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PV Based Dual Buck Converter for Agricultural Motor Loads

Vinod.S [1], Mr.S.Krishnan[*2]

Assistant Professor, Dept. of EEE, Jerusalem College of Engineering, Chennai, Tamil Nadu, India[1]

Assistant Professor, Dept. of EEE, Bharath University, Chennai, Tamil Nadu, India[2]

[*] Corresponding Author

ABSTRACT : We are today undergoing a very dark power crisis. Not only that our non-renewable resources are also depleting at a faster rate. The most affected are the agricultural paddy fields. Large paddy fields require motor pumps for water irrigation. If these machines are not supplied with power then these fields will be affected and consecutively food production will be affected. This becomes worse during the summer. This paper deals with solutions to such a problem. This paper explains on using solar power to power motor loads. Until now solar power is been used only for lightning purposes and now this paper explains on using solar power for induction motors.

KEYWORDS : converter, Hybrid system, Photo voltaic cell, Three Phase Induction Motor.

I. INTRODUCTION:

The photovoltaic (PV) power generation system is playing an important role in the development of distributed electric power systems. In order to achieve low cost and compactness, as well as increased reliability and efficiency, the concept of the transformerless PV inverter was proposed. In recent years, the Transformerless PV inverters (TLI), already well-accepted in European markets, have drawn more and more attention in other parts of the world.

The NPCTLI’s (Neutral Point Clamped Transformerless split Inductor based PV Inverter) topology can overcome the problems of leakage current and restrict the dc component injected to the grid. A dual-buck half-bridge inverter (DBHBI) was proposed in which received considerable attention in recent years. The DBHBI can avoid the shoot-through problem. But the DBHBI can only work with the bipolar modulation strategy and there is large voltage stress on the power devices. In order to solve the aforementioned problems, the multilevel leg structure was introduced which can work with the unipolar modulation strategy and reduce the voltage stress effectively.

Based on the half-bridge-type transformer less PV grid connected inverter, a novel split-inductor NPCTLI (SI-NPCTLI) with variable hysteresis band fixed-frequency is control in the proposed inverter. The voltage stress of power devices in an SI-NPCTLI is the same as in an NPCTLI, **and** an SI-NPCTLI can be also operated with unipolar modulation. The variable hysteresis band fixed-frequency control offers an excellent current reference tracking performance and fast transient response ability in comparison with other current controllers.

OBJECTIVES:

- This paper reveals the major application of power electronics for solar power conversion system, there by implementing the following technique to obtain the output.
- To design and simulate transformerless converter based PV system.
- Three level inverter with neutral point clamped circuit.
- Fabrication of low level hardware pro type for the proposed circuit.

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SOLAR ENERGY CONVERSION SYSTEM:

A solar cell, or photovoltaic cell (PV), is a device that converts light energy into energy current using the photoelectric effect. Solar cells produce direct current. which fluctuates with the intensity of the irradiated light. This usually requires conversion to certain desired voltages or alternating current (AC), which requires the use of inverters. Multiple solar cells are connected inside the modules [1]. Modules are wired together to form arrays, then tied to an inverter, which produces power at the desired voltage, and for AC, frequency/phase.
The main components of a solar energy conversion system are illustrated in Figure 1, including a PV panel and transformerless split-inductor neutral point clamped three level inverter (TSINPCTLI).

Figure.1 Solar energy conversion system

TSINPCTLI-Transformerless Split-Inductor Neutral Point Clamped Three Level Inverter

PHOTOVOLTAIC CELL:

Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibit the photovoltaic effect [2]. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaic include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide [3]. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years. Solar cells produce direct current electricity from sun light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaic was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation [4]. In this case an inverter is required to convert the DC to AC. There is a smaller market for off-grid power for remote dwellings, boats, recreational vehicles, electric cars, roadside emergency telephones, remote sensing, and cathodic protection of pipelines [5].

Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photovoltaic include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide [6]. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels [7]. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays [8].

Photovoltaic power capacity is measured as maximum power output under standardized test conditions STC in 'Wp' Watts peak.The actual power output at a particular point in time may be less than or greater than this standardized, or rated, value, depending on geographical location, time of day, weather conditions, and other factors. Solar photovoltaic array capacity factors are typically under 25%, which is lower than many other industrial sources of electricity [9].

A significant market has emerged in off-grid locations for solar-power-charged storage-battery based solutions. These often provide the only electricity available. The first commercial installation of this kind was in 1966 on Ogami Island in Japan to transition Ogami Lighthouse from gas torch to fully self-sufficient electrical power [10].

