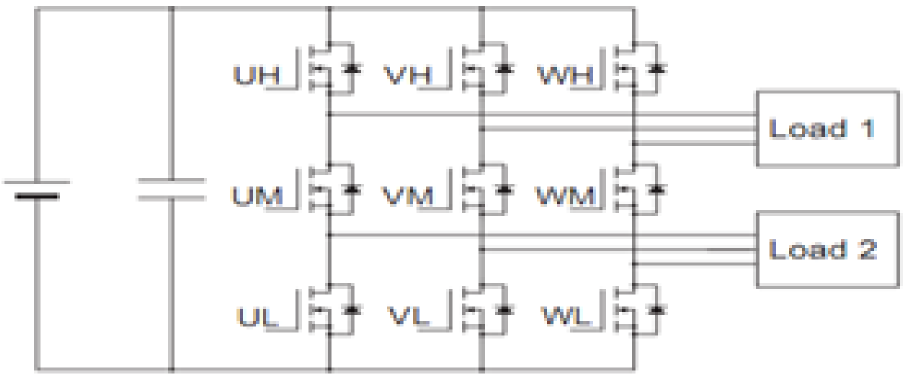

Fig 3: Main circuit of proposed nine-switch inverter.

Furthermore, the Inv1 reference exceeds carrier1 if the PWM modulation for Inv2 is calculated. Therefore, switches UL, VL, and WL are within the ON state when Inv1 is driven (mode1) and switches UH, VH, and WH are within the ON state when Inv2 is driven (mode2). Figure 4 shows the state of every mode.

Method of Realization:

The Carrier1 and also the carrier in Fig 4 are combined when generating the gate signals. Therefore, the PWM modulation of Inv1 is calculated at the upper part of a triangular wave, and also the PWM modulation of Inv2 is calculated at its lower part, as shown in Fig 5. Let a U-phase voltage reference for Inv1 be V^{ref}_{u1}, and a U-phase voltage reference for Inv2 is V^{ref}_{u2}. Assume that V^{ref}_{u1} and V^{ref}_{u2} are given by

$$v_{u1}^{ref} = A1\sin(2\pi f_1 t + \varphi_1)$$

$$v_{u2}^{ref} = A2\sin(2\pi f_2 t + \varphi_2)$$

Where A_1, A_2 are amplitudes, f1, f2 are frequencies, and Φ_1,Φ_2 are phases. A general modulation rate, m, is given by

$$m = \frac{v^{ref}}{E/2}$$

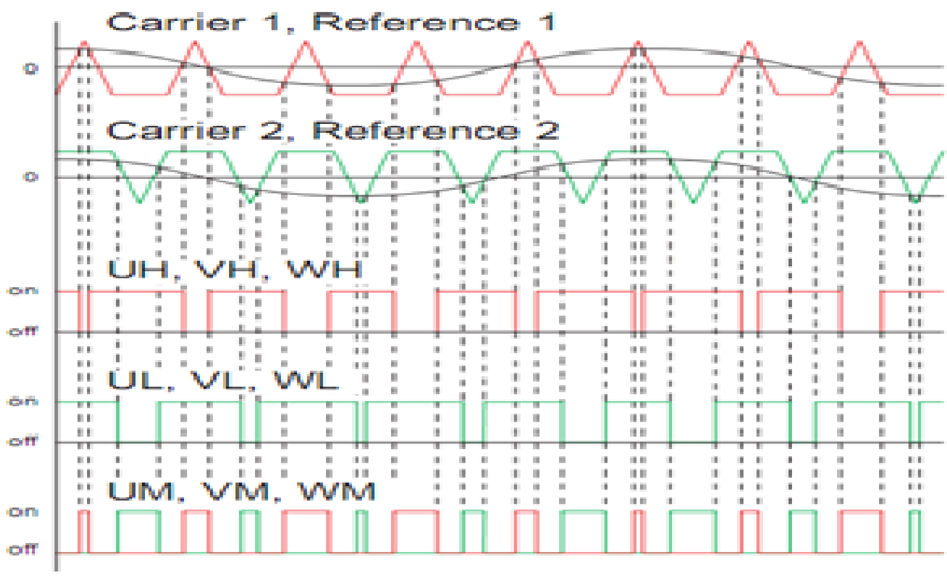

Fig 4: Principle of operation

ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

Where E could be a dc source voltage. An offset, E/4, is additionally added to the reference in (1) and an offset -E/4 is added to the reference in (2) when calculating the proposed PWM modulation. Therefore,

$$m_{1u} = \frac{v_{u1}^{ref} + E/4}{E/2} = \frac{v_{u1}^{ref}}{E/2} + \frac{1}{2}$$

$$m_{2u} = \frac{v_{u2}^{ref} - E/4}{E/2} = \frac{v_{u2}^{ref}}{E/2} - \frac{1}{2}$$

From these transformations, the range of the references for Inv1 and Inv2 become $-E/4 \le V^{ref}_{u1} \le E/4$ and $-E/4 \le V^{ref}_{u2} \le E/4$, respectively. The gate signals for the switches UH, VH, and WH are positive logic values generated by the reference for Inv1 and the upper part of the carrier.

