A Netural-Diode Clamped Multilevel Inverter Fed Induction Motor Driven Water Pump Application

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Abstract- Photovoltaic (PV) array assisted water pumping systems are gaining more popularity in household and agriculture applications in absence of grid power. In this paper, the investigations on performance of a PV based multilevel voltage source inverter (VSI) powered Induction motor (IM) based water pumping system. The neutral point diode clamped (NPC) inverter with sinusoidal pulse-width modulation (SPWM) techniques is proposed to generate three phase AC voltage in the system. The direct conversion from DC to AC reduces the switch and increases the efficiency of the proposed system. The entire system of water pumping system and all components are designed in MATLAB/Simulink environment. The obtained results are found satisfactorily performance at different load conditions.

Keywords- Photovoltaic system; Multi-level inverter; Induction motor; Water pumping system.

I. INTRODUCTION

The demand of energy is necessary for the development of the any nation. The scarcity and storage capacity of fossil fuels e. g. coal, gas, oil etc. are limited. In recent years, attraction of human being is increasing towards the power generation based on renewable energy (RE) sources due to various advantageous features such as environmental friendly, small l sizes etc. In this context, it is forced to explore more Resources to meet the demand of power supply[1,2].PV is increasingly vital RE energy source due to fast development of power generation technology and advantages such as pollution free, low maintenance, no moving parts and grid decentralization. PV cell convert directly sunlight into electricity when semiconductor is illuminated by a photon, and the performance is measured in terms of its efficiency when converting sunlight into electricity [3].The multilevel inverter (MLI) is used to convert the output of PV cell into the AC. The advantages of multilevel inverters are to reduce harmonics on AC side, low dv/dt stress, high voltage application, low switching losses, and higher voltage capability. Some multilevel inverter topologies used for domestics and industrial applications such as neutral or diode clamped (NPC), flying or capacitor clamped (FC) and cascaded H-bridge (CHB) [4]. The NPC inverter is used to generate the voltage and the gate pulse is provided by SPWM techniques for insulated gate bipolar transistors (IGBT's).The inverter is supplied to the induction motor assisted water pumped system. The induction motor is used in the water pump application because of many advantages over DC motor as low cost, batter ruggedness, higher efficiency, reliable, etc. The water pumping without any storage device can also be a cost effective solution. Due to the low cost and maintenance. In this paper, the performance of an industrial pump driven by an induction motor is analyzed, which issupported by solar PV assisted MIL with phase disposition PWM (PS- PWM). The complete system is simulated in MATLAB/Simulink and performance of the system is assessed at partially and fullload.

SYSTEMDESCRIPTION:

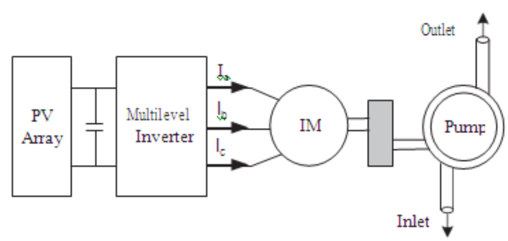


Fig.1: Block Diagram

PHOTOVOLTAIC SYSTEM AND INVERTER TOPOLOGY:

The PV array is used to generate the dc power and thenit is converted into the three phase ac with the help of multilevel inverter. The output of the inverter is fed into the induction motor driven water pumping system for remote areas.

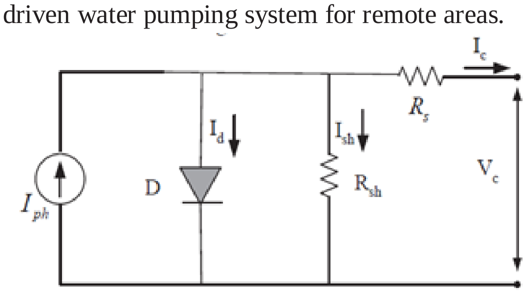


Fig.2: Equivalent Model of PV System

The output current and voltage of PV cell are expressed [11, 12] in (1), (2), and (3) respectively.

