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Design of Multi-Level Inverter and Its Application As Statcom to Compensate Voltage Sags Due to Faults

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Abstract—Modern day power systems, power electronic devices are playing vital role in every aspect of the power system network. Among various devices multi-level inverters are the most efficient devices due to their Simple circuit configuration, reliability and cost effective implementation. Application of multi-level inverters along with STATCOM using SPWM (Sinusoidal Pulse Width Modulation) technique improves the operation & utilization of power system. Because STATCOM injects reactive component into the power system during large disturbances. This paper deals with 3-Φ to ground fault using RL load. All the results are studied through MATLAB Simulink.

Keywords— Multi-level inverter, SPWM strategy, STATCOM, Total Harmonic Distortion(THD).

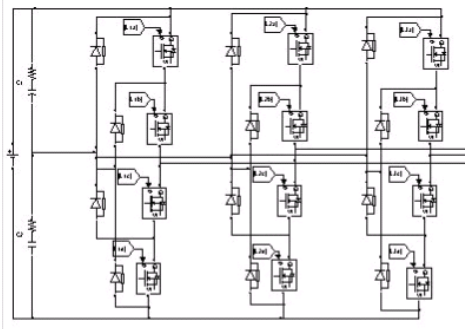
I. INTRODUCTION

Multi-level inverters are originally developed for medium voltage drive of ac motor. The technology is based on the composition of voltage waveform from dc voltage level. As the number of voltage levels increases, the output voltage waveform adds more steps and the output current waveform has the lower total harmonic distortion. Another major advantage of multi-level inverter is that their switching frequency can be lower than the conventional two-level inverter for the same Total Harmonic Distortion (THD) of the output voltage. In recent years, multi-level voltage-sources inverters have received more and more importance and attention in industrial applications and are widely used in different applications such as static power converter for high-power applications such as FACTS devices, HVDC converters etc. If static shunt devices are used in addition to this multi-level inverters, the performance of the network improves and the network can be utilize very effectively. One of the static devices which gives good support to the system under the disturbances is Static Compensator (STATCOM). The STATCOM is found more effective for large system Disturbances and it acts quickly to increase their injected current and thus provide the required reactive power. It is experimental that the STATCOM need to provide the reactive power to their full capacity only for a short period of time after the fault and provides a better option to improve short-term voltage instability problems.

The technique that is applied for the proposed multi-level inverter is Sinusoidal Pulse Width Modulation (SPWM). SPWM method is based on phase decomposition (PD) modulation technique is used which requires only one carrier signal. SPWM is better technique when we go for higher levels. By using the new SPWM strategy, effective time calculation and switching sequence selection are easily done like conventional two-level inverter. So in this dissertation work based on SPWM is designing for third & fifth levels. The advantage of multi-level inverters is that their switching frequency is less. Another major advantage of multi-level inverters are as the voltage levels increases, the output wave forms adds more steps and the output current waveform has low total harmonic distortion. In this paper, a simple SPWM method for three level, and five-level inverter and comparison of THD presented. Finally the proposed topology of multi-level inverter is verified by showing the feasibility through the simulation.

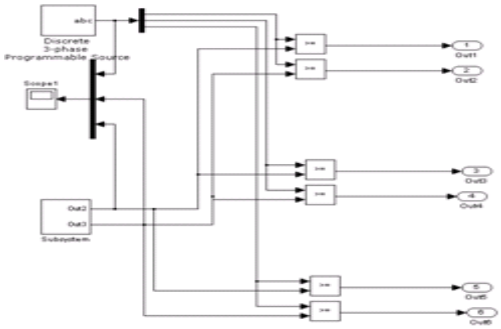
II. CONSTRUCTION OF PROPOSED MULTI-LEVEL INVERTER

(a) 3-Level multi-inverter:



Fig(1): 3-level Inverter construction circuit

The proposed three level inverter with RL load, which consists of voltage source inverter. The inverter model connected to the RL load is controlled to produce the staircase voltage and sinusoidal current. Three levels PWM based on constant carrier frequency for three level inverter system is proposed to reduce the harmonic contents in the output voltage and decrease the voltage rating of the power device.



