A Novel control topology of Quasi ZSI based PV systems

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***Abstract*— This paper shows the clear understanding of the control of the output voltage by varying the modulation index and the boost factor independently. A comparative analysis between impedance source inverter and the quasi impedance source inverter(QZSI) were made and the best suitable inverter for PV generation system is found. The closed loop strategy in the QZSI were implemented successfully with good power conversion. The unique gate pulse pattern is designed to cope up with the shoot through and non-shoot through states in MATLAB Simulink and the gate pulse pattern is generated using the PIC 16F877A..**

***Index Terms*—Boost factor, MATLAB Simulink, Modulation Index, PV systems, Quasi Impedance Source Inverter,**

1)INTRODUCTION

The Alternative resources are in great demand nowadays. The traditional resources are reducing across the world rapidly. One of the popular alternative resources is the generation of electrical power from the PV panel. Many research efforts are made to extract maximum power out of the PV panel by using different power converters as most of the power generated by the renewable sources are varying. There are different traditional power circuit topologies which has many disadvantages. The conventional Voltage Source Inverters(VSI) and DC/DC converters have certain disadvantages such as double stage conversion, maximum output voltage obtained is less than the dc voltage, complexity in the controller circuits and the inverter components should be oversized to match with the continuous variation of PV voltages which can be overcome by the proposed control topology of quasi impedance source inverter. This paper mainly focuses on the simulation of the open loop and closed loop implementation of the quasi impedance source inverter connected to the PV systems in which the output voltage can be controlled by both modulation index and the boost factor independently. This advantage makes PV generation more efficient. As the quasi impedance source inverter has the advantage of having no dead time. It is designed to operate in one of the mode named shoot through mode whether the same leg switches(upper leg and lower leg) are short switched ON so that short circuit occurs whereas in traditional VSI methods we are forced to make the dead time in order to avoid the short circuit of the same leg. A comparative analysis between impedance source and the quasi impedance source inverter were done to find out the best topology for the PV systems.

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2)QZI SOURCE TOPOLOGY

The Quasi Impedance source network is introduced after the introduction of the Impedance source inverter. This Quasi Impedance source inverter overcomes certain disadvantages of the Impedance source inverter. The quasi Impedance Source inverter has advantages over impedance source inverter such as continuous input current, higher reliability, causes less EMI problems, reduced source stress, reduced component ratings and simple control strategy. This is the most adaptive topology of PV generation systems to offer good conversion efficiency. The Quasi Impedance source network consists of the special arrangement of the LC components and this impedance network is connected between the PV panel and the inverter topology. The Quasi Impedance source network is shown below

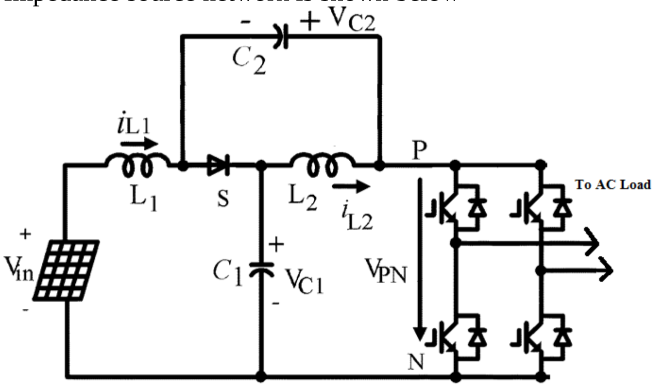

Figure 1 : The QZSI topology

The special features of the Quasi Impedance source inverter is that it has two switching modes, the first is the non shoot through mode and the second one is the shoot through mode. The non shoot through mode is that the switches in the same leg is switched ON and the short circuit occurs such that the maximum energy is stored in the inductor. This shoot through state is prohibited in the traditional VSI topology as dead time is needed to avoid the short circuit in the same leg. This voltage boost conversion and the process takes place in the same single stage power conversion.