The gate signals for switches UL, VL, and WL are negative logic values generated by the reference of Inv2 and the lower part of the carrier. The gate signals for the switches UM, VM, and WM are reversed values generated by the logical OR value of the gate signals for switches UH, VH, WH and UL, VL, WL, as shown in Fig 4.

IMPROVING VOLTAGE UTILIZATION:

The nine-switch inverter shares a single dc voltage source between Inv1 and Inv2. Thus, voltage utilization for Inv1 and Inv2 is 50%. In this section a method for improving voltage utilization can be seen.

Each inverters usage of the voltage source changes with its reference value. Let the distribution rate of voltage utilization be α (0 ≤ α ≤ 1). Initially, we derive an equation for a single phase. α is given by

$$\alpha = \frac{A_1}{A_1 + A_2}$$

An offset using this is added to the variations of the reference for Inv1 and Inv2.

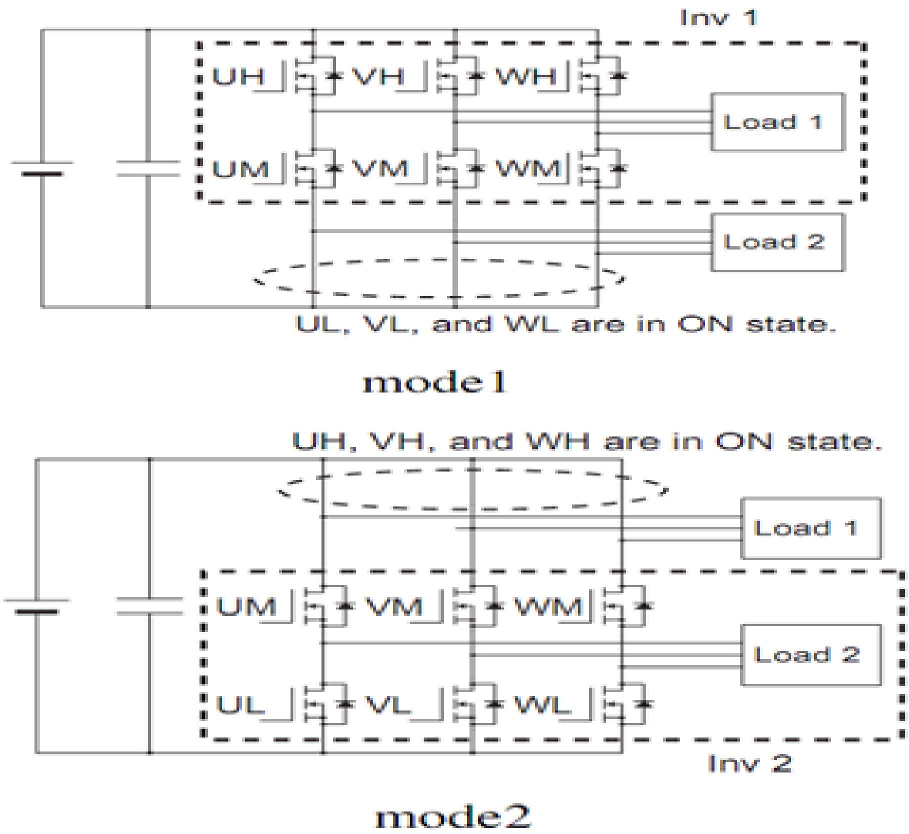

Fig 5: Operation mode (mode1 and mode2)

ISSN 2349-7815
International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

Fig 6: PWM modulation of the novel inverter

The offsets are decided as modulation rates placed on the center of the divided carrier. Thus, each offset can be given by

$$offset_1 = 1 - \alpha$$

$$offset_2 = -\alpha$$

Therefore, the modulation rate of the U-phase is given by

$$m_{1u} = \frac{v_{u1}^{ref}}{E/2} + 1 - \alpha$$

$$m_{2u} = \frac{v_{u2}^{ref}}{E/2} - \alpha$$

Next, we tend to derive an equation for three-phase operation. The maximum value of each absolute of the three-phase reference is represented by r_1 and r_2.

