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RESEARCH ARTICLE

Hybrid Cascaded Modular Multi Level Inverter for a PV Powered Water Pumping System

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ABSTRACT

In order to enhance the quality of voltage or current waveform and to decrease the harmonics content, the level of voltage source inverter is increased to make stair case like waveform and the increased level voltage source inverter is known as multilevel inverter (MLI). A Hybrid Cascaded Modular (HCM) multilevel inverter topology reduces the number of power switches, losses, installation area, voltage stress and converter cost in comparison with the conventional MLIs such as Diode clamped MLI, Flying Capacitor MLI and Cascaded H-bridge MLI. Hybrid cascaded modular MLI uses Nearest Level Control (NLC) modulation technique, which is a low switching frequency modulation technique to generate the gating pulses for the power semiconductor switches. So this HCM MLI with NLC technique becomes an efficient photovoltaic (PV) inverter. It takes the DC power from the PV array through DC-DC boost converter and gives to the induction motor based water pump. In order to maximize the power output and increase the efficiency of a PV module under varying operating conditions, MPPT control is used. MPPT block changes the duty ratio continuously under varying irradiance to keep the output voltage constant. The water pump takes the water form reservoir and stores it into the tank with a constant flow rate and under constant pressure during sunny day and the stored water can be used for domestic applications or any irrigation purposes when the solar irradiance is not available. This type of PV powered pumping system is often suitable for rural areas where the accessibility of grid is not available. It employs Simulink to model a hybrid cascaded modular MLI, DC-DC boost converter MATLAB embedded code to implement perturb and observe (P&O) MPPT algorithm.

Keywords : MPPT, HCM, NLC,TTL, NLC

INTRODUCTION

The sun is a non-polluting resource responsible for the sustained life on earth and can give us efficient renewable energy. The fact that solar energy is cleaner than any other energy produced from fossil fuels makes this resource of sustainable energy very important for the planet future. Generally around 92% of rural population [18] have no access to electricity due to the prohibitive cost of extending the existing electrical network therefore farmers face problems during their cultivation work such as water pumping etc. So the use of renewable energy like photovoltaic (PV) is one the solution for this problem. Therefore PV panel is interfaced with induction motor drive for pumping application via conventional MLI such as diode clamped MLI, flying capacitor MLI and cascade H-bridge MLI etc. But the efficiency of such PV inverter is low and the cost of the PV inverter is more because conventional MLI requires more number of switching devices. In this thesis hybrid cascaded modular (HCM) MLI is taken as PV inverter. To improve the efficiency of PV module we have to use maximum power point tracker (MPPT) [10]. The comparison between PV powered water pumping system Vs. diesel (or Gas) powered system [13] is given in the table. Configuration of a solar PV powered pumping system is shown in the figure 1. All these sections such as PV array, MPPT algorithm, DC-DC boost converter, hybrid cascaded modular (HCM) MLI and Water Pumping system are modelled using MATLAB Simulink.

Proposed System for PV Water Pumping

This thesis proposes a new PV inverter i.e. hybrid cascaded modular (HCM) multi-level inverter (MLI) which is used as an interfacing converter in PV power based pumping system. Figure 2.1 presents the proposed PV system. This includes a PV panel, a boost converter, a three phase HCM MLI nearest level control (NLC) controlled inverter, and a three phase induction motor. An MPPT block is also incorporated into the system so that the input voltage at the converter side can be kept constant.

This proposed system can be categorised into three sub system namely photovoltaic (PV) generator system, inverter unit and the load unit. In photovoltaic (PV) generator system consists of PV array, maximum power point tracker (MPPT) and DC-DC boost converter. In inverter unit, hybrid cascaded modular (HCM) multilevel inverter is used. The nearest level control (NLC) modulation technique is used for generation of gate pulses for the switches of the HCM MLI. The load unit is the induction motor based water pumping system.

The conventional PV water pumping systems consists of a battery backup alongside the components mentioned in the previous section. By incorporating a battery into the system will reduce the lifetime and will also increase the initial cost as well as the yearly maintenance cost of the entire system. With an aim of reducing the overall cost of the system and to increase the lifetime, a new design has been proposed here. The design of this system is done from the load side, taking into account the quantity of water to be pumped and the head at which it has to be stored. So the proposed PV power based water pumping system is the system without batteries unit.

Multilevel Inverter

The term multilevel began with the three level converters. Subsequently, several multilevel converter topologies have been developed. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM).

There are basically three types of multilevel inverters such as

Diode clamped multilevel inverter (Neutral Point Clamped inverter)

- Diode clamped multilevel inverter (Neutral Point Clamped inverter)
- Flying Capacitor Multilevel Inverter (Capacitor Clamped Inverter)
- Cascaded H-bridge Multilevel Inverter

Apart from these three conventional MLI there is a popular and efficient MLI called hybrid cascaded modular (HCM) MLI. The advantages of the HCM MLI are given below 1. For a given voltage level it requires less number of switches than the conventional one, which in turn results in reduction of installation area and converter cost

Less switching losses because it uses nearest level control (NLC) technique in its modulation technique to provide the gate pulse to switches.

For example in case of a 9-level multilevel inverter, each conventional MLI such as diode clamped MLI, flying capacitor MLI and cascade H-bridge MLI requires 2*(9-1)=16 switches.

