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Simulation and Experimental Analysis of Microcontroller based Grid Tied Inverter for Solar PV Applications

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ABSTRACT
In any grid tied solar PV based system, inverter is a critical component responsible for the control of electricity flow between dc source, and loads or grid. This paper presents a solar PV generation system integrated to grid. The proposed model used to mitigate the power quality issues in grid tied inverter which is simulated using MATLAB/SIMULINK in power system block set. A solar PV based grid tied inverters are used for dc-ac conversion. The conventional dc-ac inverters have square shaped line current which contain higher order harmonics. The proposed control strategy of inverter reduces total harmonic distortions in line current significantly.

Keywords: Grid Tie Inverter, Total Harmonic Distortion, Line current, Simulink, Proteus software, ac-to-dc converter.

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I. INTRODUCTION

In the recent years the power demand is increasing regularly and it can be fulfilled by the use of conventional or non-conventional energy power plants. The benefits of power generation from these sources are widely accepted. They are essentially inexhaustible and environmentally friendly. Among the different renewable-energy sources, solar energy has been one of the most active research areas in the past decades, both for grid-connected and stand-alone applications [1]. The exponential rate of growth in the worldwide cumulative PV capacity is mainly due to enhancement in grid-connected inverter topologies. The solar photovoltaic (PV) array and the battery are connected to the AC grid via a common DC/AC inverter. AC output voltage is generated by switching the full bridge. Normally pulse-width modulation (PWM) technique is used. However, for a grid tied inverter synchronization of the incoming generated voltage to the grid is a big issue. The inverter topologies can be divided with two types that are single and multi-stage inverter. The single-stage inverter has advantage such as low cost, high efficiency, robust performance, high reliability and simple structure. Thus, renewable energy sources like PV panels are used today in many applications. Solar PV based systems are being seen as a major contributor to the present power generation technology. One of the important applications of the solar PV based power generation is to feed the generated power (dc) into grid (ac). For this purpose, normally, PWM inverters are used which use gate commutated devices (IGBT, MOSFET, GTO etc.). However, apart from higher switching losses, the power handling capability and reliability of these devices are quite low in comparison to thyristors/SCR [2]. Moreover, the conventional line commutated ac-to-dc inverters have square-shaped line current which contains higher-order harmonics. The line current with the high harmonic contents generates EMI and moreover it causes more heating of the core of distribution power transformers.

It has become imperative to develop an efficient grid interfacing instrumentation suitable for PV systems. Therefore, A conventional thyristor based ac-to-dc converter is used, with a dc source and an inductor or highly inductive load, operates in the inversion mode with specific condition. The performance of the converter depends upon the switching angle, dc voltage and impedance angle. The instantaneous value of voltage may be positive or negative but the average value of output voltage will be only negative for RLE load. However, the converter may operate in fourth quadrant of voltage-current plane and power become negative. The load current may be discontinuous, just continuous (or sinusoidal) or continuous. Which depends upon switching angle and impedance angle of RL loads [3].

Thus to transfer power from solar PV module or battery (dc) to (ac) grid a midpoint converter circuit is used. The performance of the proposed circuit is simulated using MATLAB/SIMULINK power system block set. To reduce the THD in the line current and for optimum power transfer to the grid.

II. PROPOSED INVERTER CIRCUIT

A power conditioning unit (PCU) is used to charge the battery of the converter circuit. In this case, the battery voltage remains almost constant irrespective of the variation of the insolation (Figure.1).

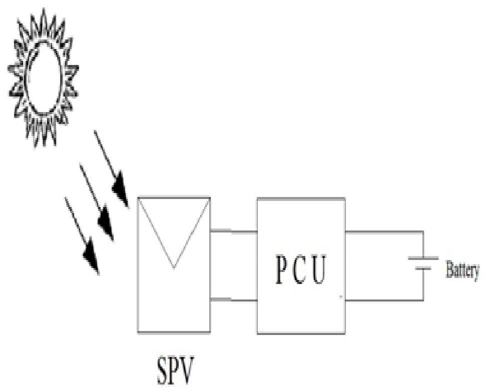

Figure.1 Block diagram of Solar PV system With PCU.

