A HARMONIC ELIMINATION METHOD FOR GRID INTEGRATED SOLAR PHOTOVOLTAIC SYSTEM

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Abstract: *This work deals with the design of control technique to eliminate harmonics in grid integrated solar photovoltaic system which supply non-linear load. The voltage source converter based control is used to eliminate harmonics in the grid integrated solar photovoltaic system. Pulse width modulation technique is used to control the voltage source converter (VSC).The simulation (MATLAB/SIMULINK) result shows that the proposed control strategy provides acceptable Total Harmonic Distortion (THD).*

Key words: *solar photovoltaic, VSC, PWM technique.*

1. INTRODUCTION

Solar energy is one of the alternative solution to meet the power demand in eco-friendly way. As commonly known, the output power quality of the renewable energy system is essentially vulnerable to the grid voltage harmonic distortion. Since solar photovoltaic array is connected to the power grid through converter harmonics would be generated as consequence. Recent advancement in power electronic devices not only help in conversion also responsible for power quality problems. This work deals with the design of control technique to eliminate the harmonics in grid integrated solar photovoltaic system. Recent advancement in the power electronics devices results effective and efficient way of power conversion but this not only having this character also it having the character which cause for harmonics. To eliminate the harmonics voltage source converter based control is used in this work.

Voltage source converter controlled in such a way that the harmonics in the grid connected solar photovoltaic system is reduced and removed. There are various harmonics extraction methods are available such as Frequency domain techniques, Time domain techniques, Signal processing techniques. Fast Fourier transform (FFT), Discrete Fourier transform (DFT) are the methods which comes under frequency domain based harmonic extraction method. Notch filter, band pass filter, 'P–Q' and 'D–Q' are the method which comes under time-domain based harmonics extraction. Fuzzy logic based control, sliding mode control, sparse signal decomposition, neural network and adaptive signal processing are the methods comes under signal processing based harmonic extraction. Harmonic alone not a cause for power quality problems and also transients, voltage variations (short duration and long duration voltage variations), voltage imbalance, waveform distortion, voltage fluctuation, power frequency variations are all the causes for power quality problems. Application of non-linear loads and power electronic devices are the major causes for harmonics which comes under waveform distortion even it is the major cause can't able to neglect the non-linear load and power electronics from the system because their requirements in the system is non-negligible.

Adaptive noise cancellation based harmonic elimination method [1] is used in grid integrated photovoltaic system. The method presented [1] is based on adaptive detection of fundamental component and neuron based extraction. In this, pulse width modulation based voltage source converter control method is used which is such a feedback based control.

The admittance based control algorithm [2] is used for harmonic elimination in standalone hybrid photovoltaic system. That also a feedback based voltage source converter control.

Compare to the closed loop control techniques the feedback independent control method having less complexity, less mathematical calculation and parameters taken into consideration are also less. The method proposed in this work is a attempt to evaluate a results when the control is without feedback dependent. This work may extended in future as closed loop based harmonic elimination method.

2. SYSTEM CONFIGURATION

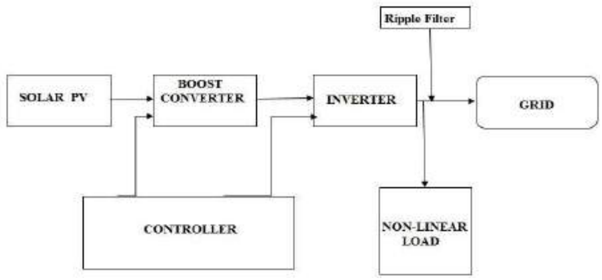

Fig.1 Block diagram

Fig.1 shows the block diagram of proposed solar photovoltaic system.

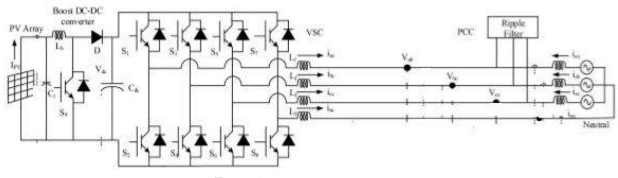

Fig.2 System configuration

System configuration is concern with the design of entire model. The term entire model concern with design of solar photovoltaic, Boost converter, Voltage source inverter and controller.

