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Solar Mppt Based 13 - Level T - Type Inverter for Switching Cell

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Abstract: Two level inverter has disadvantages like more harmonics content and les efficiency. This is overcome by three level NPC converter. Three state switching cell is used for the advantage of dividing the current evenly that flows through semiconductors has low conduction loss. This circuit consists of active bidirectional switches which are clamped to midpoint of DC voltage source which helps in added step to the multilevel inverter. The active devices help in reducing the harmonics. So, this circuit is considered for our thesis and it is enhanced to thirteen level. The PWM is also considered for analysis with T type multilevel multicell inverters. The more the levels in inverter output make the more efficient our converter system. This makes our converter suitable for higher voltages with less harmonic content, which is accepted by universal standards.

Key words: High efficiency · Multilevel converter · T-type converter · SPWM · THD

INTRODUCTION

The three-level topologies are attractive solutions for low voltage applications.When the medium or high switching frequency is employed. The efficiency for three-level neutral-point clamped (NPC) converter can be better than conventional two level inverter. The switching frequency is higher than 10 kHz. The different multilevel converter topologies reported in literature.

To increase the energy processed from static converters and other techniques have been studied in literature, including interleaving technique with the magnetically coupled cells. The three-state switching cell is presented in this paper [1].

The environmental pollution and depletion of fossil fuels are alternative energy have been progress and in particular to photovoltaic research is constantly being conducted. Electricity generated solar power system is operating energy and efficiently in connection with electricity grid andthen user's standpoint, it is more stable electricity grid-connected technology produced solar power system is becoming a lot of interest.

Electricity generated from photovoltaic system is changeable and its operation for maximum output depending upon amount of solar radiation is operating voltage and operating temperature. It is necessary to lot of energy from solar cell and increase the efficiency. The MPPT which controls operating point of solar cell in order to operate at maximum output are consideration of environmental sectors such as temperature or solar radiations as well as photovoltaic output changeable depending upon the operating and DC to DC converter controlling technique is used to provide stable DC power from inverter are essential [2].

The photovoltaic system topologies and techniques are now proposed in various ways. In existing three-phase and two-level photovoltaic inverter are implemented easily by using simple composition of already proved to controlling and PWM techniques. The 2-level inverter has some disadvantages such as high harmonic in the output voltage and efficient limitationfor the switching element (IGBT). The 3-level T-Type topology has some advantages for inverter's efficiency of the existing 2-level inverter is high harmonic content and less stress of switching element, the disadvantage that its circuit is more complex than that of the existing 2 level inverter [3].

In this paper, the competitiveness of the three-level T-type converter (3LT2C) for low-voltage applications is analysed. Compared to the three-level NPC topology, the T-type employs an active bidirectional switch to dc-link voltage midpoint and gets along with two diodes less bridge leg. It is an alternative to more complex three-level

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topologies. The active neutral point clamped converters or split-inductor converters. The 3LT2C basically combines the positive aspects of two-level converter such as low conduction losses, small part count and as impel operation principle of advantages of the three-level converter low switching losses and superior output voltage quality [4].

A discussion on the possible switch configurations, the commutation steps and the available. The main advantages are compared to the three-level NPC topology are highlighted. The impact the combination of different switch types and switching losses is investigated. The converter efficiency is calculated with generic approach considering the temperature dependence on the loss components [5].

It will be shown that the semiconductor losses of the 3LT2C are decreased and distributed over several devices. This leads a small increase in the junction temperature allows for choosing smaller semiconductor on chip sizes or for keeping high efficiency and high reliability. The inverters produce an output voltage with levels are 0 or +-V are known as two level inverters. The high-power and high-voltage applications are two-level inverters have some limitations for operating at high frequency are mainly due to switching losses and constraints of device rating. Multilevel inverters are advantageous. Increased number of voltage levels in the inverter and without requiring higher rating for individual devices can beincreasedby power rating. The unique structure of multilevel voltage source inverters' allows reach high voltages with low harmonics without use of transformers synchronized-switching devices[6]. The harmonic content output voltage waveform is decreases significantly.