The operation of Quasi Impedance source inverter is divided into two switching states.1)active state(non shoot through state) 2)Shoot through state

1)Active state:

In the active state, the switching pattern of the quasi impedance source inverter is similar to that of the traditional VSIs. In the active state for the interval of T_1 during a

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switching cycle of time period *T*. The voltage equations are given below,

$$V_{C_1} - v_{out} = v_{L_1} = -V_{C_2}$$
$$V_{in} - V_{C_1} = V_{in} - v_{out} + V_{C_2} = v_{L_2} \quad (1)$$

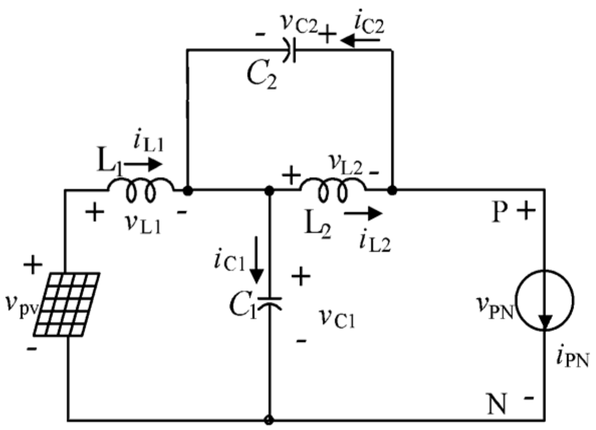

Figure 2: Equivalent circuit of Active state

2)Shoot through mode:

In this mode the switches in the same leg are switched on for a very short period of time. The input voltage will not get short circuited but instead the voltage gets boosted due to the presence of LC network. In the active state for the interval of T_0 during a switching cycle of time period *T*. The voltage equations are given as follows,

$$V_{C_1} = v_{L_1}$$
$$V_{C_2} + V_{in} = v_{L_2}$$
$$v_{out} = 0 \quad (2)$$

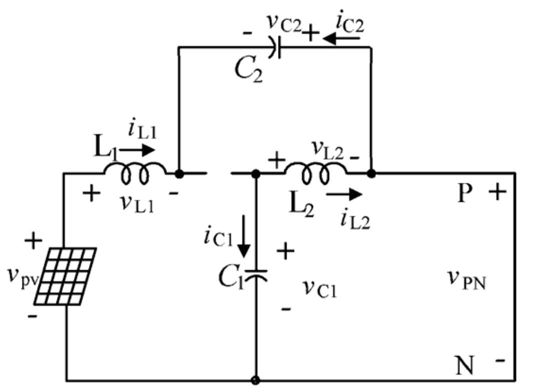

Figure 2: Equivalent circuit of Shoot through state

In the steady state, the average value of the inductor v_{L_1} over one switching period of T will be zero from (1) and (2),

$$V_{L_1} = \frac{T_0 . V_{C_1} + T_1 . (-V_{C_2})}{T}$$

$$V_{C_1} = \frac{T_1 . v_{outp}}{T} \quad (3)$$

From the above equations (2) and (3),

$$V_{C_2} = \frac{T_0 . v_{outp}}{T}$$

$$v_{outp} = V_{C_1} + V_{C_2} \quad (4)$$

In the steady state, the average value of the inductor v_{L_2} over one switching period of T will be zero from (1) and (2),

$$V_{L_2} = \frac{T_0 . (V_{C_2} + V_{in}) + T_1 . (V_{in} - V_{C_1})}{T} = 0$$

$$V_{outp} = \frac{T}{T_1 - T_0} . v_{in}$$
$$V_{in} = V_{C_1} - V_{C_2} \quad (5)$$

And from equations (3),(5) and (6)

$$V_{outp} = V_{C_1} = \frac{T}{T_1 - T_0} . v_{in}$$

The dc link voltage we obtained is the sum of the capacitor voltages V_{C_1} and V_{C_2},

$$v_{dcp} = V_{C_1} + V_{C_2} = BV_{in} \quad (6)$$

$$V_0 = MBV_{in} \quad (7)$$

The dc link voltage will be the multiplication of the boost factor and the input voltage. So, the output voltage will be the product of the boost factor B and the modulation index M. Thus in our proposed control topology of the PV panel the boost factor and the modulation index are changed separately to control the inverted output voltage.