Fig(2): SPWM generator circuit of 3-level inverter

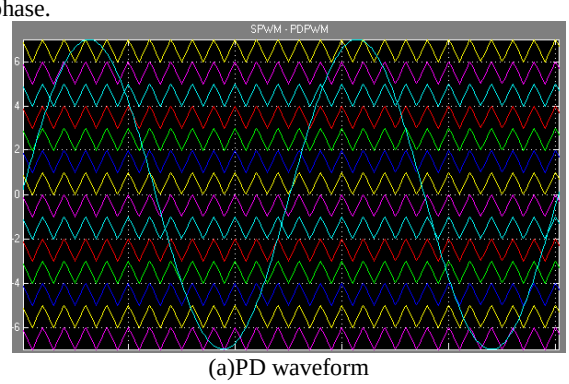
The output of the three level multi-inverter is observed by applying 3-phase-to-ground fault to the system having 50HZ, 400V rating by taking fault time as 0.1sec. Due to the widespread use of high-power switch devices, a lot of reactive and harmonics current are produced, which have a worse effect on electric power equipment. Now, a high-order harmonic current and reactive current compensation are crucial tasks that need to be settled urgently in power systems. STATCOM is an advanced static VAR compensator introduced in 1990. It is different from the conventional VAR compensators such as thyristor-switched capacitors (TSC), thyristor-switched reactors (TCR) and the mechanically switched capacitors. STATCOM is a static VAR compensator with no rotating parts, and is composed of new-generation high-power force-commutated semiconductor valve based inverters, DC capacitors and output transformers. Nowadays, most of the STATCOMs that have been in use at home and abroad are made up of multi-level inverters. In order to use this combination more effective, SPWM technique offers some advantages. One of the advantage is, it requires only one carrier signal because this is based on phase disposition modulation.

About Spwm Strategy

Low ratio of carrier frequency to modulation frequency is the best form of modulation for high power application, which is operating domain for multilevel inverter. For this purpose digital control of multilevel inverter using DSP/Microcontroller is preferred due to their dynamic controlling property. However DSP/Microcontroller based system uses symmetrical regular sampling, asymmetrical regular sampling or re-sampling technique .These sampling techniques either introduces delay in switching or requires dedicated controller .In this work a novel mathematical model of SPWM technique for multilevel inverter is presented which approaches the performance of traditional natural Sinusoidal Pulse width Modulation (SPWM). A single sinusoidal reference is compared with each carrier signal to determine the output voltage for the inverter. Three dispositions of the carrier signals are used to generate the pulse width modulation signal.

(1)Phase Disposition (PD):

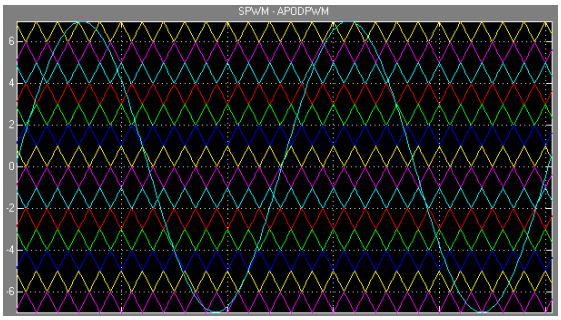
Where all carrier signals are in-phase.



(a)PD waveform

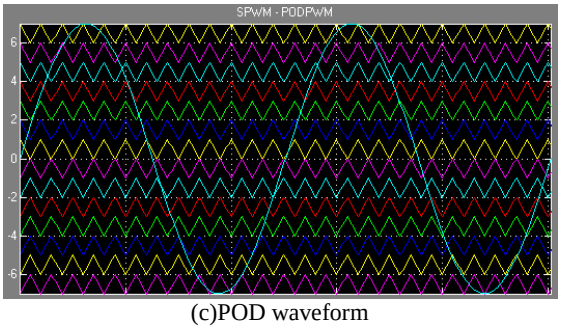
(2)Alternative phase opposition disposition (APOD):

Where each carrier is phase shifted by 180 degrees from its adjacent carrier.