A full wave midpoint converter circuit with RLE load works in two modes of operation *i.e.* rectification mode and inverter mode. It works in inversion mode when the switching angle of each of the converter is greater than 90˚ and RLE load. When the circuit works in inversion mode, the dc source transfer power to the ac source [4]. Ideally, there should be a lossless inductor but practical inductor are not free resistance. Therefore, a series resistance is also incorporated in the circuit. The dc load side has been isolated from the grid via centre-tapped transformer. The proposed inverter circuit diagram is shown in Figure.2.

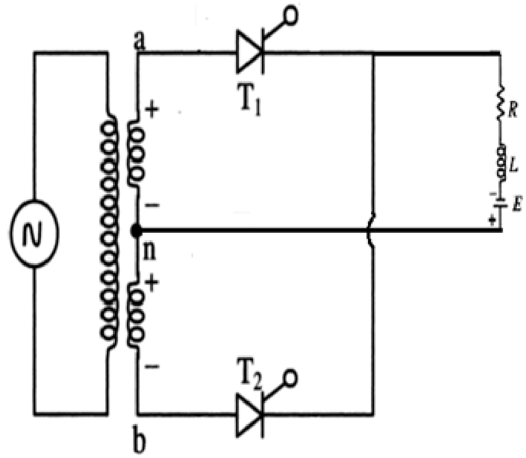

Figure.2 Single phase full wave mid-point converter with RLE(-) load.

III. SIMULATION OF CIRCUIT IN MATLAB/SIMULINK

A MATLAB/Simulink model has been simulated to simulate the working of the line commutated inverter. The model can be used to calculate instantaneous load current, THD of the waveform, various harmonic present as well as the power output. The simulation also enables to determine whether the inverter is operating in continuous conduction mode or discontinuous conduction mode.

The single phase grid tied inverter has been simulated in simulink package available in MATLAB. The simulink model is shown in the Figure.3. The trigger pulses given from the pulse generator block of simulink library block set. The pulses to both the thyristors of centre-tapped windings are given at a phase difference of 180^0. Resister is included in series of the inductor to simulate a real inductance. The value of inductor is 50 mH. The series resistor is 0.5 ohm. The centre-tapped winding transformer ratio is 50V :: 50V:0V:50V. The simulation work is basically done to study the variation of THD of the line current and average power transferred to the grid with the triggering angles.