3)SIMULATION RESULTS

The special gate pulse generation for the quasi impedance source inverter were done using the MATLAB Simulink. In the proposed gate pulse specific pattern which makes the output voltage very effective and the power conversion efficiency was better than the other methods.

For this different kind of gate signals for the switches(S1 to S4) two PWM strategies were used. One for constant PWM and the other for the sinusoidal PWM. The sinusoidal PWM is done by comparing the sinusoidal voltage of 50Hz with the triangular wave of frequency 3kHz.The constant PWM can be done by varying the constant voltage with the triangular wave of the same frequency. The comparison of sinusoidal wave and the triangular wave is given below.

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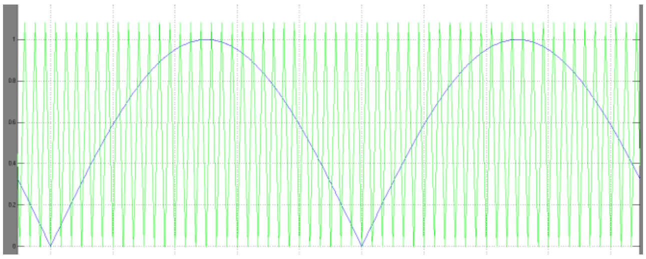

Figure 4:Comparison of triangular wave and the sinusoidal wave

The output frequency is made as 50Hz.So,the duration of ON and OFF time of the lower leg switches are made according to 50Hz.The gate pulse pattern are generated such that during the first half of the full time period T one of the lower leg switch(S2) is ON and the other lower leg switch(S4) is OFF. During this first half of the total time period T the upper leg switch(S1) is switched under the sinusoidal PWM and another upper leg switch(S3) is switched under constant PWM. During the next half of the time period the gate pulse pattern reverses. This kind of gate pulse pattern have independent control of the output voltage by varying the modulation index and the boost factor. This proposed gate pulse pattern provides good results during the shoot through and the non-shoot through modes of the quasi impedance source inverter.

The following figure shows the special pattern of generating the gate pulse done in the MATLAB Simulink. The above mentioned type of gate pulse pattern is generated using the help of the MATLAB Simulink blocks in the library

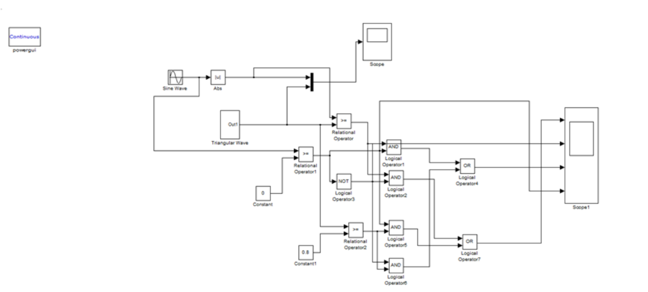

Figure 5:MATLAB Simulink Model for Gate pulse generation

The following figure shows the gate pulse pattern for the quasi impedance source inverter in the MATLAB simulink. The pattern is generated for all the switches present in the quasi impedance source inverter as shown below.

topology for the PV generation.

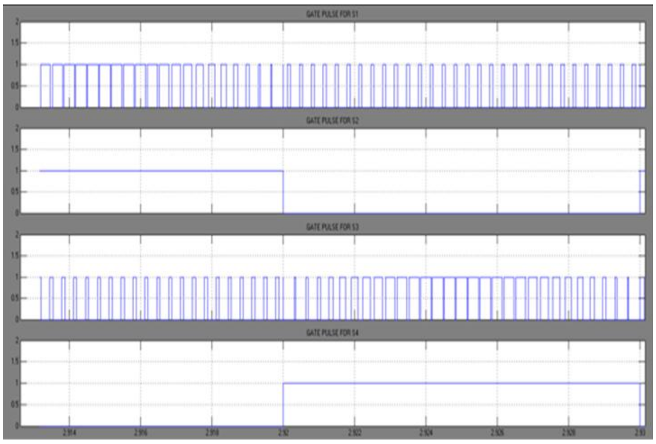

Figure 6: Gate signals obtained which is to be given to all the four switches

Assume a PV panel which offers 24V continuously in which it is connected to impedance network and the output voltage is simulated. This whole topology is done in the MATLAB Simulink.