A dc-to-ac converter output is desired to output voltage and frequency is called inverter.The inverters can be broadly classified into

- Voltage Source Inverters(VSI)
- Current Source Inverters(CSI)

A voltage source inverter is controlled ac output is voltage waveform.A current source inverter is controlled ac output is a current waveform.

On the basis of connections for semiconductor devices and inverters are classified as;

- Bridge inverters
- Series inverters
- Parallel inverters

Some industrial applications of inverters are adjustable- speed ac drives, induction heating stand by air-craft power supplies, UPS for computers, HVDC transmission lines.

The structure of three-level Neutral-point clampedinverter is shown in Fig. 1. It may be coupled directly to a level of voltage of 3.3 kV using a GTO of 4.5 kV [7-11]. Taking for reference one leg of the converter as switching states the GTO, to obtain the voltages 0, E=2 and E three (3) states per leg and thusfor a three-phase converter there are 27 states in total. A structure of aMultilevel converter; in this case we use (M – 1)*2*3 GTO, (M-1)*2*3 diodes are anti-parallel (M-1)*(M-2)* 3 clamping diodes and (M-1) capacitors. The transitions ofthe switches are leg according to indicated states shows thedirection of the current flow for each state. (S11, S14); (S21, S24); (S31, S34) are the mainswitches are directly by control pulses. (S12, S13); (S22, S23); (S32, S33) are auxiliary switches for allow connection ARE output of each phase to neutral point (0). (D11–D32) intervene in this operation. The M = 51 for a direct connection with a 69-kVnetwork, 300 GTOs and diodes in antiparallel, 50 capacitors, 7350 clamping diodes areneeded. The second type converter is the following advantages:

When M is very high, the distortion level is low that the use of filters is unnecessary. Constraints on the switches are low because switching frequency is lower than 500Hz (there is a possibility of switching at the line frequency).Reactive power flow can be controlled.

An alternative of three-level T-type converter for low voltage applications, which is extension for conventional two-level topology and addition of active bidirectional switch to the DC-link midpoint providing superior output voltage. In this paper 13-level cascade multilevel inverterA voltage source inverter is one of the independently controlled ac output is voltage waveform. A current source inverter is one of the independently controlled ac output is a current waveform.which uses PLL and DC sources to interact with the power grid.In this proposed inverter, an active bidirectional switch is introduced between the mid-point of each leg and the DC link mid-point.

Energy Extraction Chracteristic Study of Solar Photovoltaic Cells: The characteristics ofsolar cells, modules and arrays are order to operate the design, energy extraction and gridintegration for solar PV generator. In most solar cells are absorption for photons

