ARTICLE IN PRESS

Renewable and Sustainable Energy Reviews xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

A techno-commercial review on grid connected photovoltaic system

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ARTICLE INFO

Keywords:
Anti-islanding
Filter
Maximum power point tracking (MPPT)
Neutral point clamp inverter(NPC)
Phase locked loop(PLL)
Photovoltaic(PV)
Pulse width modulation(PWM)
Synchronous reference frame(SRF)

ABSTRACT

Owing to rapid depletion of fossil fuels and environmental hazard, different non-conventional sources of energy like wind, geothermal, nuclear, photovoltaic etc, have been taken into consideration for power generation. Environmental familiarness, reduced installation cost, improved power quality, abundant availability of source makes photovoltaic based distributed generation as one of the most popular alternative source of energy production. Improvement in power electronics technology makes synchronization of PV system with grid more viable. Power output from the PV module changes continuously with time depending upon the climatic condition. In order to get maximum output from the PV system different types of MPPT algorithm present in literature are studied and improvement proposed are described in this paper. Furthermore, different types of inverter topologies along with different grid synchronization technique and PWM topologies used to connect the PV system with the 3-phase AC grid are presented. In order to minimize the harmonic content of the inverter output, different types of filters used are presented in the proceeding section.

Nextly different commonly used advanced islanding detection techniques for the safety purpose of PV based distribution generation system have been addressed and based on advantages and limitation of anti-islanding techniques, a comparison table has been presented. Afterward based on parameters like input, output voltage & current, MPP range, used standards etc, a comparison table between different commercially available grid tied PV inverters are presented in this paper. Finally, drawbacks of the prevailing grid connected PV system have been discussed.

1. Introduction

Increasing power demand, scarcity of fossil fuel, environmental hazard have led the use of different non-conventional sources of energy production. Moreover, the power production from different non-conventional energy is environmental friendly (As PV can reduce CO_2 emission by 970 g/kWh of electrical energy). In non-conventional energy, growth of solar based power production has shown steady upraise worldwide with a growth rate of 30% in past three decade (Fig. 1). Till date many solar projects with capability more than 100 MW have been commissioned in different countries like Germany, China, Japan, USA, India etc [1]. The 850 MW Longyangxin Dam Solar Park project in China, 579 MW Solar Star project in the United States, 300 MW Cestas Solar Farm project of France, 166 MW Solar Park Meuro project in Germany, 148 MW Eurus Rokkasho Solar Park project in Japan are some of the biggest projects in different countries worldwide.

The solar irradiance received by India is $4-7\ kWh/m^2/day$ with 270 sunny days on average, which makes India one of the most suitable country for producing electrical energy using solar power. Some of the major solar power projects in India are 360 MW Kamuthi Solar project in Tamil Nadu, 345 MW Charanka Solar Park project in Gujrat, 151 MW Welspun Solar MP project in Madhya Pradesh. Out of 44783.33 MW installed grid connected renewable power capacity, 8062 MW are solar power based grid connected systems. According to National Solar Mission of India, the installed capacity will be increased up to 20 GW by 2020, 100 GW by 2030 and 200 GW by 2050 while reducing the cost/kWh less than 0.10$.

PV system can be divided into two categories (1) Standalone PV system and (2) Grid connected PV system. Power produced in the standalone system is being utilized at the place where it is produced and it is not possible to transmit over a long distance. For that reason grid connected PV system is gaining much attention nowadays. For high voltage range PV modules are connected in series or parallel combination. There are different types of architectures to interface multiple PV modules with the utility grid that are as follows [2]: (1) Central Power Conditioning System (PCs) (2) String Power Conditioning System (3) Multistring Power Conditioning System (4)

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http://dx.doi.org/10.1016/j.rser.2017.06.045
Received 4 October 2016; Received in revised form 8 March 2017; Accepted 16 June 2017
1364-0321/

Please cite this article as: Chatterjee, S., Renewable and Sustainable Energy Reviews (2017), http://dx.doi.org/10.1016/j.rser.2017.06.045

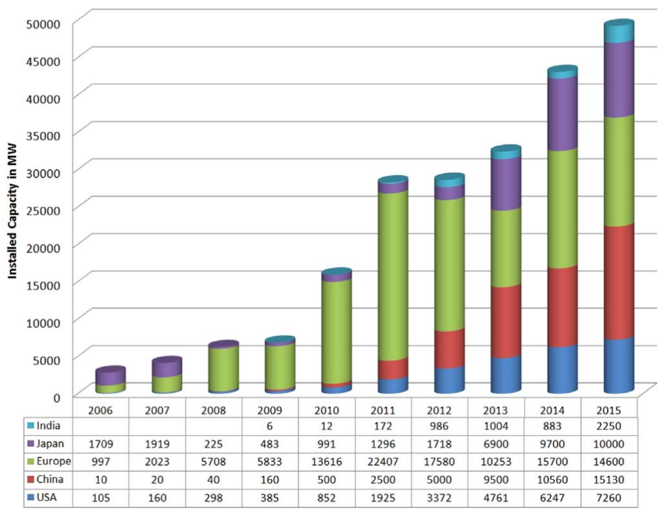

Fig. 1. Annual growth of PV installation by different countries [1].