(b)APOD waveform

(3)Phase Opposition disposition (POD):
Where the carriers above zero voltage are 180 degrees out of phase with those below zero voltage.



(c)POD waveform

The SPWM technology corrects the output voltage according to the value of the load by changing the Width of the switching frequency in the oscillator section. As a result of this, the AC voltage from the Inverter changes depending on the width of the switching pulse. To achieve this effect, the SPWM Inverter has a SPWM controller IC which takes a part of output through a feedback loop. The PWM controller in the Inverter will makes corrections in the pulse width of the switching pulse based on the feedback voltage. This will cancel the changes in the output voltage and the Inverter will give a steady output voltage irrespective of the load characteristics.

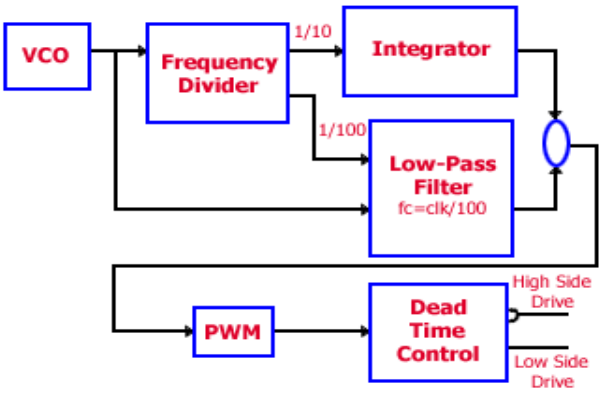


Fig (3): Block Diagram of PWM

(b) Five-Level multi-inverter:

The construction and working of both 3 & 5 level inverters are same except the number of increased levels. Fig(4) shows the SPWM generator circuit for 5-level inverter. As the number of levels increases THD will decrease and give the same output voltage of conventional multi-level inverter, as the rated current and number of conduction devices are same. So the conduction loss is also same as STATCOM provides further requirements to the network. Fig(4) shows the general simplified circuit of SPWM generator circuit.

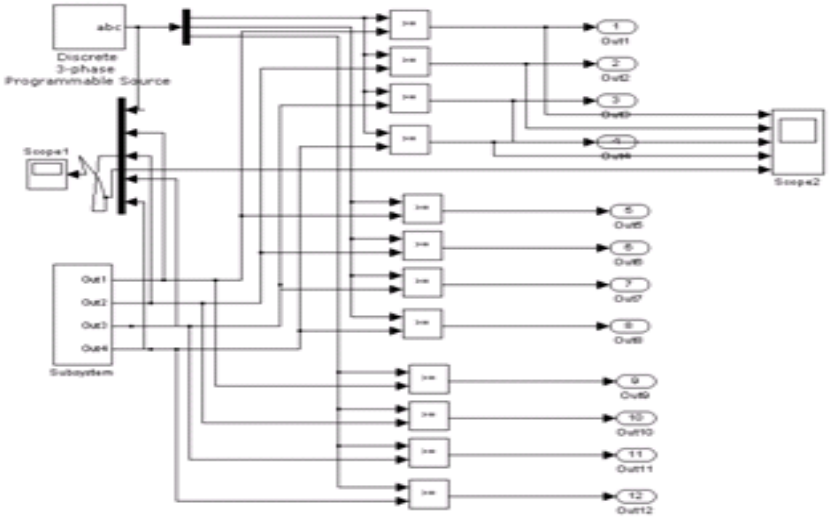


Fig (4): SPWM generator circuit of 5-level inverter

III. MATLAB SIMULATION

Construction of multi-level inverter using SPWM is a very simple technique for harmonic reduction. In this technique pulse magnitude will be constant and only pulse time (width) can be changed. In this pure sine wave is compared with carrier (triangular) wave and producing gate pulses. Sine wave has fundamental frequency and carrier wave can be taken more than fundamental frequency.