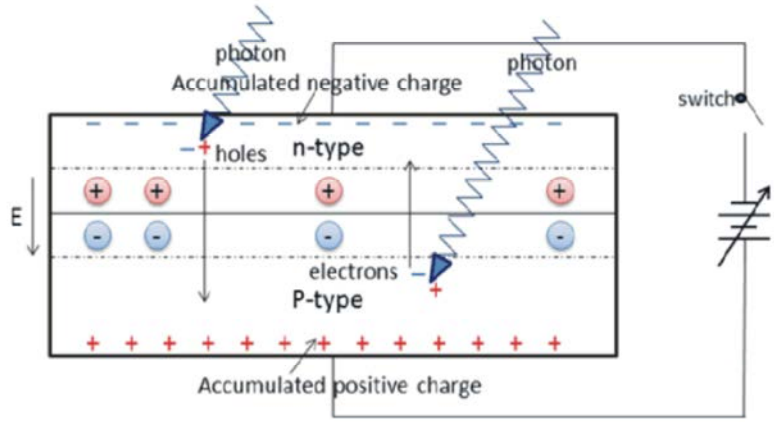


Fig. 1: Illustration of drift current for photogenerated current and voltage

takes place semiconductor materials,resulting in the generation of the charge carriers and subsequent separation of photogeneratedcharge carries. Therefore semiconductor layers are important parts of a solarcell. A solar cell device that converts the energy of sunlight directly into electricity for thephotovoltaic effect [2]. There are many kinds of solar cells developed by using differentsemiconductor materials; the operating principle is very similar. The solar cell is configured as a large-area p-n junction made from silicon. A piece of p-typesilicon is placed in contact with a piece of n-type silicon, a diffusion of electrons are occursfrom the region high electron concentration into the region of low electronconcentration. Holes are flow in the opposite direction during diffusion. The diffusion current ID from the p side to n side. When the electrons diffuseacross the p-n junction, they recombine with holes on the p-type side. The diffusion of carriersdoes not indefinitely because electric field is created by imbalance ofcharge immediately either side of the junction which this diffusion creates. The electric fieldare established by p-n junction generates diode to promotes charge flow, known as driftcurrent IS, that opposes toeventually balances diffusion current ID. The region ofelectrons and holes have diffused across junction is called depletion zone.

A visible light photon energy above the band-gap energy strikes a solar celland is absorbed by solar cell and excites an electron from the valence band. Thisnewfound energy transferred from photon and the electron escapes from normal positionassociated with its atom, leaving a localized "hole". When mobile chargecarriers reach vicinity of depletion zone, electric field sweeps the holes into the p-sideand pushes in the electrons into n-side, creating a photogenerated drift current. The p-sideaccumulates holes and n-side accumulates electrons creates a voltage thatcan be used to deliver the photo generated current to load. At same time, the voltage built upthrough photovoltaic effect shrinks size of the depletion region and p-n junction diode is an increased diffusion current through depletion zone. The solar cell isnot connected to external circuit, the rise of photogenerated voltage eventually causes diffusion current ID balancing out the drift current is until a new equilibrium state is reached inside a solar cell.

A solar cell is connected to an external circuit, the photogenerated currentlyand travels are p-type semiconductor-metal contact,through the wire, powers the load and continues through wire until it reaches n-typesemiconductor-metal contact. Under certain sunlight illumination, current passed to theload from solar cell depends on external voltage applied to solar cell normally through apower electronic converter for a grid-connected PV system. The applied external voltage isphotogenerated voltage is needed make current flow from the solar cell to external system. Nevertheless, if the external voltage is high, a high photogenerated voltagemust be built up to push the current flowing from the solar cell to the external system. Highvoltage increases the diffusion current. So that net outputcurrent solar cell is reduced.

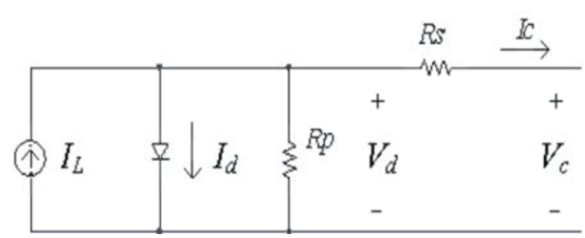


Fig. 2: Solar cell circuit model

To analyse behaviour of a solar cell, to create a model which is electricallyEquivalent. The solar cell can be modelled by a current source, representing photo generated current IL and parallel with diode, representing the p-n junctionof a solar cell. In a real solar cell, there exist other effects, not accounted for by the ideal model. Those effects of influence external behaviour of a solar cell, which is particularly critical forintegrated solar array. Two extrinsic effects are include: 1) current leaks proportionalto terminal voltage of a solar cell 2) losses of a semiconductor itself and metalcontacts with semiconductor. The first is characterized by parallel resistance Rp accountingfor current leakage through the cell to edge of the device between contacts are different polarity. The second is characterized by series of resistance Rsand extra voltage drop between junction voltage and terminal voltage of the solar cell for same flow of current.

