



Three-level Inverter with LSMC-SVPWM Control in Power Quality Control of a Solar Power Generator

¹ Dr. Arul P, ²Gopalakrishnan R

¹ Professor,

²Assistant Professor

¹Department of Electrical and Electronics Engineering,
Kongunadu College of Engineering and
Technology(Autonomous), Tamilnadu, India.,

²Department of Electrical and Electronics Engineering,
Kongunadu College of Engineering and
Technology(Autonomous), Tamilnadu, India.,

Abstract : The solar power generation is a DC power which has to be converted to AC. While converting it to AC power there is a need of maintenance of power quality. The term power quality says about the total harmonic distortion (THD) and power factor. In this paper the solar power generator which is generating the power can also maintain the quality of the power. The loads like linear and nonlinear loads are taken into consideration for checking the power quality of the proposed system. The performance of harmonics and power factor is compared with and without the level shifted multicarrier SVPWM (LSMC-SVPWM) technique for three level inverters. A PHEV is connected at the load side which can work as bidirectional. Including this the power quality has to be maintained. MATLAB is used here to model the system.

IndexTerms – SVPWM, Multi-level inverter, Power Quality, PHEV, LSMC.

I. INTRODUCTION

The PV power plant implementation is increasing in recent years as it has more benefits. And there are many researches available in solar to improve the tracking power tracking and stability. In [1] the power quality improvement with PV power plant is explained with new techniques. The [2] discusses about the distribution generation (DG) integration in the power system. The electric vehicle charging system is explained in [3]. About the circuit available for the vehicle charging is explained in [4]. Power quality in the power system due to electric vehicle is discussed in [5]. Under smart grid environment usage of plugin electric vehicle is explained in [6]. Bidirectional operation of the electric vehicle battery is explained in [7]. In a residential area charging a electric vehicle is discussed in [8]. In a distributed solar power generation charging a battery is explained in [9]. A detailed literature survey of electric vehicle transportation is given in [10]. Chagrin a local smart grid battery with vehicle is detailed in [11]. Grid connected residential and plug-in electric vehicle (PHEV) concept is explained in [12]. Power quality management in a PV which is supplying to grid is explained in [13].

The design of various converters and power quality of those converters are detailed in [14]. Time and frequency analysis are carried out in [15]. Voltage regulation by using statcom is discusses in [16]. A mathematical method of extraction of sinewave is explained in [17]. Bidirectional onboard charger is explained in [18]. Other articles on power quality with PV power generation is given in [19-25]. In this paper a three-level inverter with multicarrier SVPWM is explained for power quality issues when it is connected to linear and non-linear load and connected to grid. The PV power generation is integrated to this inverter for transfer the power to grid. The MATLAB is used to carry out the experimentation of various cases.

