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MLI Application in Running Induction Motor using PV Panel

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Abstract—*As the energy demand is increasing and fossil fuel are coming to an end more emphasis is given to the use of renewable energy which leads us to solar energy. This paper represents use of solar energy to run induction motor (IM) with the help of cascaded H-Bridge MLI, it also discusses the main topologies of multilevel inverter namely H Bridge, NCP (neutral point clamped) and flying capacitor. The H-bridge inverter is mainly focused as it eliminates the excessively large number of (i) transformers required by conventional multilevel inverters (ii) one of the popular topology used in high power medium voltage drive. The detailed study is carried out using MATLAB software.*

Keywords*: Multilevel inverter, THD, NCP, cascaded H-bridge.*

1. INTRODUCTION

Over past decade, there is an enormous increase in energy demand so the exploitation of natural resource took a pase which has drastically reduced the deposit of fossil fuel and also environmental pollution is alarmingly high .This problem lead the search of an alternate clean and abundant energy resource and solar energy gave us hope .To harness solar energy a photovoltaic array is employed , another technological revolution gave us MLI which is best suited for medium voltage high power applications. Multilevel inverter(MLI) come as revolution in field of inverter technology[1,2],as their application to medium and high level voltage is remarkable(2-13kV) which includes ac drives[3]traction system, power distribution[4],PV application[5],electric motor vehicle[6]etc. Main advantages of MLI: (a) reduction of input voltage stress on component thereby reducing voltage rating of device (b) decrease in conduction time, (c) lower device switching frequency for same number of output voltage level ultimately reducing the THD. Apart of these advantages its disadvantage are (a) complex circuit, (b) problem of voltage balance, (c) high cost etc.

2. DISADVANTAGES OF CLASSSICAL INVERTERS

(a)VOLTAGE SHARING-difference in leakage current and switching frequency leads to unequal distribution of voltage among IGBTs which can puncture them.

(b)HIGH THD-as output has only two levels its THD content is very high.

(C)LOW ORDER HARMONICS- to filter these harmonics (3, 5, and 7) LC filter required is very difficult to design and bulky in nature too for high power.

3. MAJOR TOPOLOGIES OF MLI

3.1 Neutral Point Clamped(NPC)

It is proposed by A.NABAE, I.TAKAHASHI and H.AKAGI [7, 8].The incoming dc voltage is common for all phases and is splitted into (m-1) equal level there by providing neutral points. The given 3 level NPC configuration does not include capacitor because it has a problem of capacitor voltage balancing which require a control strategy .In practical scenarios for higher voltage rating the diode should bear that voltage so large a number of diode is required therefore NPC is used to three level usually for practical purpose.

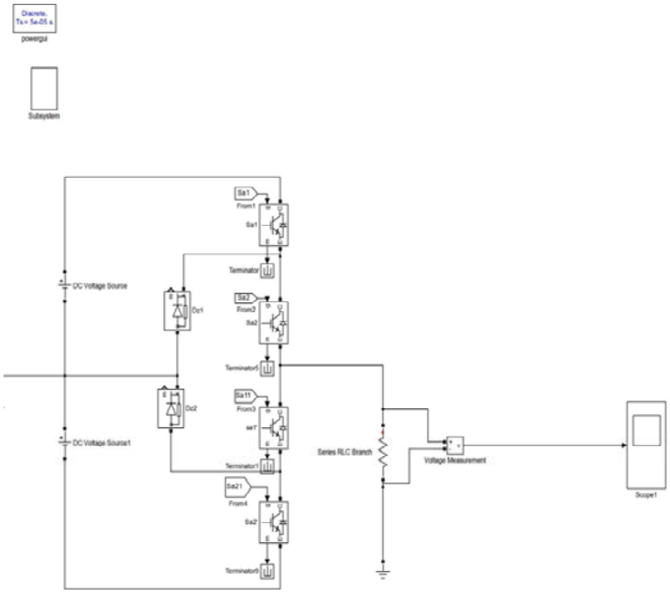


Fig. 1: Phase A of 3-Level NPC.