The mathematical model of solar cell is described by;

$$I_c = I_L - I_0\left(e^{\frac{qV_d}{mkT}} - 1\right) - \frac{V_d}{R_p}, \qquad V_c = V_d - I_c \cdot R_s$$

where IL is proportional to sunlight illumination intensity, m is diode ideal factor (for an ideal diode) and diode reverse saturation current I0 depends on temperature, q is elementary charge, k is the Boltzmann's constant and T is absolute temperature. For allstudies presented in dissertation,IL=6A,I0=6•10-6A,RP=6.6Ω,RS=0.005Ωand T=25. Which represents full sun condition used [7]. Thus, characteristics of solar cell can besimulated using a circuit simulation tool based on equivalent circuit model or computeddirectly. Important characteristics for solar cell consist ofoutput current Ic and power Pc versus output voltage Vc characteristics. TypicalI-V and P-V characteristics of solar cell under ideal condition and consideration ofparallel and series resistance obtained by Spice simulation tool. As it can be seen from fig. 2, if external voltage applied to solar cell is low net output current of solar cell, depending primarily photogenerated current, is constant. The external voltage increases power is outputted from the solar cell.

Maximum Power Point Tracking: PV generation systems have major problems, they are conversion efficiency of electric power generation is very low (9-17%), especially under low irradiation conditionsfor amount of electric power generated by solar arrays arechanges continuously with weather conditions. The power delivered by PV system is photovoltaic cells dependent on the irradiance, temperature and current drawn from cells. In general, a unique point on the I-V and P-V curve, called the maximum power point (MPP), at the entire PV system operates with maximum efficiency and produces the maximum output power. The location of MPP can be located, either through calculation models are searching algorithms. To maximize output power of PV system, continuously tracking maximum power point of system is necessary. The many different approaches to maximizing power from PV system. The range from using simple voltage relationships, intelligent and adaptive algorithms. Typical MPPT techniques are proposed in the Short-Circuit Current method, Open-Circuit Voltage method, Perturb and Observe methods, Incremental Conductance (IC) methods [12-15] and Adaptive P&O method, Intelligent and Fuzzy Logic methods. Techniques vary between eachother in many aspects and including simplicity, convergence speed, system stability and MPPtracking effectiveness. Primary challenges for maximum power point tracking for a solar PVarrays are include: 1) how to get to a MPP quickly, 2) To stabilize at a MPP and 3) how tosmoothly transition from one MPP to another sharply changing weather conditions. Ingeneralfast and reliable MPPT is critical power generation from the solar PV system.

The grid-connected solar PV system three parts an array for an solarcells, power electronic converters is an integrated control system. The control systemof solar PV array contains two parts: MPPT and grid interface control. Both control functions are achieved through power electronic converters. In general, dc/dc converter implements in MPPT function and the dc/ac converter performs gridinterfacecontrol.

The power extracted from PV array Pa is determined by terminal voltage Va andoutput current Ia of the array. The terminal voltage Va depends on control the dc/dcconverter while output current Ia depends on temperature, irradiation level and the PV arrayterminal voltage. During a day, solar irradiation and temperature fluctuates over time, causing MPP of the PV array changes continuously. PV systemoperating point must adjusted constantly to maximize the energy.

The SCC method is observation that IMPP is linearly proportional toISC of a PV array (Fig. 3),

