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Battery Based Quasi Z-Source Inverter for PV power Generation Connected to Grid

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ABSTRACT
The demand for Renewable energy resources for power generation is increasing from the past decade. Solar power plants are plays vital role in supplying increased power demand. PV array with battery based quasi z source inverter makes more reliable under PV fluctuations. Traditional voltage source and current source which are connected to grid or motor loads having the main drawback of shoot through in the inverter bridge leg. Shoot through can over come by using quasi z source inverter. Svpwm and modified Svpwm provides more output voltage, less switching losses and gives high efficiency compared to other pwm techniques
Keywords – PV array, modified svpwm, quasi z source inverter, shoot through, svpwm

I. INTRODUCTION

Most of the countries are using conventional energy resources for their power generation ,and all are shifting from conventional energy sources to non conventional energy sources because of their availability and reduced running cost of power plant . After the 21st century non renewable sources are near to their exhaust condition .Even our neighboring country china had shutdown the last thermal power plant. India is producing power of nearly 20.5 million MW till date. A rapid growth is taking place in solar power generation from the last two decades . Most of the solar plant are supplying power to the nearest load centre's. And these are also connected to local grid. PV cell is the main building block of solar power generation unit. A group of PV cells connected together to form a PV module. and when these modules(two or more) combined to produce the panel. A group of PV panels collectively to form array. An PV array refer to complete power generation unit. By connecting PV modules in both series, parallel will produce required amount voltages, current and power these power can be used for on grid or off grid power demand . A PV cell can produce a voltage of 0.5V to 0.6V and 1W to 1.5W at standard test conditions ie..,25 degree and irradiance of 1000W/Sq. M and when there is a change in temperature the voltage decreases or increase by 2.3mv/degree . Nominal PV panel used for house hold purpose are about 12V to 17V volts and are stepped up to 230V for domestic usage i.e.., lighting ,fan loads. In the year 2013 the efficiency of solar cell is increased to 44.7% by soitec and fraunhofer institute in which they use triple junction concentrators of compound semi conductors (gallium arsenide and gallium nitrite) but their cost is so high and are used in space applications[1]. The efficiencies varies from the manufacture to manufacturer it fluctuates about 17- 25% for commercial usage and they are cost effective.

By using maximum power point tracking system we can improve the power output from the PV panel. Different MPPT techniques are available Like perturb & observe ,incremental conductance and neural network etc. perturb & observe method is minimum in complexity and convergence speed is medium, sensed parameter is voltage and neural network possess much complexity and convergence speed is fast, sensed parameters are voltage and current[2],[10]. Traditional PV array connected to grid requires two circuits one is boost converters and another is inverter circuit such that the system efficiency decreases , but with the existence of z source and quasi z source inverter they can buck boost the dc rail voltage such that the cost of the system is reduced and space is optimized.

The z-source and quasi z-source are introduced to overcome the drawbacks of voltage source inverters[3]-[5]. They can handle wide range of PV voltages. Input to these z source inverter can be the voltage source, current source or fuel cell stack or rectified dc voltage etc In an voltage source inverter when upper and lower switch are turned on the complete bridge leg will fails. This can be overcome by quasi or z-sourcee inverters. Due to the elements like inductor and capacitor the switches will carry less amount of short circuit current. Electromagnetic interference can reduced by providing dc rail voltage between PV panel and inverter[6]-[8] .

A battery is providing power whenever there is shortage of PV panel power . and these both

are tied to grid circuit In this paper solar panel with mppt pulse width modulation and space vector and modified space vector modulation based quasi z source inverter, transformation and control strategy is being discussed

II. PV CELL DESIGN

PV cell is a current source with series resistance and shunt resistance , current flowing through the Rsh can be neglected. Connection of more PV cells to form a module and all these modules combined to form a PV array. Depend up on our voltage, current requirement these modules are connected in series and shunt .