II. PROPOSED SYSTEM

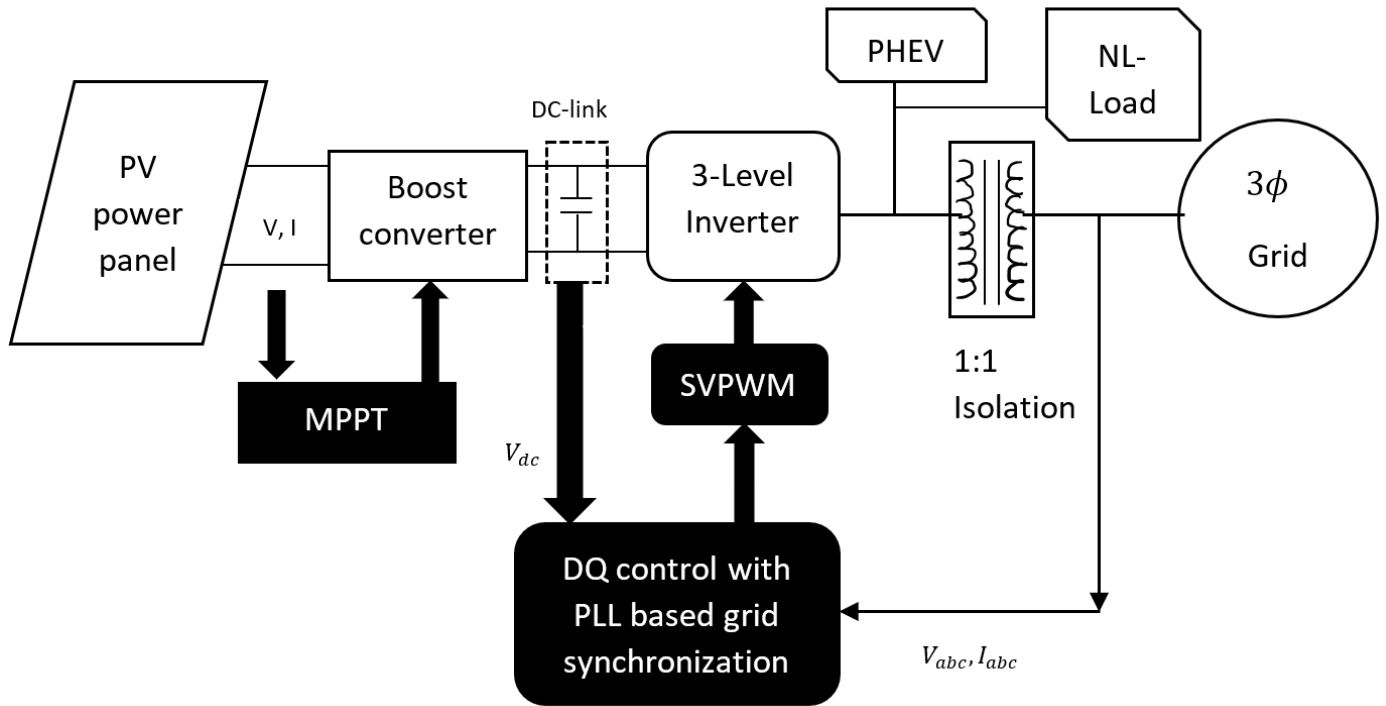


Figure 1. Proposed system

The figure shows the PV connected to a boost converter where the boost converter is controlled with feed forward control loop of MPPT control. The MPPT control controls the PV voltage at maximum power point. Then it outputs the pulses. Then the boost converter boosts the voltage according to the required DC link. The DC link then provides it to DC to AC converter. Here a three-level inverter is used with new multicarrier SVPWM. Then this AC voltage is connected to the grid. Here there are linear as well as non-linear load combinations are connected. The inverter has to take care of the power quality problems created by linear as well as non-linear load combinations.

III. LEVEL SHIFTED MULTI CARRIER SVPWM

Compared to the traditional SVPWM this LSMC SVPWM is using the (N-1) carriers for a N-level converter. Geometrically, it is shifting of the hexagon where the reference is, to the smallest centre hexagon. This is discussed detail in [26].

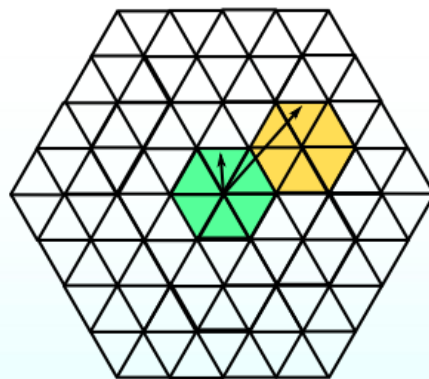


Figure. 2 Hexagon diagram for LSMC

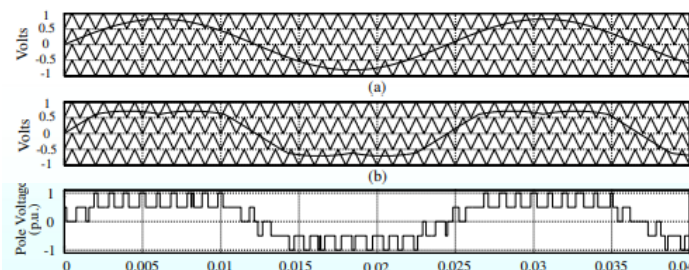


Figure. 3 proposed LSMC SVPWM (a) multicarrier PWM for sine wave. (b) level shifted multi carrier for SVPWM reference (c) output of the inverter

IV. RESULT AND DISCUSSION

The Table I shows the specifications used in the simulation. The control is done to test the power quality of the system even when PHEV and non-linear loads are connected. When the non-linear load is connected the harmonics may be more and the power factor also distorted. The simulation is done for four cases,

- i) Linear load without controller
- ii) Linear load with controller
- iii) Non-linear load without controller and
- iv) Non-linear load with controller.

Here in all the cases the PHEV is connected to the system. This creates the non-linearity. This non-linearity gets increased when it is connected to the non-linear load specified in table I.

Table I- Parameter list

S.no	Components	ratings
1	PV array	Voc = 64.2V, Vmp=54.7V
		Isc = 5.96A, Imp=5.58A
		No. of series 6 panels
		No. of series 48 panels
2	Grid	V=440V
		F=50HZ
3	Transformer	1:1, 100KVA, 50HZ
4	Linear Load	80kW
5	Non-linear load	Rectifier bridge with R= 50-ohm, L=2mH
6	Boost converter	Vin= 300, Vout=700V
7	Inverter	3-level, SVPWM
8	PHEV	48V li-ion battery with 50Ah