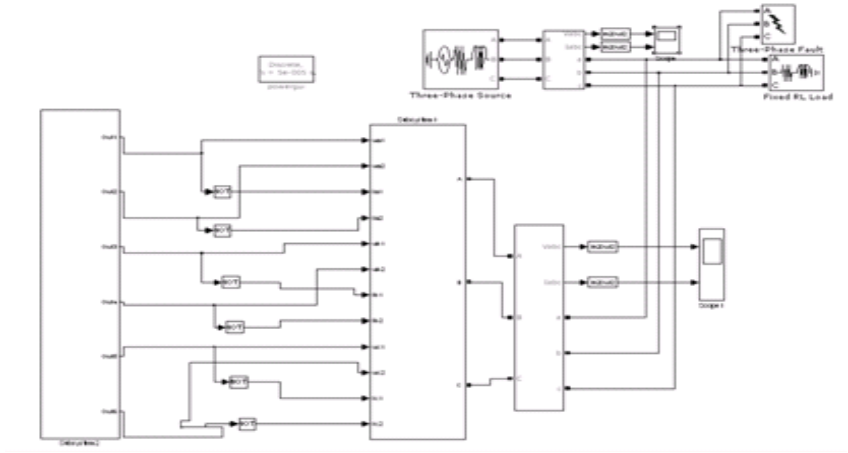


Fig (5): Simulation Circuit of 3-level inverter with SPWM technique.

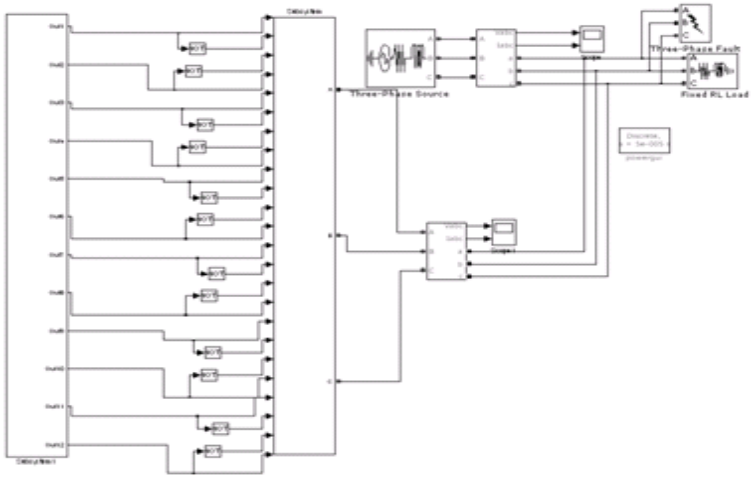
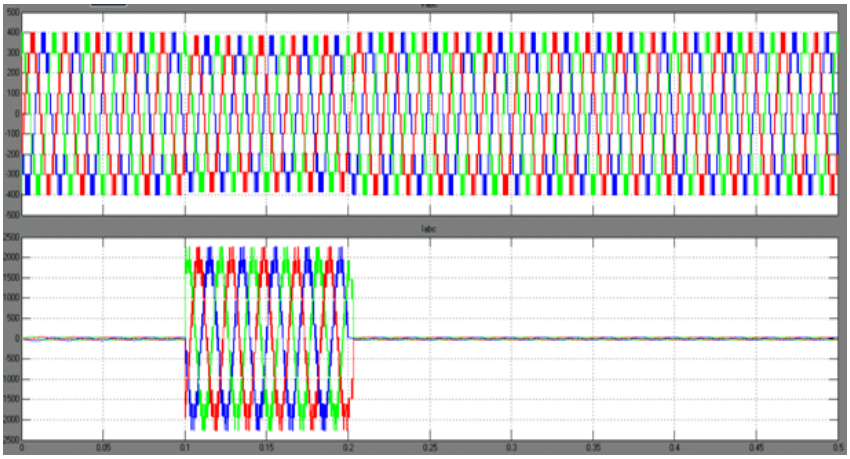
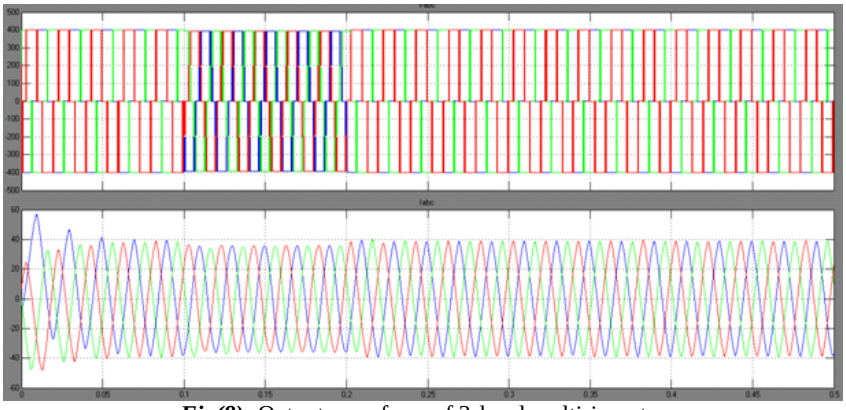