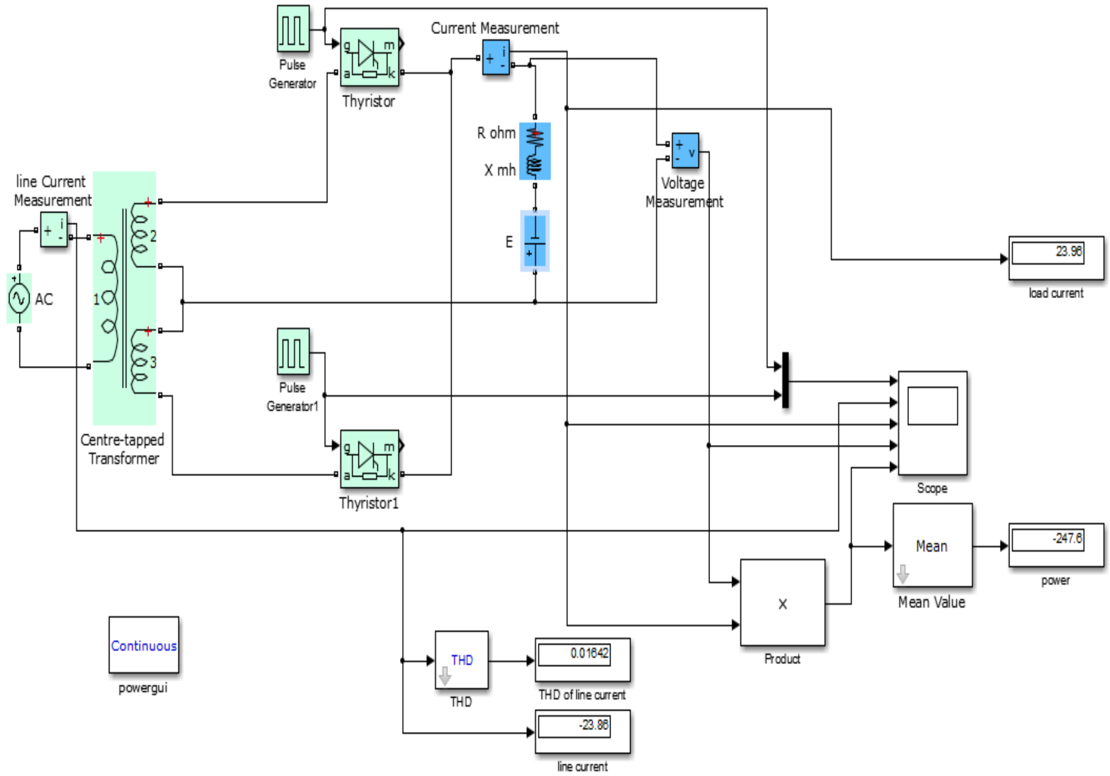

Figure.3 Simulink circuit of a grid tied inverter

IV. MICROCONTROLLER BASED TRIGGERING CIRCUIT

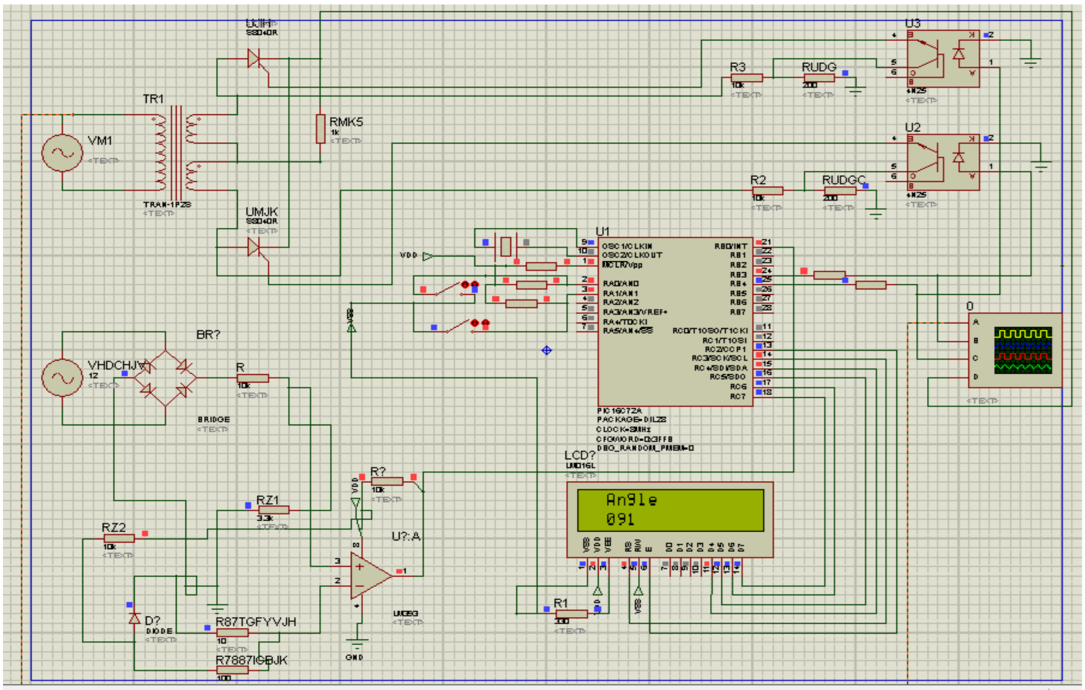

Figure.4 Microcontroller PIC16F72 based triggering circuit on Proteus software ISIS professional editing window