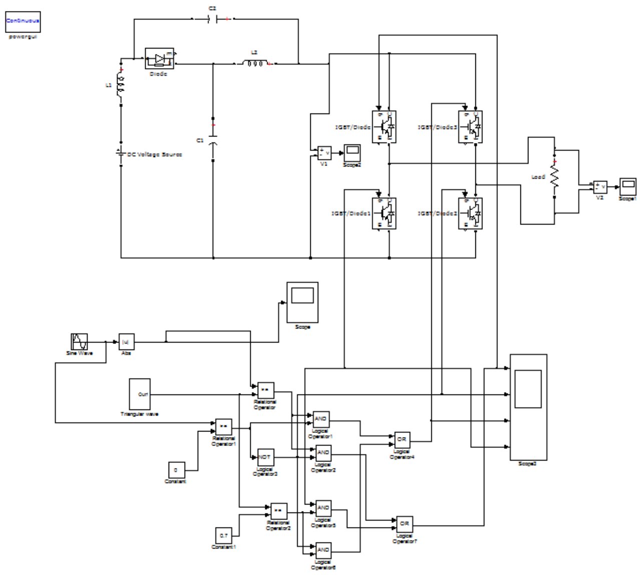

Figure 7:MATLAB Simulink model for the Quasi Impedance Source inverter

In the open loop condition the whole circuit is investigated in two cases. In the first case the modulation index is kept constant and the boost factor is varied and in the other case the modulation index is varied and the boost factor is kept constant. The output voltage for the modeled Quasi Impedance source inverter was taken from the MATLAB simulink workspace. The simulation was done for different values of modulation index and boost factor for both impedance source and quasi impedance source inverter and the results were tabulated to find out the best inverter

The parameters used in the system are tabulated as follows

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Input Voltage Vin(app)	24V
Output frequency	50Hz
Switching frequency	3kHz
Capacitance C1,C2	1000e-6micro Farad
Inductance L1,L2	1e-6
Power rating	240W

Table 1 : Parameters used in the simulation of the topology

The output voltages of the impedance source inverter and the quasi impedance source inverter were taken by keeping the modulation index MI=0.923 and by varying the boost factor.

Boost Factor	Impedance source inverter(Vout)	Quasi Impedance source inverter(Vout)
0.9	74.2	329.5
0.8	97.3	368.5
0.7	99.8	393.3
0.6	101.6	408.6
0.5	102.8	421.2
0.4	107.4	431.23
0.3	113.3	438.5
0.2	170.6	444.3
0.1	300	380.3

Table 2 : Comparison of the output voltage between impedance and trans impedance inverters with Rload Vin=24V,MI=0.923 by varying the Vmpp.

The output voltages of the respective inverter by keeping MI=0.5 and by varying the boost factor is tabulated as follows.

Boost Factor	Impedance source inverter(Vout)	Quasi Impedance source inverter(Vout)
0.9	77.5	330.1
0.8	102.5	369.1
0.7	101.74	392.2
0.6	102.74	409.7
0.5	103.8	421.5
0.4	107.8	431.5
0.3	113.2	438.5
0.2	170.2	444.42
0.1	102.5	380.18

Table 3 : Comparison of the output voltage between impedance and trans impedance inverters with Rload Vin=24V,MI=0.5 by varying the Vmpp.

By the above mentioned collected data we conclude that the quasi impedance source inverter is the better option for the PV generation system.

The prolific waveform which is obtained for different cases of the modulation index and the boost factor is shown as below.

By varying the boost factor as 0.5,0.6,0.7,0.8 and keeping the modulation index 0.5 as constant for the solar input voltage of Vin=24V.

