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Investigations of an improved PV system topology using multilevel boost converter and line commutated inverter with solutions to grid issues

Krithiga S., Ammasai Gounden N. *

Department of Electrical and Electronics Engineering, National Institute of Technology, Tiruchirappalli, Tamil Nadu, India

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A B S T R A C T

A photovoltaic (PV) system using multilevel boost converter (MBC) and line commutated inverter (LCI), operating in both grid-connected mode and stand-alone mode has been analysed. This proposed system extracts and feeds the maximum power to a single phase utility grid and stand-alone system simultaneously. The duty ratio of the MBC is estimated from the theoretical analysis of the proposed system, for extracting maximum power from PV array. The proposed system tracks the maximum power with the determined duty ratio which remains the same for all irradiations, for a fixed firing angle of LCI. The flexibility of supplying required proportion of extracted power to grid and stand-alone load and the elimination of a separate MPPT controller are the major benefits of the proposed system under normal grid conditions. In addition to it, the grid issues like voltage swell, blackout and brownout are considered and necessary remedial measures have been taken in the proposed system. Based on the issues, either the firing angle of LCI is adjusted or LCI is disconnected and replaced by a battery. Simulation studies have been carried out and the dynamic response of the system is observed. A laboratory prototype is built and experimental investigations have also been carried out. The theoretical analysis, simulation and experimental results are found to be closely associating with each other proving the efficacy of the proposed configuration.

1. Introduction

Renewable energy comes from sources that are essentially inexhaustible such as the sun, the wind and the heat of the Earth, or from replaceable fuels such as plants. Prior to the industrial revolution, these sources were virtually the only forms of energy used by humans. During the past 150 years, we have become increasingly dependent on fossil fuels – oil, coal and natural gas. As fossil fuels are limited resources, we started using renewable energy for the production of electricity. Geothermal, solar, wind, hydro, biomass and wave are some examples of renewable energies. One of the widely used renewable energy generation systems – photovoltaic system, directly converts sunlight into electricity which supplies the power to the standalone load or to the utility grid with the help of power converters.

Stand-alone PV systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain dc or ac electrical loads. The power converter is used between the array and load to utilize the

* Corresponding author. Tel.: +91 4312503253.
E-mail address: ammas@nitt.edu (N. Ammasai Gounden).

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available maximum power output of the array. Mostly, dc-dc converter and dc-ac converter are used for interfacing dc and ac load respectively. These systems use MPPT controllers for extracting the maximum power [1]. The grid-connected PV systems use a full-bridge inverter towards the grid, either self-commutated or line commutated along with the controllers for feeding the maximum power to the grid [2–5]. The self-commutated inverter requires additional circuits for grid synchronization apart from the PWM generator whereas the line commutated inverters does not require these extra circuits.

The photovoltaic system in [6] is capable of supplying power to both the standalone load and utility grid simultaneously using a multi output boost converter and line commutated inverter (LCI). From detailed analysis, it is to be noted that the system does not require a separate MPPT controller and works efficiently with a single duty ratio for proposed configuration at fixed firing angle of LCI. Also there is no need for separate synchronization circuits as the system is tied to the grid through LCI.

In order to make the system more reliable, the power quality issues in the utility grid such as blackout, brownout, and voltage swell should be taken care of [7–12]. Hence, this paper proposes an updation to the above system considering these issues. Further, a battery is connected at the output of MBC as a storage device at times of grid failure.

2. Description of the proposed system

Fig. 1 shows the block diagram of the proposed scheme. This scheme consists of a PV array, a multi output boost converter, a line-commutated thyristor inverter, a battery, a dc motor and controllers for generating gate pulse to IGBT, and firing pulses to thyristors. The system also has three relays for changeover of connection at the output terminals of MBC and a controller for triggering the relays. Many loads can be simultaneously supplied as the dc-dc multilevel converter is used as multi output boost converter which is an advantage of the proposed configuration [13]. The capacitance C_i is connected between the PV array and MBC to obtain a steady direct voltage from the PV panels. Across four capacitors (Fig. 2), the total output voltage of the converter is divided into equal voltages. Through a relay (R1) and a dc link inductance L_{dc}, the output across C_1 is connected to a single phase LCI. Battery is also connected to L_{dc} through another relay (R2). To this battery, a DC load is also connected through a third relay (R3). Between the points A and B (across C_3 and C_4) of MBC, a separately excited DC motor is connected as shown in Fig. 2. The major portion of maximum power extracted from PV array is fed to the grid at fixed firing angle of LCI and remaining power is fed to the DC motor. The duty cycle is found to be constant for fixed firing

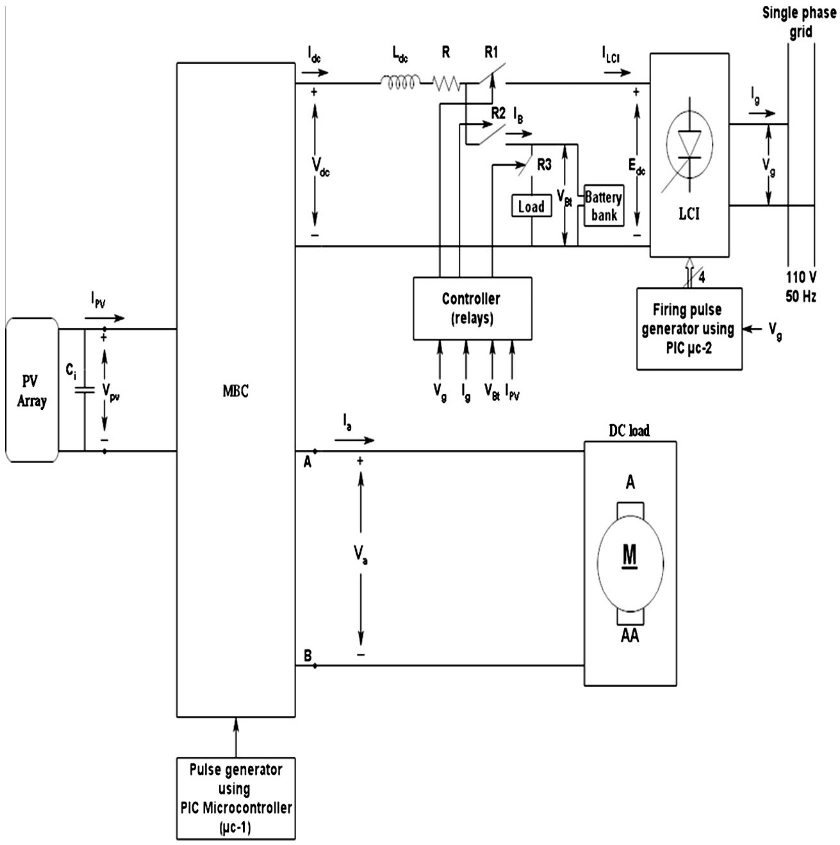

Fig. 1. Block diagram of the proposed system.