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SOP-Based Hybrid H-Bridge Nine Level Inverter Using PI Controller

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Abstract

This paper over observed the medium-voltage (MV) multilevel converters with an emphasis on attaining less harmonic distortion and worthy effectiveness at low switching frequency operation. Generating of gate signals for hybrid cascaded multilevel inverter at low switching frequency using Synchronous Optimal Pulse width Modulation technique. The PI controller controls the output voltage of nine levels MLI by manipulating the modulation index of gate driver circuit. In proposed inverter the number of DC sources in cascaded hybrid MLI is reduced by incorporating of diodes and capacitors. This hybrid cascaded multilevel inverter allows operation at multiple of dc-link voltage and reduce the total harmonic distortion (THD). Low switching frequency reduces the switching losses of the power semiconductor devices.

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INTRODUCTION

Inverters are o used to provide power to electronics devices in the case of a power outage or for activities such as camping, where no power is available. The inverter converts a direct current (DC) or battery power into an alternating current (AC) or household power. The lot of industrial applications require high power apparatus in recent years. Some of the medium and high voltage motor drives, utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is problem to connect only one power semiconductor switch directly. As a result multilevel inverter structure has brought in for high power and medium voltage application. A multilevel inverter not only achieves high power ratings and also enables to use in on renewable energy sources. Renewable energy sources such as photovoltaic, wind and fuel cells are easily interfaced with the multilevel converter system for a high power application.

The concept of multilevel inverters brought in since 1975.[1] The term multilevel commenced with the three level inverters.[2] Afterwards, several multilevel inverter topologies have been formulated. However, the elementary concept of a multilevel inverter is used to achieve higher power by use a series of power semiconductor switches with several dc voltage sources to perform the power changeover by synthesizing a staircase voltage waveform.

Renewable sources like solar, wind mills, batteries, capacitors are used as an multiple dc sources in order that achieved expected voltage, nevertheless, the valued voltage of the semiconductor devices depends only upon the rating of the dc voltage sources connected to it. A multilevel inverter is a more powerful inverter than ordinary standard inverter except gives energy in higher power application.[3] Inverters converts DC power into AC power through waves called sine waves or modified sine waves.

The sine waves are pure and they have less extent in harmonics, but Modified sine waves are made to imitate sine waves. Inverters with modified sine waves work good for backup power in houses and that are less expensive. Though there are several types of inverters used only less switch, or in other words, less power circuit.[4]

Dislike standard inverters, renewable resources, Wind mills, fuel cells and photovoltaic energy are used to a multilevel power inverter as DC sources. These energy sources can be converted into AC currents by switching of power devices. However, multilevel inverters are able to produce large amounts of energy, the amount of energy acquired is depend upon amount DC power is being used. The Connecting of higher sources as DC power will give more potent AC power. A Multilevel power inverter system is an easier solution than being given direct power lines for different voltages.[5]

Three common structures of multilevel inverters[6]:

- Neutral Point Clamped (NPC)
- Cascaded H-Bridge(CHB)
- Flying Capacitor (FC)

PROPOSED MULTILEVEL TOPOLOGY

To reduce the number of separate DC sources for high-voltage, high-power applications with multilevel converters, diode-clamped or capacitor-clamped converters could be used to replace the full-bridge cell in a cascaded converter. An example is shown in Figure 1. The nine-level cascade converter incorporates a three-level diode-clamped converter as the cell. The original cascaded H-bridge multilevel converter requires four separate DC sources for one phase leg and twelve for a three-phase converter. If a five-level converter replaces the full-bridge cell, the voltage level is effectively doubled for each cell. Thus, to achieve the same nine voltage levels for each phase, only two separate DC sources are needed for one phase leg and six for a three-phase converter. The configuration has mixed-level hybrid multilevel units because it embeds multilevel cells as the building block of the cascade converter. The advantage of the topology is it needs less separate DC sources.[7–15]