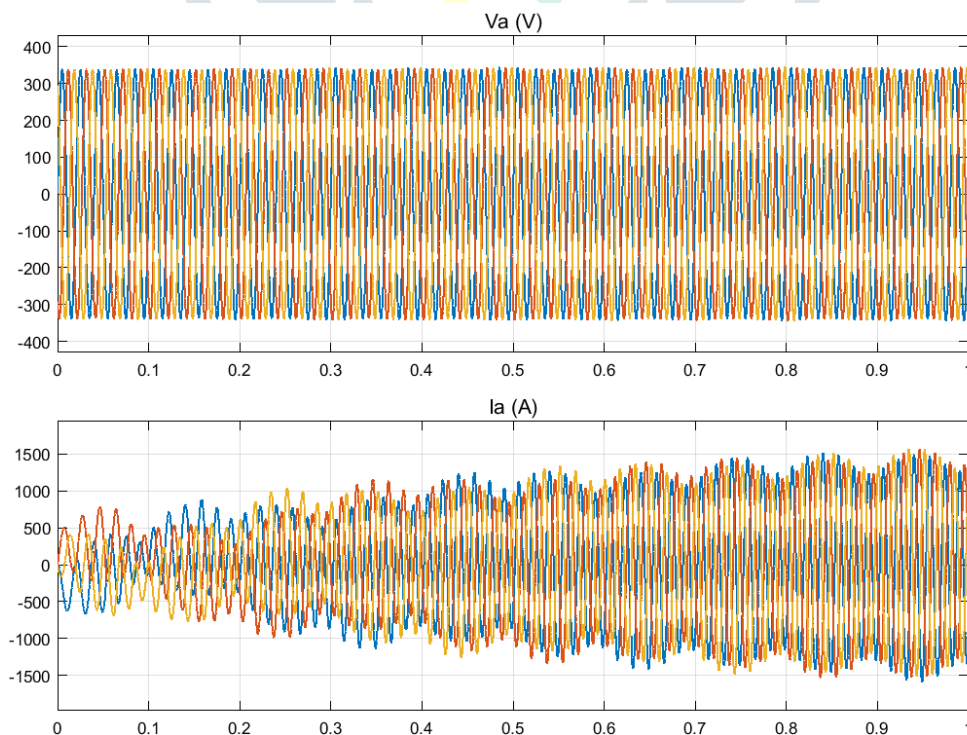


Figure. 4 Grid voltage and current when not connected to controller with linear load