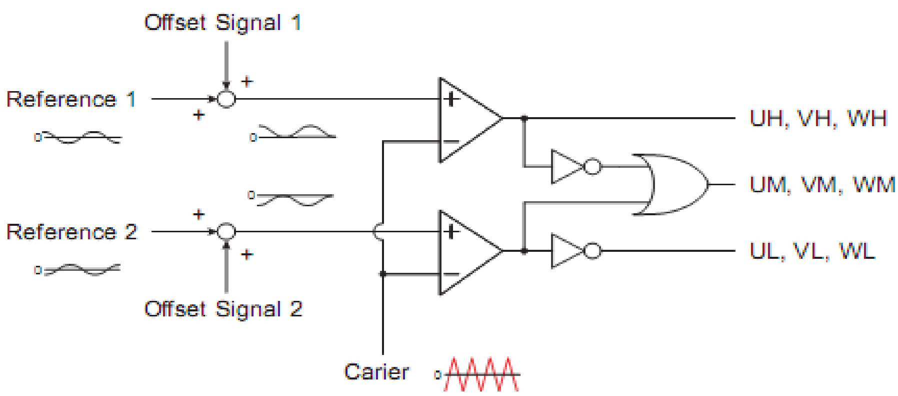

Fig 7: Method of generation gate signals

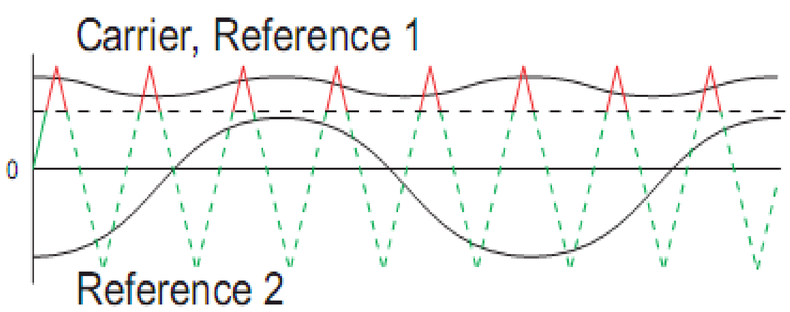

Fig 8: PWM modulation with the distribution rate of voltage utilization

ISSN 2349-7815

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

Finally, the rate of apportionment α and the modulation rate are given by

$$\alpha = \frac{|r_1|}{|r_1| + |r_2|}$$

$$m_u = \frac{v_1^{ref}}{E/2} + (1-\alpha)e$$

$$m_2 = -\frac{v_2^{ref}}{E/2} - \alpha e$$

Where

$$v_i^{ref} = [v_{ui}^{ref}\ v_{vi}^{ref}\ v_{wi}^{ref}]^T$$

$$m_i = [m_{ui}\ m_{vi}\ m_{wi}]^T$$

$$e = [1\ 1\ 1]^T$$

$$i = 1{,}2;\ -1 \le m_i \le 1$$

This methodology will improve voltage utilization of either Inv1 or Inv2. PWM modulation with the distribution rate of voltage utilization is shown in the figure 8.

V. SIMULATION RESULTS

The simulation circuit of the proposed system with fuel cell, battery, bidirectional dc-dc converter, nine switch inverter is as shown below

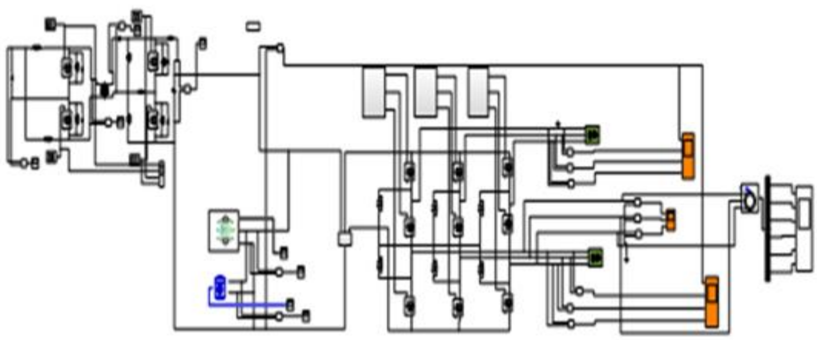

Fig 9: Simulation circuit of proposed system

The output from the bidirectional dc-dc converter is shown in fig 10.