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NEUTRAL POINT CLAMPED INVERTER:

One of the multi level structures that has gained much attention and widely used is Neutral Point Clamped Inverter. With the traditional method, the standard voltage source inverter (VSI) is composed of only one switching cell per-phase. But in the field of high power drive systems, the level of DC bus voltage constitutes an important limitation on the handled power. On the other hand, the very high dv/dt generated by the two-level VSI with high DC-link voltage is responsible for the electromagnetic interference (EMI) and motor winding isolation stress [11]. So the multi-level VSI is widely studied in high power/voltage AC drive. For the three-level VSI, the voltage stress of switch is the half of the two-level inverter for the same DC voltage, and generates lower harmonics at the same switching frequency [12].

The performance of the three-level inverter mainly depends on the PWM algorithm. The SVM is extremely flexible and well suit for implementation on DSP. A typical SVM uses the nearest three output vectors (the nodes of the triangle containing the reference vector) to approximate the desired vector. When the reference vector changes from one region to another, it may induce an abrupt change in the output vector [13]. The switching sequence and switching-time of each state are determined by acquiring the volt-seconds produced by switching vectors equal to the reference vector. However, the computational complexity is greatly increased with the increasing number of the voltage vector and it is a main limitation of the application of SVM [14].

II. REPRESENTATION OF THE NPC INVERTER:

The conventional three-level NPC inverter is shown in the Figure 2 with this inverter topology, it is possible to produce three voltage levels at the output of inverter leg namely $V_{dc}/2$, 0 and $2V_{dc}/2$.

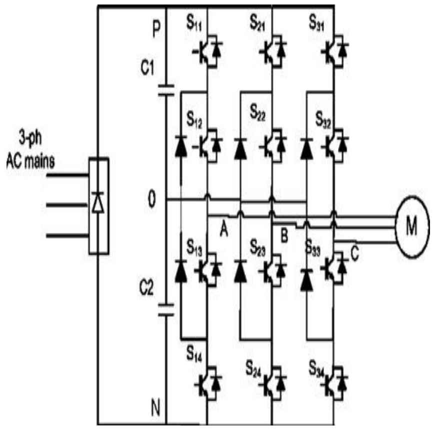

Figure 2 Proposed circuit of neutral point clamped inverter

PRINCIPLE OF OPERATION:

The conventional three level NPC inverter has 27 switching state. These 27 switching states are classified into three groups A, B and C. When switching states in group A are used in a three-level NPC inverter, the load is connected between the terminal P and N or to either one [15]. In this case, the current through the capacitors will be equal and there will not be any voltage unbalance problems, in the capacitors C_1 and C_2. When the switching states in group B are used for inverter control, the neutral point is connected along with the terminals P and N to the output load. In this case, the currents flowing through the capacitors will be different and this will cause a voltage unbalance. When the switching states in group C are used, the load is connected between the terminal P or N and the neutral point [16].

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EQUIVALENT CIRCUIT OF NEUTRAL POINT CLAMPED INVERTER:

The Figure 3 below shows equivalent circuit of the voltage source NPC motor drive configuration. In the proposed topology, only one active voltage source of $V_{dc}/2$ is used. The rated DC link voltage can be obtained by switching the voltage source between the top capacitor (C_1) and the bottom capacitor (C_2) with a duty ratio of 0.5.
The capacitors will charge to $V_{dc}/2$ with a constant frequency irrespective of the load currents. Therefore the load current flowing through the capacitors will not create any neutral-point fluctuations. Here, the diode bridge rectifier and filter capacitor C_3 is used as input voltage source [17]. To switch the voltage source between the capacitors C_1 and C_2, two extra switches and two extra diodes are required, as shown.

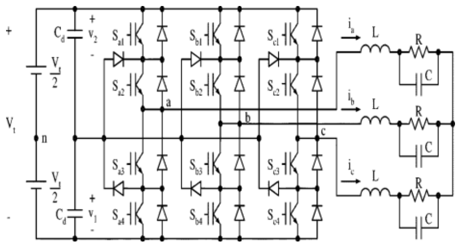

Figure 3 Equivalent circuit of neutral point clamped inverter

The Neutral Point Clamped inverter has been explained and a detailed analysis about the Space Vector Modulation technique for controlling the Neutral Point Clamped inverter has been efficiently explained in this chapter.