A PIC16F72 microcontroller base triggering circuit has been designed to control the triggering angle and it is shown in Figure.4. A zero-crossing circuit is used for synchronization. Zero crossing detectors are used to sense the zero crossing of supply voltage. It acts as a reference signal for control pulse and microcontroller generates the pulses. The angle is controlled by given the time delay to the generated pulse. To isolate the triggering circuit from the converter circuit opto-coupler is used [5]. Before design a practical circuit, similar circuit is simulate on proteus software and the performance of the circuit is taken on the oscilloscope of ISIS professional.

The figure.5 waveform for supply voltage, two controlled (triggering) pulse, voltage across resistive load of single phase fullwave mid-point converter circuit, respectively. Practical triggering circuit is shown in Figure.6.

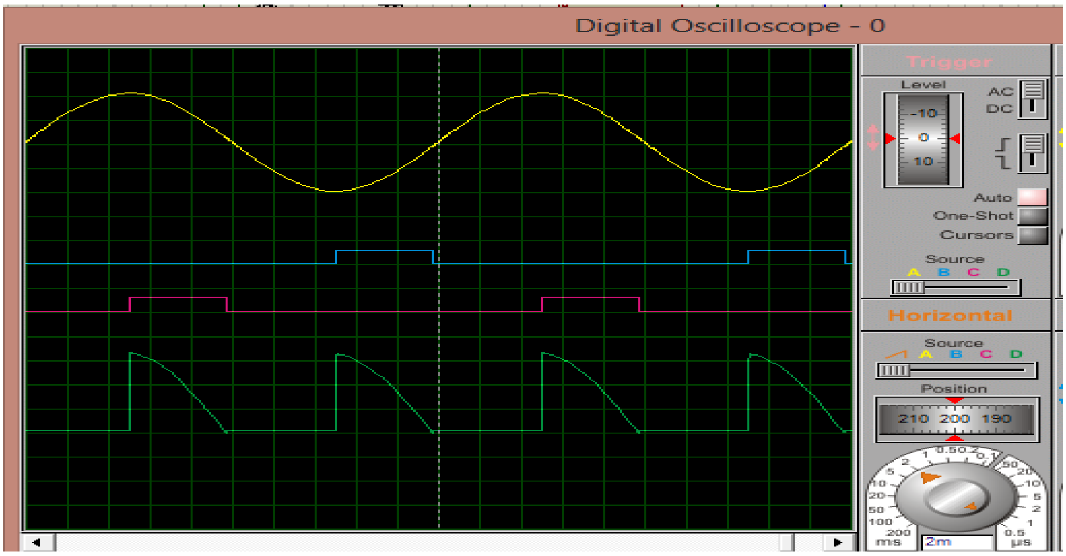

Figure.5 Waveform on Digital Oscilloscope

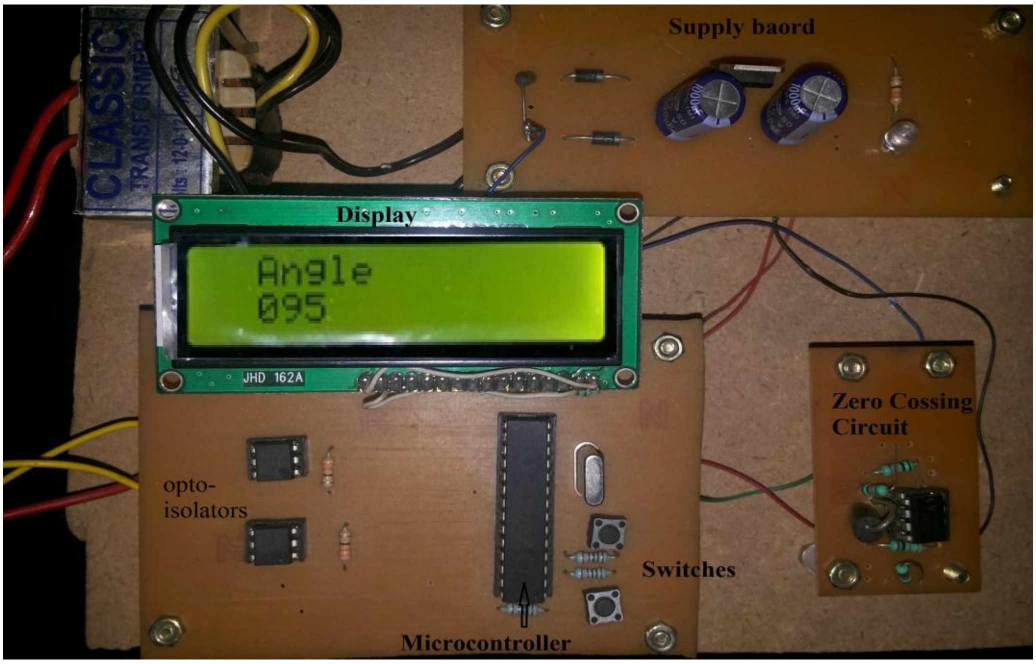

Figure.6 Microcontroller PIC16F72 based practical triggering circuit

V. SIMULATION AND EXPERIMENTAL VERIFICATION

THD and power flow analysis is done for various configuration of switching angles. Since the output dc voltage of a solar PV panel is not constant (vary with insolation, temperature and load), therefore a charger circuit is used to charge