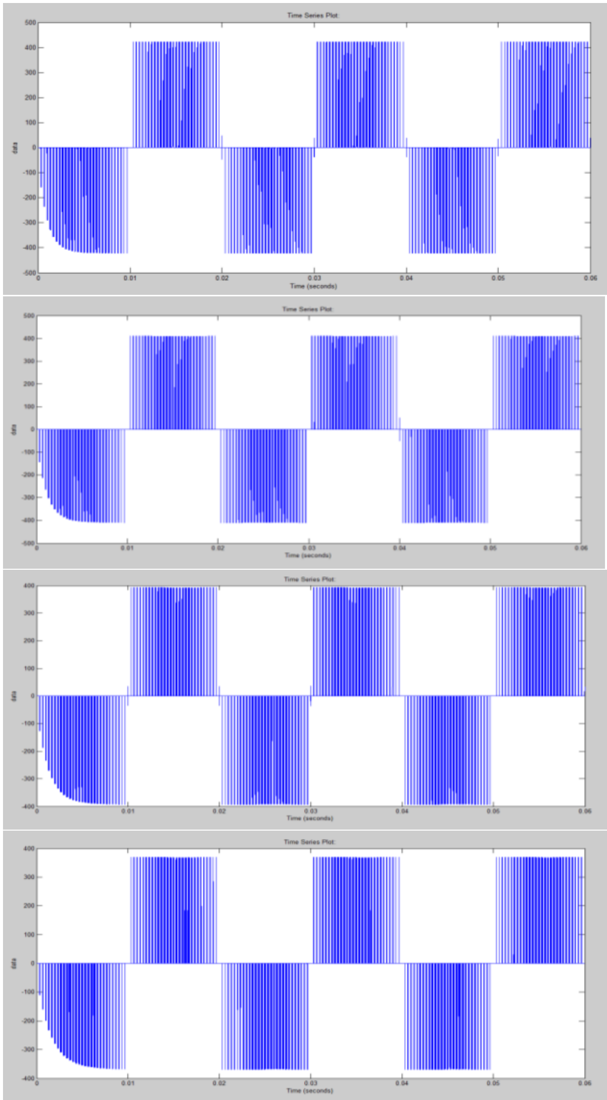
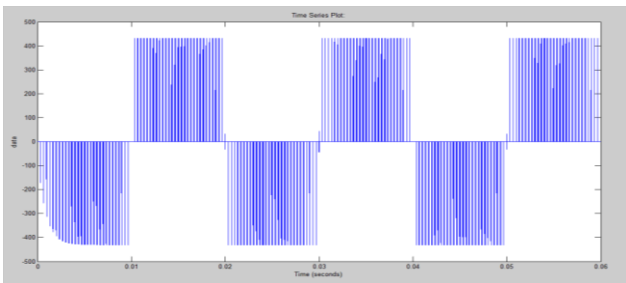


Figure 8: R load with MI=0.5 and Vmpp=0.5,0.6,0.7,0.8,.9 for Vin=24V respectively for trans impedance source inverter

By varying the modulation index as 0.3,0.5,0.8 and 0.9 and keeping the boost factor 0.4 as constant for the solar input voltage of Vin=24V the following waveforms were obtained.