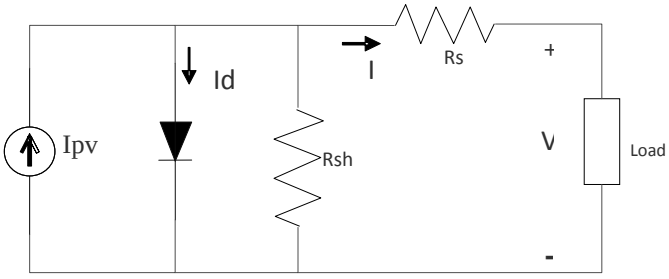

Fig.1: Basic generalised circuit of PV cell

Generalized equations of PV cell

$$I_O = I_{RR}[\frac{T^3}{T_C^3}].\exp[(\frac{q.E_g}{AK})(\frac{1}{T_C} - \frac{1}{T})] \quad (1)$$

$$I = I_{PV} - I_D \quad (2)$$

$$I_D = I_O(\exp^{QV/N_S KT} - 1) \quad (3)$$

$$I = N_P I_{PV} - N_P I_O(\exp^{QV/N_S KT} - 1) \quad (4)$$

Where

I_D = Diode current
I = Current output from the PV cell or panel
I_{PV} = Photo current of the PV cell or panel
N_S, = No of series connected PV cells
N_P = No of parallel connected PV cells
K = Boltzmann's constant
Q = Charge of electron
I_{RR} = Reverse saturation current of diode
T =Temperature

They are different types of design techniques for PV cell like thin film solar cell, mono crystalline solar cell poly crystalline solar cells, nano crystalline, amorphous silicon solar cell, multi junction solar cell etc. depending upon the cost the solar cell efficiency varies from 17 to 44.6%.

Designed values PV array voltage =250-270V
Current= 8-10amps,
Power=2KW-2.7KW

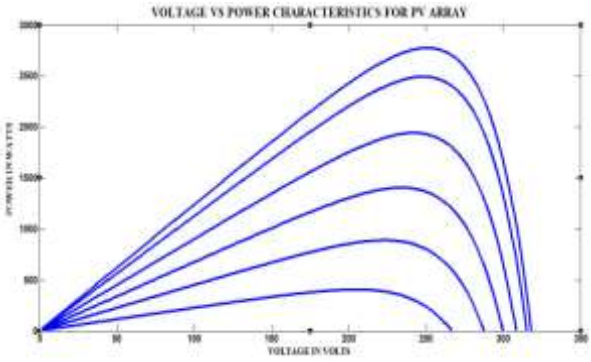

Fig.2: Voltage VS Power plot of PV array

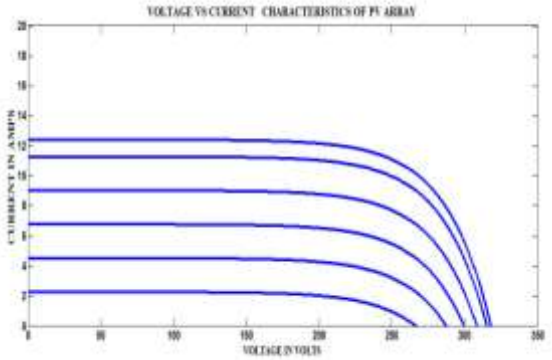

Fig.3: Voltage VS Current plot of PV array

2.1 Maximum power point tracking system

There are different types of mppt methods i.e. perturb and observe algorithm, incremental conductance method, fractional short circuit current , fractional open circuit voltage, neural networks, fuzzy logic control. We use P&O method for simplicity and its convergence speed is moderate.