Whereas hybrid cascaded modular (HCM) MLI requires only 8 switches for 9-level. Therefore it can be an efficient photovoltaic (PV) inverter for various applications. And to increase overall efficiency of the system hybrid cascaded modular MLI will be incorporated with the photovoltaic (PV) panel to drive induction motor

Modulation Technique

Here we have used tThe nearest level control (NLC) modulation technique to control the output voltage of the hybrid cascaded modular (HCM) multilevel inverter (MLI).Mainly modulation technique can be classified into two types depending upon the switching frequency such as high frequency modulation and low frequency modulation

The Nearest level control (NLC) is low switching frequency control technique. This method is also called as round method. Usually this NLC method is used to provide gate pulse to switches of HCM MLI. This methods leads to reduction in switching losses. The output voltage can be found out by considering a reference sine wave in accordance with nearest voltage level (v). Given a voltage reference vref , the nearest output Voltage level (v) can be determined with

$$v = V * round\ \{ Vref/V_C \}$$

Where, v is the nearest voltage level V is the supply dc voltage The function returns the nearest integer of the input number (e.g., round (3.4) = 3, round (3.6) = 4) .This nearest integer multiplied by 'V' corresponds to the closed level to the reference that is generated by the inverter. Based upon the integer value one switching state is chosen at a time to provide corresponding desired voltage level at output. The reference waveform with the existing output voltage with level count 'L' as depicted in Figure 4.2. Its Implementation is illustrated in Figure 4.3.

$$Vref = m * \{(L-1)/2\} * V * sin(wt) = Vmsin(wt)$$

Where, m is modulation index

Vref is the reference voltage

Vc is the voltage across capacitor

Vm is the peak value of reference voltage

Simulation & Result

The simulation of 1 phase 9-level HCM MLI was done using MATLAB and SIMULINK. The output voltage waveform output voltage waveforms with reference waveform are shown in the figure **5** and figure 6 respectively.

CONCLUSION

In this thesis an efficient and simple PV powered water pumping system was proposed. Hybrid cascaded modular MLI was used as a PV inverter which has less number of switches than the conventional MLIs for a given voltage level. The PV array, MPPT algorithm block, DC-DC boost converter, 9 level HCM MLI and a single phase induction motor based centrifugal water pump were simulated using MATLAB Simulink environment

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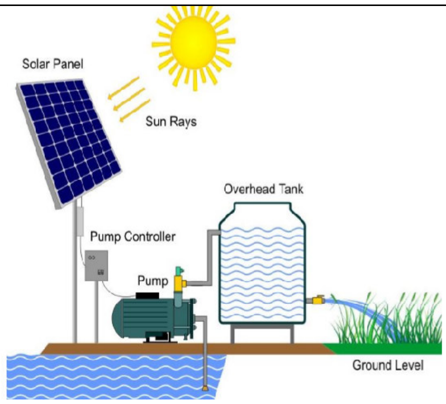


Figure 1 Configuration of a solar PV powered pumping system

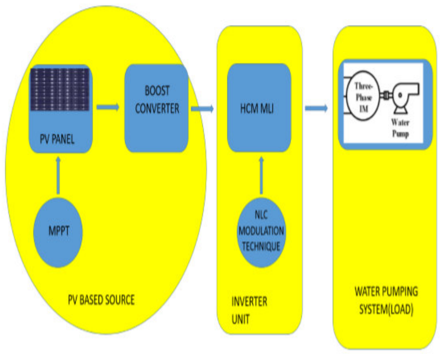
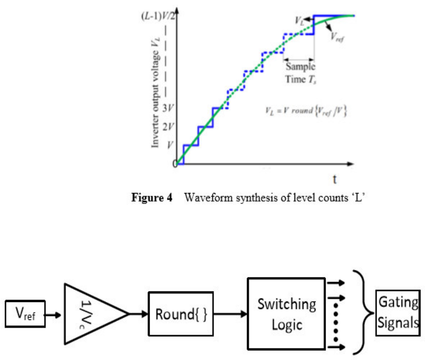


Figure 2 Proposed System for PV water pumping



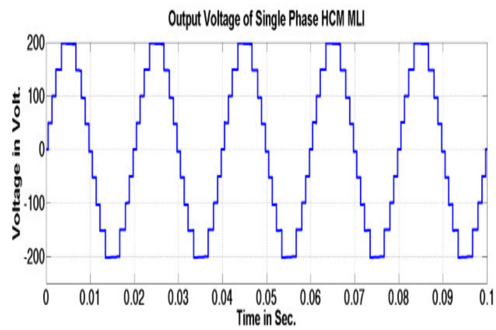


Figure 4 Waveform of Output voltage

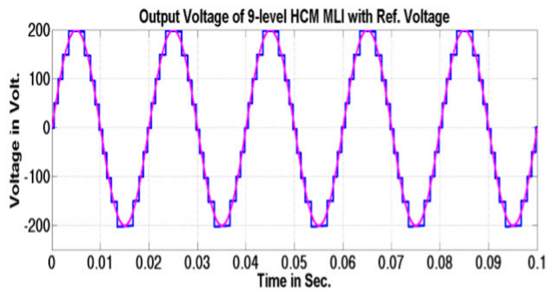


Figure 5 Waveform of output Voltage with Reference Waveform