$I_{MPP}(S) = k_{SC} * I_{SC}(S)$

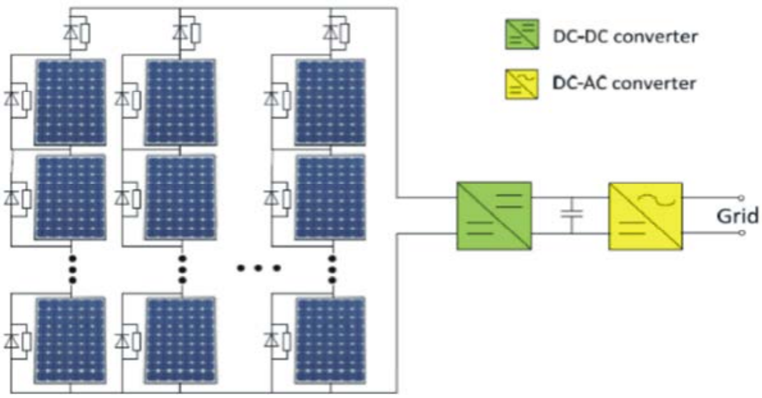


Fig. 3: Configuration for grid-connected solar PV system

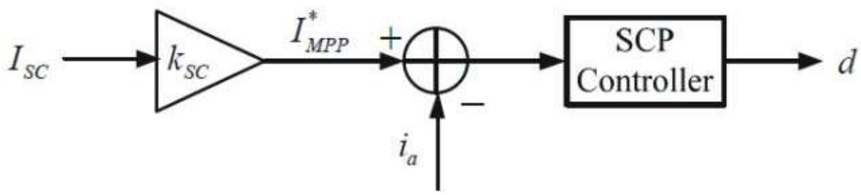


Fig. 4: Control scheme of SCC

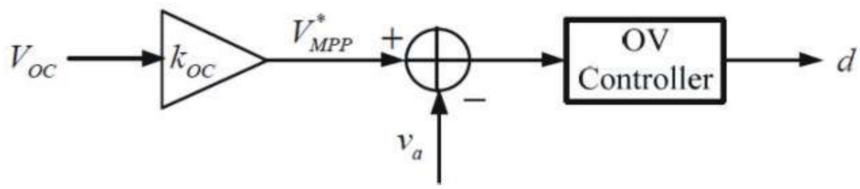


Fig. 5: Control scheme of OCV

where kSC is constant. According to SCC controller generates controlsignal to dc/dc converter based on the error signal between the actual current of the PV arrayIa and the IMPP calculated from above equation.

This method measurements of ISC. Therefore static switch in parallel with PVarray is needed to create the short-circuit condition for solar irradiation levelchange, which cause large oscillation of PV array output power. Another disadvantage iscomputation of IMPP is very sensitive to kSC and relation between IMPP and ISC is not100% linear. Thus, a small deviation of IMPP, calculated by reduce the outputpower of the PV array greatly.

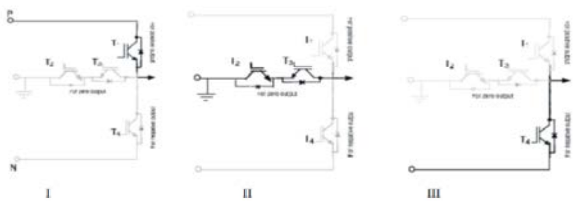
The OCV method is observation that VMPP is about linearly proportional to VOC of PV array (Fig. 5),

$$V_{MPP}(S) = k_{OC} * V_{OC}(S)$$

where kOC is constant. Based on close-loop control scheme is developed to bring PVarray voltage to VMPP calculated. The SCC method, the OCVmethod requires measurements for VOC. A static switch in series with PV array isnecessary to create the open-circuit state for each weather condition change fora large oscillation of PV array output power. In addition, VOC varies temperature and other factors and relation of VMPP and VOC is affected by shading, actualVMPP for practical PV application is difficult to get.

T-Type Topology: The basic topology is three level T-Type converter. The conventional two levelvoltage source converter topology is extended to an active, bidirectional switch to dc-link midpoint. The conduction is takes place in form of T shape to three level output voltage. The high side and low-side switches (T1 /D1 and T4 /D4) are usually implemented with1200-V IGBTs/diodes are full dc-link voltage has to be blocked. The bidirectional switch to thedc-link midpoint has to block for half of the dc-link voltage. It can be implemented having alower voltage rating, in the hand two 600-V IGBTs including antiparallel diodes are used [16]. The reduced blocking voltage and middle switches are very low switching losses and acceptable conductionlosses, although two devices connected in series. The Additional benefits are using single 1200-Vdevices to block the full dc-link voltage are reduced in conduction losses, if bipolar devices are considered.Whenever output is connected to (P) or (N), forward voltage drop is only one device occurs, contrary toNPC topology where always two devices are connected in series. The conduction losses areconsiderably reduced by the 3LT2C an interesting choice even for low switching frequencies.

Switch Configuration: For positive output switch T1 is ON, for negative output switch T4 is ON, zero output switch T3 and T4 isON.



Current Commutation for switching transition is different levels (I)Positive output(II)Zero output ,(III) Negative output.

