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SOLAR PV SYSTEM WITH MULTI-LEVEL INVERTER USING PI AND FUZZY LOGIC CONTROLLER

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ABSTRACT

This paper presents a single-phase multi-string Nine-level PV inverter topology for grid-connected photovoltaic (PV) systems with a novel PWM control and fuzzy logic scheme. The Multilevel inverters are extensively used due to their increased power rating reduced EMI, improving harmonic performance. Multilevel inverters are switched at low switching frequency when compared to two level inverters, a single-phase multi-string nine-level PV inverter topology for grid-connected photovoltaic (PV) systems using novel PWM control Technology.

A photovoltaic (PV) system generates electricity by direct conversion. The PV strings are cascaded together in parallel configuration and connected to a Nine-level inverter to generate output voltage. Two reference sinusoidal signals are identical to each other with an offset equivalent to the amplitude of the triangular carrier signal were used to generate gate signals for the nine level inverter switches and it is to implement this PWM using PI current control algorithm. The proposed nine level inverter offers much less THD and can operate at near unity power factor. the frequency of it will be 50Hz and from the result we minimizes the number of components and devices as well as switching losses are reduced when compared to the conventional multilevel inverter topology and its interconnects for grid utilization. Fuzzy Logic Control (FLC), originating from control theory focused on mathematical representations of the open-loop mechanism to be controlled, is an integral aspect of fuzzy reasoning. Fuzzy Logic Control has been successfully extended to a wide range of practical issues, including warm water control, robot control, heat exchange, traffic junction control, cement kiln control, vehicle speed control, automotive engineering, and mcar parking and turning, power system and nuclear reactor, on-line shopping, washing machines, etc. The validity of the proposed inverter is verified through simulation andcompared with other technique. The output voltage will be in the form of stepped waveform. The proposed system produces less THD and reduction of steady state time

KEYWORDS –*Maximum Power Point Tracking(MPPT) algorithm, Boost Converter, FLC contreoller, PWM technique.*

I. INTRODUCTION

In current scenario, the Multi- level inverters are extensively used due to their increased power rating reduced EMI, improving harmonic performance. Multilevel inverters are switched at low switching frequency when compared to two level inverters, a single-phase multi-string Nine-level PV inverter topology for grid-connected photovoltaic (PV) systems using Fuzzy Logic Controller (FLC).To generate a pure sinusoidal output voltage and low total harmonic distortion (THD) Inverter output current.

In case of a two-level inverter, the switching frequency should be having high inductance in the output filter inductor recommended to satisfy the required THD, hence multi-level inverters (MUs) are introduced for grid connected inverter[3-5]. Multi-level inverters are classified into 3 types are diode clamped multi-level inverter, cascaded H bridge multi-level inverter, flying capacitor type multi-level inverter.

The applications of multilevel inverter are reactive power compensation, variable speed drives etc. The topological structure of Multi level inverters should be capable of withstanding high input voltage for high power applications. A new multi- level inverter is proposed which is capable of reducing problems faced by usage of conventional multi -level inverters.

Recent advances in power electronics with PI Controller and Fuzzy logic controller have made the multilevel concept practical. In fact, the concept is so advantageous that several major drives manufacturers have obtained recent patents on multilevel power converters and associated switching techniques. The database of a rule-based system may contain imprecisions which appear in the description of the rules given by the expert. Because such an inference cannot be made by

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the methods which use classical two valued logic or many valued logic, Zadeh in (Zadeh, 1975) and Mamdani in (Mamdani, 1977) suggested an inference rule called "compositional rule of inference". Using this inference rule, several methods for fuzzy reasoning were proposed. Zadeh (Zadeh, 1979) extends the traditional Modus Ponens rule in order to work with fuzzy sets, obtaining the Generalized Modus Ponens (GMP) rule.

The certain class of FLC systems is universal approximators: they are capable of approximating any real continuous function on a compact set to arbitrary accuracy. This class is characterized by

- Gaussian membership functions,
- Product fuzzy conjunction,
- Product fuzzy implication,
- Center of area defuzzification

II. PHOTO VOLTAIC CELL

PV cells are generally semiconducting diode. This semiconductor diode have p-n junction which is exposed to light. When illuminated by sunlight it generates electric power. PV cell are made up of various semiconductor materials. But mono-crystalline silicon and poly-crystalline silicon are mainly used.