$$I_c = I_{ph} - I_d - I_{sh} \quad (1)$$

$$I_c = I_{ph} - I_0\left[\exp\left(\frac{e(V_c + R_s I_c)}{AkT_c}\right) - 1\right] - \left(\frac{V_c + R_s I_c}{R_{sh}}\right) \quad (2)$$

$$V_c = \frac{AkT_c}{e}\ln\left(\frac{I_{ph} + I_0 - I_c}{I_0}\right) - R_s I_c \quad (3)$$

The short circuit current and open circuit voltage of a PV cell can be expressed in (4) and (5) as,

$$I_{sc} = I_{ph} - I_0\left[\exp\left(\frac{qR_s I_{sc}}{AkT_c}\right) - 1\right] - \left(\frac{R_s I_{sc}}{R_{sh}}\right) \quad (4)$$

$$V_{oc} = \frac{AkT_c}{e}\ln\left(\frac{I_{ph} + I_0}{I_0}\right) \quad (5)$$

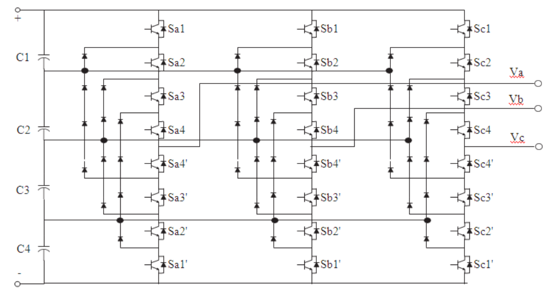
The cell temperature of a PV cell can be shown in (6) as

$$T_c = T_a + \frac{S_x}{800}(T_{noc} - 20) \quad (6)$$

Where,I_{ph}Photocurrent(Amp.),$I_d$diodecurrent(Amp.), I_o revers saturation current of diode (Amp.), I_{sc} short circuit current, V_{oc} open circuit voltage (Volt.) and T_{noc} normal operating cell temp. (approx. 42ºC).

MULTILEVEL INVERTERTOPOLOGY:

The most commonly used multilevel topology is the diode clamped inverter, in which the diode is used as the clamping device to clamp the dc bus voltage so as to achieve steps in the output voltage. The main concept of this inverter is to use diodes to limit the power devices voltage stress. The voltage over each capacitor and each switch is Vdc. An n level inverter needs (n-1) voltage sources, 2(n-1) switching devices and (n-1)(n-2) diodes. 5-level diode clamped multilevel inverter. A three -level diode clamped inverter consists of two pairs of switches and two diodes. Each switch pairs works in complimentary mode and the diodes used to provide access to mid-point voltage. In a three-level inverter each of the three phases of the inverter shares a common dc bus, which has been subdivided bytwo capacitors into three levels. The DC bus voltage is split into three voltage levels by using two series connections of DC capacitors,C1 and C2. The voltage stress across each switching device is limited to Vdc through the clamping diodes Dc1 and Dc2. It is assumed that the total dc link voltage is Vdc and mid point is regulated at half of the dc link voltage, the voltage across each capacitor is Vdc/2 (Vc1=Vc2=Vdc/2)



Advantages:

All of the phases share a common dc bus, which minimizes the capacitance requirements of the converter. For this reason, a back-to-back topology is not only possible but also practical for uses such as a high-voltage back-to-back inter-connection or an adjustable speed drive.

1. The capacitors can be pre-charged as a group.
2. Efficiency is high for fundamental frequency switching and when the number of levels is high enough, harmonic content will be low enough to avoid the need for filters.

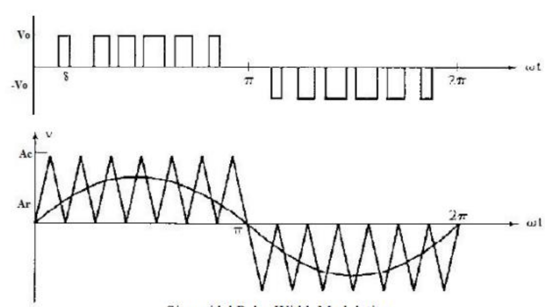
SINUSOIDAL PULSE WIDTH MODULATION:

In this modulation technique are multiple numbers of output pulse per half cycle and pulses are of different width. The width of each pulse is varying in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The gating signals are generated by comparing a sinusoidal reference with a high frequency triangular signal.