the battery. Thus PV is replaced by a dc source for simulation and experimental setup. Variation of THD and power with switching angle for single phase inverter is shown in Table.1 for 24voltage battery, 50 volt ac grid voltage.

Variable		Experimental Reading					MATLAB/Simulation Reading			
S. No.	Angle	Power (watt)	Voltage across RLE(-) (volt)	Current (amp)	THD F	THD R	Power transfer to grid (watts)	Voltage Across RLE (volt)	Current through Inductor (amp)	THD (%) For R
1.	130	36	-23.3	1.4	20.2	19.8	35.96	-23.03	2.74	17.24
2.	125	40	-23.1	1.8	15.2	15.0	44.08	-23.03	3.17	16.35
3.	120	50	-23	2	10.3	10.2	50.94	-22.87	3.50	6.072
4.	118	52	-22.9	2.1	8.6	8.57	116.4	-21.24	6.81	24.86
5.	115	60	-22.7	2.4	7.84	7.82	164.9	-19.82	9.69	32.02
6.	113	68	-22.5	2.8	9.13	9.07	205.3	-18.40	12.57	35.76
7.	110	80	-22.3	3.4	11.9	11.8	251.8	-16.20	17.00	38.98
8.	107	90	-22.0	3.8	13.8	13.7	279.3	-13.98	21.50	40.87
9.	105	100	-21.8	4.4	14.1	13.9	286.7	-12.47	24.55	41.76
10.	103	110	-21.5	4.8	14.6	14.4	285.0	-10.95	27.61	42.45
11.	100	124	-21.2	5.4	14.7	14.5	264.6	-8.647	32.24	43.27
12.	97	140	-21.0	6.4	14.6	14.5	222.6	-6.321	36.91	43.89
13.	95	156	-20.9	7.0	15.1	14.9	182.0	-4.751	40.06	44.23

Table.1 Power transfer and THD of line current with different switching angle combinations for both MATLAB/Simulink and Experimental setup. The battery voltage is 24V and R=0.5Ohm L=0.052Henry.