SPLIT- INDUCTOR NPCTLI:

The power switches in the DBHBI with a diode-clamped three-level switch cell being substituted and the independent freewheeling diodes of the DBHBI being omitted, a novel topology that is compact and similar to NPCTLI is derived. The earth connection point is the important detail in this topology, while the midpoint of PV cluster does not earth, the output end of the SI-NPCTLI can be connected to the grid freely; otherwise, once the midpoint of PV cluster earths, both the midpoint of capacitor's bridge leg and the midpoint of PV cluster must be connected to the neutral line of the grid. In the instantaneous voltage across points 1 and 3 is defined as u_{13} and the instantaneous voltage across points 2 and 3 is defined as u_{23}. In waveforms of the switch driving signals and the output current of the SI-NPCTLI are illustrated

III. EQUIVALENT CIRCUIT OF SINGLE PHASE SI-NPCTLI:

Figure 4 illustrates the states equivalent circuits of single phase transformerless split inductor neutral point clamped three level inverter.

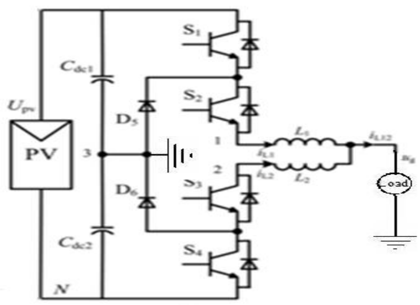

Figure 4 Equivalent circuit of transformerless split inductor NPCTLI

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IV. REPRESENTATION OF SPLIT INDUCTOR NPCTLI:

Considering the proposed SI-NPCTLI for PV grid-connected applications, the schematic block is shown in Figure 5.The reference current iL_{12} (ref) of the inductor current iL_{12} can be obtained by calculating the product of the reference amplitude I_{ref} and the phase of the grid voltage. As the result of hysteresis current control, the inductor current iL_{12} can achieve the error-free tracking to the reference current. Then, the MPPT algorithm can be fulfilled by calculating Ug and reading I_{ref}. Lastly, the driving signals of the inverter can be generated by comparing the real-time hysteresis band h with the error of inductor current iL_{12} and reference current iL_{12} (ref) provided

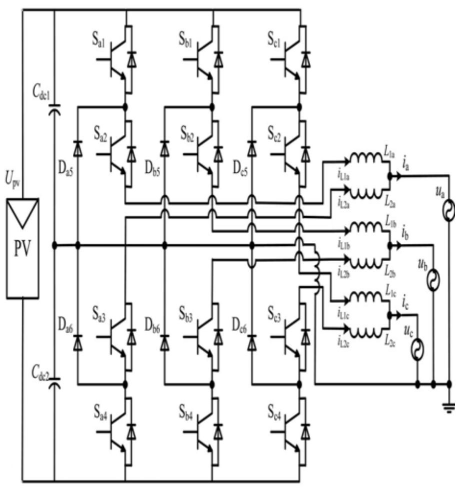

Figure 5 Proposed circuit of three phase transformerless SI-NPCTLI

MODES OF OPERATION:

The switches of the DBHBI are modulated at half of the line cycle, so the switching and conduction losses are reduced and the efficiency can be improved. The proposed SI-NPCTLI is modulated at half of the line cycle current as well. Before analysis, the following assumptions are given:

1) All power switches and diodes are the ideal devices with ignored switching time and conduction voltage drop;

2) All inductors and capacitors are ideal, and $C_{dc1} = C_{dc2}$, $L_1 = L_2 = L$; and

3) The inverter operates at the unity power factor, i.e., the inductor current iL_{12} is in phase with the grid voltage u_g. Taking the operation during the half-cycle of the positive grid voltage, e.g., the detailed analysis of the inverter operation modes is described.

Mode 1

With switches S_1,S_2 ON and S_3,S_4 OFF the output voltage of the bridge leg is the voltage of capacitor C_{dc1}, i.e.,u_{13} = (1/2)Upv . At this duration iL_1 indicating the current of inductor L_1 increases.

