1

A Literature Review on PV Inverter Topologies Connected to Grid

Arpita Banik, Bansilal Bairwa, Mamatha N
arpita.b@reva.edu.in

School of EEE, REVA University, Bangalore, India 560064

Abstract

The global power sector is witnessing a gradual transition from typical thermal power-generating sources toward clean energy technologies. Non-conventional sources of energy are the most appropriate solution to give clean and inexhaustible energy to conquer the worldwide energy emergency. The renewables share was 8.6 percentage within the world energy combine in 2010 and is predicted to extend to 22.5 percentage in 2020 as per a recent thematic analysis report renewable energy by the data collected globally. With the advancement in power electronics technology, photo-voltaic system (PV) is getting more popularity in generation of electricity. Inverters connected to grid have developed significantly with high decent variety. Efficiency, estimate, weight, dependable execution have all improved significantly with evolvement of technically advanced and innovative electrical converter configurations and these factors have diminished the expenses of inverters. This study incorporates a short dialog on network associated PV inverter, overall development of PV system, classification of inverter topologies, expected properties of PV inverters to perform better, selection of PV inverters and a comparative study on different inverter topologies in terms of their pros, cons, cost and rating.
Keywords: MLI , SCC, Boost converter, Pulse Width Modulation.

An Edited Volume, 9–16.

1.1 Introduction

Sustainable power source is particularly fundamental for gathering present and future energy necessities[1]. Photo-voltaic (PV) control, in light of the fact that it is perfect and boundless supply of energy, is maybe the best innovation among all sustainable power sources and in this way a generous amount of investigation and research is being led towards improving photo-voltaic system effectiveness and to use the PV control, network interconnection of PV system is required. Being a clean contamination free and inexhaustible source of energy, photo-voltaic system has got extraordinary enthusiasm as an alternative source of energy. Major confinement to the utilization of PV power was the surprising expense of the PV modules [2]. But with advancement of technology and decrease in price for PV modules, in past few decades, PV inverters connected to the grid have advanced significantly and have turned out to be a standout amongst the best and quickest creating innovations in power electronics and power system field. In total global installed capacity of renewable energy sources PV system had a share of 8.7% in 2010, which got increased up to 32.4% in 2017 and is expected to get increased up to 39.6% by 2020[3]. PV systems are mainly divided into 2 classes as, the standalone (off-grid) system and the the grid-connected (on-grid) system [4]. The standalone (off-grid) system works free of the utility grid while, the grid-connected applications use PV system related to the grid network. As of now, contrasted with the standalone system, the usage of grid-connected system is wide embraced in pragmatic applications[5, 6]. A normal structure grid connected PV system is shown in Figure 1.1.

1.2 Worldwide growth of photo voltaic (PV)

Overall development of photo-voltaic has been near exponential somewhere in the range of 1992 and 2018. During this time frame, photo-voltaic (PV), otherwise called sunlight based PV, created from a claim to fame market of little scale applications to a standard power source. At the point when sunlight based PV technology was first perceived as a promising sustainable power source innovation, endowment programs, for example, feed-in taxes, were actualized by various governments so as to give financial motivating forces to ventures. The worldwide exponential development of photo-voltaic up to 2018 is presented in Figure 1.2 [7].

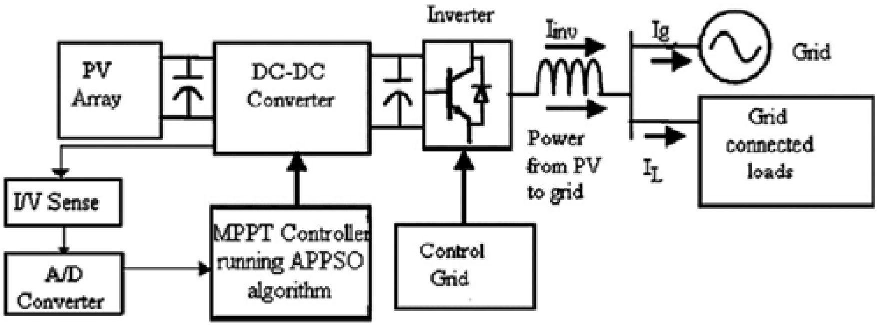

Figure 1.1 structure of grid connected PV system.