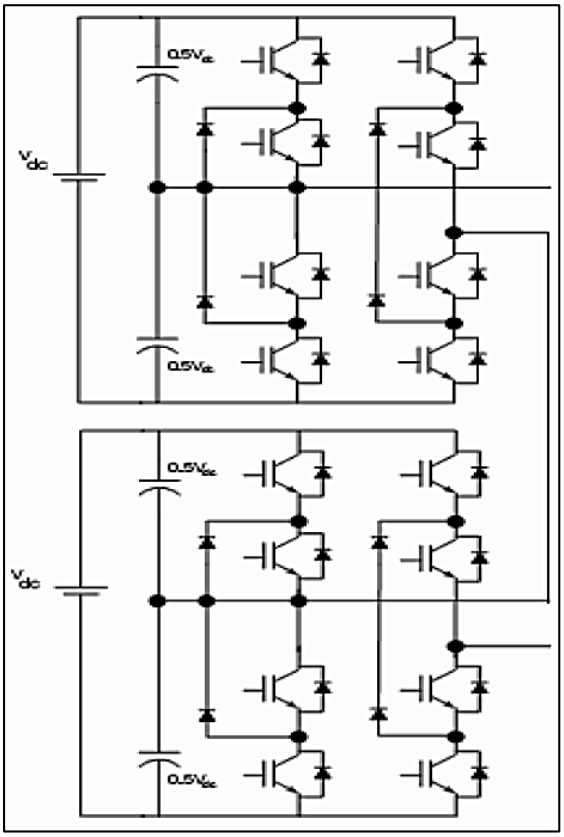

Fig. 1. *Nine Level Hybrid Cascaded Multilevel Inverter.*

SYNCHRONOUS OPTIMAL PULSE WIDTH MODULATION (SOP)

SOP produces best switching pulse configurations of semiconductor devices in a multilevel inverter. Synchronized PWM is used in low-switching frequency applications where carrier signal at frequency (f_s) and sinusoidal control signal at frequency (f_1) are synchronized with each other, i.e., f_s/f_1 is an integer in order to eliminate sub harmonic frequencies which are undesirable in many applications. Synchronized PWM

results in lower number of switching instants per fundamental period and even a little variation in these switching angle values will have considerable influence on the harmonic distortion of output voltage.[16]

Modulation index ma= A_m/KA_c

where Am is the amplitude of reference signal, Ac the amplitude of carrier signal, k the no of carrier signal and Ma<1 is for the proposed topology modulation index.

PI CONTROLLER

In automate process, the "feedback loop" is closed and an error signal (+ or –) is obtained. The PI controller acts upon the error with parallel proportional and integral and make attempt to drive the error to zero. Let αVo be a scaled down replica of Vo. When αVo equals Vset then the error is zero.
The operation of PI controller is shown in Figure 2.[17]

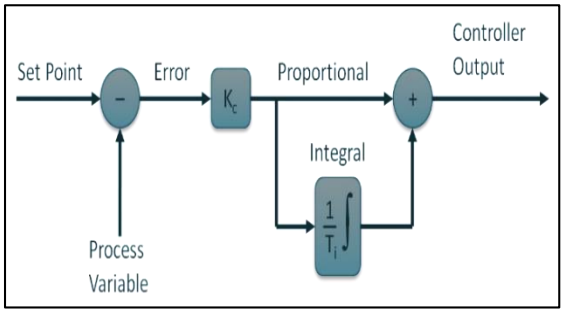

Fig. 2. *Block Diagram of PI Controller.*

BLOCK DIAGRAM OF PROPOSED METHOD

The structure of hybrid cascaded multilevel inverter in closed loop with PI controller is shown in Figure 3.

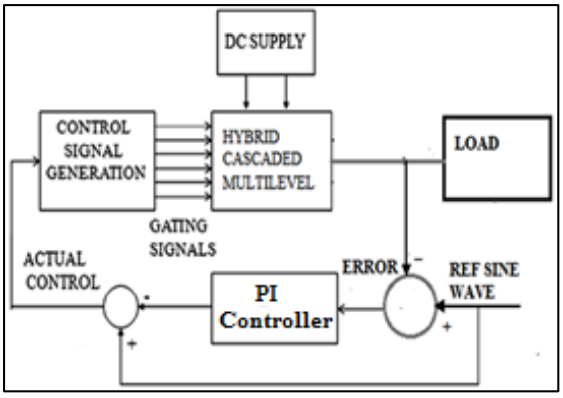

Fig. 3. *Overall Block Diagram of Proposed Method.*

The PI controller which is used to generate the PWM reference signal for switches in multilevel inverter.