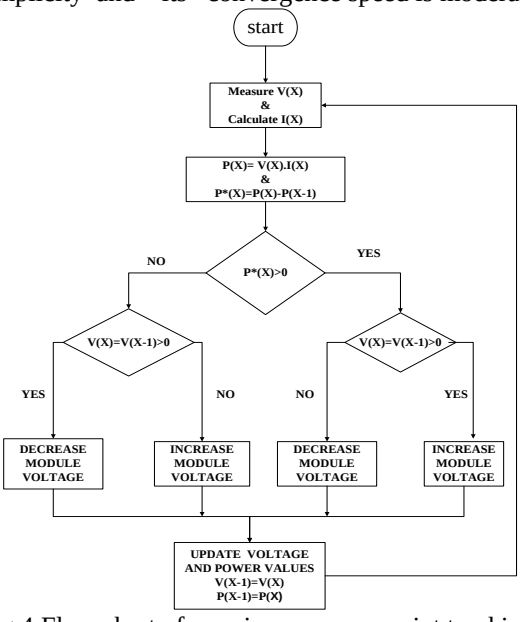

Fig.4:Flow chart of maximum power point tracking system

Perturb and observe method takes the voltage as reference. It increments and decrements the PV array voltage to make change in power is zero such that it operates maximum power point. We can use this technique for slow and medium change in temperature and irradiance.

III. BATTERY BASED QUASI Z SOURCE INVERTER

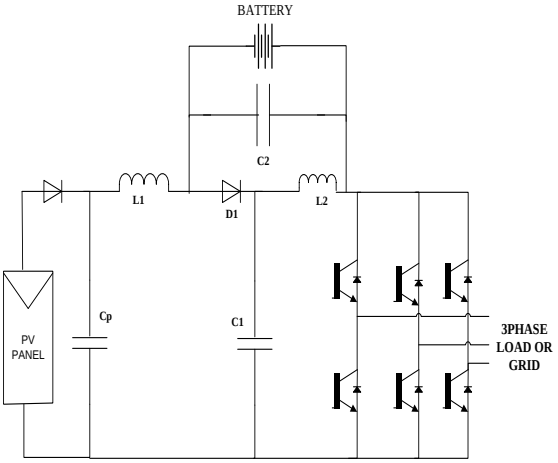

Fig.5:Battery based quasi z-source inverter

Battery based quasi impedance source inverters consists of inputs as PV array and a battery . A diode is connected in series with the PV array such that only unidirectional current will flow through the impedance source inverter. Capacitor Cp is used to maintain steepness of voltage waveform. Battery is connected to parallel to the capacitor C2 which is used to supply power to inverter under low power conditions of PV array. IGBT switches are used for inverter since switching frequency is 2000HZ .

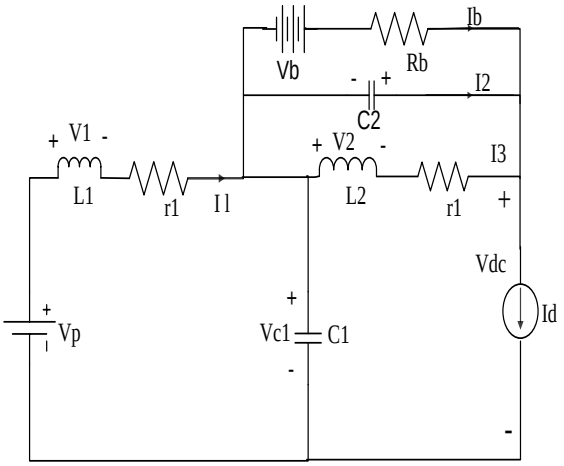

Fig.6: Shoot through of quasi ZSI

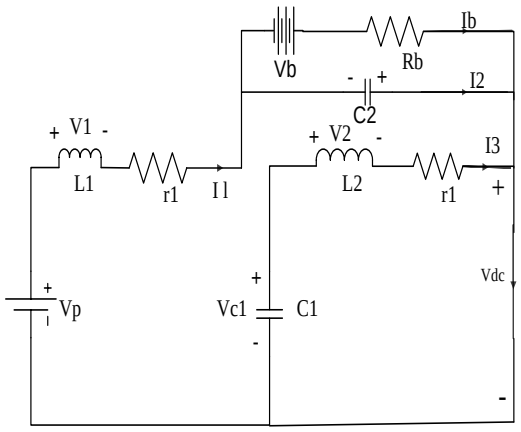

Fig.7: Non shoot through of quasi ZSI

Whenever both the switches of inverter bridge leg conducts circuit is getting short circuited and there by huge amount of current flows, by connecting a z source or quasi z source the current flow can be minimized by the impedance network. Especially L2 and C2 plays a key role.