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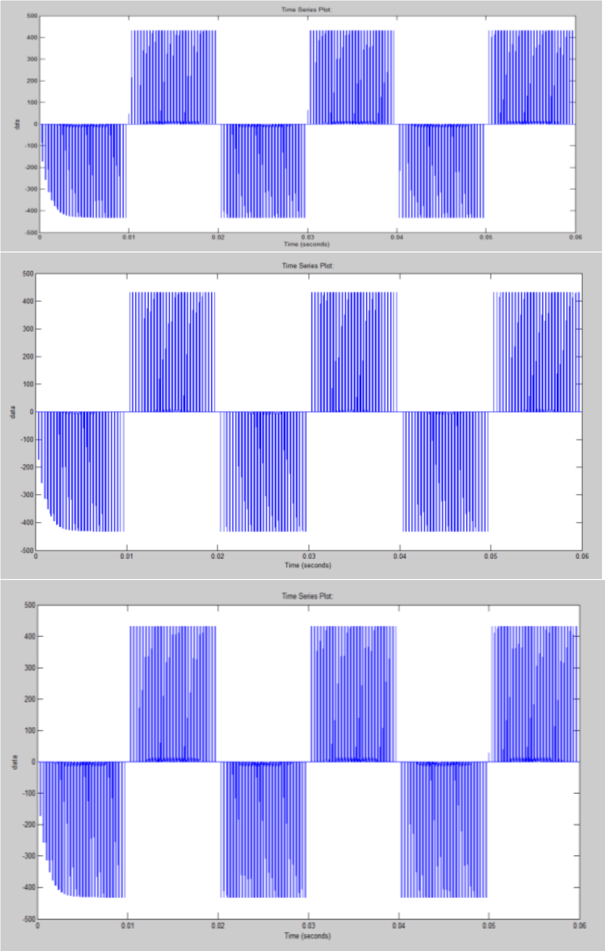

Figure 9: R load with MI=0.3,0.5,0.8,0.9 and Vmpp=0.4 for Vin=24V trans impedance source inverter

In the closed loop condition the capacitor voltage is taken and is compared with the reference voltage which is then given to the boost factor to produce the maximum output voltage.

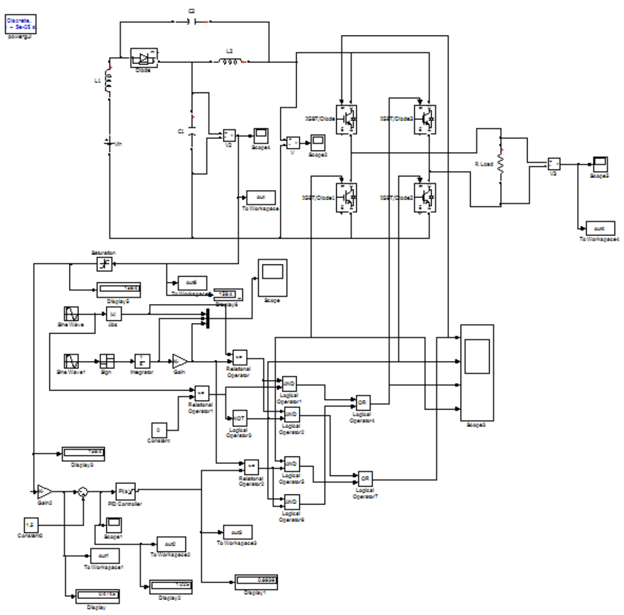

Figure 10:Closed loop topology of the QZSI

The output voltage which is obtained from this closed loop operation of the Quasi Impedance source produces the capacitor voltage and the peak value of the capacitor voltage is compared with the reference voltage which is then given to the PI controller. Then the output of the PI controller is given to the boost factor which is then compared with the triangular wave to produce the pulse. This is the appropriate method of controlling the Quasi Impedance source inverter with the PV generation systems

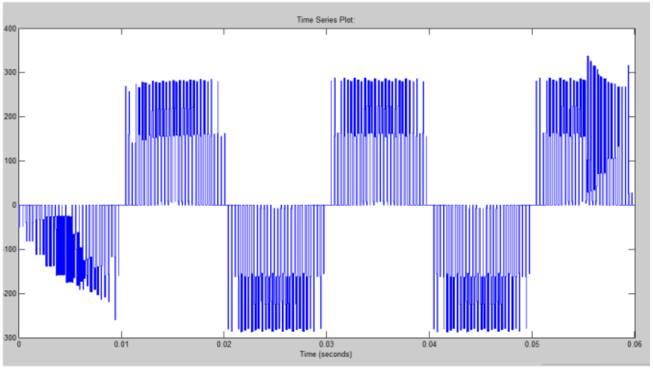

Figure 11: The output voltage of the closed loop operation of the Quasi Impedance source inverter