The gate signal for MLI is generated by using the control signal generation circuit.

The pulse from pulse generator is controlled by modulation index. Modulation index is the output of PI controller. The comparator compared the output voltage of hybrid cascaded MLI to the reference voltage and the error was given to the PI controlled.

SIMULATION RESULT

Hybrid cascaded MLI structure for single phase is shown in Figure 4.

The output of each H-Bridge contains five-levels and thus it is possible to obtain nine-level waveforms in each phase. Each phase requires two dc power sources.

The output of inverter is directly connected to inductance load with a LC filter.

The magnitude of each phase DC source used in designing nine level MLI is 400V and the value of capacitor is 270 μf.[18]

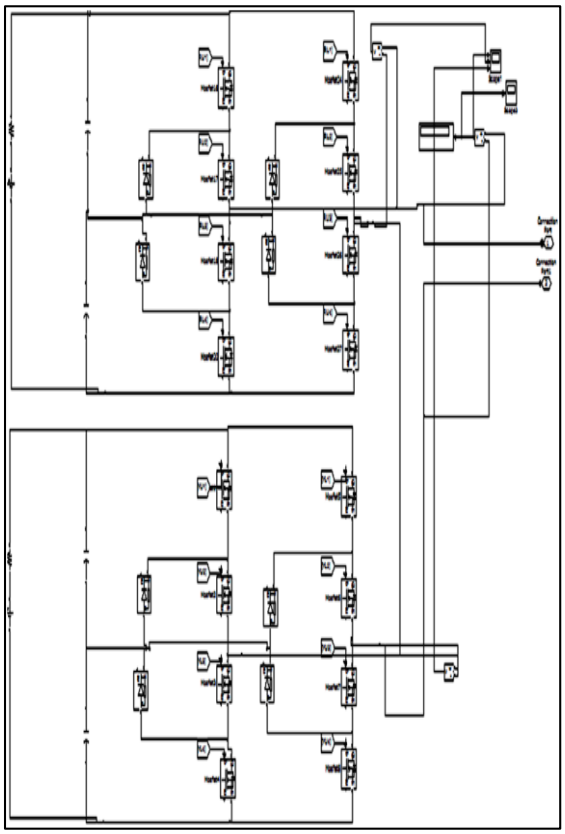

Fig. 4. *Single Phase Nine Level Structure.*

The output single phase nine level MLI is shown in Figure 5. For positive and negative half cycle (800, 600, 400, 200, 0, –200, 400, 600, 800 V) the stair case output is generated.

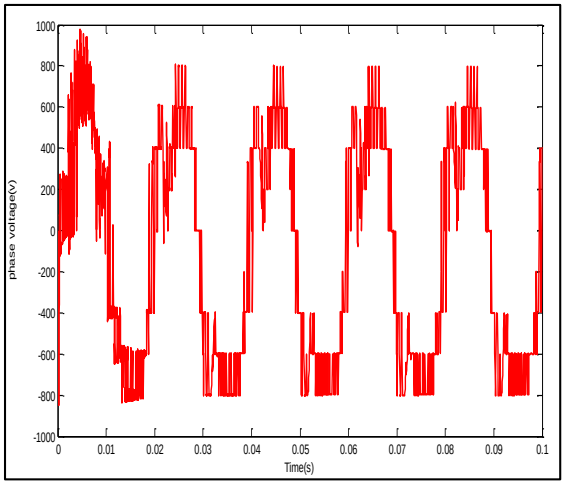

Fig. 5. *Nine Level Output.*

Figure 6 shows the Simulink block diagram of overall hybrid cascaded MLI.