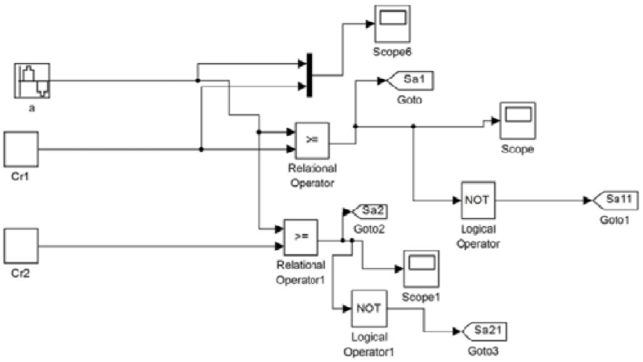


Fig. 2: Switching sub system of 3-Level NPC.

Fig. 3: Voltage wave form of 3-Level NPC.

3.2 Flying Capacitor

Introduced by MEYNAR AND FOCH [9], Its working is identical to NPC only contrast is it uses capacitor in place of clamping diodes. The only ease of this topology is its less complexity and can be easily used for higher voltage rating, although bulky nature of capacitor, problem of voltage balance and thus complex control strategy make its use less common in industrial applications.

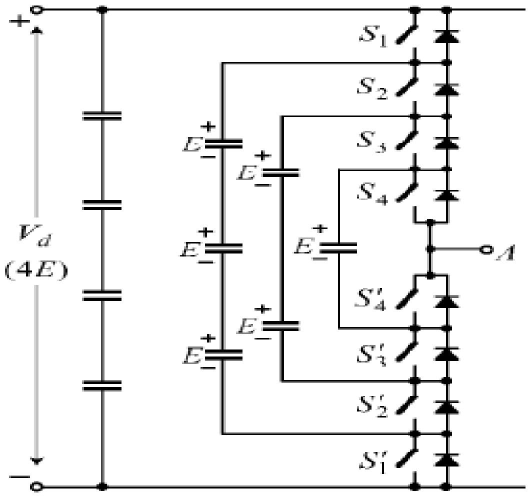


Fig. 4: 5-level FLYING CAPACITOR inverter for phase-A.

3.3 Cascaded H Bridge

It is composed of two inverter legs with two IGBT devices in each leg [10]. Each level can be obtained by connecting dc source to ac output by proper combination of switches (i) number of output level m=2s+1 where s=number of dc source.

