Renewable and Sustainable Energy Reviews 34 (2014) 628–641

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Review of grid integration schemes for renewable power generation system

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ARTICLE INFO

Article history:
Received 9 November 2013
Received in revised form
10 February 2014
Accepted 12 March 2014
Available online 9 April 2014

Keywords:
Boost converter
Fuel cell
Fuzzy controller
Photovoltaic cell
Voltage source inverter

ABSTRACT

Multi-input converters, used to integrate different renewable energy sources, accommodate a range of sources and pools to their advantage such that the energy source is diversified to enhance utilization and reliability of the renewable source. The literature reports the development of several front-end DC–DC converters that could interface the sources. The topologies were classified based on the energy conversion stages, namely, DC–DC boost converter and voltage source inverter, and the kinds of controllers that control the circuit to ensure stabilization of load and input voltage, maintain component tolerance and system ageing. This is a comprehensive study of mapping the progress of diverse inverter topologies from the recent literature. Advantages, disadvantages, and limitations are given in this critical literature survey, along with the basic operating principles of several topologies.

Contents

Abbreviations: DCM, discontinuous conduction mode; FLC, fuzzy logic controller; HM, hysteresis modulation; IEA, International Energy Agency; MV, manipulated variable; MPPT, maximum power point tracking; PV, photovoltaic; PCS, power conditioning system; PID, proportional integral derivative; PWM, pulse width modulation; SPWM, sinusoidal pulse width modulation; SMC, sliding mode control; SVM, space vector modulation; VSCS, variable structure control system theory; ZCS, zero current switching; ZVS, zero voltage switching

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http://dx.doi.org/10.1016/j.rser.2014.03.034
1364-0321/

1. Introduction

Renewable energy capacity and the technology to harvest it has grown rapidly over the past decade. Driven by the economic development and associated increasing demand for energy, countries have been looking for ways to utilize the natural resources available to meet the demands. Greenhouse emissions is a crucial threat to the sustainability of the environment driving the governments and policies to arrive at solutions that could produce clean energy and at a reduced cost.

European Union has come forward to reduce the greenhouse gas emission 40% below 1990 levels by 2030. The efforts of other countries also hover to somewhat similar levels: the United States – 25–31%; Japan – 38–48%; Canada – 26–41%; and Russia – 14–27% [1]. China and India have made a voluntary greenhouse emission of 40–45% and 20–25% by 2020 [2,3].

Several options are available to reduce greenhouse emissions. Some can be enumerated as end use efficiency improvement [4,5], fuel switches, reduction of losses during transmission and distribution, and efficiency improvement of existing power plants and new power plants [6].

In India, the energy system is largely based on coal, which means that the expected emissions could surge relatively fast in the future [7]. Nevertheless, India has put enormous effort to improve the efficiency of the electricity production sector with the inclusion of a shift from coal to other fuels, such as renewable energy [8,9].

The renewable energy sources, such as wind, solar, wave energy, hydropower, tidal power, biofuels, and ocean thermal energy conversion, are being considered as efficient alternatives for the fossil fuels. Although many types of alternative or renewable resources are available, this study has limited its focus to photovoltaic (PV) and fuel cells and to propose hybrid alternative energy systems.

The National Solar Mission of India has taken solar power seriously and has been the driving force to make it a chief contributor of future energy mix. The critical mission has substantially supported both the centralized and decentralized power generation, in addition to providing power to rural India for health, education, and employment. At present, the solar power is expensive, i.e., at least three to four times that of coal based power. However, due to the increasing manufacturing capacity, along with support from government, scale deployment, research and development, the cost of the solar power production could reduce to grid parity in the near future. It is one of the crucial technology options that India has to meet the long-term energy security. By 2020, solar power capacity is anticipated to increase to 20,000 MW. India is blessed with good solar radiation in most parts; deploying solar technology even on 1% of the land can generate over 500,000 MW of power [2].

Having understood the necessity of generation of solar power and the capacity available with India, in this study, we have surveyed the literature extensively to find the methods that would bring energy efficiency methods, such as DC–DC boost converters, voltage-source inverter, controllers used for DC–DC converter and controllers used for voltage-source inverters. The review attempts to understand the existing methods available, the deficiency in the methods and the improvement required for these to make it commercially viable.

In Section 2 the DC–DC boost converter categories like DC–DC converter based on the multi-winding transformer, soft switching boost converter and multi-input converters were reviewed. In Section 3 the voltage-source inverter types like bi-directional full-bridge inverter, multilevel inverter and matrix inverter were reviewed. In Section 4 the controllers used for DC–DC converter are depicted in-depth with the advantages of different methods implemented and In Section 5 the controllers used for voltage-source inverter are described in-depth with the merits of different methods adopted. In Section 6 the proposed grid integration scheme for hybrid power generation has been described and Section 7 concludes the work.

2. DC–DC boost converter topologies for hybrid power generation system

Photovoltaic (PV) power generation system has attracted the interest of governments, industry and researchers alike due to its zero greenhouse gas emission. The emissions that are produced while manufacturing its components are the only emissions that are recorded.

Photovoltaic (PV) system consisting of solar cells converts sunlight into electricity through the photoelectric effect. They are being used regularly to supply electricity to individual and grid connected systems [10–12]. The solar panels are formed through connecting the solar cells in series and parallel to produce the required output voltage (Fig. 1). Typically, a PV cell yields less than 2 W at around 0.5 V DC. In order to increase the current output, surface area of each cell is increased or they are connected in parallel. Photovoltaic systems are chiefly used to generate power directly from the solar panels and consumed immediately and is also used to store the generated energy and utilize it later when required.

PV systems can be installed on rooftops and in deserts too. They are suitable for remote areas, where no electricity network is possible. It powers remote satellites, residences, water pumps, highway signs, navigation buoys, communication stations [13,14].

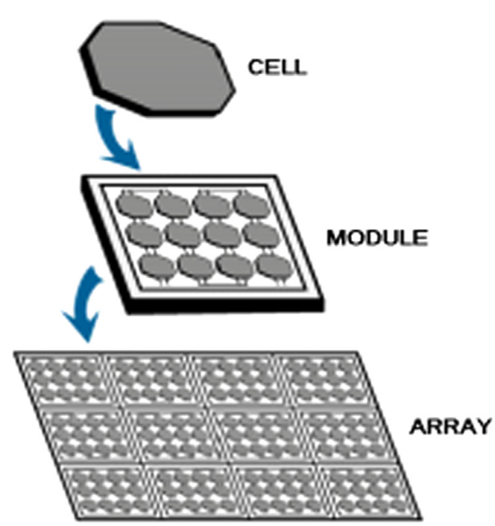

Fig. 1. Photovoltaic system.