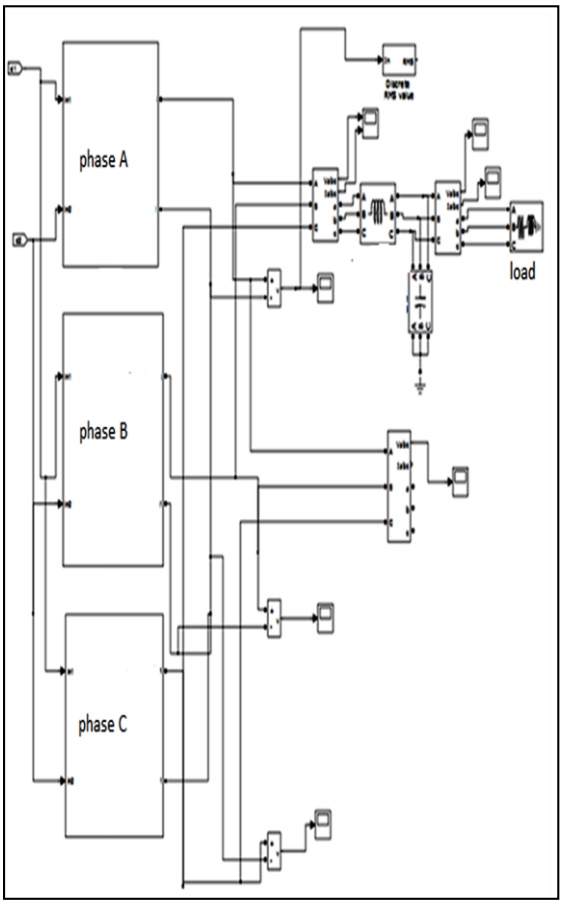

Fig. 6. *Overall Three Phase MLI Structure.*

The load voltage, current and FFT Analysis for nine level inverter without filter and controller is shown in Figures 7–10.