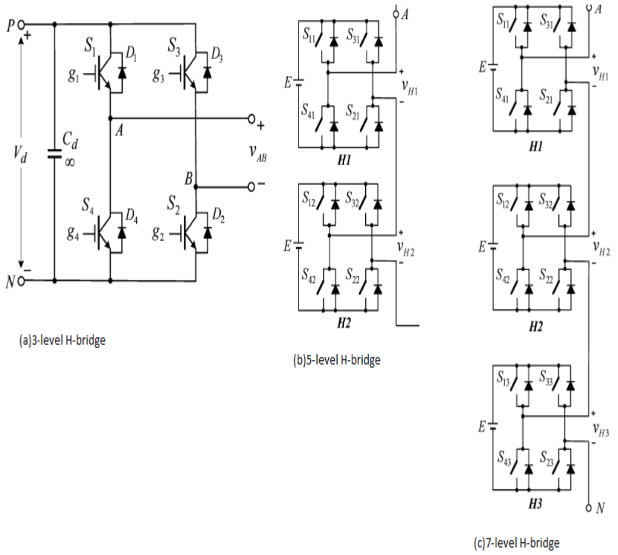


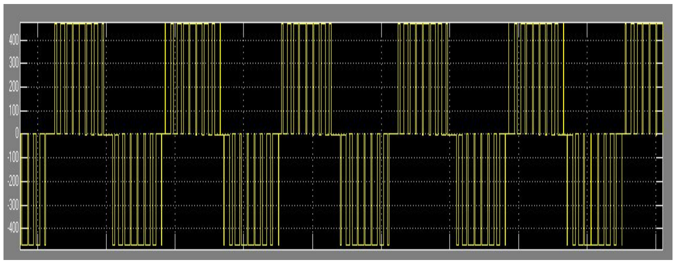
Fig. 5: 3, 5, 7-Level H-bridge inverter

The inverter phase voltage is given as

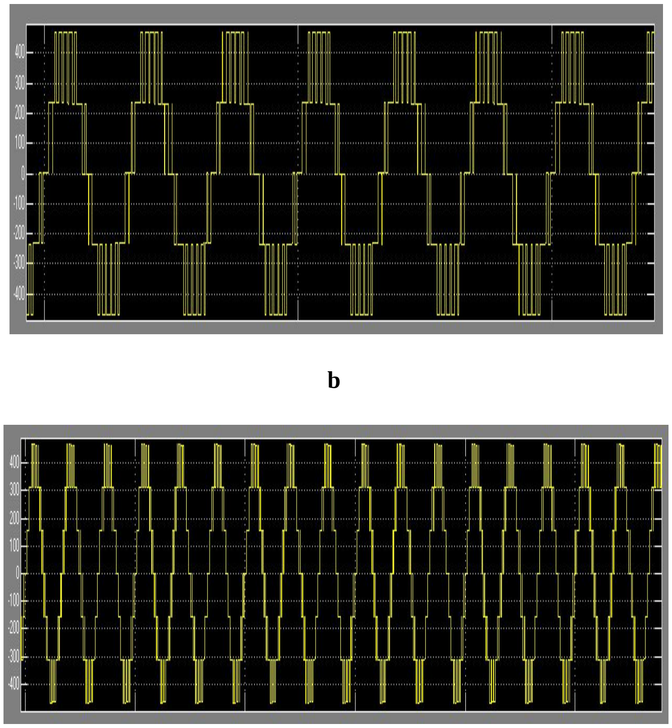
$$vAN = vH1 + vH2 + vH3$$

H-bridge requires a number of isoated dc suppies which make it suitable converter of distributed generation supplies i.e power from batteries ,fuel cell ,photovoltaic cell can be united under one roof.

The upper and lower switches in each leg operates in complementary mode so for three level we require two gate signals for S1 and S3 which are generated by comparing the sinusoidal wave by the two triangular carrier wave as shown in the sub sustem. Since the wave form of voltage between terminal A and B switches between the positive and negative dc voltage Vd, this scheme is known as bipolar modulation.If the incoming dc voltages are all same then it is known as symmetrical H-bridge configuration otherwise it is is known as asymmetrical H-bridge configuration.



a



b

C

Fig. 6: Output waveform of (a)3-level,(b)5-level,(c)7-level

When switches S_{11}, S_{21}, S_{12}, and S_{22} conduct, the output voltage of the H- bridge cells $H1$ and $H2$ is $v_{H1} = v_{H2} = E$, and the resultant **inverter phase voltage** is $v_{AN} = v_{H1} + v_{H2} = 2E$, which is the voltage at the inverter terminal A with respect to the inverter neutral N. Similarly, with S_{31}, S_{41}, S_{32}, and S_{42} switched on, $v_{AN} = –2E$.

The number of voltage levels in a CHB inverter can be found from

$$m = (2H + 1) \qquad (7.3\text{-}1)$$

Where H is the number of H-bridge cells per phase leg.

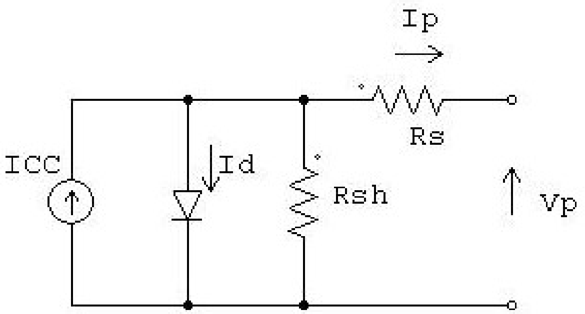
The total number of **active switches** (IGBTs) used in the CHB inverters can be calculated by

$$N_{SW} = 6(m – 1)$$

Where m is the number of H-bridge cells.