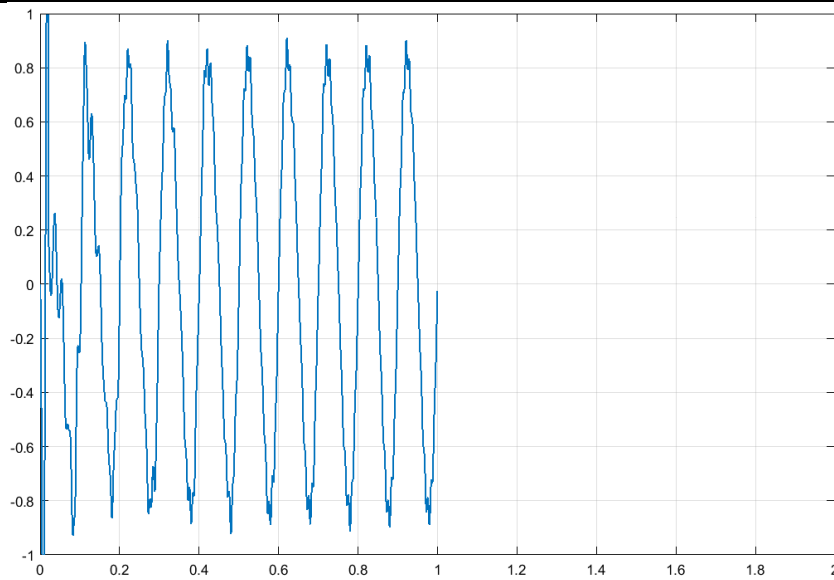


Figure 5 power factor without controller linear load

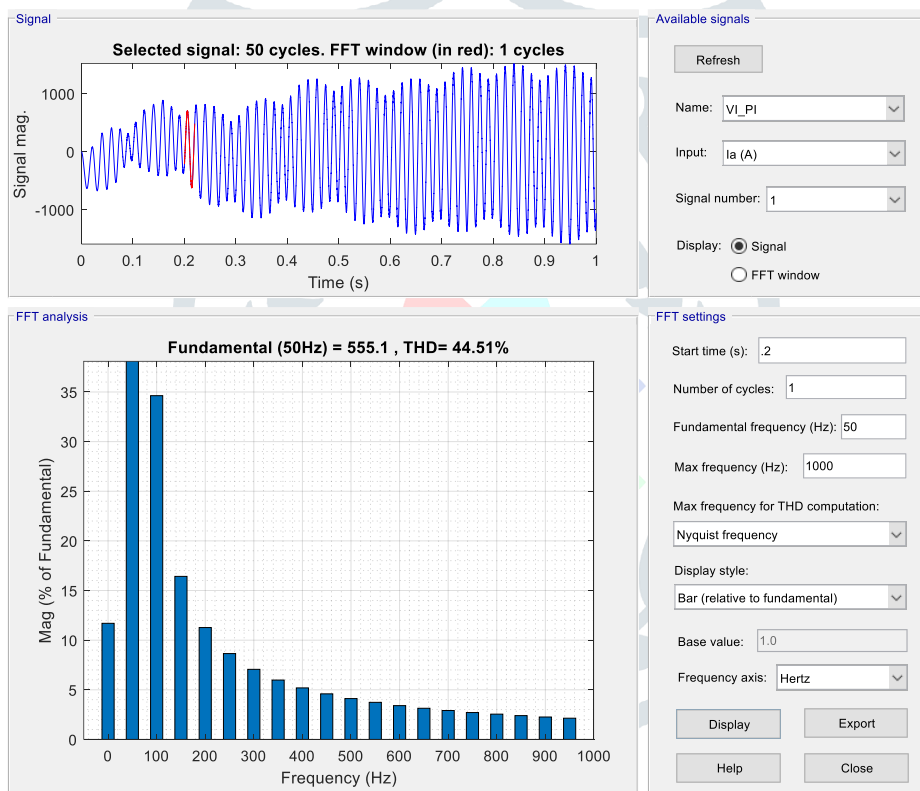


Figure.6 THD without connecting controller with linear load

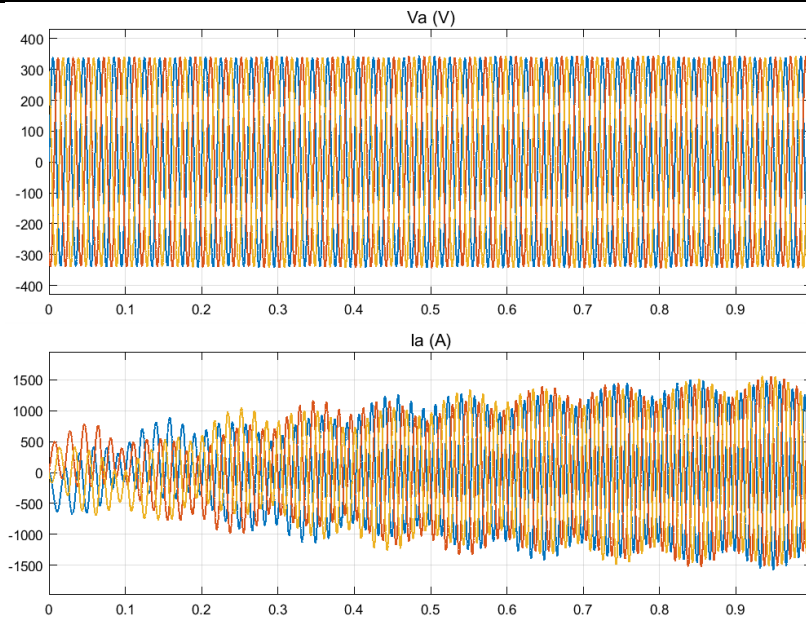


Figure.7 Grid voltage and current when not connected to controller with non-linear load

