

Grid interfaced solar photovoltaic system using ZA-LMS based control algorithm

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ARTICLE INFO

Article history:

Received 18 September 2017

Received in revised form 7 February 2018

Accepted 1 March 2018

Keywords:

Renewable energy sources

Solar photovoltaic

ZA-LMS

Power quality

ABSTRACT

Renewable energy sources such as solar photovoltaic can meet increasing energy demand in countries where there is sufficient availability of sun light. Intermittent nature of this kind of renewable energy sources demands a control which can handle fast dynamics of the system. This paper presents a grid coupled solar photovoltaic (SPV) system which includes solar photovoltaic array, incremental conductance based MPPT and boost converter. Grid integration of SPV array is performed using three phase voltage source converter (VSC) controlled with a fast and robust control algorithm. A Zero Attracting Least Mean Square (ZA-LMS) based controller is proposed to generate reference grid currents. These currents are compared along with sensed grid currents to generate switching pulses for three phase VSC. The proposed system is used to feed real power demand of load along with power quality refinement features such as suppression of harmonics, maintaining grid current at unity power factor and balancing of loads. Performance of the ZA-LMS controller is compared with conventional controllers such as normalized least mean square (NLMS) and dq0 frame theory. These controllers are compared for various characteristics concerning weight convergence, mathematical complexity, computational burden on real time controller and harmonic compensation. Proposed controller is implemented using dSPACE 1104 and tested on developed laboratory prototype of grid connected VSC working as shunt active power filter. Performance of the controller is observed and verified for steady state and dynamic load conditions.

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1. Introduction

Nowadays power sector industries are concerned about utilizing renewable energy sources (RESs), because energy demand is increasing and the fossil fuels are depleting. In near future, emphasis will be on the use of clean and green energy by the use of RESs. Sources like Photovoltaic, wind, biomass, biofuels etc. in the form of DG (Distributed Generation) are gaining increased importance [1,2]. Among these, RESs based photovoltaic is an emerging energy source especially in the tropical countries where there is sufficient availability of sun light. The characteristics of SPV system are exponential in nature and depend upon the weather conditions.

The SPV is required to track the maximum power point to improve the efficiency of SPV system [3]. The aim of maximum power point tracking (MPPT) is to achieve SPV array operation always at a specified value of output voltage and current. Therefore, MPPT is required to adjust the SPV array output voltage and current to appropriate values to provide maximum power to the grid. The tracking of maximum power point (MPP) requires implementation of suitable MPPT algorithm along with a DC–DC boost converter [4]. A number of MPPT algorithms [5–9] are proposed in the literature for maximum power point tracking (MPPT) such as incremental conductance (Inc), perturb and observe (P&O), fractional open circuit voltage, fractional short circuit current, fuzzy logic, ripple correlation control etc. Small units of solar photovoltaic can be installed locally to augment conventional generation. However, due to intermittent nature of RESs and different voltage and power level, these sources cannot be integrated to the grid directly [10,11]. Power electronic converters are required to interface these to the utility grid. These electronic converters are mainly voltage

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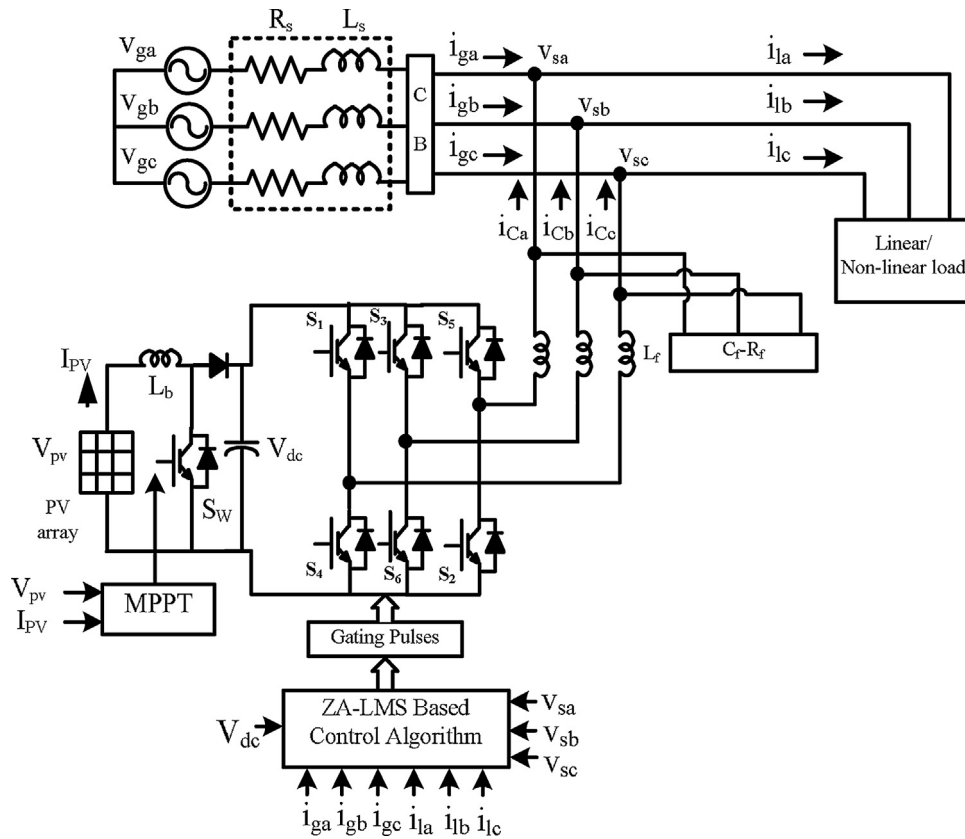