A. Design of solar photovoltaic array:

Generally solar photovoltaic array is designed based on the required power demand and area available to install the solar PV. Here solar PV array is designed based on the power demand. Power demand is calculated by evaluating the annual energy consumption of particular application. Example if solar PV array is need to be installed in a home roof top the annual energy consumption of that home is calculated then solar PV is designed for 90% of the annual energy consumption of that home. The data taken to design solar PV are given in appendix.

Basically the parameters which decide the solar PV outputs are a)Solar irradiation b)Temperature c)No.of series connected cell in the solar PV array d)No.of parallel connected cell in the solar PV array e)Short circuit current of a cell or PV array f)Open circuit voltage of a cell or PV array g)Fill factor. Other than this parameters are also considered to design a solar PV for specific application.

The maximum output power of the solar PV is determined by

$$P_{max} = V_{mp} * I_{mp}$$

(or)

$$P_{max} = V_{oc} * I_{sc} * FF$$

Where

P_{max}=Maximum output power

V_{mp}=Open circuit Voltage at maximum output power

I_{mp}=Short circuit Current at maximum output power

V_{oc}=Open circuit Voltage

I_{sc}=Short circuit Current

FF=Fill factor

Where Fill factor is nothing but the ratio of practical maximum out power to theoretical maximum output power.

$$FF = P_{max(practical)} / P_{max(theoretical)}$$

i.e. $FF = (V_{mp} * I_{mp}) / (V_{oc} * I_{sc})$

as shown in figure 3.

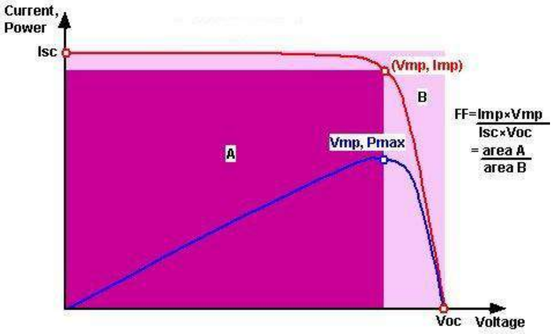

Fig.3 Fill factor

The quality of a solar cell is determined by fill factor. For a good quality cell the fill factor should be from 0.7 to 0.8.

An equivalent circuit of a solar cell is as shown in figure 4.The concept of open circuit voltage and short circuit current can be understand by viewing the equivalent circuit shown. When number of series connected cell increases the open circuit voltage is increases as well as when number of parallel connected cell increases the short circuit current also increases.

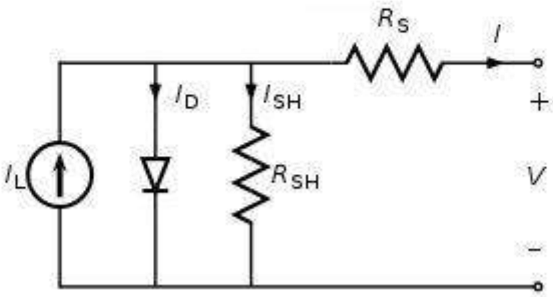

Fig.4 Equivalent circuit of a solar cell

B. Design of Boost converter:

The boost converter is required in this work to boost the voltage which come out from solar PV array. The voltage boosting is done where the power transfer is required. When higher the voltage lower will be the current so transmission losses will be reduced. Boost converter also having important role in maximum power point tracking. For that feedback control is required to track maximum power point for that the solar photovoltaic voltage and current is feedback and from that required pulse width modulation signal is generated to track maximum power point.

Design of boost converter is concern with required output voltage, output current and available input voltage. Depends upon the input voltage and output voltage requirement the duty cycle, capacitor, inductor values are calculated. Specifications of those parameters are denoted in appendix.