The rms ac output voltage,

$$V_o = V_s\sqrt{\frac{p\delta}{\pi}} \rightarrow V_s\sqrt{\sum_{m=1}^{2p}\frac{\delta_m}{\pi}}$$

3. Where p=number of pulses and δ= pulse width.



Sinusoidal Pulse Width Modulation

Features for comparing various PWM Techniques:

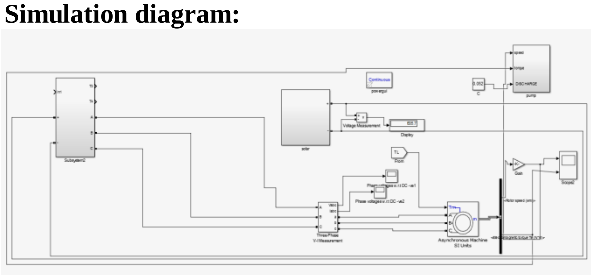
- Switching Losses

- Utilization of Dc power supply that is to deliver a higher output voltage with the same DC supply
- Linearity in voltage and current control
- Harmonics contents in the voltage and current.

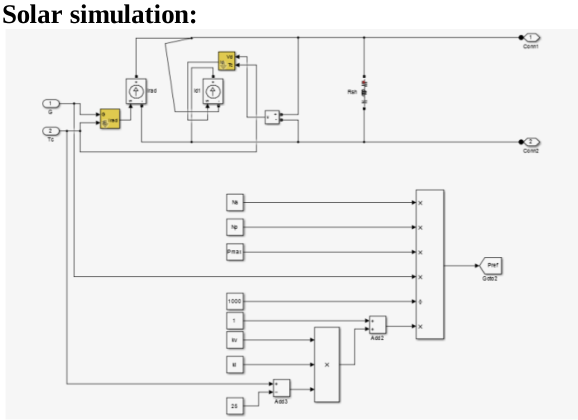
Sine Wave Generation The most common and popular technique for generating True sine Wave is Pulse Width Modulation (PWM). Sinusoidal Pulse Width Modulation is the best technique for this. This PWM technique involves generation of a digital waveform, for which the duty cycle can be modulated in such a way so that the average voltage waveform corresponds to a pure sine wave. The simplest way of producing the SPWM signal is through comparing a low power sine wave reference with a high frequency triangular wave. This SPWM signal can be used to control switches. Through an LC filter, the output of Full Wave Bridge Inverter with SPWM signal will generate a wave approximately equal to a sine wave. This technique produces a much more similar AC waveform than that of others. The primary harmonic is still present and there is relatively high amount of higher level harmonics in the signal.

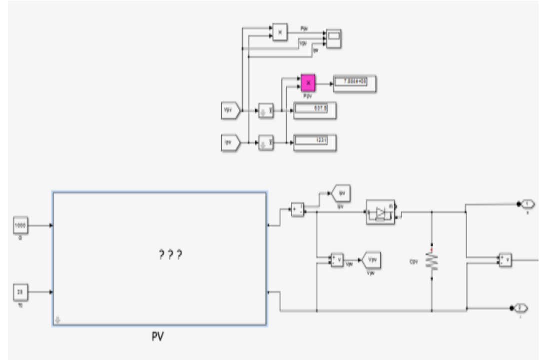
II. RESULTS AND DISCUSSION

Simulation diagram:

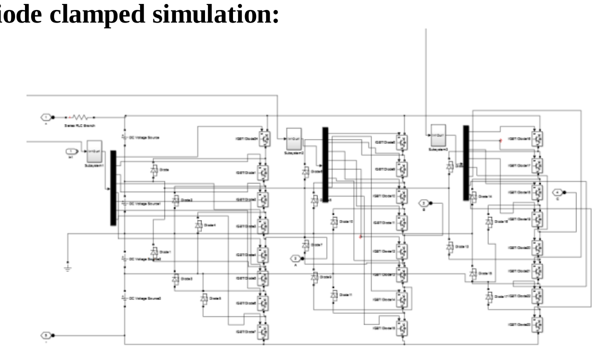


Solar simulation:

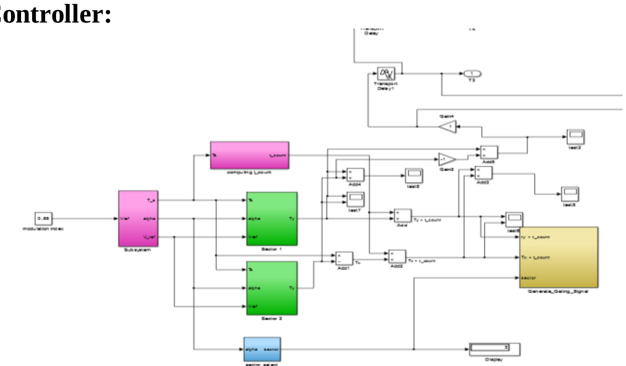




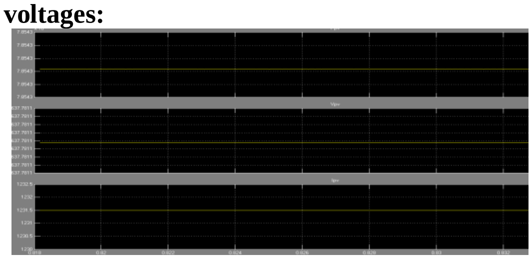
Diode clamped simulation:



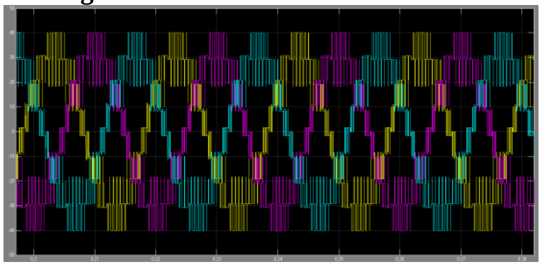
Controller:

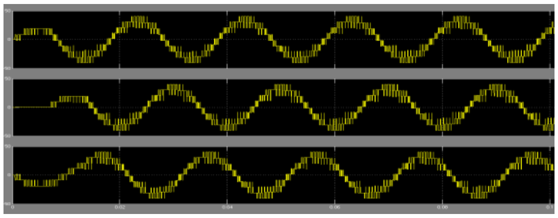


Input voltages:

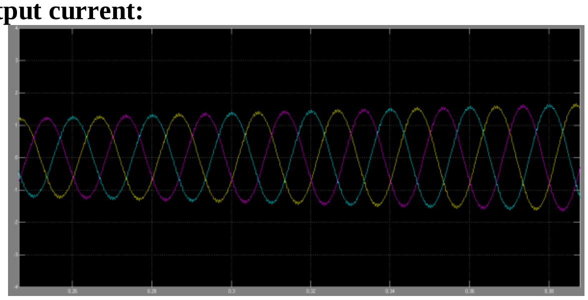


Output voltages:

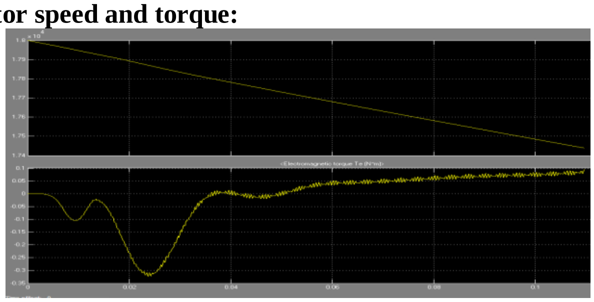




Output current:



Rotor speed and torque:



III. CONCLUSION

The PV array based multilevel inverter performance has been analysis for motor driven pump system. The PD-PWM technique is used for controlling the gate pulse for MLI. The result has been carried at no load, half load and full load conditions and the performance analysis has been done. When the load increased from initial condition to full load condition then IM takes small time to reach in steady state. The THD of the stator current of IM is obtained as 5.78 %. Overall system performance is found satisfactory for industrial pumpapplication.

IV. REFERENCES

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