Switching Stages:

State	V_{out}	T_1	T_2	T_3	T_4
P	$V_{dc}/2$	On	Off	Off	Off
O	0	Off	On	On	Off
N	$-V_{dc}/2$	Off	Off	Off	On

Modulation: The modulation strategies are three-level NPC converter can be applied to the 3LT2C. Themodulation strategy is important point for converter efficiency [10]. In this paper phasedisplacement pulse width modulation scheme simulate the circuit. Control signal generation is Universal control scheme. It is used to implement control circuit. For N level output are require (N-1)carrier signal and output is three level so required carrier signal are two, triangular wave is takenforcarrier signal and sinusoidal wave is taken for reference wave with an amplitude 0.85. The dc-link voltage is symmetrical and constant, but most of the cases the dc-link is asymmetrical the control ofasymmetrical voltage is difficult to several attempt to control the DC-Link voltages asymmetrically in multi-levelinverters have been reported. They can be differentiated according to pulse width modulation(PWM) schemes.

Linear Modulation: The simplest modulation interpret is where the average ON time of the pulses varies proportionally to the modulating signal. The advantage of linear processing for application lies in the de-modulation. The modulating signal are recovered from PWM by low pass filtering. A single frequency sine wave as modulating signal modulating to width of a fixed frequency (fs) pulse train the spectra is as shown in Fig. 6A low pass filter can be extract modulating component fm.

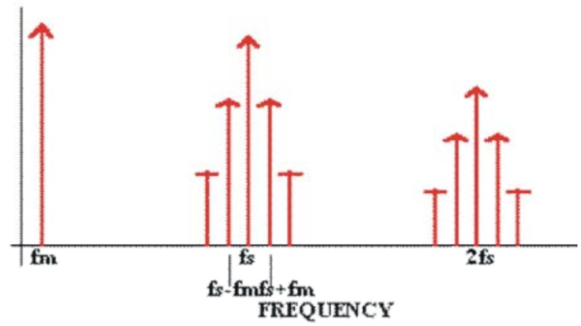


Fig. 6: Spectra of PWM

Saw Tooth PWM: The simplest analog form generating to fixed frequency PWM comparison with a linear slope waveform such as a saw tooth. The output signal goes to high when sine wave is higher than saw tooth. This is implemented using comparator whose outputvoltage are goes to HIGH when ne input is greater than the other.

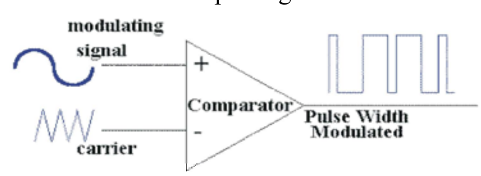


Fig. 7: Sine wave using Sawtooth PWM

In signals with straight edges can be used modulation for rising ramp carrier will generate PWM with Trailing Edge Modulation.

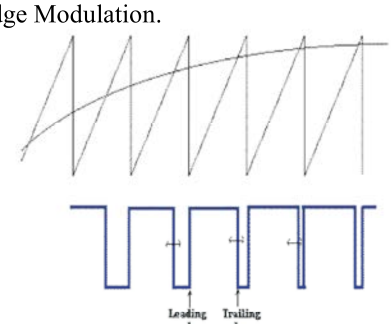


Fig. 8: Trailing Edge Modulation

It easier to integrator with reset to generate the ramp but modulation is inferior to double edge modulation.

Regular Sampled PWM: A switching edge at instant of crossing of the sine wave and the triangle. This is implemented using the analog electronics but suffers imprecision and drift of all analog computation as well as having difficulties to generating multiple edges when the signal has even a small added noise. Many modulators are implemented digitally is difficulty of computing the precise intercept of the modulating wave and the carrier. Regular sampled PWM width of pulse proportional to value of the modulating signal at the beginning of the carrier period. The intercept sample values are triangle determine the edges of the Pulses. A sawtooth wave of frequency fs the samples are at 2fs.