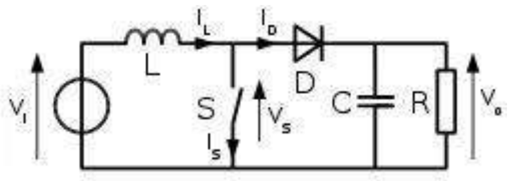

Fig.5 Schematic diagram of Boost converter

The formulas to calculate the parameters are

Duty cycle (D) =1-(V_{in}/V_{out}),

Inductance (L) = ((D*V_{in}*(1-D))/(2*F_s*I_{out}),

Capacitance(C)=(I_{out}/(F_s*Voltage ripple)

Where,

V_{in}=Input voltage of Boost converter

V_{out}=Required output voltage of Boost converter

I_{out}=Required output current of Boost converter

F_s=Switching Frequency

The schematic diagram of Boost converter is shown in figure 5.

C. Design of Voltage Source Inverter (VSI):

To connect the solar PV array with the power grid and AC load it is required to use inverter. Here the inverter used is three phase four leg voltage source inverter. The output of the voltage source inverter is controlled by controlling the switches of the inverter. Pulse width modulation technique is used to control the switches of the inverter. Depends upon the duty cycle the inverter output is varied.

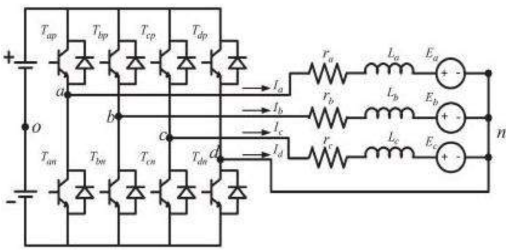

Fig.6 Four leg three phase VSI

The inverter is connected with grid through the transformer and transmission lines. The inverter used in this work is three phase four leg voltage source inverter as shown in figure 2. It is like three phase four wire design.so single phase and three phase load can be connected.

D. PWM Technique:

Pulse width modulation (PWM) is a powerful technique for controlling analog circuits with a microprocessor's digital outputs. PWM is employed in a wide variety of applications, ranging from measurement and communications to power control and conversion by controlling analog circuits digitally, system costs and power consumption can be drastically reduced. PWM is a way of digitally encoding analog signal levels. In this (as shown in figure 7) reference wave form is compared with carrier wave this result the output is Pulse Width Modulated wave form. By the way of changing the Pulse Width Modulation technique can generate the wave form which can change the switching behavior and switching frequency of each switches in the converter. This changes in the switching behavior and switching frequency can have the ability to control the power electronic Voltage Source Converter output.

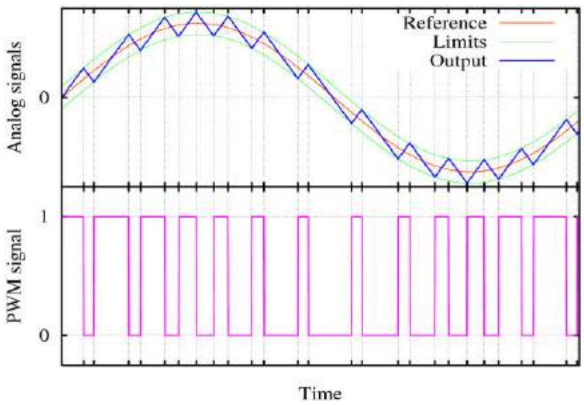

Fig.7 PWM Technique

3. SIMULATION AND RESULTS

A. Simulation:

MATLAB is used to simulate the proposed system. The simulated performance of this proposed solar photovoltaic system is presented at a constant power point. Figure 8 shows the solar PV design, Figure 9 shows the solar PV array connected with the boost converter. The overall model of the solar photovoltaic system which connected with grid is shown in figure 10.

