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A Design and Analysis of Voltage Source Inverters for Renewable Energy Applications

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Abstract

The paper proposes design of voltage source inverters for renewable energy applications such as HEV. The wind and solar are growing energy sources to world this sources to be converted alternating one for grid interfacing. Conventional inverters are electronic thyristor which has some drawbacks. To improve its efficiency and performance MOSFET based inverters using controllers has been designedusing PIC controllers. In this project the hardware details of three phases, 50Hz, 60W, 180 degree conduction mode of VSI output waveforms under various load conditions were presented and discussed. This paper will be a significant contributes for forthcoming development of Hybrid Electric Vehicle (HEV). In which Voltage source inverters is operation is performed in Single PIC microcontroller.

Keyword: *voltage source inverters, MOSFET, PIC microcontroller, hybird electric vehicles*

1. Introduction

The global desire to reduce the vehicle emissions and improve fuel economy accelerated the development of Hybrid Electric Vehicle (HEV). The technology advancements in the area of electric drive systems, battery technologies, fuel cells and the internal combustion engine (ICE) resulted in highly efficient HEV.

Electric vehicle (EV) is a road vehicle that employs a modern electric propulsion system. It provides emission free urban road transportation. The EVs are classified into three types such as Battery EV (BEV), Fuel Cell EV (FCEV) and HEV [1]. The HEV eliminates the disadvantages of both pure EV (BEV) and conventional vehicle. The FCEVs are still under development and they are costlier also. The HEV uses two or more kinds of energy sources to propel the wheels and one should be electrical energy. Energy source can be gas, natural gas, battery, ultra capacitor, fly wheel, solar panel, etc. HEV is a vehicle which utilizes the multiple sources of propulsion [2]. Simply the HEV consists of an internal combustion engine and an electric motor. The important advantages of the HEV are optimized operating efficiency of ICE and long driving range.

Rectifiers, inverters, and dc/dc converters are used in HEVs [3]. The power electronics components not only improve the overall system reliability but also reduce the cost, size, etc. In addition to power electronics, the technology of the electric motor plays a major role in the vehicle’s dynamics and the type of power converter for controlling the vehicle operating characteristics [4]. The transistorized inverter is used in the HEVs. Compared to the thyristorized inverter it has some special advantages in the area of size, weight, cost, efficiency and commutation. The VSI provides necessary power supply to electric motor from the energy storage system. The electric motor or traction motor provides electric propulsion in HEVs [5]. Nowadays MOSFET based VSI is used in HEVs. Fuel cell vehicles (FCV) use hydrogen as fuel to produce electricity; therefore they are basically emission free. When connected to electric power grid (V2G), the FCV can provide electricity for emergency power backup during a power outage [6]. Due to hydrogen production, storage, and the technical limitations of fuel cells at the present time, FCVs are not available to the general public yet. HEVs are likely to dominate the advanced propulsion in coming years. Hybrid Technologies can be used for almost all kinds of fuels and engines [8]. Therefore, it is not a transition technology. Figure 1 explains the road map of hybrid technologies and current status.

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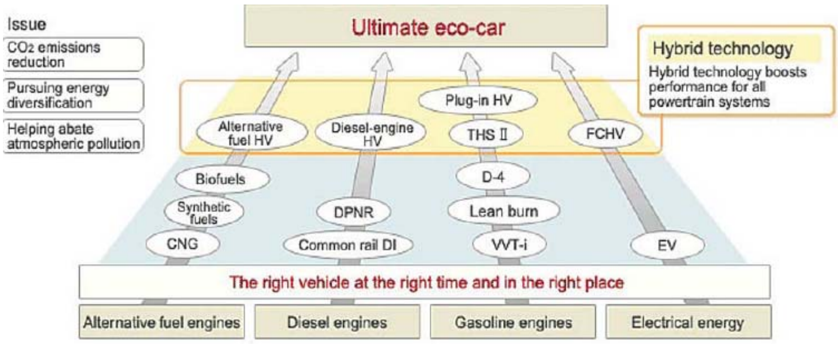

Figure 1. Road map of hybrid technology

Single-phase VSIs are used primarily for low power range applications, while three-phase VSIs cover both medium and high power range applications. Figure 2 shows the Three-Phase Voltage Source Inverter Circuit Schematic [3].