The equations represents state space equations of shoot through and non shoot through states of battery based quasi impedance source inverter.

$$\frac{di_{L1}(t)}{dt} = -\frac{r_L}{L_1} i_{L1}(t) - \frac{R_b}{L_1} i_b(t) + \frac{R_b}{L_1} v_p(t) + \frac{1}{L_1} V_B \quad (5)$$

$$\frac{di_{L2}(t)}{dt} = -\frac{r_L}{L_2} i_{L2}(t) + \frac{1}{L_2} v_{C1}(t) \quad (6)$$

$$\frac{dv_{C1}(t)}{dt} = -\frac{1}{C_1} i_{L2}(t) \quad (7)$$

$$\frac{di_b(t)}{dt} = \frac{1}{R_b C_2} i_{L1}(t) - \frac{1}{R_b C_2} i_b(t) \quad (8)$$

In the non shoot through mode it operates like a general voltage source inverter , all the passive elements are in conducting state.

$$\frac{di_{L1}(t)}{dt} = -\frac{r_L}{L_1} i_{L1}(t) - \frac{1}{L_1} v_{C1}(t) + \frac{1}{L_1} v_p(t) \quad (9)$$

$$\frac{di_{L2}(t)}{dt} = -\frac{r_L}{L_2} i_{L2}(t) + \frac{R_b}{L_2} i_b(t) - \frac{1}{L_2} v_b \quad (10)$$

$$\frac{dv_{C1}(t)}{dt} = \frac{1}{C_1} i_{L1}(t) - \frac{1}{C_1} i_d(t) \quad (11)$$

$$\frac{di_b(t)}{dt} = -\frac{1}{R_b C_2} i_{L2}(t) + \frac{1}{R_b C_2} i_d(t) - \frac{1}{R_b C_2} i_b(t) \quad (12)$$

Specifications:

Pv array voltage	250-270V
Pv Current	8-10amp
Battery terminal voltage	96V
Capacitors C1,C2	470µF
Inductors L1,L2	1mH
Battery parasitic resistance Rb	0.68Ω,
Inductor parasitic resistance	0.15Ω
Filter resistance R	0.0049Ω
Filter inductance L	13mH,
Filter Capacitance C	0.1625µF