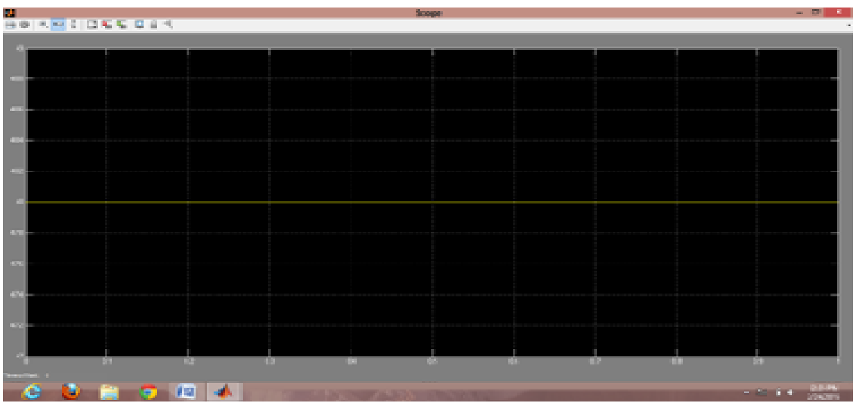

Fig 10: Output from the bidirectional dc-dc converter

International Journal of Recent Research in Electrical and Electronics Engineering (IJRREEE)
Vol. 2, Issue 2, pp: (109-118), Month: April 2015 - June 2015, Available at: www.paperpublications.org

This is in turn given to the multilevel inverter where the three phase ac are generated to be given to the ac loads.