Switches in any of the three legs of the inverter cannot be switched off simultaneously due to this resulting in the voltages being dependent on the respective line current's polarity. States 7 and 8 produce zero AC line voltages, which result in AC line currents freewheeling through either the upper or the lower components. However, the line voltages for states 1 through 6 produce an AC line voltage consisting of the discrete values of Vi, 0 or –Vi. For three-phase SPWM, three modulating signals that are 120 degrees out of phase with one another are used in order to generate phase load voltages. PWM is generated with a single carrier signal, the normalized carrier frequency, mf, needs to be a combination of three. That the magnitude of the phase voltages same, which is out of phase with each other by degrees 120. The maximum phase voltage amplitude in the linear region in which ma less than or equal to one, is $\mathbf{v_{phase} = v_i / 2}$. The maximum obtainable line voltage amplitude is $\mathbf{V_{ab1} = v_{ab} \cdot \sqrt{3} / 2}$ **which is** only way to control the load voltage is by changing the input DC voltage to minimum level.

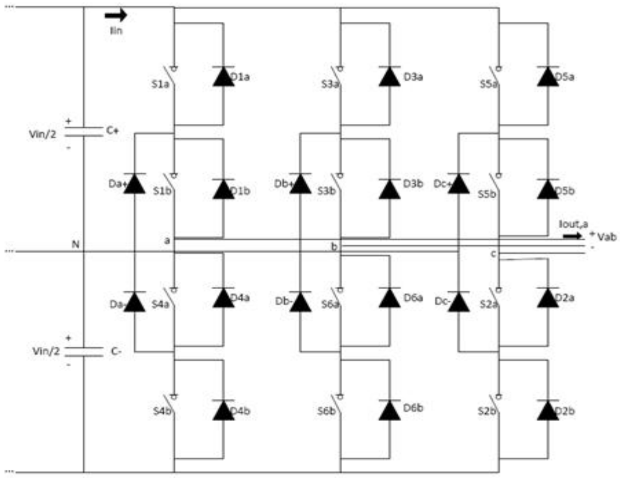

Figure 2. Three-Phase Voltage Source Inverter Circuit Schematic

2. Fabricated VSI

The fabricated VSI is designed with PIC 167F877A controller which controls the series of opto-coupler and show information through LCD the transistor IRFP 250 signals is applied through controller's opto-coupler acts as solid state relay contains a photodiode opto-isolator which drives a power switch, usually a complementary pair of MISFETs. Slotted optical switch contains a source of light and a sensor and optical channel are in open, allowing modulation of light by external objects obstructing the path of light or reflecting light into the sensor. The PIC micro controller has been very successful in 8-bit microcontrollers. The main advantage is that Microchip Technology has continuously upgraded the device architecture and added needed peripherals to the microcontroller to suit customers' requirements. It has the features like internal ADC and midrange architectures. The MCT2E has features 5300 VRMS isolation test voltage and Input-output coupling capacitance < 0.5 pF. In Figure 3 shows the experimental setup of VSI. It consists of 6V, 10Ah Lead Acid Battery unit power circuit (IRFP250 Power MOSFETs), PIC 16F877A microcontroller, MCT2E opto-couplers, DC voltage regulator, 200W, 250V balanced three phase lamp load. The phase voltage waveforms, phase current waveforms, line voltage waveforms and line current waveforms under various load conditions are captured with the help of digital storage oscilloscope. The magnitude of the firing pulses immediately after PIC 16F877A microcontroller, the magnitude of the firing pulses after MCT2E Opto-coupler, magnitude of the phase voltages and line voltages are measured.