3.1 Control of battery based quasi z- source Inverter connected to grid

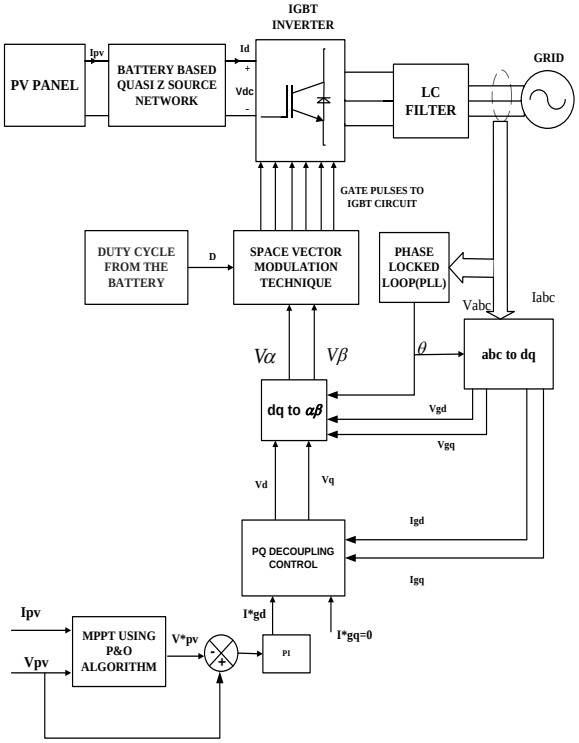

Fig.8:Control circuit battery based quasi Z-source connected to grid

The PV panel output is given to the battery based quasi z source network, and voltage will be input to the inverter circuit. The output from the inverter is stepped voltages and currents. And by using filter we can obtain nearly sine wave. This voltage will be given to grid for usage. ABC to dq transformation is used to transform three phase stationary reference to two phase rotating reference frame

Parks transformations (ABC to DQ)

$$V_{gd}=\sqrt{\frac{3}{2}}((\cos(Ø)* V_a+ \cos(Ø-2\pi/3)* V_b+ +(\cos(Ø-4\pi/3)* V_c)) \quad (13)$$

$$V_{gq}=\sqrt{\frac{3}{2}}(-(\sin(Ø)* V_a- (\sin(Ø-2\pi/3)* V_b) - - (\sin(Ø-4\pi/3)* V_c)) \quad (14)$$

PQ decoupling control takes the Igd , Igq currents from the transformation block and I*gd from mppt with pi controller. The only active currents will flow through the pq control and gives output as Vd , Vq also maintain unity power factor . DQ to αβ block is used for converting the dq0 parks components in rotating reference frame to αβ0 Clarks components in fixed reference frame. Vα, Vβ , duty cycle from the shoot through control is given to the svpwm block . And these svpwm block produces gate signals to IGBT inverter circuit. And there by output voltage is maintained constant.

3.2 Space vector pulse width modulation

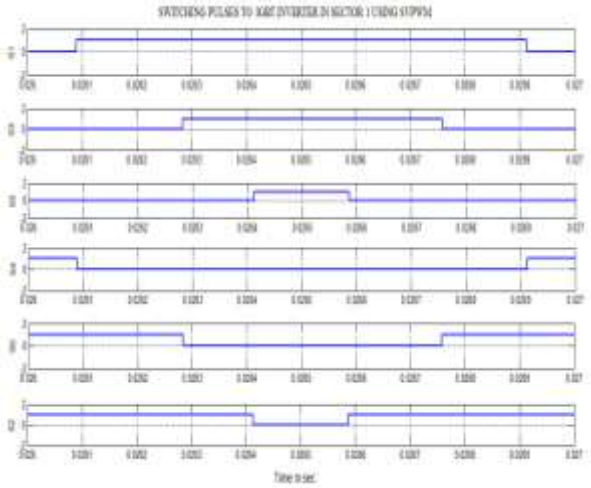

Fig.9: Gate pulses to inverter switches devices

For SVPWM there are 6 active states and two zero states these active state participate in conduction of current and other two states will make all upper switches as on or lower switches on . No current will be flowing through the inverter circuit . T1 is the switching time of active state vector U1, T2 is the switching time of active state vector U2,T0 is the switching time of zero state vector U0 and TS is the switching period.

Reference voltage is $U_{REF}= U_1 \frac{T_1}{T_S} + U_1 \frac{T_2}{T_S}$ (15)