Fig (6): Simulink model of 5-level inverter

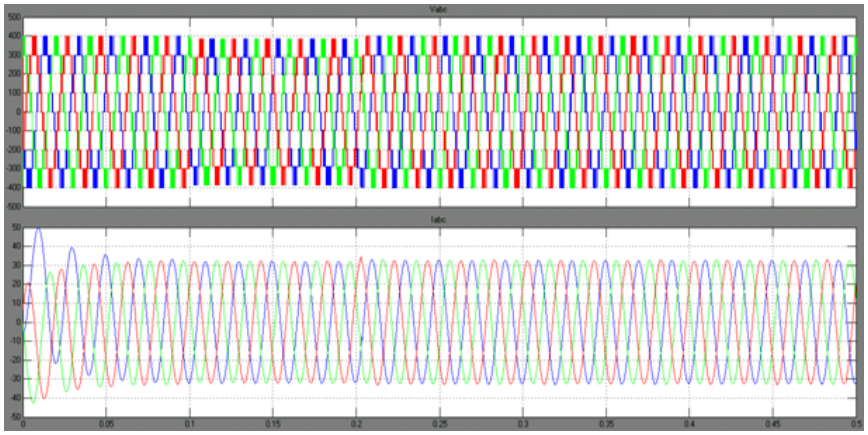
IV. SIMULATION RESULTS



Fig(7): Volatage & current across STATCOM during fault



Fig(8): Output waveform of 3-level multi-inverter



Fig(9): Output voltage of the 5-level inverter

Fig(7) shows the output voltage and current waveforms across the STATCOM. And it shows how STATCOM injects reactive power into the network under the fault conditions. Fig(8) and Fig(9) shows the output voltage and current waveforms of the 3-level and 5-level inverters. Switching devices in the proposed multi-level inverter are synchronized with reference signal of the output voltage. Therefore the voltage distortion and switching loss is very small.

The configuration of the circuit is simple because the PWM signal is generated by using only one carrier signal and the switching devices used in the circuit are less. Thus the reliability of the proposed system is high and the price of making can be small.

By comparing the 3 & 5 level multi-inverter output wave forms as the number of voltage levels increases the output voltage waveform adds more steps and the output current waveform has the lower total harmonic distortion(THD) and the efficiency is also increased.

V. CONCLUSION

This paper proposed a new multi-level inverter topology using phase disposition with SPWM technique. The performances of two multilevel inverter topologies have been analyzed. Multicarrier SPWM with PD techniques has been applied to these inverters and their control effects have been investigated.

The simulation of the inverters namely conventional three and five level inverter was carried using sinusoidal pulse width modulation (SPWM) .It has shown that decrease in voltage and current THD in moving from three level inverter to five level inverter. This paper briefly explains theory of sinusoidal pulse width modulation (SPWM) for three and five level inverter and performance of both inverters was tested using RL load. It has shown that load current for five level inverter are much more sinusoidal and improvement in the line current waveform and decrease in the THD from three level to five level inverter and decrease in the THD as the frequency is increased.

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