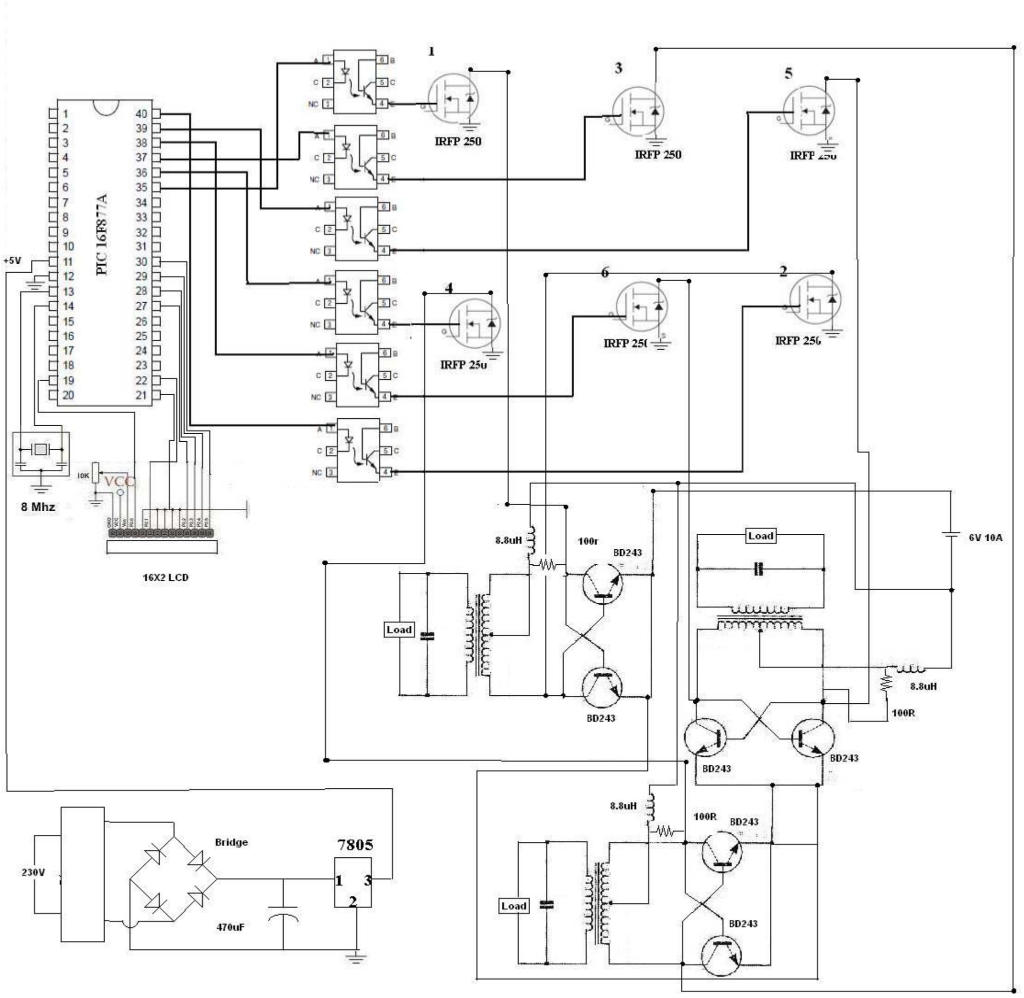

Figure 3. Proposed System diagram

3. Experiment Results

The proposed systems was tested experimentally in order to evaluate the performance of the proposed fabricated VSI in under different gate pulse and load conditions An analysis of the influence of the MCT2E is opto-coupler in the controlled output current is beyond the scope of the this work.Gate Pulses Generated Using PIC 16F877A. The individual gate pulses for six power MOSFETs are generated with 10ms ON period and 10ms OFF period using PIC 16F877A. The Figure 4 shows the gate pulses of the MOSFETs 1, 2 and 3. In Figure 5 the gate pulses of the MOSFETs 4, 5 and 6. The phase shift between the triggering of the two adjacent MOSFETs is 60^o (3.33 ms). Each MOSFET conducts for 10 ms as shown in the gate pulse waveforms.

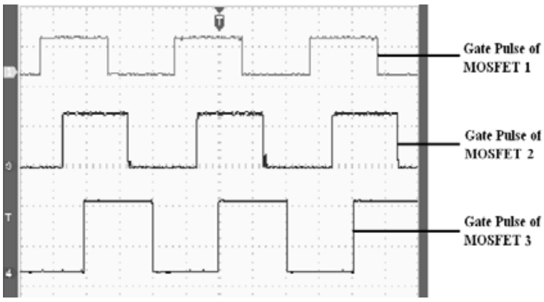

Figure 4. Gate pulses of MOSFETS 1, 2 and 3

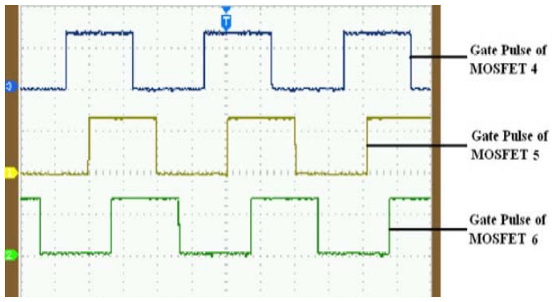

Figure 5. Gate pulses of MOSFETs 4, 5 and 6

4. No Load Results

When no-load condition the fabricated voltage source inverter line voltage waveform as shown fig.6. The no load output voltage waveform is a quasi-square wave. It has a conduction period of 120^0 (6.6ms) and a dead band of 60^0 (3.33ms). The theoretical study of the 180^0 conduction mode of the Voltage Source Inverter is thus realized through the hardware set up under no load condition.