$$L\, diL_1/dt=1/2U_{pv}-U_g$$

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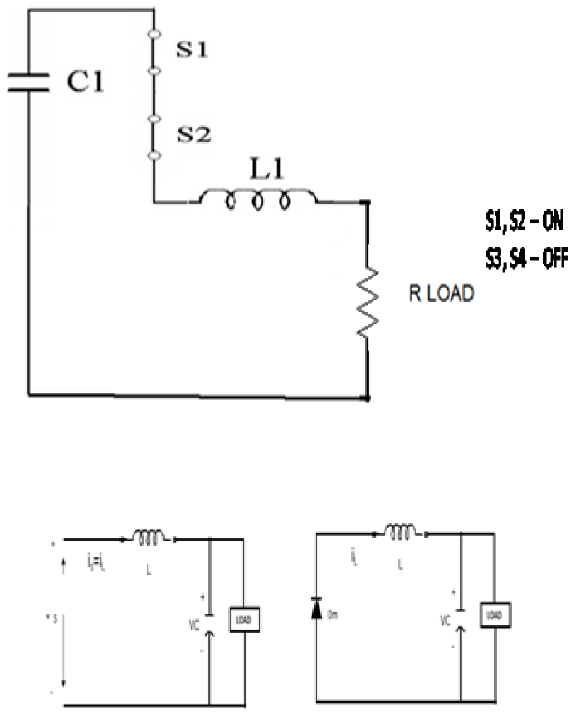
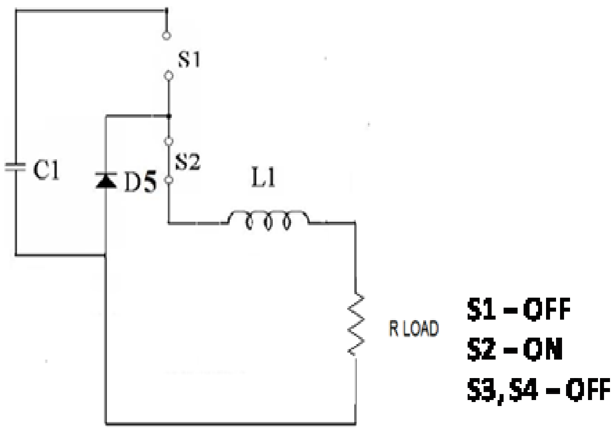


Figure 6 Mode of Operation 1

Mode 2

With S_1 OFF, S_2 ON and S_3, S_4 still OFF, the voltage on S_1 is clamped to the half of the input voltage by the diode D_5 , and the output voltage of the bridge leg is zero, i.e., u_{13} = 0. At this duration, the current of inductor L_1 states in the freewheeling stage and *i*L1 decrease.

$$L\, diL_1/dt = 0 - ug$$



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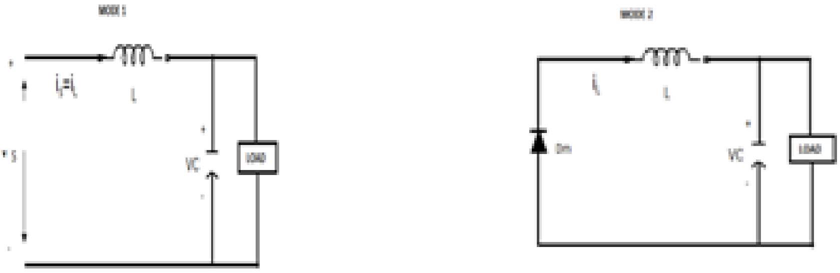

Figure 7 Mode of Operation 2

Mode 3

The operation during the negative half-cycle is similar to the positive one. During the positive half-cycle of the grid voltage the output-voltage levels of the bridge leg include zero and (1/2) Upv. Similarly, during the negative half-cycle, the output voltage gets the two levels of zero and −(1/2)Upv.