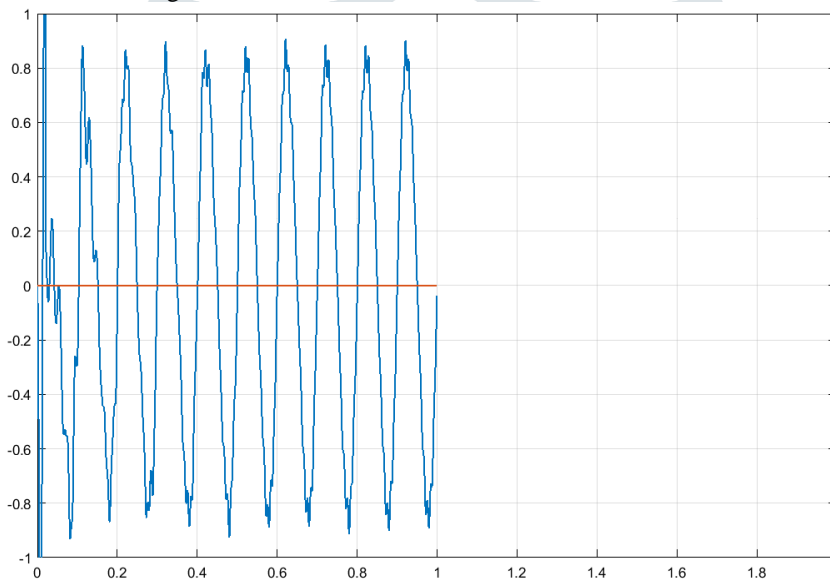


Figure. 8 power factor without controller non-linear load

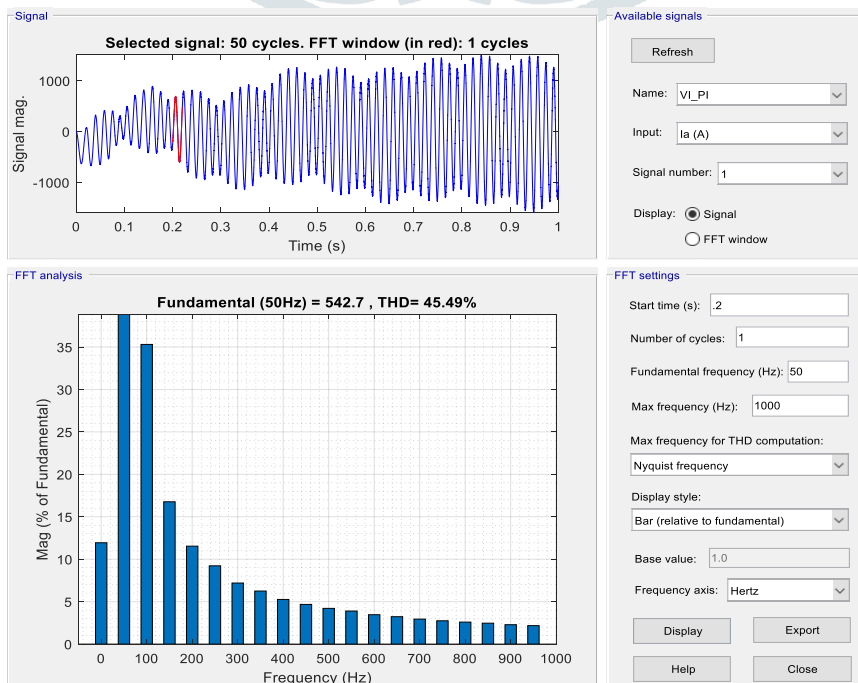


Figure.9 THD without connecting controller with non-linear load

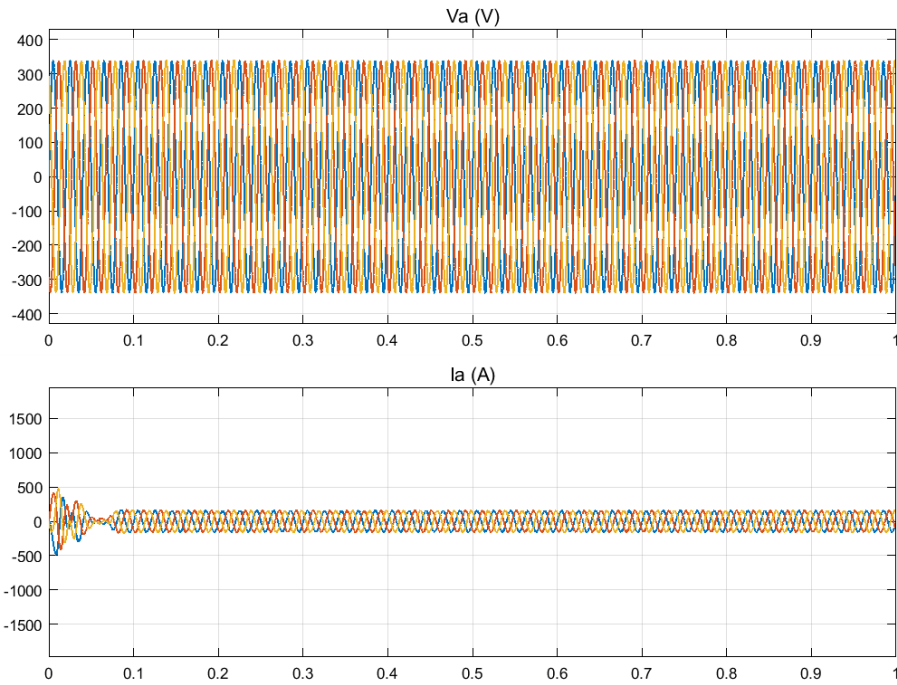


Figure.10 Grid voltage and current with controller with linear load

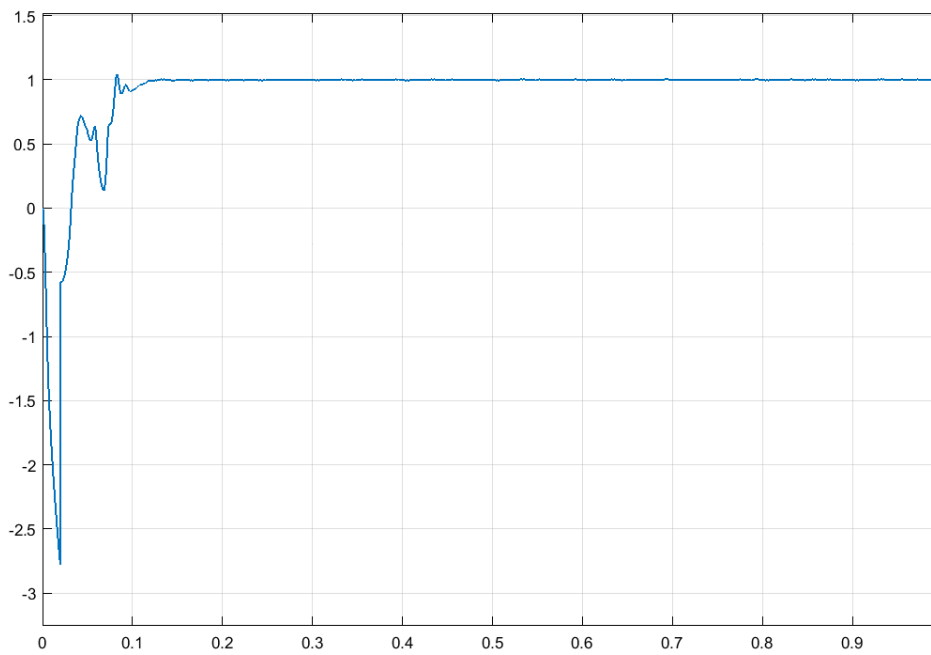


Figure. 11 power factor with controller linear load

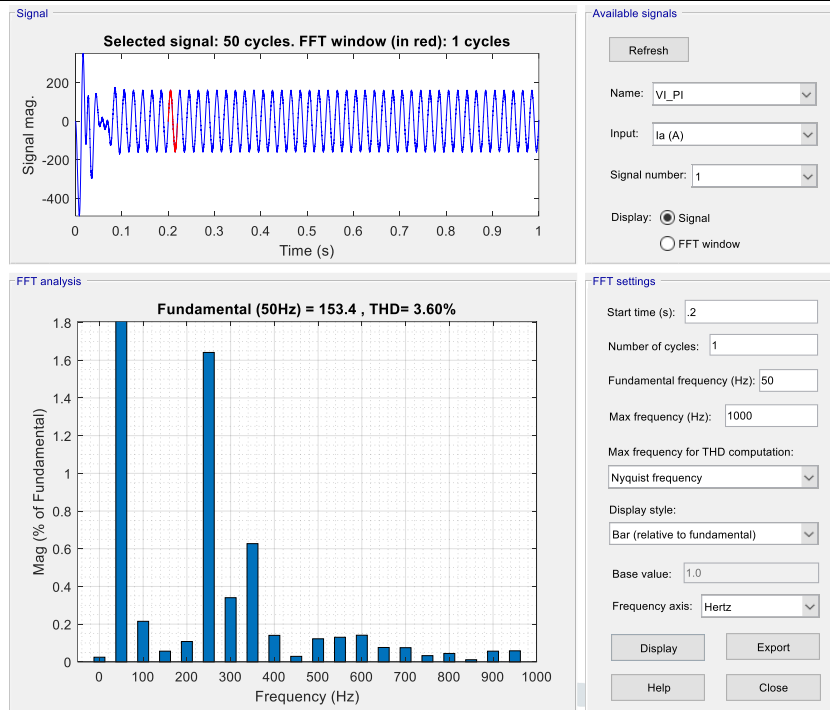


Figure.12 THD with connecting controller with linear load

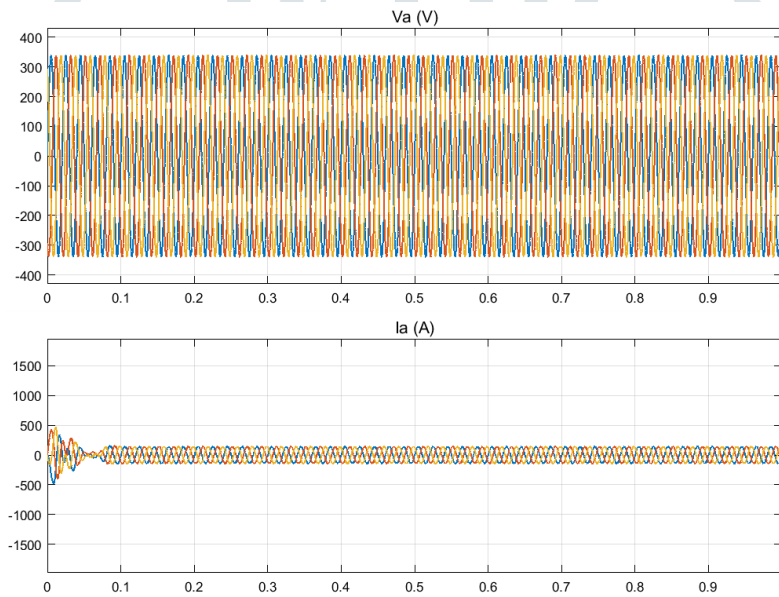


Figure.13 Grid voltage and current with controller with non-linear load

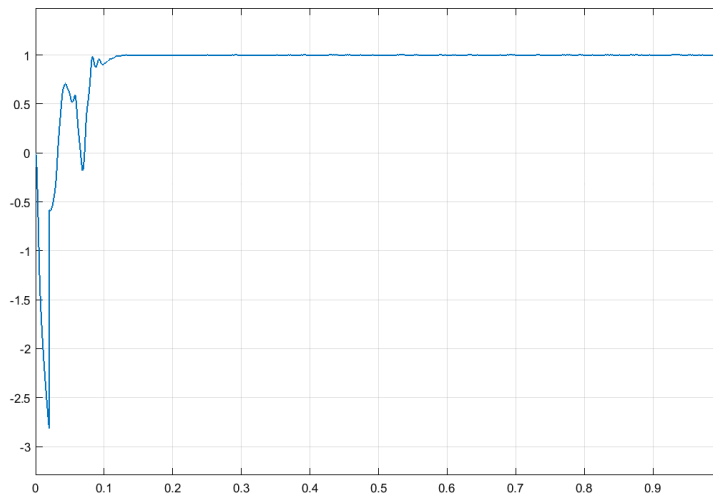


Figure. 14 power factor with controller non-linear load

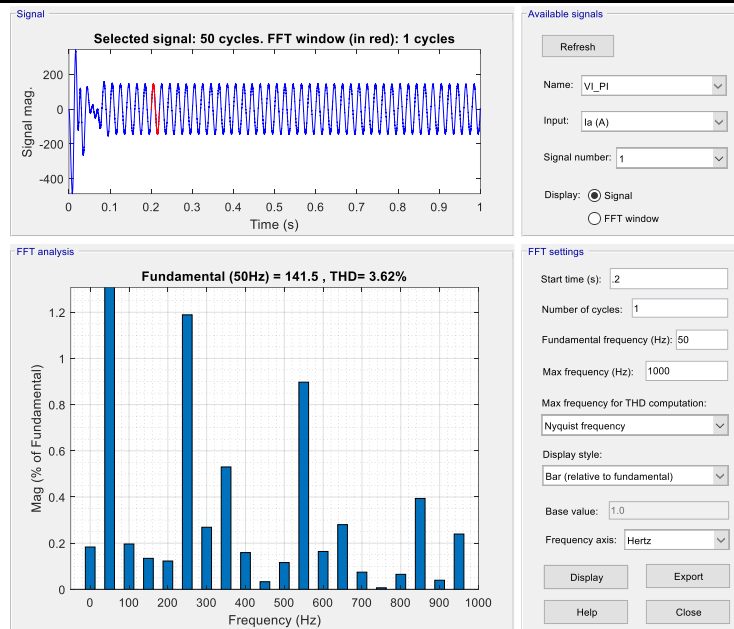


Figure.15 THD with connecting controller with non-linear load

The grid voltage and current is shown in Fig. 4 with linear load and without controller. The Fig 5 shows the power factor without controller with linear load. The power factor is poor as it goes to positive and negative and as in The current is distorted due to non- connection of the controller. The Fig.6 shows the THD without connecting controller with linear load and THD is higher around 44%. Then the Fig.7 shows the Grid voltage and current when not connected to controller with non-linear load. The Fig. 8 shows the power factor without controller non-linear load. Then the Fig.9 shows the THD without connecting controller with non-linear load. The THD is 45% and power factor is distorted as the grid current is distorted as it is not connected with the load.