4. MODELING OF SOLAR PV CELL

The working condition of the solar cell depends mainly on the load and solar isolation. They operate in the open circuit mode and short circuit mode. Based these characteristics, the output voltage, current and power can be computed.[11]



Iph – Photodiode current

Vd – Diode voltage

Id – Diode current

n - Diode factor (1 for ideal and >2 for real conditions)

Io - Reverse saturation current

T - Temperature for the solar arrays panel in Kelvin

K – Boltzmann's constant =1.38*10^-23 j/k

Q – Electron charge =1.6 x 10^{-19}C

Rs – Intrinsic series resistance usually in milli-ohms

Rsh – Shunt resistance usually in kilo-ohms

The I-V characteristics of a solar cell while neglecting the internal shunt resistance is given by

$$I_{out} = I_{ph} - I_o \left[\exp\left(\frac{q}{nKT\ln(V + LoutRs)} \right) - 1 \right] \qquad (1)$$

In the event that the circuit is shorted indicating that the output voltage is =0. The current through the diode is being omitted. The short-circuit current, Isc = I can be represent by

$$I = I_{ph} - \frac{RsI}{Rsh} \text{--} \qquad \text{--(2)}$$

Generally with the relationship that exists between Isc and Iph, the output current is given below. From the relationship, output current is approximately the almost the same as the photocurrent.

$$I = I_{sc} = \frac{I_{ph}}{\left(\frac{1+Rs}{Rsh} \right)}$$

The Pmax relationship is also represented in terms of Vmppt. The Pmax is the maximum output power and Vmppt is the optimal output voltage.[12]

$$Pmax = I_{ph} \left\{ \begin{matrix} Voc - \left(\frac{nkT}{q} \right) \ln\left(\frac{1 + qV_{mppt}}{nkT} \right) - \frac{Voc}{\left(qV_{mppt} + nkT \right)} + \\ nkt \left(\frac{1}{V_{mppt}} \right) \ln\left(1 + \frac{qV_{mppt}}{nkt} \right) \end{matrix} \right\}$$

Iph – Photodiode current

Vd – Diode voltage .

When the circuit is in open-circuit mode, the output current I is =0. At this point, the open-circuit voltage, Voc is calculated.

$$Voc \blacksquare Vmax = \left(\frac{(nkT)}{q*ln*\left(\frac{Iph}{Is}\right)}\right)$$

The output power can be expressed based on the open circuit voltage and short circuit current.

$$P = IV \blacksquare \left(\frac{Iph-Id-Vd}{Rsh}\right) \blacksquare V \text{---} \qquad \text{--(3)}$$

5. SIMULATION DIAGRAM AND RESULTS

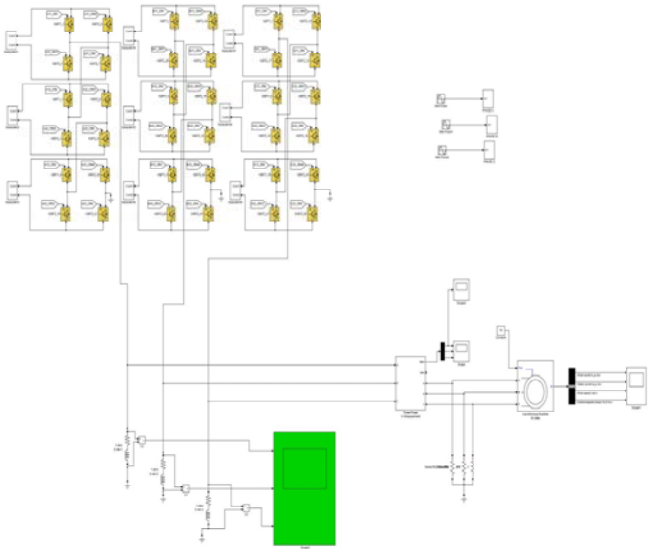


Fig. 7: Schematic diagram showing PV panel supplying dc voltage to seven level cascaded H-Bridge and the switching scheme of inverter.