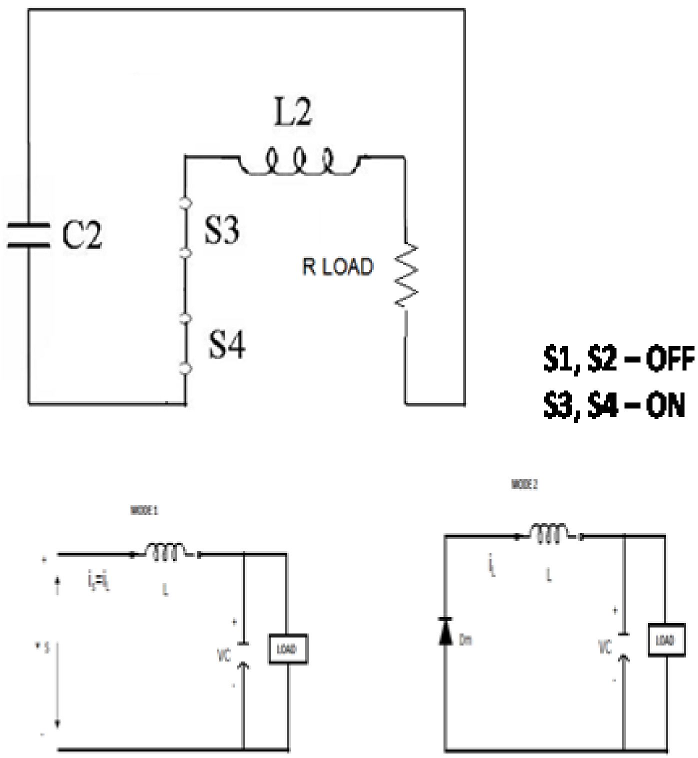

Figure 8 Mode of Operation 3

Mode 4

During the negative half-cycle is similar to the positive one. So, during the positive half-cycle of the grid voltage the output-voltage levels of the bridge leg include zero and (1/2)Upv . Similarly, during the negative half-cycle, the output voltage gets the two levels of zero and (1/2)Upv.

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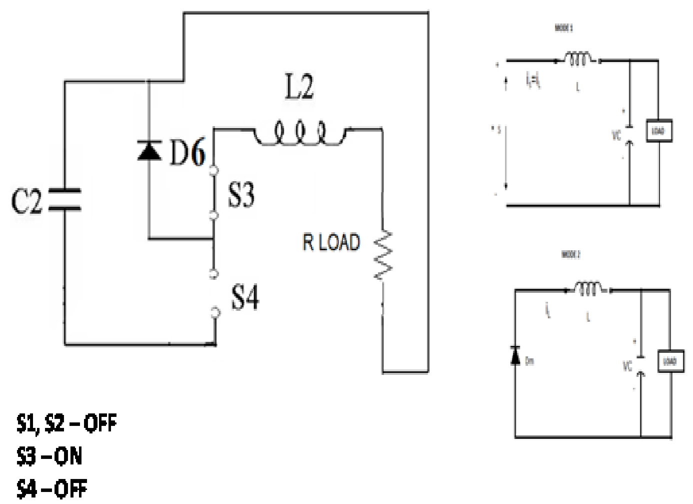

Figure 9 Mode of Operation 4

In this chapter the split inductor neutral point clamped three level inverter is proposed and the operation of the split inductor NPCTLI is explained in detail, with various equivalent circuits.

V. SIMULATION RESULTS

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building.
MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN.
The simulations tests are carried on with the parameters of 3.2 kilowatt wind turbine system and the results are displayed in graphical format and the parameters used are also displayed as follows.

OPEN LOOP SIMULATION:

The open loop circuit of the Neutral Point Clamped Inverter has been simulated with 3phase R-load and the simulated circuit is shown in the Figure 10

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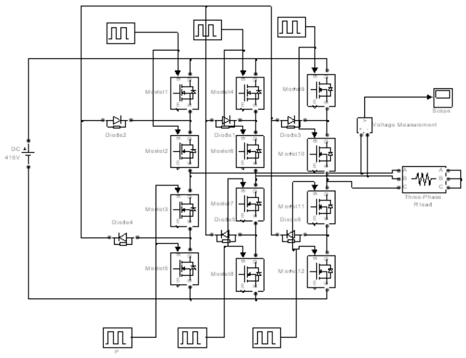

Figure 10 NPC inverter open loop

CLOSED LOOP SIMULATION (with ordinary PWM control):

The closed loop circuit of the Neutral Point Clamped Inverter is implemented using the proportional controller and the proportional integral controller. The desired voltage is obtained by controlling the high frequency pulses provided to the MOSFETs. The circuit was simulated in MATLAB and it is shown in the Figure 12