3.3 Modified space vector modulation

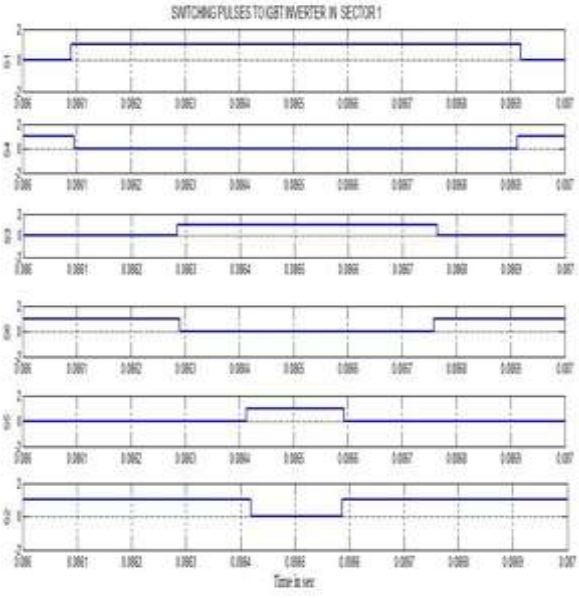

Fig.10: Gate pulses to inverter switches devices using modified Svpwm

The shoot through time period t_{sh} in switching period divided into six parts, and is a combination of active vector and zero vector. In sector 1 the first switch leg consisting of S1,S4

switches will distribute a time of $T_{Sh}/4$ and $T_{Sh}/12$ and the middle bridge leg consists of S3,S6 switches will distribute a time $T_{Sh}/12$ and $T_{Sh}/12$ and last bridge leg distribute a time of $T_{Sh}/12$ and $T_{Sh}/4$.
Reference voltage

$$U_{REF} = U_1 \frac{T_1}{T_S} + U_1 \frac{T_2}{T_S} + U_0 \frac{T_0}{T_S} + U_1 \frac{T_{sh}}{T_S} \quad (16)$$