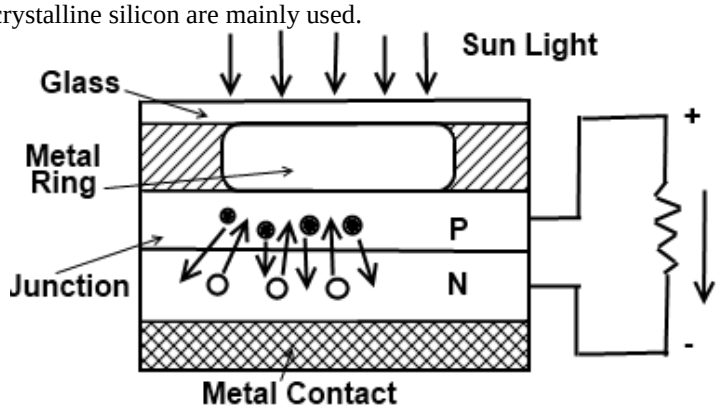

Fig. 1 PV Cells

The photo voltaic array is developed by the basic equations of photovoltaic cells. The photo voltaic cell output voltage is expressed as

$V_C = \frac{AKTc}{e} in\left(I_{ph} + I_0 - I_C\right) - R_S I_C$(1.1)

$V_{pv} = V_C * N_S$ (1.2)

$I_C = \frac{I_{pv}}{N_p}$(1.3)

$C_{Tv} = 1 + \beta_T T_a - T_y$(1.4)

$C_{T1} = 1 + \frac{\gamma T}{Sr} T_y - T_a$(1.5)

Where

b_T - slope of the coefficient.

C_T - Solar irradiation levels on photo voltaic cell voltage and current.

T_a&T_y- Ambient temperature of the cell.

S_c - Benchmark reference solar irradiation level during cell testing.

S_r -Reference solar irradiation level.

S_x-slope of the change in the solar irradiation level.

I_{ph}- Photo Current.

V_c- Cell Output Voltage.

α =Voltage Coefficient.

β =Current Coefficient.

γ = power Coefficient.

Where,

b_T = 0.004 and cT = 0.006. These two parameters are used to scale the effects of high temperature and solar irradiation levels on photo voltaic cell voltage and current.

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III. PROPOSED SYSTEM SCHEMATIC DIAGRAM

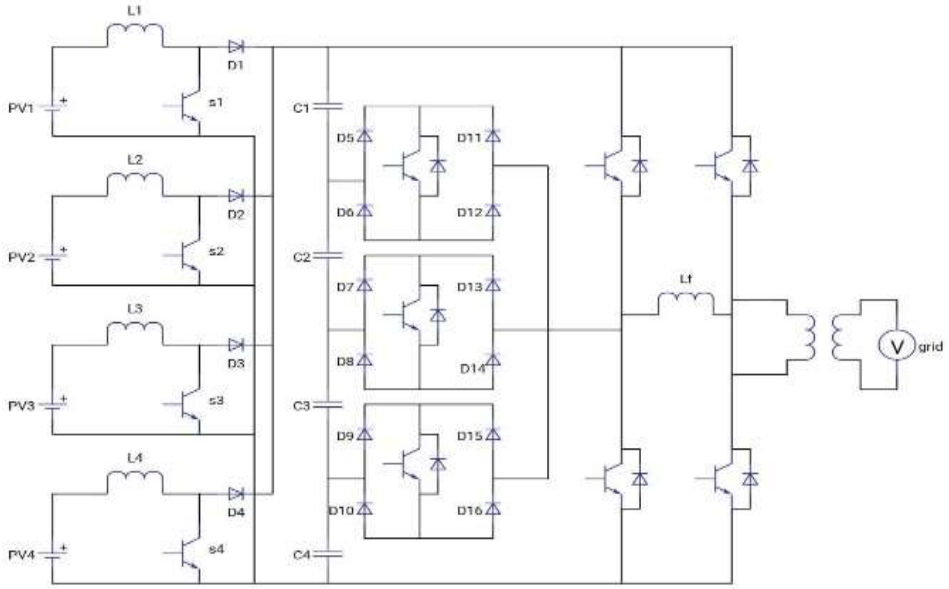

Fig. 2proposed Multi-String Nine Level schematic diagram

This paper mainly focused on the design and implementation of new topology of a PV source with MNLI inverter by using PI Current Control unit.The total harmonic distortion and enhances the output voltages for proposed work of MNLI inverter.