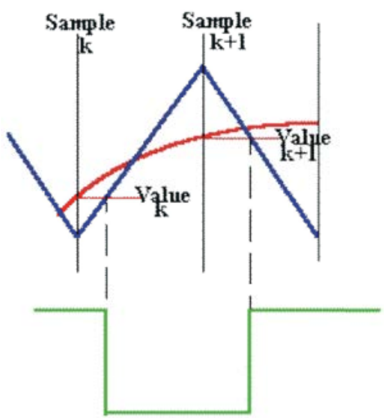


Fig. 9: Regular Sampled PWM

There are many ways for generate a Pulse Width Modulated signals are fixed frequency sine saw tooth. Three phase systems modulation are Voltage Source Inverter can be generate a PWM signal for each phase leg by comparison of the desired output voltage waveform for each phase with the same saw tooth. One alternative which is easier to implement computer and gives larger MODULATION DEPTH is using SPACE VECTOR MODULATION.

In recent years, industry begun to demand high power equipment, which reaches to megawatt level. Controlled AC drives in the megawatt range are usually connected to the medium-voltage network. To connect single power semi-conductor switch directly to medium voltage grids. Multilevel inverters has emerged for the solution for working with high voltage levels.

Multilevel inverters are power semiconductors and capacitor voltage sources, the output of which generates voltages stepped waveforms with less distortion, less switching frequency, higher efficiency, lower voltage devices and better electro-magnetic compatibility. The switches addition of the capacitor voltages are reach high voltages for the output, while the power semiconductors must withstand only reduced voltages. Multilevel inverter structures are developed to overcome shortcomings for solid-state switching device can be applied to higher voltage systems. The multilevel voltage source inverters unique structure allows to reach high voltages with low harmonics without use of transformers. The multilevel inverter is to synthesize desired AC voltage from several levels of DC voltages. The advent of transform less multilevel inverters topology brought forth various pulse width modulation (PWM) means to control the switching of the active devices in each of the multiple voltage levels in the inverter. Multilevel power conversion technology is rapidly growing area of power electronics with potential for further development. The most attractive solutionfor this technology medium-to-high-voltage range and includes motor drives, power distribution and power conditioning applications. The advantages of this approach summarized as follows:

- They can be generate output voltages with extremely low distortion and lower dv/dt.
- They draw input current with very low distortion.
- They are operate with a lower switching frequency.
- The efficiency is high (>98%) because of minimum switching frequency.
- They are suitable medium to high power applications.
- Multilevel waveform naturally limits large voltage transients

Applications of Multi Level inverters:

- High Power Applications.
- Whenever need sinusoidal supply, this type of inverter circuit can be implemented.
- To improve harmonic characteristics, a seven-level inverter could be modulated by multilevel carrier technique such as five-level carrier modulation.

Multilevel Inverter Performance: The three-phase converters is related to the maximum power. Which can be delivered to load, which is related to maximum voltage and