IV. RESULTS

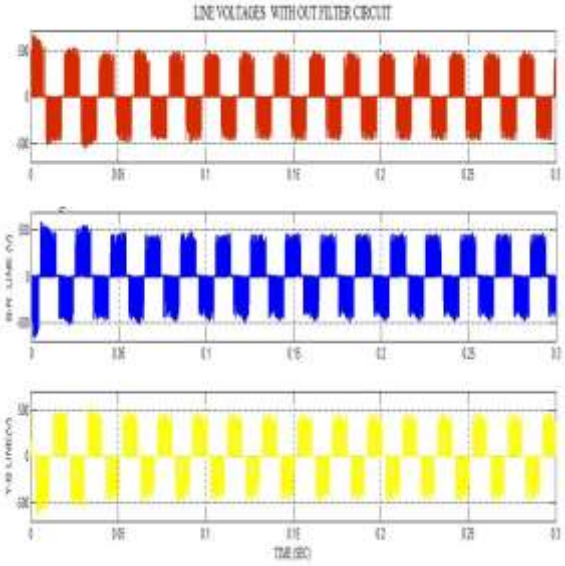

Fig.11: Line voltages before the RLC filter circuit using svpwm

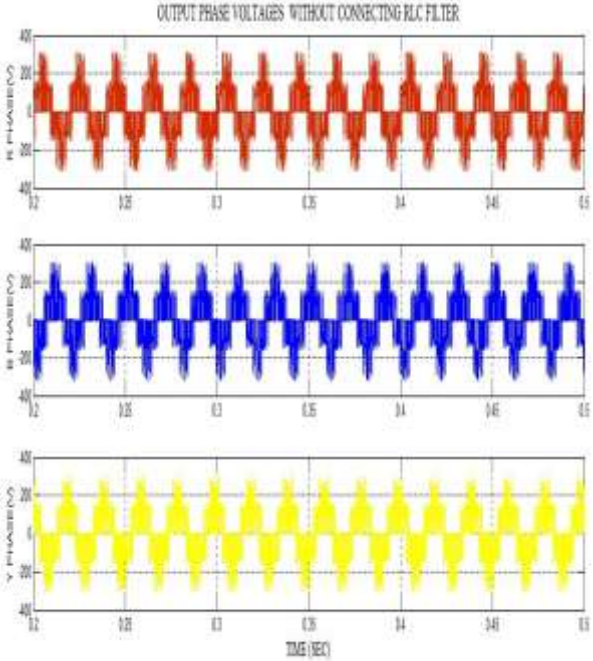

Fig.12: Phase voltages before connecting to Filter circuit using svpwm

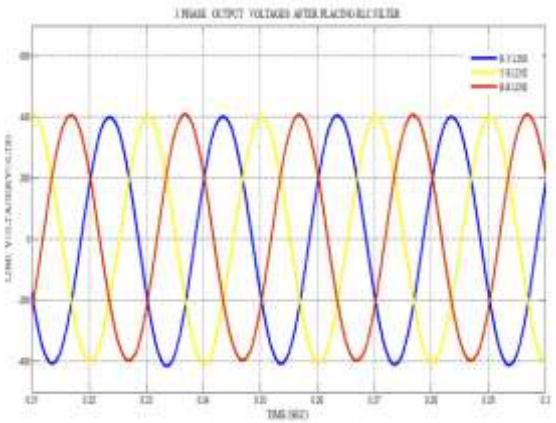

Fig.13: 3 Phase voltages supplied to grid circuit using svpwm

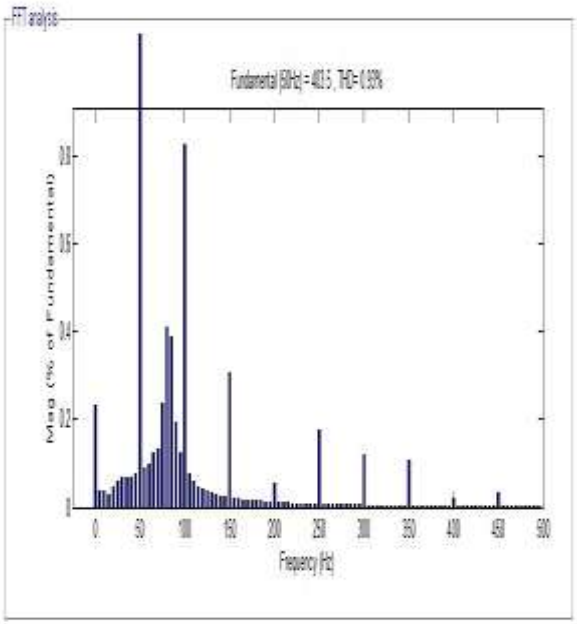

Fig.14: FFT analysis of voltage supplied to grid

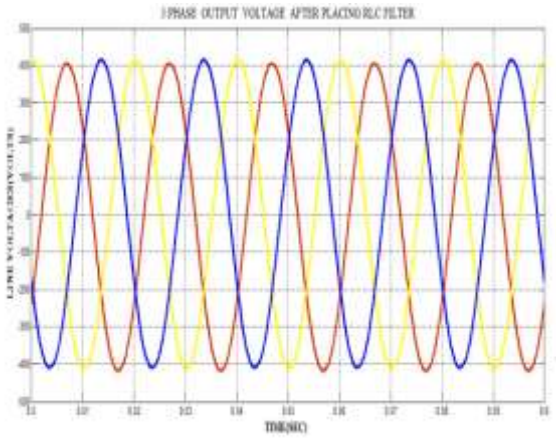

Fig.15: 3 Phase voltages supplied to grid circuit using modified svpwm

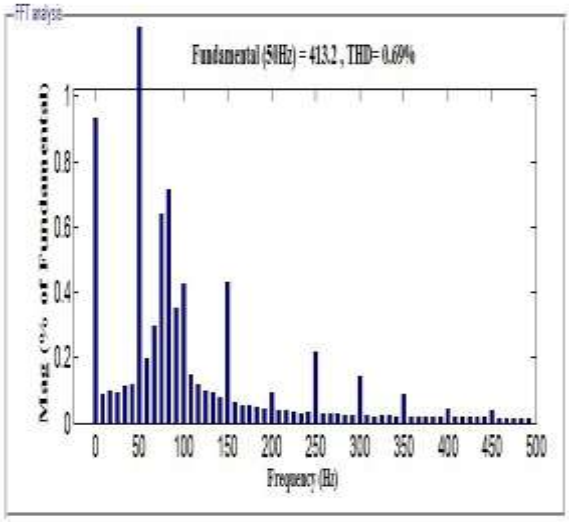

Fig.16: FFT analysis of voltage supplied to grid using modified svpwm

V. CONCLUSION

Quasi Z-Source and Z-Source inverter are popularly used for non conventional type of power generation. The switching frequency of the inverter is less such that the damage of switches of inverter switches are decreased. Thereby life span for switches are increased. Space vector pulse modulation (svpwm) and modified svpwm technique gives more output voltage and less harmonic distortion compared to other pwm techniques. By using most efficient PV cells we can enhance more output from the PV array. Battery placing makes to supply power under low PV power condition. Such that power supplied to grid is constant. By using RLC filter circuit R=0.0049Ω, L=0.013H , C=0.1625μF we obtained total harmonic distortion as nearly 0.93 for svpwm and 0.63 for modified svpwm . We can enhance the continuity of power by interconnecting other resources like fuel cell and wind power generating stations.

REFERENCES

[1]. www.ise.fraunhofer.de

[2]. X.Sun W.Wu, Xin Li , A Research On Photovoltaic Energy Controlling System With Maximum Power Point Tracking, Power Conversion Conference,2002 PP 822-826

[3]. F. Z. Peng, "Z-source inverter," IEEE Trans. Ind. Applicat., vol. 39, no.2, pp. 504–510, Mar./Apr. 2003