Table II – comparison table

cases	THD	With control
Case i	44%	0.82
Case ii	45%	0.8
Case iii	3.6%	1
Case iv	3.62%	1

The Fig.10 shows the Grid voltage and current with controller with linear load. Is it is within the standard value. It depicts 3.6 % of THD. Then the power factor is unity. So the proposed control technique takes care of the harmonics and it improves the power factor. The Fig. 11 shows the power factor with controller linear load. Then the Fig.12 shows the THD with connecting controller with linear load. The Fig.13 shows Grid voltage and current with controller with non-linear load. And Fig. 14 shows the power factor with controller non-linear load. The Fig.15 shows the THD with connecting controller with non-linear load.

V. CONCLUSION

The PV power plant with the power quality conditioning is done using the 3-level inverter. The comparison of THD and power factor is explained. There are four cases considered here. The proposed control technique is with multicarrier SVPWM which controls the 3-level inverter. The performance of the THD and power factor is better compared to the 4-leg inverter presented in [1]. And the power quality with PHEV using the linear and non-linear load comparison is also done.

REFERENCES

- [1] Arun Kumar Verma, Bhim Singh, Dilip Tekchand Shahani & Chinmay Jain (2016) Grid-interfaced Solar Photovoltaic Smart Building with Bidirectional Power Flow Between Grid and Electric Vehicle with Improved Power Quality, Electric Power Components and Systems, 44:5, 480-494, DOI: 10.1080/15325008.2015.1120818