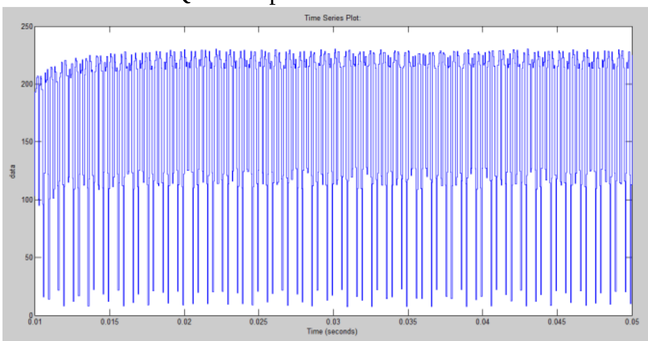

Figure 12: The capacitor voltage(C1) of the closed loop operation

A comparative analysis is made between impedance source inverter and quasi impedance source inverter and it is concluded that quasi impedance source inverter with this specific gate pulse pattern and the control circuit is found to be most suitable than any other traditional inverters.

4)GATE PULSE PATTERN GENERATED THROUGH PIC 16F877A

The PIC16F877A microprocessor manufactured by Texas instruments is a high performance, highly integrated processor used as a controller for the inverter circuit. The PIC16F877A has a C Compiler Optimized Architecture with Optional Extended Instruction Set. It consists of 100,000 Erase/Write Cycle Enhanced Flash and its program memory is typical one. Flexible oscillator option is available in this PIC16F877A. It includes Four Crystal modes, including High-Precision PLL for USB. It has two External Clock modes, Up to 48 MHz. The Internal Oscillator consists of 8 user-selectable frequencies, from 31 kHz to 8 MHz Dual

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Oscillator Options allow Microcontroller and USB module to run at different Clock Speeds. These features makes the PIC microcontroller PIC16F877A most suitable for generating the specified pulses.

The proposed gate signal is programmed and generated using the PIC microcontroller 16F877A which can be used to drive the power electronic switches through the gate driver IC which is suitable.

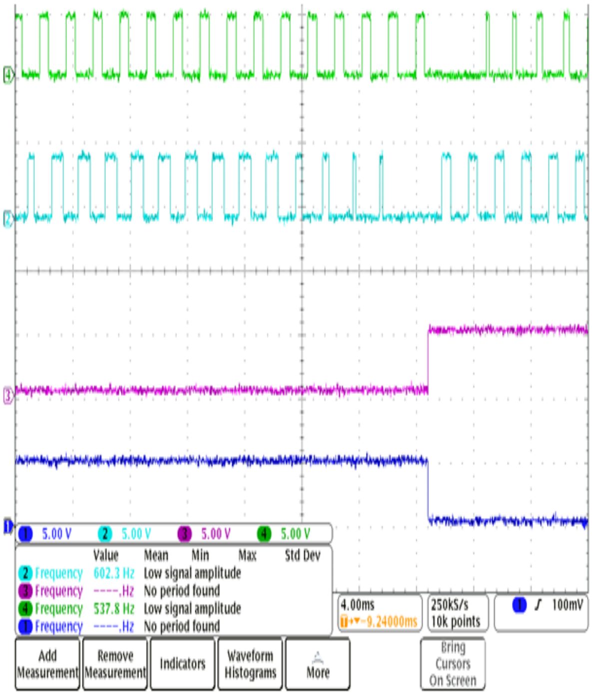

Figure 13 : Gate pulse pattern for all the switches which are generated using the PIC 1F877A

5)CONCLUSION

In this paper, the interface between the PV dc source and the load is accomplished by a Quasi Impedance source inverter. The unique gate pulse pattern is simulated in MATLAB for the impedance source network and trans impedance source network. Both impedance source inverter and the trans impedance source inverters are simulated in MATLAB simulink and the output voltages are compared and tabulated by changing various values of the maximum voltage and keeping modulation index as constant and vice versa. The trans impedance source inverter was found to be more advantageous than others due to the advantages of single stage power conversion, increased voltage gain and reduced voltage stress. The gate pulse pattern is coded and implemented in the real time implementation.

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