[4]. M. Shen, A. Joseph, J. Wang, F. Z. Peng, and D. J. Adams, "Comparison of traditional inverters and Z-source inverter for fuel cell vehicles," IEEE Trans. Power Electron., vol. 22, no. 4, pp. 1453–1463, Jul.2007

[5]. M. Shen, J. Wang, A. Joseph, F.Z. Peng, L.M.Tolbert, and D.J.Adams, "Constant boost control of the Z-source inverter to minimize current ripple and voltage stress," IEEE Trans. Ind. Applicat., vol. 42, no. 3, pp. 770–778, May/Jun. 2006.

[6]. Yushan Liu, B.Ge Haitham Abu Rub, F.Z.Peng. "Control System Design of Battery assisted Quasi-Z-Source Inverter for grid- tie Photovoltaic Power generation " IEEE Trans. Sustain Energy vol 4, no 4 Oct.2013.

[7]. H.Abu Rub, B. Ge, F.Z.Peng, Q. Lei, A. de Almeida, F. Ferreira, D. Sun, and Y. Liu, "An energy stored quasi-Z-source inverter for application to photovoltaic power system," IEEE Trans. Ind. Electron., vol.60, no. 10, pp. 4468–4481, Oct. 2013

[8]. D.Hui and X. Lai, "Battery energy storage system (BESS) based smoothing control of photovoltaic(PV) and wind power generation fluctuations," IEEE Trans. Sustain. Energy, vol.4, no. 2, pp. 464–473, Apr. 2013.

[9]. J.Dannehl, C.Wessels, and F.W.Fuchs, "Limitations of voltage oriented PI current control of grid connected PWM rectifiers with filters," IEEE Trans. Ind. Electron., vol. 56, no. 2, pp. 380–388, Feb.2009

[10]. M.A.Elgendy, B.Zahawi, and D.J.Atkinson, "Assessment of perturb and observe MPPT algorithm implementation techniques for PV pumping applications," IEEE Trans. Sustain. Energy, vol. 3, no. 1, pp.21–33, Jan. 2012

[11]. M.Von Zimmermann, M.Lechler, and B.Piepenbreier, "Z-source drive inverter using modified SVPWM for low output voltage and regenerating operation," in Proc. 13th Eur. Conf. Power Electronics and Applications (EPE'09), Sep. 8–10, 2009, pp. 1–10.