A. PV STRINGS

The power produced by a single PV cell is not enough for general use. So by connecting many single PV cell in series (for high voltage requirement) and in parallel (for high current requirement) can get us the desired power.
Generally a series connection is chosen this set of arrangement is known as a module. Generally commercial modules consist of 36 or 72 cells. The modules consist of transparent front side, encapsulated PV cell and back side. The front side material is usually made up of low-iron and tempered glass. The efficiency of a PV module is less than a PV cell. This is due to the fact that some radiation is reflected by the glass cover and frame shadowing etc.

B. MPPT ALGORITHM

Usually manufacturers provide these parameters in their datasheets for a particular PV cell or module. By using these parameters we can build a simple model but for more information is required for designing an accurate model. The characteristics of PV Cell and PV Characteristics With MPPT are given in Figure 3.3, 3.4 and 3.5

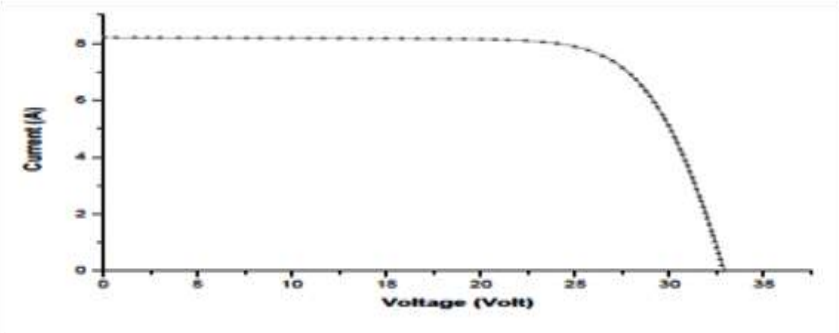

Figure 3 Characteristics of a PV cell

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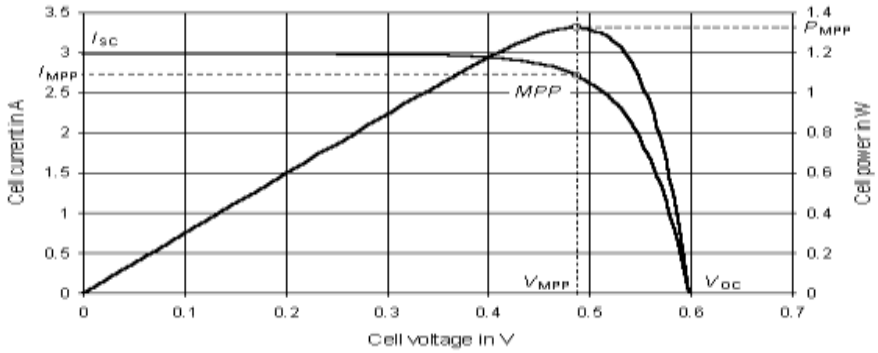

Figure 4 PV characteristics of Solar Cell

Perturb & Observe (P&O) is the simplest method and use only one sensor, that is the voltage sensor, to sense the PV array voltage and so the cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing on both the directions. When this happens the algorithm has reached very close to the MPP and we can set an appropriate error limit or can use a wait function which ends up increasing the time complexity of the algorithm.

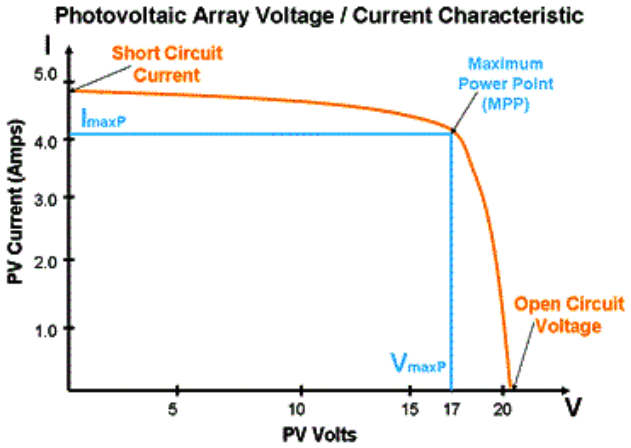

Figure 5 PV Characteristics With MPPT

However the method does not take account of the rapid change of irradiation level (due to which MPPT changes) and considers it as a change in MPP due to perturbation and ends up calculating the wrong MPPT. To avoid this problem we can use incremental conductance method