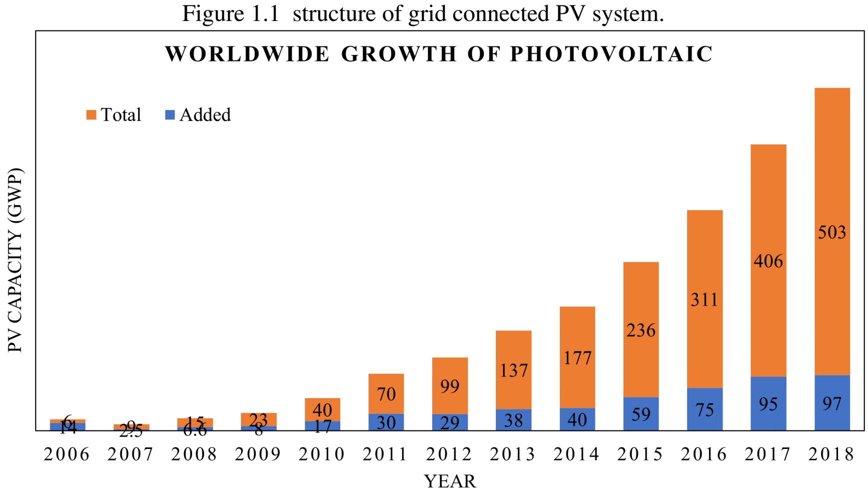

Figure 1.2 Worldwide growth of photo voltaic.

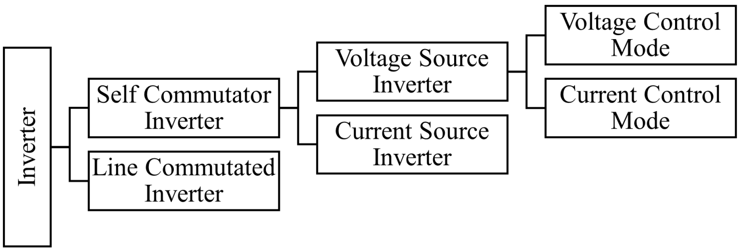

Figure 1.3 classification of inverters.

1.3 Classification of power electronic inverters

Phase, frequency, and voltage extent of the three-phase AC happening to the PV system is required in a PV system associated with the grid for the suitable synchronization with the grid. The transformation from DC to AC is finished by power electronic inverter which is the core of network associated PV system [7, 8, 9]. These inverters are primarily of two classes named as self commutated inverters and line commutated inverters. Self commutated inverters can control turn-ON and turn-OFF procedure of switching devices splendidly. Whereas, line commutated inverters performance is dependent upon circuit parameters and switching performance is controlled by the direction of current flow. Classification of grid connected inverters is shown in Figure 1.3.

1.3.1 Line-commutated inverter

In case of line-commutated Inverter commutation of the switching devices is performed by reversing the polarity of Alternating voltage and in this manner the flow of negative current (or zero current) starts the turn-OFF method. Line commutated inverters uses mainly semi controller devices like thyristors where turn-on process is controlled through gate terminal and turn-off is controlled by line current or grid voltage. In case of force commutation, external commutation circuit can also be included in such semi controlled devices[10, 11, 12, 13].

1.3.2 Self-commutated inverter

In Self-Commutated Inverter gate terminal controls turn-on and turn-off procedure of the power semiconductor device (switch). Shifting of current among various devices is performed in a systematic way. Power semiconductor devices I.e., MOSFETs and IGBTs are mainly used as switching devices in self-commutated inverters. For applications beyond 100kW and 20 kHz, IGBTs are used. Whereas, for a high frequency and low power application of 20– 800 kHz, 20kW, MOSFETs are generally used[14, 15].