- [2] Bollen, M., and Hassan, F., Integration of Distributed Generation in the Power System, NJ: John Wiley & Sons, Inc., 2011.
- [3] Ferreira, J. C., Monteiro, V., and Afonso, J. L., "Smart electric vehicle charging system," 2009 IEEE Intelligent Vehicles Symposium (IV), pp. 758–763, Xi'an, China, 3–5 June 2009.
- [4] Gomez, J. C., and Morcos, M. M., "Impact of EV battery charg- ' ers on the power quality of distribution systems," IEEE Trans. Power Del., Vol. 18, No. 3, pp. 975–981, July 2003.
- [5] Du, Y., Lukic, S., Jacobson, B., and Huang, A., "Review of high power isolated bi-directional DC-DC converters for PHEV/EV DC charging infrastructure," Proc. 2011 IEEE Energy Conversion Congress and Exposition (ECCE), pp. 553–560, Phoenix, AZ, 17–22 September 2011.
- [6] Shireen, W., and Patel, S., "Plug-in hybrid electric vehicles in the smart grid environment," Transmission and Distribution Conference and Exposition, 2010 IEEE PES, pp. 1–4, 19–22 April 2010. [13] Lund, H., and
- [7] Zhou, X., Lukic, S., Bhattacharya, S., and Huang, A., "Design and control of grid-connected converter in bi-directional battery charger for plug-in hybrid electric vehicle application," Proc. Vehicle Power and Propulsion Conference, 2009 VPPC '09 IEEE, pp. 1716–1721, Dearborn, MI, USA, 7–11 September 2009.
- [8] Clement-Nyns, K., Haesen, E., and Driesen, J., "The impact of charging plug-in hybrid electric vehicles on a residential distribution grid," IEEE Trans. Power Syst., Vol. 25, No. 1, pp. 371–380, February 2010.