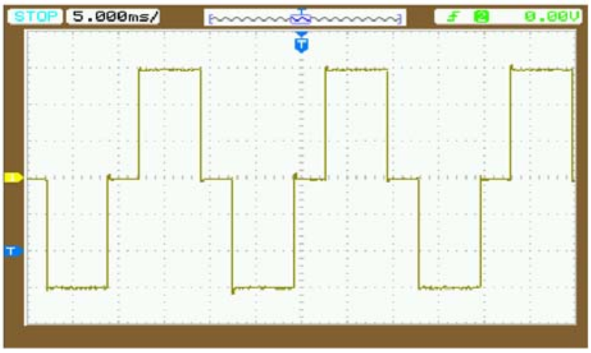

Figure 6. No load line voltage waveform

When fabricated voltage source inverter connected under loaded conditions in two loads under star and delta load conditions in Star connected the observed phase voltage and phase current waveforms of the VSI for star connected load are shown in Figure 7. From the waveforms it is seen that the phase voltage and phase current are six step waveforms. Each step has a time period of 60^0 (3.33ms). It gives output for the entire 180^0 (10ms) duration. The observed line voltage and line current waveforms of the VSI for star connected load are shown in Figure 7. From the waveforms it is seen that the line voltage is a quasi square wave. It has a conduction period of 120^0 (6.6ms) and a dead band of 60^0 (3.33ms). But the line current is a six step wave. The phase current and line current waveforms are similar. Thus the experimental results match the theoretical study of the 180^0 conduction mode of the VSI under star connected load.

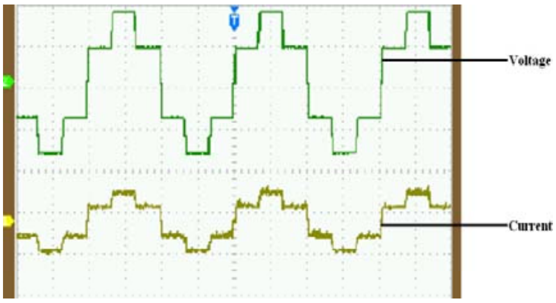

Figure 7. Phase voltage and phase current waveforms for star connected load

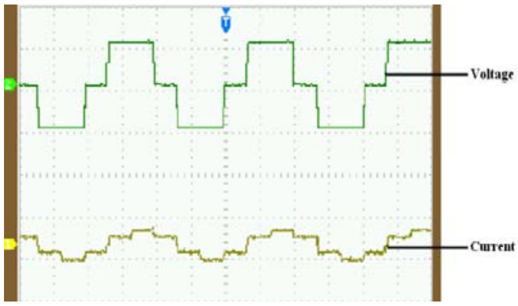

Figure 7. Line voltage and line current waveforms for star connected load

The observed phase voltage and phase current waveforms of the VSI for delta connected load are shown in Figure 8. From the waveforms it is seen that the phase voltage and phase Current are quasi-square waves. The waveforms have a conduction period of 120^0 (6.6ms) and a dead band of 60^0 (3.33ms). The observed line voltage and line current waveforms of the VSI are shown in Figure 9. From the waveforms it is seen that the line voltage is a quasi-square wave. But the line current is a six step wave. Each step has a time period of 60^0 (3.33ms). The phase voltage and line voltage waveforms are similar.

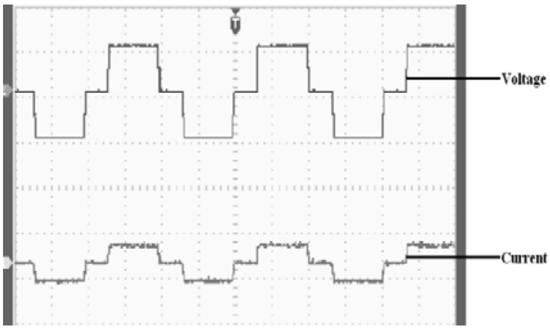

Figure 8. Phase voltage &current for delta connected

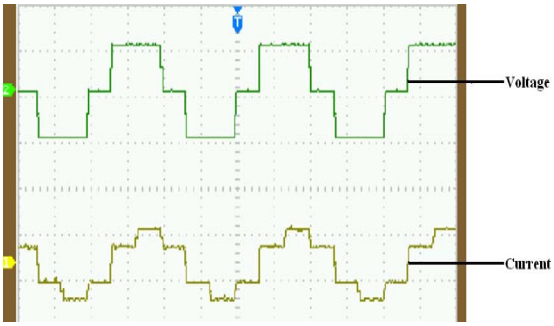

Figure 9. Line voltage &current for delta connected

5. Conclusion

In this work fabricated voltage source inverters is introduced. Then new controller is designed using PIC167F877A with advantage of static design and low power consumption. With introduction MCT2E opto- coupler harmonics has been reduced from results under No load condition and loaded condition. The results under star and delta loaded condition is very stable which motor loads can be connected to Hybrid Electric Vehicle is the emerging technology for present and future generation. Developed voltage source inverter is suitable for all type of electric motor drives in various road loads used in HEVs. Converter plays vital role in HEVs the proposed fabricated voltage source inverters will be significant one. With the more stringent regulations on emissions and fuel economy, global warming, and constraints on energy resources, the electric, hybrid, and fuel cell vehicles have attracted more and more attention by automakers, governments.

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