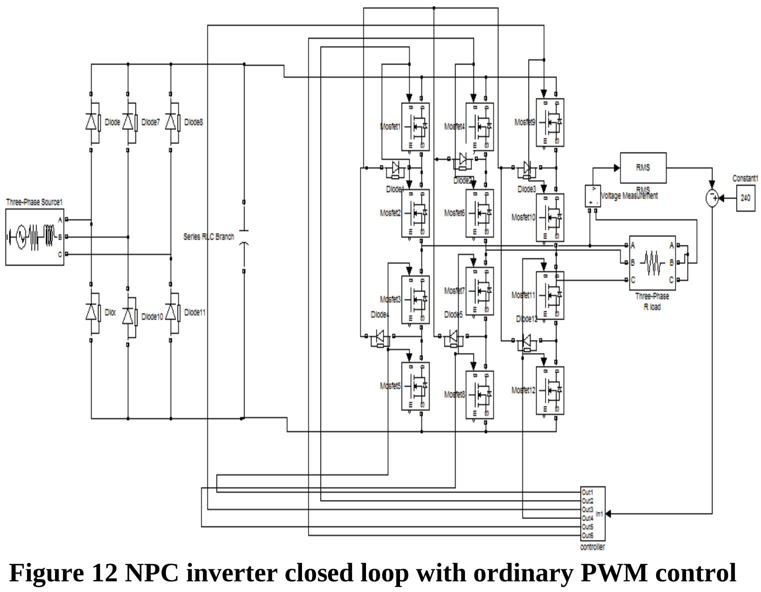

Figure 12 NPC inverter closed loop with ordinary PWM control

The output voltage waveform for the open loop NPC inverter is of high frequency square wave which is shown in the Figure 13

Figure 13 Output voltage waveform for NPC inverter closed loop

PULSE PATTERN

The pulse is generated for the four switches by using the logical operator was shown in fig14.The width of S_1 and S_2 will decides the buck level.

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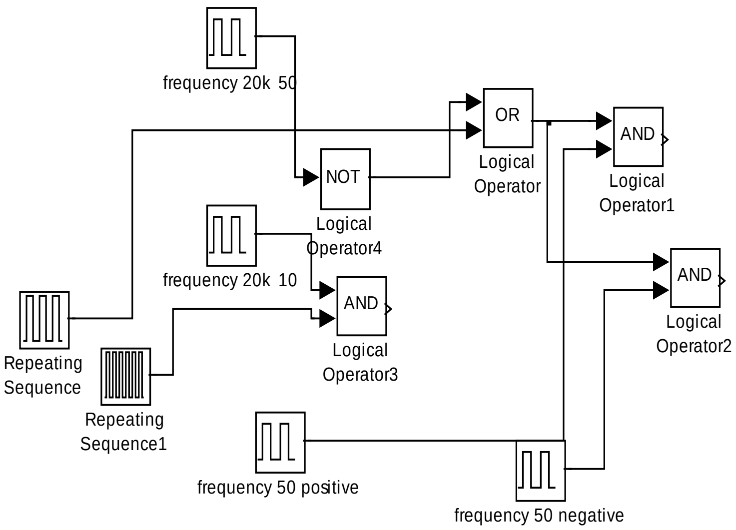


Figure 14 Pulse Generation Circuit

The generated pulse is shown in figure 15

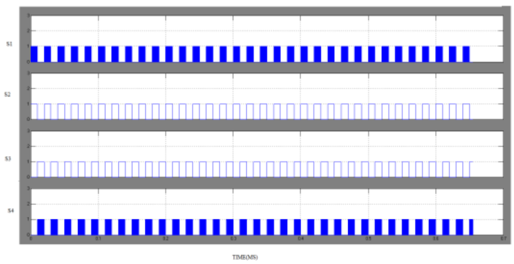
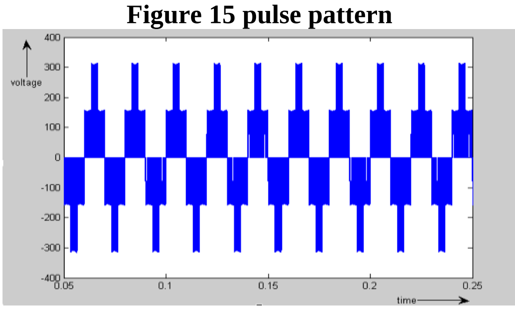


Figure 15 pulse pattern



SPLIT INDUCTOR NPCTLI WITH R-LOAD :

The open loop circuit of the Split Inductor Neutral Point Clamped Three Level Inverter has been simulated with 1phase R-load and the simulated circuit is shown in the Figure 16

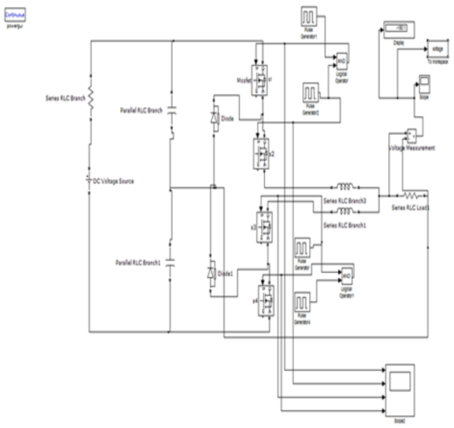


Figure 16 Split Inductor NPCTLI with R load

The output voltage and output current waveform obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 1phase R-load is shown in the Figure 17 and Figure 18 respectively.