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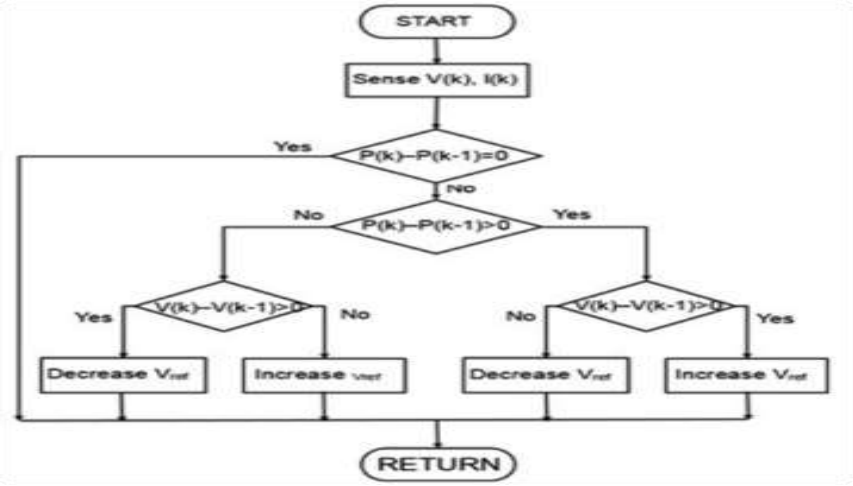

Fig. 6 proposed schematic diagram

C. CONTROL STRATEGY-PWM

The optimized carrier-based phase disposition (PD) PWM method is employed as the control strategy for the proposed converter, as depicted .

Four groups of triangle carriers with same frequency $f_c$and amplitude U_c, which are represented as U_a, U_b, $U_c$and $U_d$respectively, are disposed as upper and lower four layers. And they are symmetrically distributed in two-side of the horizontal axis, comparing with a sine modulation wave.

Assuming carrier amplitude value of UC and its frequency f_c, modulation wave expression of $uS = US \cdot sin\alpha$,

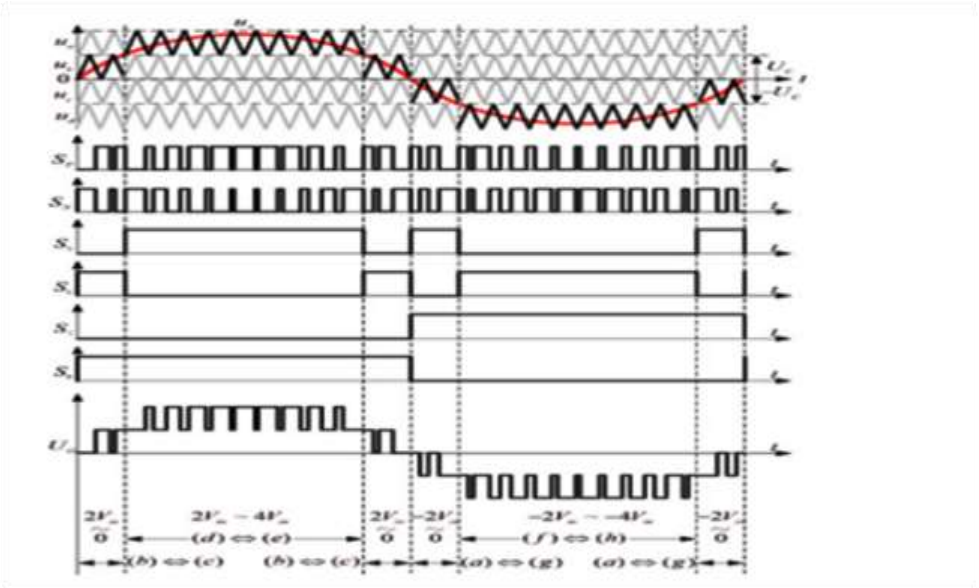

Fig. 7 The Optimized Carrier-Based PD PWM Method

where α is phase angle with value of 2πfs and $f_s$means the frequency of modulation wave, and its amplitude value.