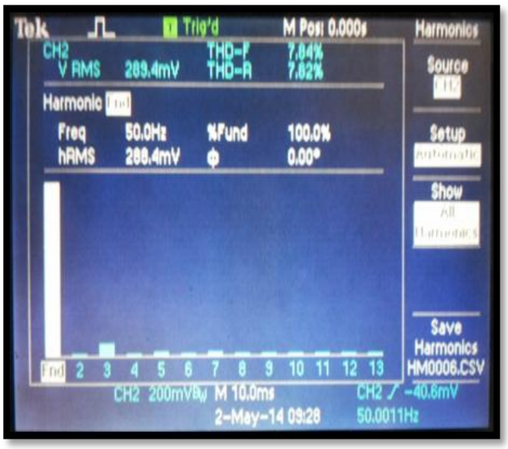

Figure.7 Hormonics analysis on digital oscilloscope in experimental setup for swiching angle 115 degree.

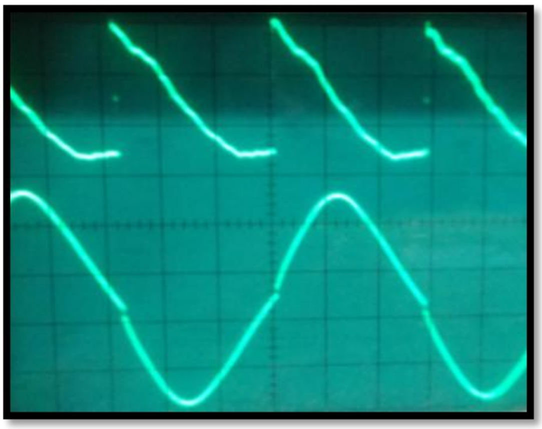

Figure.9 waveform of voltage across RLE(-) load and line current for switching angle 115 degree.

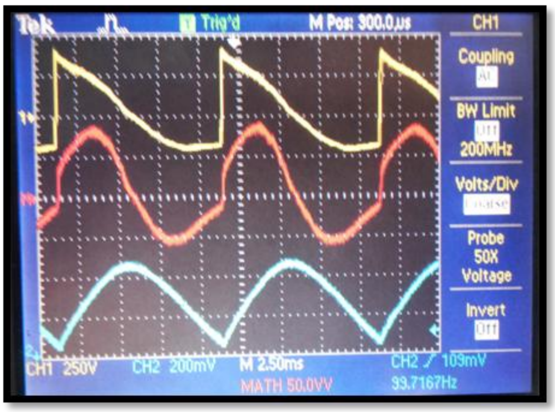

Figure.8 waveform of voltage across RLE(-) load, power and load current respectively yellow, red and blue colour waves for switching angle 115 degree.

Figure.10 Hormonics analysis on digital oscilloscope in experimental setup for swiching angle 105 degree.