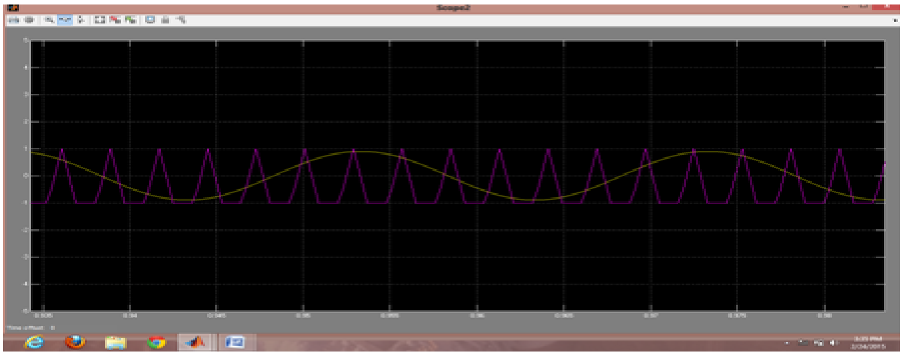

Fig 11: Pulse comparison in pulse generator of multilevel inverter

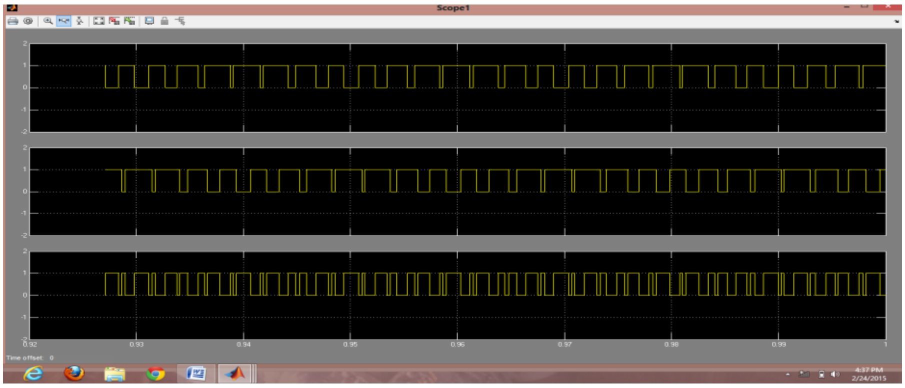

Fig 12: Pulse output of the pulse generator in multilevel inverter

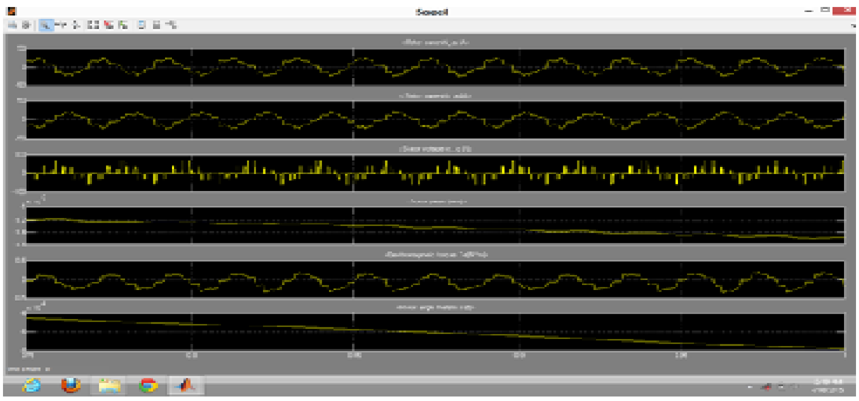

Fig 13: Traction motor output

The pulse comparison in the pulse generator and the pulse output of the multilevel inverter is shown above and the traction motor outputs of the proposed system are simulated and results are as shown.

VI. CONCLUSIONS

This project describes a simulation of locomotive control of traction motors with a new bidirectional DC-DC-AC converter using Renewable Energy Sources. The dc motors were utilized for traction for more than one hundred years because they were inherently compatible with traction power supplies and easy to mount within locomotive bogies. But their efficiency was low and speed control was not synchronized with other motors.

In this project a ZVS bidirectional DC-DC converter and nine switch multilevel inverter are proposed for efficient performance and also speed control of two three phase ac loads. Usually in traction systems the number of motors adds on according to the compartments and therefore by this configuration two ac loads can be supervised at a time. This feature

(Z-source) of the inverter provides the elimination of dead time in the circuit, thus increasing the reliability and reducing the output distortion. To prove the effectiveness of ZSI in reducing THD, performance of ZSI is evaluated using MATLAB/SIMULINK model developed for ZSI feeding motor load.

The complexity of this model has been reduced due to the reduction of switches from 12 to 9. Thus the switching losses are also minimized. As the switches are minimized, harmonic factor gets reduced which results in the minimization of distortion factor. Therefore third harmonic distortion factor are considerably minimized. The current type Z-source nine switch inverter can also boost the input current. The number of semiconductor switches is reduced in this model which in turn reduces the cost.

In the proposed multilevel inverter the THD is reduced with the implementation of Z-source inverter. It is also used to boost up the voltage, reduces the voltage fluctuations in the nine switch Z-source inverter. In a fuel cell powered traction system bidirectional dc-dc converter and inverter both are essential for the traction motor to perform efficiently.

The simulation of dual converters is implemented using MATLAB/SIMULINK and rotor current, stator current, stator voltage, rotor speed, electromagnetic torque and rotor angle are obtained for traction motor.

REFERENCES

[1] B. Wu, J. Pontt, J. Rodr´ıguez, S. Bernet, and S. Kouro, “Current-source converter and cyclo converter topologies for industrial medium-voltage drives,” IEEE Transaction on Industrial Electronics, Vol. 55, No. 7, pp. 2786-2797, Jul. 2008.

[2] T. Kominami and Y. Fujimoto, “A novel nine-switch inverter for independent control of two three-phase loads,” in Proc. IEEE Ind. Appl. Soc. Annu. Conf. (IAS), 2007, pp. 2346–2350.

[3] K.Wang et al., “Bidirectional dc to dc converters for fuel cell systems,” in Proc. IEEE Workshop Power Electron. Transport, 1998, pp. 47–51.

[4] T. Reimann, S. Szeponik, G. Berger, and J. Petzoldt, “A novel control principle of bidirectional dc-dc power conversion,” Proc. IEEE Power Electron. Spec. Conf., pp. 978–984, 1997.

[5] M. Jain, P. K. Jain, and M. Daniel, “A bidirectional dc–dc converter topology for low power application,” in Proc. IEEE Power Electron. Spec. Conf., 1997, pp. 804–810.

[6] De Doncker, R.W.A.A., Divan, D. M. & Kheraluwala, M. H. (1991). A three-phase softswitched high-power-density DC/DC converter for high-power applications. IEEE Transactions on Industry Applications, Vol. 27, No. 1, (Jan./Feb. 1991), pp. 63-73, ISSN 0093-9994

[7] Inoue, S. & Akagi, H. (2007). A Bidirectional DC-DC converter for an Energy storage system With Galvanic Isolation. IEEE Transactions on Power Electronics, Vol. 22, No. 6, (2007), pp. 2299-2306, ISSN 0885-8993

[8] Jain, A. K. & Ayyanar, R. (2010). PWM Control of Dual Active Bridge: Comprehensive Analysis and Experimental Verification. IEEE Transactions on Power Electronics, Vol. PP, No. 99, (2008), pp. 1, ISSN 0885-8993.