1.4 Different Inverter topologies

Inverters can be categorized into various types depending upon the types of components used and the configuration. These various types of topologies are discussed as follows:

1.4.1 In view of stages to process power

As per the no. of power processing stages, inverters can be categorized as single-stage and multiple-stage inverter. Both are discussed with diagram below:

1.4.1.1 single-stage inverter

A single-stage inverter with line frequency transformer contributes in control of currents injected to the grid, the amplification of voltage and maximum power point tracking process [16]. The inverter is designed so as to deal with a peak power twice of the ostensible power which can be expressed by the below equation (1).

$$P_{grid} = 2P_{grid}sin^2(\omega_{grid}t) \tag{1.1}$$

In single-stage inverter the line frequency transformer increases the weight of the inverter and also causes peak efficiency loss of about 2% . These drawbacks of line frequency transformers can be overcome by using high frequency transformers or transformer less inverters.

1.4.1.2 Multiple-stage inverter

In this type of inverters, DC is first collected from the PV module and then it is controlled through the buck-boost converter[**?**]. Finally DC-DC converter output is given to DC-AC converter (Inverter) and finally the output from this inverter is given to the grid. The input voltage to the converter here is very low as no transformer used is here.

1.4.1.3 Single-stage and multiple-stage inverters with de-coupling capacitor

Single-stage and multiple-stage inverters require decoupling capacitors to filter out the voltage spikes present in PV module output[**?**]. Highly capacitive bulky electrolytic capacitors are used here for this purpose.

1.4.2 Cascade Inverter

In cascaded inverter used in PV system output of two full bridge inverter gets associated in arrangement to raise the quantity of voltage levels. Single inverters with three dissimilar to voltage levels can deliver AC output voltage of five levels with the assistance of cascaded topology. Historical overview of grid connected PV inverter gives clear idea on past and present technology of grid connected PV inverter[**?**].

1.5 Selection of inverters for grid connection and their control methods

1.5.1 Lawful necessities

- **Galvanic isolation:** Galvanic isolation is one of the most important factors to provide safety. Mainly to interrupt the flow of leakage current it is done through isolation transformer or isolation switch in case of transformer less inverters.
- **Detection of anti-islanding:** In this process PV system supplies power to the nearby load even if the connection of power grid is removed. This factor must be taken serious care because it may damage the equipment's and cause harm to the workers as well.

1.5.2 Properties expected from standalone inverters

Standalone inverters are expected to have following properties [20]:

- Output voltage should be sinusoidal
- System disconnection when the DC-link voltage goes low
- Output voltage and frequency must be maintained within permissible values
- Cables capable of withstanding large fluctuations in the input voltage
- Regulation of output voltage
- System must be highly efficient in light loads
- Capacity to handle surges must be there
- THD generated by the inverter must be low
- Must be capable of handling frequency variations, under and over voltage fluctuations

1.5.3 Properties expected from grid-connected inverters

Grid-connected inverters are expected to have following properties[20]:

- Dynamic response must be faster
- Unity power factor is expected
- Proper frequency control
- Output with low harmonics
- Synchronization with grid must be Accurate
- Fault current tolerance
- Under or over frequency and voltage protection

1.6 Conclusion and future work

PV inverter connected to the grid is one of the most developing technologies to support electricity generation using renewable source of energy and to satisfy the increased load requirement in an effective manner. PV system has got more focus as it is environment friendly and inexhaustible. With enormous support given by government and continuous improvements done by researchers have made this system highly efficient and cost effective. In this review paper, various types and topologies of PV inverters connected to grid are examined along with their pros and cons. The performance parameters of inverters and how they are expected of performing is also discussed here in this paper. Overall global growth of PV system is discussed and shown in Figure 1.2. It is expected that, in coming future improved design and updated technology will make this grid connected inverters perform with highest efficiency and reliability. Selection of proper controller for this grid connected inverters is not discussed here. In future a review can be done on selection of controller part to make this inverter more efficient and cost effective.