Fig. 1. Schematic diagram of grid integrated SPV system.

source converters (VSC) which can be controlled for real power transfer from SPV array. Additionally, these can be controlled to improve power quality features such as maintaining grid current at unity power factor, suppression of harmonics and load balancing [12].

Numerous standards (by IEEE and IEC) are in existence to stipulate the limit of total harmonic distortions (THDs) of the grid voltages and currents [13]. The behavior of VSC used in SPV system mainly depends upon type of control algorithm used. A grid coupled solar photovoltaic power generating system is developed using current synchronous detection controller along with power quality refinement features in paper [14]. Single stage three phase SPV system using Improved Linear Sinusoidal Tracer (ILST) based control is used to feed electric power evacuated from solar PV into the grid along with enhanced power quality features at distribution level [15]. Several other control algorithms such as power balance theory [16], leaky least mean square forth (LLMF) [17], adaptive neuro fuzzy inference system-least mean square (ANFIS-LMS) [18], Comprehensive synchronous reference frame (dq0) [19], recursive least square [20] sliding mode control [21] have been reported in the literature and some of these have been realized for the control of SPV.

This paper presents the design and development of solar photovoltaic (SPV) feeding linear as well as nonlinear loads. The SPV source is interconnected at the DC side of the voltage source converter. Modeling of photovoltaic (PV) array with boost converter and incremental conductance based maximum power point tracking (MPPT) is performed. The control of VSC is developed using Zero Attracting Least Mean Square (ZA-LMS) algorithm. Steady state performance is improved with ZA-LMS algorithm vis. a vis. standard LMS technique especially in highly distorted environment because this algorithm incorporates cost function L_1 differently. This gives a modified LMS update with zero attractor, hence the name the Zero-

Attracting LMS (ZA-LMS). The main advantage of ZA-LMS is that its computational complexity is comparatively less than conventional LMS, NLMS adaptive filters [22–25].

A complete evacuation of SPV array is expected during day time and in the night time VSC can be used as shunt active power filter. Real power demand of the load along with power quality compensation features such as maintaining grid at unity power factor, harmonics suppression, and retaining grid stability in case of unbalanced load are performed with the proposed ZA-LMS based control algorithm. Performance of the proposed control algorithm is compared with normalized least mean square (NLMS) [25], and dq0 frame based controller to demonstrate fast and accurate operation of the SPV system.

2. System configuration

Fig. 1 illustrates the diagram of the system whose system parameters are indicated in Appendix A. Linear/nonlinear load is connected with small line impedance (connected in series as feeder impedance, R_s - L_s) to the utility grid of 415 V, 50 Hz. Voltage source converter (VSC) is coupled at the PCC with series inductor at the AC side of VSC. Solar photovoltaic (SPV) array representing renewable energy source (RES) is interfaced to the DC side of the VSC. The SPV system actually comprises SPV array, boost converter and power semiconductor devices (such as IGBTs) based three leg VSC. Each leg of VSC incorporates two IGBT switches with diode connected in reverse. The SPV converter is connected to the grid through an L_f - C_f filter where R_f is introduced to provide damping. Moreover, the values of these parameters are chosen to avoid resonance. Value of R_f is selected to be small ($<1 \Omega$), so that power losses can be minimized. This system is developed using Matlab/Simulink and Sim Power System (SPS) tool box.

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