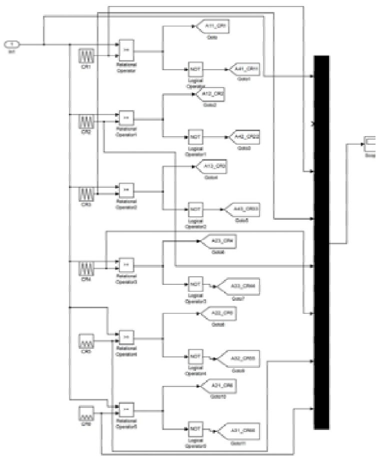


Fig. 8: Switching scheme of phase A.

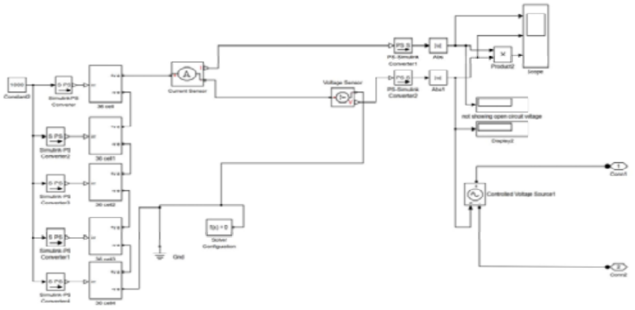


Fig. 9: PV panel supplying dc voltage.

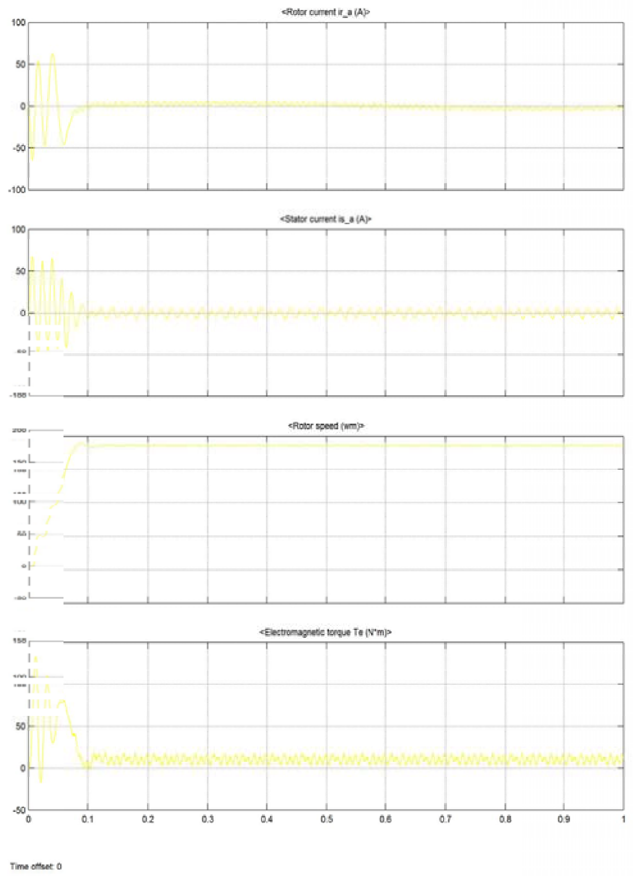


Fig. 10: Showing smooth waveforms of rotor current, stator current, rotor speed and electromagnetic torque.

6. CONCLUSION

MLI proves to run IM smoothly as compare to conventional converter as it is clear from low THD and lesser harmonics in torque waveform also it shows that solar energy can be hope for future power aspects.

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