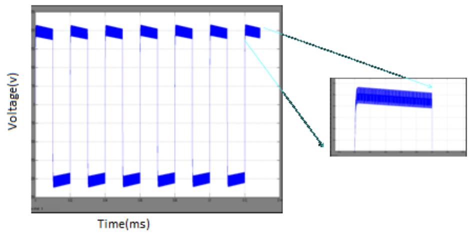


Figure 17 Output voltage waveform for SI- NPCTLI (R-Load)

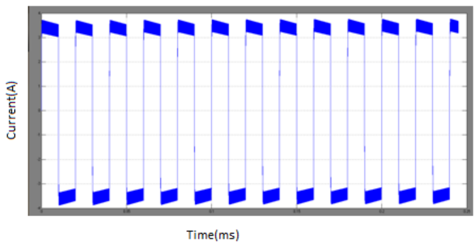


Figure 18 Output current waveform for SI- NPCTLI (R-Load)

SPLIT INDUCTOR NPCTLI WITH R-L LOAD:

The open loop circuit of the Split Inductor Neutral Point Clamped Three Level Inverter has been simulated with 1phase R-L load and the simulated circuit is shown in the Figure 19

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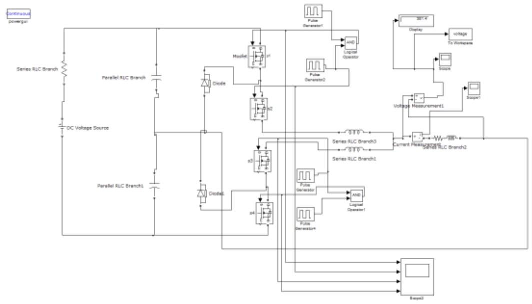

Figure 19 SPLIT INDUCTOR NPCTLI with R-L load

The output voltage waveform obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 1phase R-L load is shown in the Figure 20.

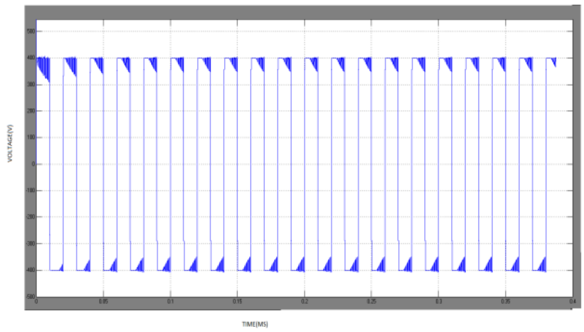

Figure 20 Output voltage waveform for SI- NPCTLI (R-L Load)

THREE PHASE SPLIT INDUCTOR NPCTLI WITH R-LOAD:

The open loop circuit of the Split Inductor Neutral Point Clamped Three Level Inverter has been simulated with 3phase R-load and the simulated circuit is shown in Figure 21.

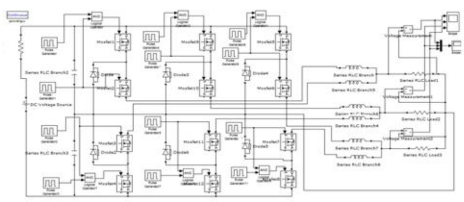

Figure 21 SPLIT INDUCTOR NPCTLI with R Load(3 Phase)

The output voltage waveform obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 3phase R-load is shown in Figure 22.

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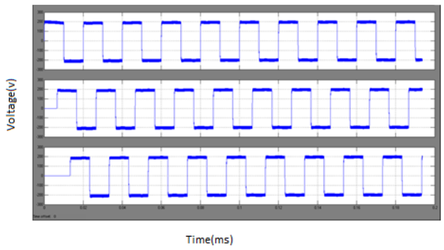

Figure 22 Output voltage waveform for SI- NPCTLI with R-Load(3 Phase)

THREE PHASE SPLIT INDUCTOR NPCTLI WITH MOTOR LOAD :

The open loop circuit of the Split Inductor Neutral Point Clamped Three Level Inverter has been simulated with 3phase Motor Load and the simulated circuit is shown in Figure 23.

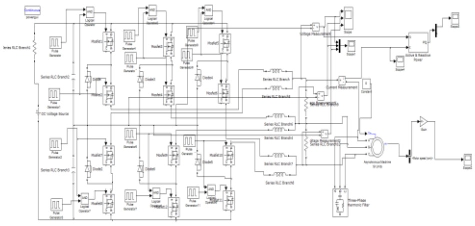

Figure 23 SPLIT INDUCTOR NPCTLI with Motor Load(3 Phase)

The speed of the motor obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 3phase Motor Load is shown in Figure 24.