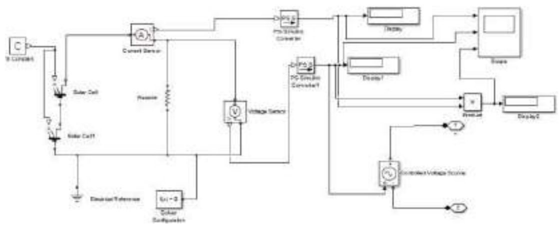

Fig.8 Solar PV design

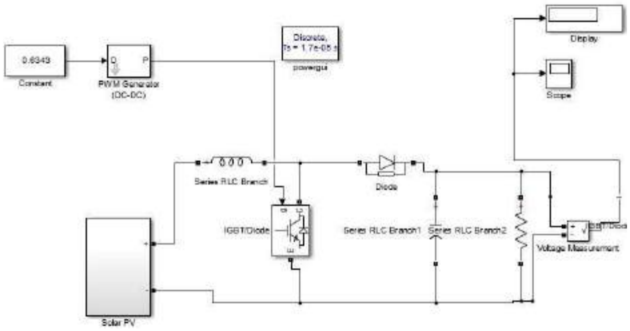

Fig.9 Boost converter connected with Solar PV

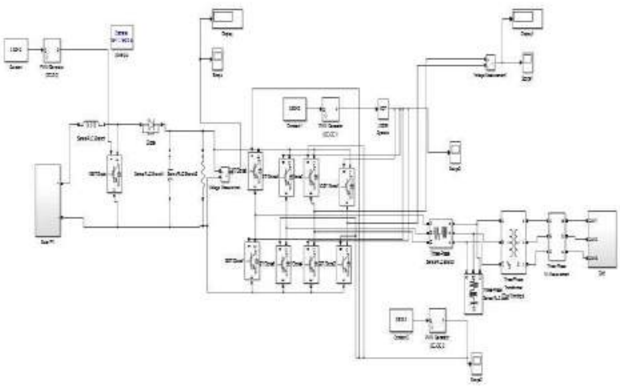

Fig.10 Overall simulation model

B. Results:

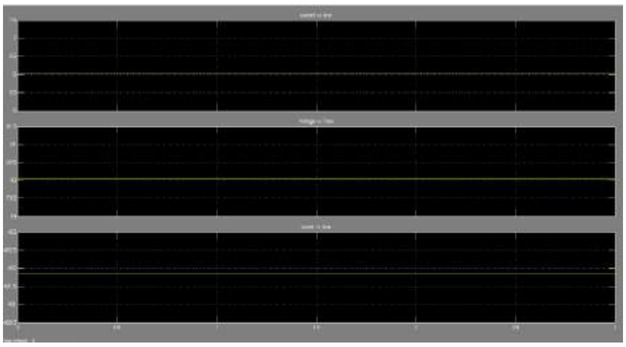

Fig.11 Output current, voltage and power from solar PV

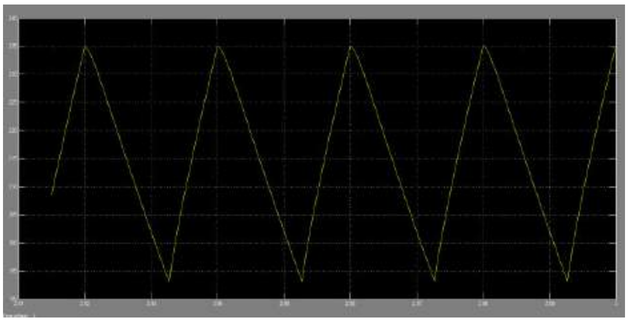

Fig.12 Output voltage of Boost converter

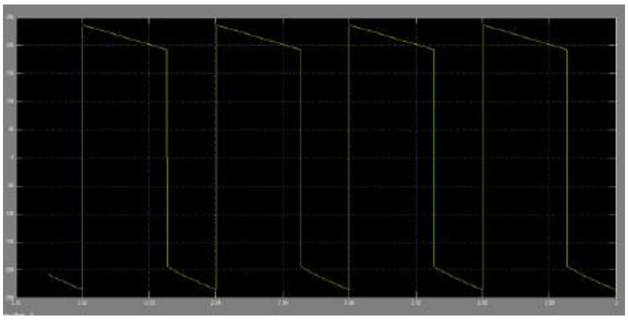

Fig.13 Output voltage of VSI

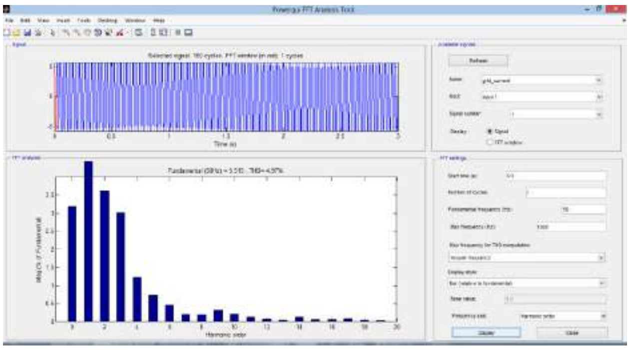

Fig.14 THD of Grid current

4. CONCLUSION

Thus a control technique to eliminated harmonics in grid integrated solar photovoltaic system which supply non- linear load was designed. The voltage source converter based control is used to eliminate harmonics in the grid integrated solar photovoltaic system. The simulation (MATLAB/SIMULINK) result shows that the proposed control strategy provides acceptable Total Harmonic Distortion (THD)

5. ACKNOWLEDGEMENT

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6. REFERENCES

[1] Arun Kumar Verma Chinmay Jain, Bhim Singh and Dilip Tekchand Shahan, 'Adaptive noise cancellation based harmonic elimination in grid integrated photovoltaic system', IET Renew. Power Gener,2016.
[2] Jincy Philip, Chinmay Jain,Krishan Kant, Bhim Singh and Sukumar Mishra, "Control and Implementation of a Standalone Solar Photo-Voltaic Hybrid System", IEEE Transactions on Industry Applications,2016.