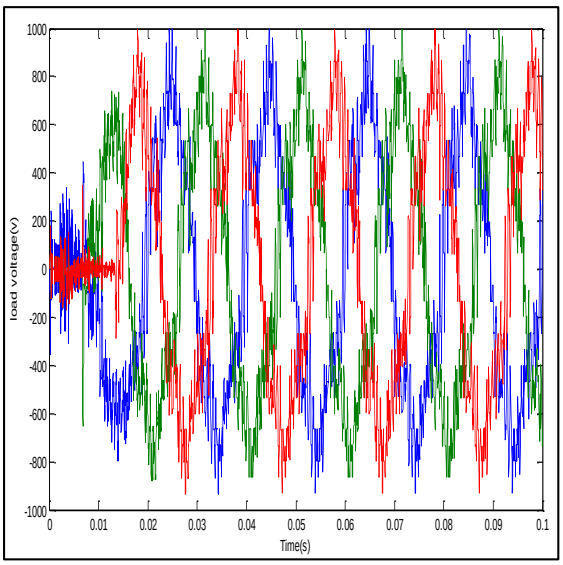

Fig. 7. *Load Voltage of Nine Level Inverter without Filter and Controller.*

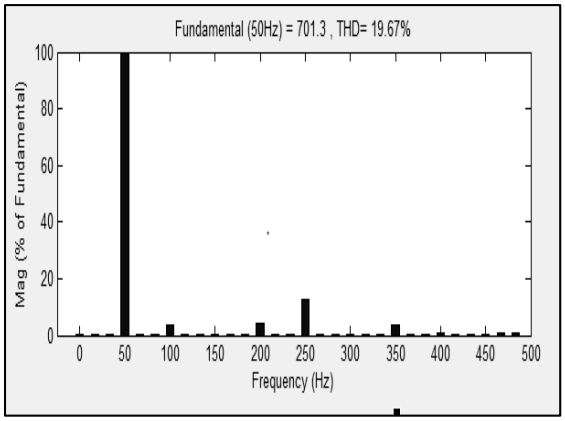

Fig. 8. *FFT Analysis of Load Voltage without Filter and Controller.*

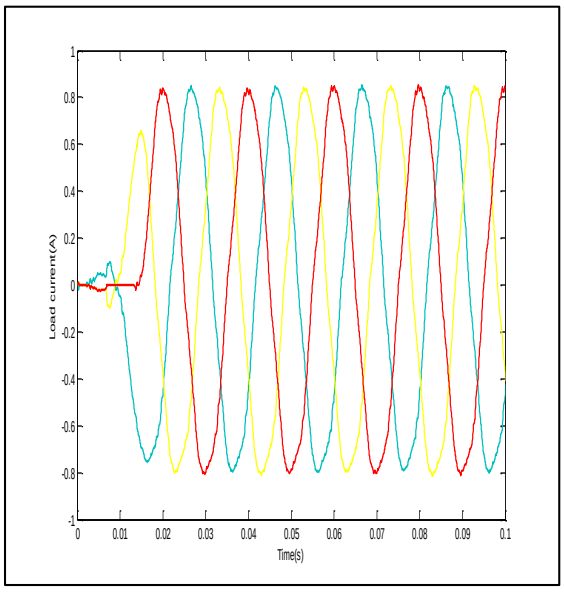

Fig. 9. *Load Current of Nine Level Inverter without Filter and Controller.*

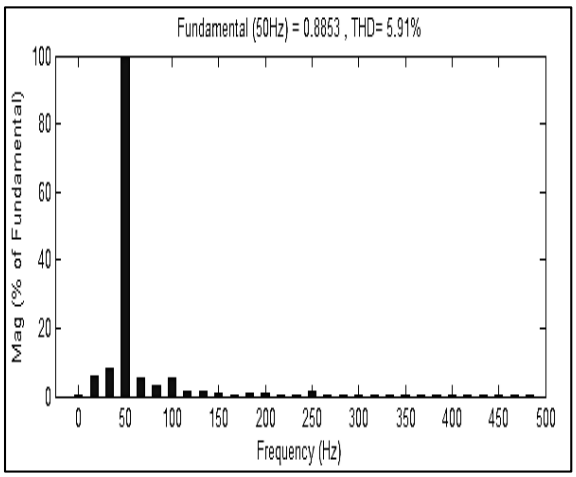

Fig. 10. *FFT Analysis for Load Current without Filter and Controller.*

CONTROL OF HYBRID CASCADED MLI

The PI tuning is used to test and evaluate the proposed PI controller. The tuning is mainly depends on proportional (k_p) and integral (k_i) gain in PI command window. The Simulink model for PI controller is shown in Figure 11.

The output voltage of the inverter is compared with the reference sinusoidal waveform to compute the error. The error is given as input to the PI controller. The output obtained from the PI controller is again compared with the reference sinusoidal waveform to get the required duty cycle (sine wave).[19]

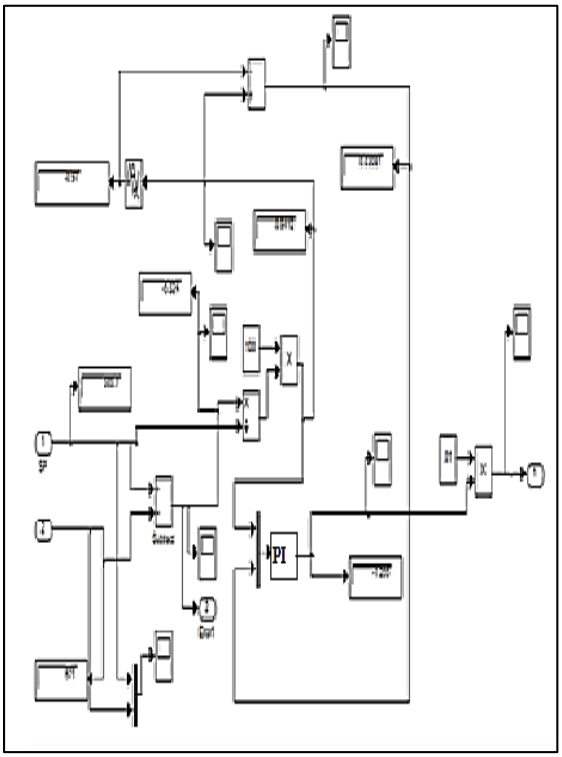

Fig. 11. *Simulation of PI Controller.*

The output of three phase MLI is a sinusoidal wave with peak output voltage of 800 V, where the RMS value equal 565.9 V and the output frequency 50 Hz. It can be observed that the PI controller has resulted in better output current and voltage for the inductive load as shown in Figures 12 and 13, respectively.