AC module Power Conditioning System. A comparison between these PV PCs is given in Table 2.

This paper mainly focuses on grid connected PV system and its architecture. The generic block diagram of grid connected PV system is shown in Fig. 2. In order to connect the PV inverter to the grid certain standards must be maintained, otherwise the utilities connected to the grid will be malfunctioned. Section 2 describes different important standard which should be maintained while installing PV system and during operation. For the purpose of extracting maximum power from the PV modules different type of MPPT algorithm like Perturb & Observe (P & O), Incremental Conductance (IC), Fractional Open Circuit Voltage (FOCV) etc have been proposed. Section 3 describes different MPPT algorithm along with their advantages over the other.

PV inverter is the core part of PV based DGs. The function of PV inverter is to convert the DC into AC. Beside this the inverter is responsible for controlling power supplied to grid, DC link voltage control, grid synchronization etc [3]. Section 4 discusses about some basic as well as advanced inverter topologies used for grid connected PV system. Electrical grid are effected by many disturbance like disturbance and resonance due to flow of harmonic current through the line, fault due to lightning strikes, and gross error in the operation of electrical equipment [4]. Some of the grid requirements are: (1) Operation with certain power factor that are close to unity, (2) Limited harmonic content of injected current, (3) Continuous operation under voltage distortion, etc. So it is important to monitor the requirements of grid and synchronize the variable according to the requirement of grid [5].

Section 5 explains different relevant methods for grid synchronization techniques used in PV system. Section 6 discusses controller structure for grid connected PV system. To get the desired output from the inverter with low harmonics content, the inverter needs to switched by using PWM technique. Section 7 presents different types PWM topologies used in literature. The output current of inverter contains harmonics but according to IEEE 519 maximum allowable harmonics in current is 5%. So filters are introduced at the output of inverter to suppress that harmonics [6]. Section 8 focuses on some advanced version of filters used in grid connected PV system. Islanding is a critical safety issue which occurs when grid is

Table 1
List of important Standards for grid connected PV system.

Standards	Year	Title	Ref.
Grid connection			
IEEE 1547	2003	Standard for Interconnecting Distributed Resources with Electric Power Systems	[128]
DIN EN 50530	2011	Overall efficiency of grid connected photovoltaic inverters	[129]
IEEE 2030	2011	Draft guide for smart grid interpretability of energy technology and information technology operation with the electric power system, and end-user applications and loads	[130]
IEC 62446	2009	Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection	[131]
PV-power converter			
IEC 61727	2002	Photovoltaic (PV) systems - Characteristics of the utility interface	[9]
DIN EN 61683	2000–08	Photovoltaic systems - Power conditioners - Procedure for measuring efficiency (IEC 61683:1999)	[132]
IEEE 921, UL1741	2010	Standards for inverters, converters and controller for use in independent power system	[133]
Design & Testing Procedure verification			
CEI 62124	2004	Photovoltaic (PV) standalone systems - Design verification	[134]
DIN EN 62108 (VDE 0126–33)	2008–07	Concentrator photovoltaic (CPV) modules and assemblies Design qualification and type approval (IEC 62108:2007)	[135]
IEEE 1547.1	2005	Standard for conformance test procedures for equipment interconnecting distributed resources with electric power system	[136]
Measurement and Analysis			
IEEE 929	2000	Recommended practice for utility interface of photovoltaic system	[137]
IEC 61000–4–15	2010	Electromagnetic compatibility testing end measurement technique	[138]
IEC 60904–8	2014	Photovoltaic devices - Part 8: Measurement of spectral responsively of a photovoltaic (PV) device	[139]
IEC 61829	2015	Photovoltaic (PV) array On-site measurement of current voltage characteristics	[140]
IEC 61724	1998	Photovoltaic system performance monitoring Guidelines for measurement, data exchange and analysis	[141]
IEEE 512	1999	IEEE recommended practices and requirements for harmonic control in electrical power systems	[142]
EN 50160	1999	Public distribution voltage quality	[143]
Islanding			
IEC 62116	2008	Utility-interconnected photovoltaic inverters - Test procedure of islanding prevention measures.	[144]
DIN EN 62116 (VDE 0126–2):	2012–01	Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters (IEC 62116:2008, modified)	[145]
IEC 60364–7–712	2002	Electrical installations of buildings - Part 7–712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems	[146]
Safety			
VDE 0126–1–1	2006	Automatic disconnection device between a generator and the public low-voltage grid	[14]
IEC 60269–6	2014	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems	[147]
IEC 62109–1	2010	Safety of power converters for use in photovoltaic power systems - Part 1: General requirements	[148]
DIN EN 61730–2 (VDE 0126–30–2)	2007–10	Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing (IEC 61730–2:2004, modified)	[149]