[3] Zhao, H., Jin, T., Wang, S., et al.: 'A real-time selective harmonic elimination based on a transient-free inner closed-loop control for cascaded multilevel inverters', IEEE Trans. Power Electron., 2016.
[4] S. G. Malla and C. N. Bhende, "Enhanced operation of stand-alone "Photovoltaic-Diesel Generator-Battery" system", Journal of Electric Power Sys. Research, 2014.
[5] M. Datta, T. Senjyu, A. Yona and T. Funabashi, "Photovoltaic Output Power Fluctuations Smoothing by Selecting Optimal Capacity of Battery for a Photovoltaic-Diesel Hybrid System", Electric Power Components and Systems, 2011.
[6] Singh, B., Shahani, D.T., Verma, A.K.: 'Neural network controlled grid interfaced solar photovoltaic power generation', IET Power Electron., 2014.
[7] Wang, Q., Wu, N., Wang, Z.: 'A neuron adaptive detecting approach of harmonic current for APF and its realization of analog circuit', IEEE Trans. Instrum. Meas., 2001.

7. APPENDIX:

a)Annual energy consumption of a home:

MONTH & YEAR	UNIT(kwh)
JAN-FEB/2016	140
MAR-APR/2016	120
MAY-JUN/2016	110
JUL-AUG/2016	155
SEP-OCT/2016	91
NOV-DEC/2016	180
TOTAL	796

As per Tamilnadu 1kw panel can generate upto 1500kwh per annum.so to generate 796 kwh the solar panel size required is 0.5307kw in terms of Watt 530.6 w.90% of the 530 is 477 w. For 1kw panel area required is 12m^2.

b)Solar PV array:

PARAMETERS	VALUE
Irradiation	1000 w/m^2
No.of series cell	72
Quality factor	1 N
P_{max}	480W
V_{oc}	80V
I_{sc}	8A
V_{mp}	80V
I_{mp}	6A
Fill Factor	0.75
Area required	6m^2
Load resistance	13.3 Ohm

c) Boost converter:

PARAMETERS	VALUE
L	0.0370 H
C	0.1000
R	1 ohm
D	0.6343
F_s	50 HZ