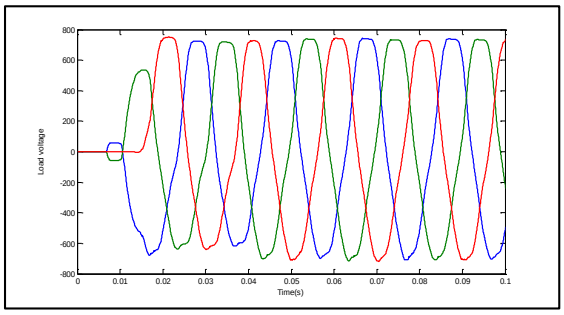

Fig. 12. *Load Voltage of Nine Level Inverter with Filter and Controller.*

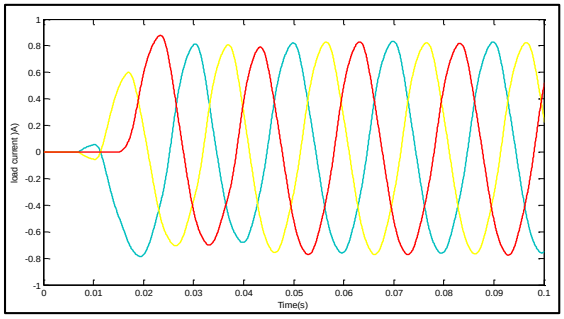

Fig. 13. *Load Current of Nine Level Inverter With Filter and Controller.*

The corresponding frequency spectrum of the output voltage and current shown in Figures 14 and 15, respectively.

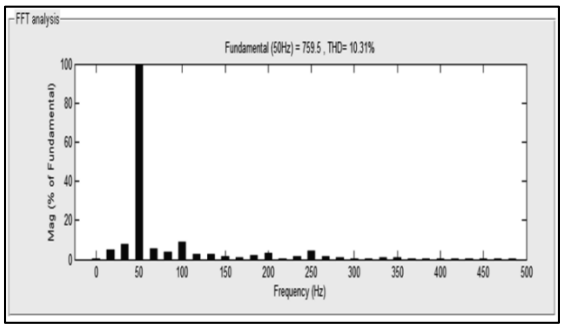

Fig. 14. *FFT Analysis of Load Voltage with Filter and Controller.*

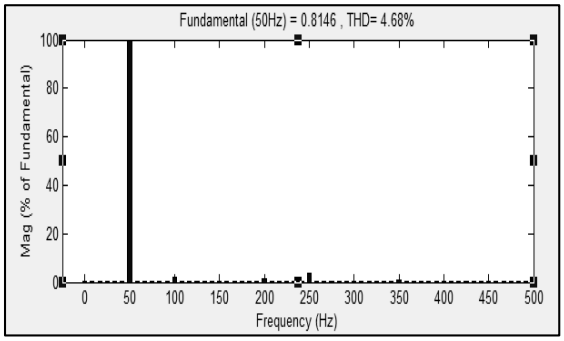

Fig. 15. *FFT Analysis of Load Current with Filter and Controller.*

CONCLUSIONS

Recently, inverters play an important role in various renewable energy applications and drives.

Much progress has been made in successfully applying PI in industrial control systems.

PI techniques represent means of both collecting mathematical analysis and dealing with uncertainties in the process of control.

The following points are accomplished[20–22]:

- Employing SOP for the control of medium voltage inverter reduces the harmonic content of the generated waveform.
- It enables operation at low switching frequency.
- This reduces the switching losses of the power semiconductor switches.
- Reducing the switching losses permits one to increase the output of a given inverter.

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