- [9] Hill, C. A., Such, M. C., Chen, D., Gonzalez, J., and Grady, W. M., "Battery energy storage for enabling integration of distributed solar power generation," *IEEE Trans. Smart Grid*, Vol. 3, No. 2, pp. 850–857, June 2012.
- [10] Su, W., Eichi, H., Zeng, W., and Chow, M.-Y., "A survey on the electrification of transportation in a smart grid environment," *IEEE Trans. Ind. Inform.*, Vol. 8, No. 1, pp. 1–10, February 2012.
- [11] Pang, C., Dutta, P., and Kezunovic, M., "BEVs/PHEVs as dispersed energy storage for V2B uses in the smart grid," *IEEE Trans. Smart Grid*, Vol. 3, No. 1, pp. 473–482, March 2012.
- [12] Gurkaynak, Y., and Khaligh, A., "Control and power management of a grid connected residential photovoltaic system with plug-in hybrid electric vehicle (PHEV) load," *Twenty-Fourth Annual IEEE Applied Power Electronics Conference and Exposition, 2009. APEC 2009*, pp. 2086–2091, Washington, DC, USA, 15–19 February 2009.
- [13] Chen, X., Fu, Q., Yu, S., and Zhou, L., "Unified control of photovoltaic grid-connection and power quality managements," *Proceedings of the Workshop on Power Electronics and Intelligent Transportation System*, pp. 360–365, Guangzhou, 2–3 August 2008.
- [14] Mohan, N., Undeland, T. M., and Robbins, W. P., *Power Electronics Converters, Applications, and Design*, 3rd ed., reprint, New Jersey, USA: Wiley India Press (P.), 2009.
- [15] Karimi Ghartemani, M., and Ziarani, A. K., "A nonlinear timefrequency analysis method," *IEEE Trans. Signal Process.*, Vol. 52, No. 6, pp. 1585–1595, June 2004.
- [16] Singh, B., Murthy, S. S., and Gupta, S., "Analysis and design of STATCOM based voltage regulator for self-excited induction generator," *IEEE Trans. Energy Convers.*, Vol. 19, No. 4, pp. 783–790, December 2004.
- [17] Ziarani, A. K., and Konrad, A., "A method of extraction of nonstationary sinusoids," *J. Signal Process.*, Vol. 84, pp. 1323–1346, 2004.
- [18] Erfani, M. J., *Design of a Bi-directional on Board Battery Charger in Hybrid Electric Vehicle application*, Master of Science Thesis, Division of Electric Power Engineering, Department of Energy and Environment, Chalmers University of Technology, Goteborg, Sweden, 2011.
- [19] P.Jintakosonwit, H. Fujita, H. Akagi, and S. Ogasawara, "Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system," *IEEE Trans. Ind. Appl.*, vol. 39, no. 2, pp. 556–564, Mar./Apr. 2003.
- [20] J. P. Pinto, R. Pregitzer, L. F. C. Monteiro, and J. L. Afonso, "3-phase 4-wire shunt active power filter with renewable energy interface," presented at the Conf. IEEE Renewable Energy & Power Quality, Seville, Spain, 2007.
- [21] J. M. Carrasco, L. G. Franquelo, J. T. Bialasiewicz, E. Galván, R. C.P. Guisado, M. Á. M. Prats, J. I. León, and N. M. Alfonso, "Power-electronic systems for the grid integration of renewable energy sources: A survey," *IEEE Trans. Ind. Electron.*, vol. 53, no. 4, pp. 1002–1016, Aug. 2006.
- [22] Eswaran Chandra Sekaran, "Analysis and simulation of a new shunt active Power filter using cascaded multilevel inverter" *Journal of electrical engineering*, vol. 58, no. 5, 2007, 241–249.
- [23] M. Elshaer, A. Mohamed, and O. Mohammed, "Smart Optimal Control of DC-DC Boost Converter in PV Systems" *IEEE Transmission and Distribution Conference and Exposition Latin America*, 2010, pp. 978-1-4577-0487-1/10.
- [24] Zulkifile Ibrahim, "Performance investigation of photovoltaic grid connection for shunt active power filter with different PWM generation" 20th November 2013. Vol. 57 No.2.
- [25] Wang, D., & et.al. "Coordinated Dispatch of Virtual Energy Storage Systems in LV Grids for Voltage Regulation", *IEEE Trans. Ind. Inform.* 2018, 14, 2452–2462.