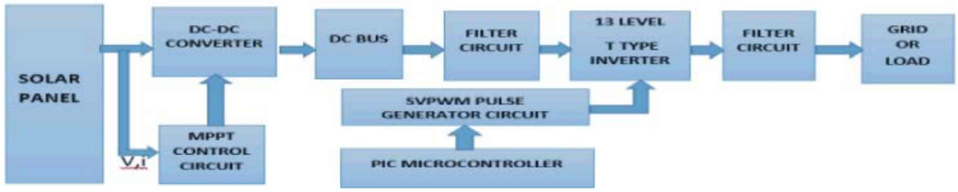


Fig. 10: Block diagram of 13 level T type multistate switching cell Inverter

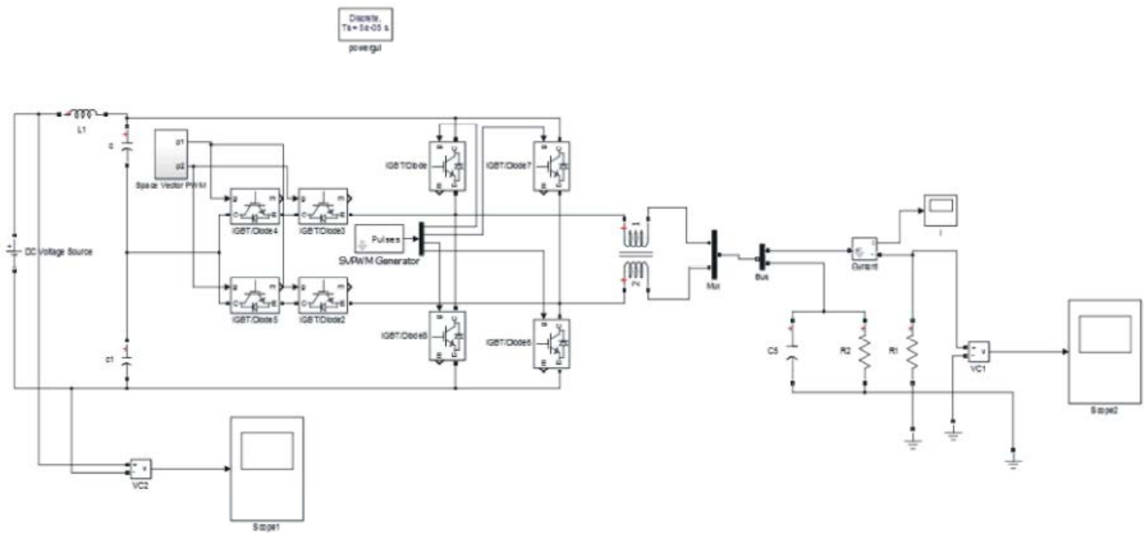


Fig. 11: Simulink Diagram

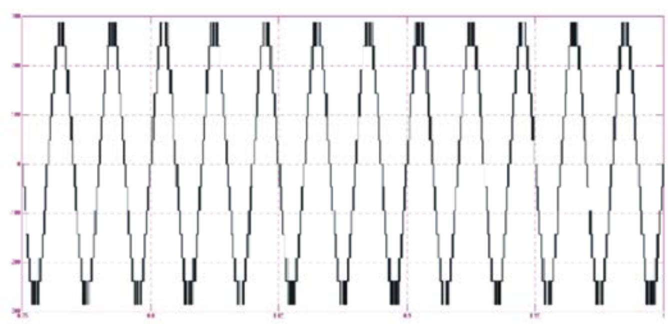


Fig. 12: Output for 13 Level Cascaded Inverter

current of a component. Furthermore, higher the power switch lower is the switching frequency. An initial solution to overcome this switches in series or in parallel. The series connection of more semiconductor devices is really difficult for impossibility to perfectly synchronize their commutations. In fact one component switches off faster than others it will blow up because it will be subjected to the entire voltage drop designed for the series. Instead of parallel connection is slightly less complicated for the property of MOSFETs and more recent IGBTs to increase their internal resistance with the increment of junction temperature. When switches on faster semiconductors block the entire dc voltage, but share load current. Several combinational designs are emerged some involving cascading fundamental topologies. These designs can create higher power quality for a given number of semiconductor devices than the fundamental topologies alone due to a multiplying effect for number of levels.

The main advantages are comes from halved commutation voltage reduces the switchinglosses compared to the two-level topology. The conduction losses are not change considerably. The voltagestress decreases the switches and the THD will improve by using the Space Vector Pulse WidthModulation than SPWM. Three level multilevel inverter had the advantages due to the cost it is notgot the market penetration. This three level T-type converter had the advantages of both two level VSC andThree level NPC so it's the best alternative for the existing three level multilevel inverter and two level VSC.

CONCLUSION

The proposed topology presents the presence of 13 levels output voltage before the filter lower harmonic and lower volume and weight of the magnetic components, reducing cost and volume of the converter. Furthermore 13Level T-Type-MSSC low conduction losses due to current sharing between the semiconductors devices. They are compared with multilevel inverters topologies. Finally 5 kW prototype are designed and built and experimental results are obtained. The results are demonstrated to high performance of propose converter. Due to its high performance, in proposed inverter is a competitive industrial applications in the field of low voltage and high power.

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