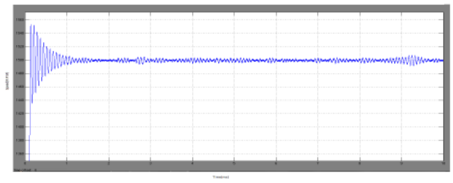

Figure 24 Speed of the Motor for SI- NPCTLI (3-Phase)

The output current waveform obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 3phase Motor load is shown in Figure 25

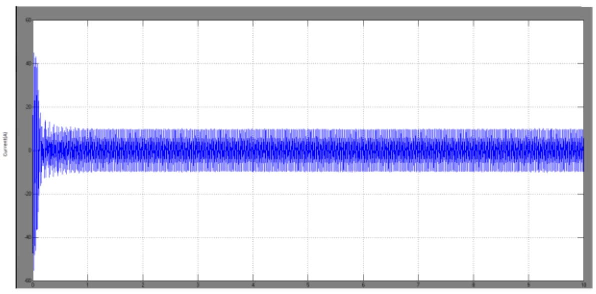

Figure 25 Output current waveform for SI- NPCTLI

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The output voltage waveform obtained from the open loop Split Inductor Neutral Point Clamped Three Level Inverter 3phase Motor load is shown in Figure 26

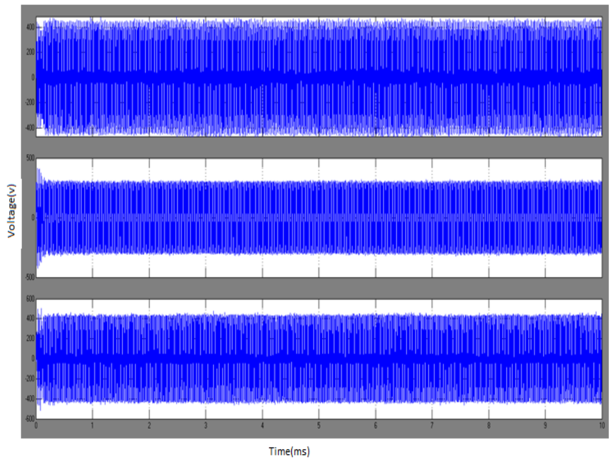

Figure 26 Output Voltage waveform for SI- NPCTLI

CLOSED LOOP CIRCUIT WITH DISTURBANCE:

The process of closed loop system was shown in fig 27.It shows the simulated circuit in closed loop with source side disturbance.

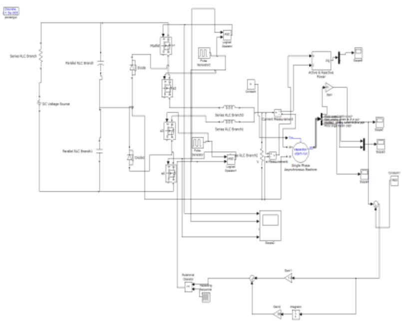

Figure 27. closed loop of proposed system

The speed of the motor obtained from the closed loop Split Inductor Neutral Point Clamped Three Level Inverter with source disturbance is shown in Figure 28.

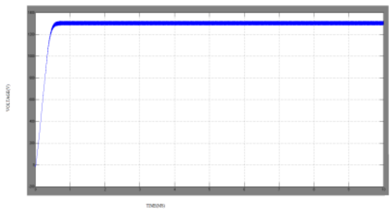

Figure 28 Speed of the Motor for SI- NPCTLI in Closed Loop

The transformerless Split inductor neutral point clamped three level inverter are simulated for open loop and the performance was compared with R load and motor load.

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VI. CONCLUSION

The performance characteristics of the open loop and the closed loop of the Neutral Point Clamped Inverter and transformerless split inductor neutral point clamped three level inverter circuit are evaluated . A split-inductor three-level inverter with high reliability and low-leakage current characteristics is presented in this paper. The proposed inverter features low device voltage stress and constant common-mode voltage, which exists in the traditional neutral-point clamping three-level circuit structure. At the same time, it can avoid the shoot-through issue like a dual-buck half-bridge inverter. The proposed inverter can achieve high efficiency, low cost, low leakage current, and high reliability to satisfy the requirements of the transformerless split inductor NPCTLI.

Closed loop system with Neural Network will be carried out and open loop prototype system will be developed.

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