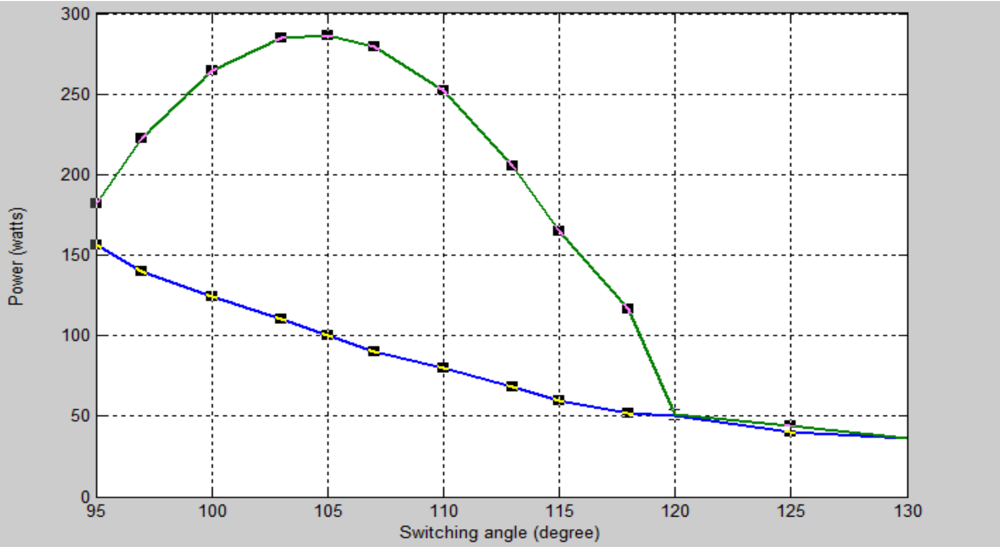

Figure.11 Power transfer to grid versus switching angle curve for both MATLAB/Simulink and Experimental data

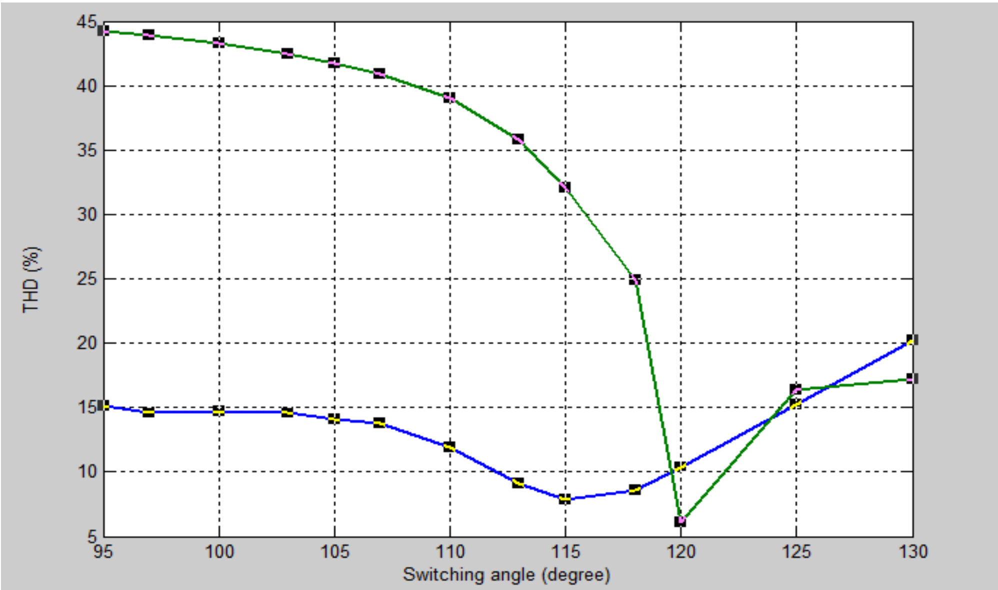

Figure.12 THD of line current versus switching angle curve for both MATLAB/Simulink and Experimental data

V. RESULT

For the MATLAB/Simulink and experimental model of grid tied inverter, the variation of THD and power with different switching angle are studied and it is observed that the optimum results obtain for battery voltage 24V and resistor R=0.5Ohm, inductor L=0.052Henry. In the experiment maximum power is 156 watts at THD 5.1% at 95^0 switching angle and minimum THD (i.e. 7.84%), 60W obtain at 115^0 switching angle. In the proposed circuit, a centre-tapped transformer is used for simulation and ideal transformer model is used which is lossless experimental work it is not ideal that's why there is some power losses in transformer. For the sake of comparison between simulation and experimental work two graphs are shown in Figure.11 and Figure.12.

VI. CONCLUSIONS

A centre tapped converter circuit which works as inverter for single-phase grid tied system has successfully been implemented in simulation and experimental. A thorough study has been made to obtain optimal performance with battery as dc source. The system is simulated, the practically realized and optimum conditions are found. With reduced THD, it will to be a better re-placement for square wave inverter in various distributed system connected to the grid.

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