References

[1] Ishikawa T Grid-connected photovoltaic power systems: survey ofinverter and related protection equipments. Report IEA (International Energy Agency) PVPS T505; 2002. ⟨http:www.iea-pvps.org⟩

[2] Rahim NA, Saidur R, Solangi KH, Othman M,Amin N, Survey of Grid-connected photovoltaic inverters and related systems.

[3] https://www.power-technology.com

[4] El Nozahya MS, Salama MMA. Technical impacts of grid-connected photo- voltaic systems on electrical networks—areview. JRenew Sustain Energy 2013;5:032702.

[5] Akorede MF, Hizam H, ArisI, Ab Kadir MZA. A critical review of strategies for optimal allocation of distributed generation units in electric power systems. IREE 2010;5(2):593–600.

[6] Nema P, Nema R, Rangnekar S. A current and future state of art development of hybrid energy system using wind and PV-solar: a review. Renew Sustain Energy Rev 2009;13(8):2096–103.

[7] ”China's solar capacity overtakes Germany in 2015, industry data show”. Reuters. 21 January 2016.

[8] Lai, Chun Sing; Jia, Youwei; Lai, Loi Lei; Xu, Zhao; McCulloch, Malcolm D.; Wong, Kit Po (October 2017). ”A comprehensive review on large-scale photovoltaic system with applications of electrical energy storage”. Renewable and Sustainable Energy Reviews. 78: 439–451. doi:10.1016/j.rser.2017.04.078.

[9] ”China Targets 70 Gigawatts of Solar Power to Cut Coal Reliance”. Bloomberg News. 16 May 2014. Retrieved 16 May2014.

[10] "China's National Energy Administration: 17.8 GW Of New Solar PV In 2015 (20% Increase)". CleanTechnica. 19 March 2015.

[11] "Snapshot of Global Photovoltaic Markets 2017" (PDF). report. International Energy Agency. 19 April 2017. Retrieved 11 July2017.

[12] "2018 Snapshot of Global Photovoltaic Markets" (PDF). International Energy Agency. 2018. Report IEA PVPS T1-33:2018.

[13] MyrzikJMA,CalaisM.Stringandmoduleintegratedinvertersforsingle-phasegrid connected photovoltaic systems—a review. In: Proceedings of the IEEE Bologna PowerTech conference. vol. 2; 2003. p. 430–7.

[14] Kjaer SB, Pedersen JK, Blaabjerg F. Power inverter topologies for photovoltaic modules—a review. In: Proceedings of conference rec IEEE-IAS annual meeting. vol. 2; 2002. p. 782–8.

[15] Haeberlin HEvolution ofinverters forgrid connected PV-systemsfrom to2000.In: Proceedings of the 17th European photovoltaic solar energy conference. 2001. p. 426–430; 1989.

[16] A review of PV. Inverter technology cost and performance projections, NREL/SR620-38771; January 2006.

[17] IEA International Energy Agency. Grid-Connected photovoltaic power system: surveyof inverterandrelated protectionequipments, TaskV,Report IEA-PVPST5T05; 2002.

[18] Ishikawa T. Grid-connected photovoltaic power systems: survey of inverter and related protection equipments. Report IEA (International Energy Agency) PVPS T5- T05 ⟨http:www.iea-pvps.org⟩; 2002.

[19] Calais M, Agelidis VG. Multilevel converters for single-phase grid connected photovoltaic systems—an overview. In: Proceedings of the IEEE ISIE'98. vol. 1; 1998. p. 224–9.

[20] Azmi SA; Dept. of Electron. Electr. Eng., Univ. of Strathclyde, Glasgow, UK; K. H. Ahmed; S. J. Finney; B. W. Williams, Comparative analysis between voltage and current source inverters in grid-connected application. In: Proceedings of IET Conference on Renewable Power Generation (RPG 2011); 6-8 Sept. 2011. P. 1–6.