D. FUZZY LOGIC CONTROLLER DESIGN

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The control parameters of traditional controllers such as P, PI, and PID are set at the time of design. As a result, traditional controllers are only effective for linear systems. As the system's operating point is modified, the parameters of traditional controls must be redesigned, and certain trials and previous system knowledge are used to construct the parameters of the conventional controllers should be designed again, and some trials and prior information of the systems are needed to design the parameters.

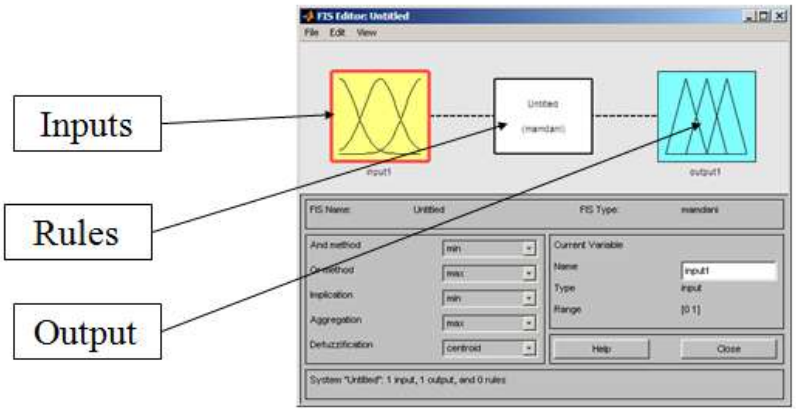

Fig 8 Basic of Fuzzy Logic Controllers

The FLC is used to overcome the drawbacks of the conventional controllers. The control structure of the proposed DVR with FLC is shown in Figure

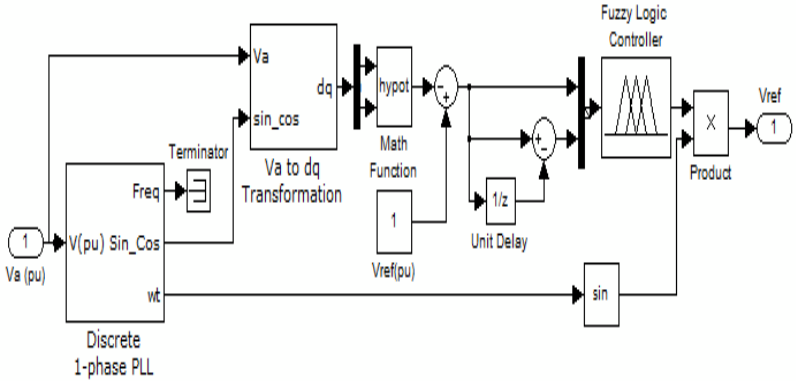

Fig 9 Fuzzy Controller

In the proposed method, discrete single phase PLL is used to track the phase angle of the source voltage and generates a reference signal with a magnitude of unity, locked to supply frequency. The supply voltage is converted into p.u. The p.u value of supply voltage is converted into |Vs| through d-q transformation, and error is obtained from the difference of |Vs| and reference value (V_{ref} (pu)).

Error and change in error are the inputs of FLC. The output of FLC is used to generate the V_{ref}. The V_{ref} in p.u. is fed to the Sinusoidal Pulse Width Modulation (SPWM) generator to produce switching pulses for VSI. The basic idea of SPWM is to compare a sinusoidal control signal (V_{ref}) of normal frequency 50 Hz with a triangular carrier waveform ($V_{carrier}$) with 1080 Hz signal to produce the PWM pulses. When the control signal is greater than the carrier signal, the switches turned on, and their counter switches are turned off. The output voltage of the inverter mitigates the sag, swell and outage.

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E. FUZZY MEMBERSHIP FUNCTIONS

The fuzzy set is a powerful tool and allows us to represent objects or members in a vague or ambiguous way. The fuzzy set also provides a way that is similar to a human being's concepts and thought process. However, just the fuzzy set itself cannot lead to any useful and practical products until the fuzzy inference process is applied. To implement fuzzy inference to a real product or to solve an actual problem, as we discussed before, three consecutive steps are needed, which are: Fuzzification, fuzzy inference and defuzzification.

The membership functions of the error and change in error inputs and output variables are shown in Figs.5.4, 5.5 and 5.6. The membership functions are triangular shaped with 50% overlap for a precise control.

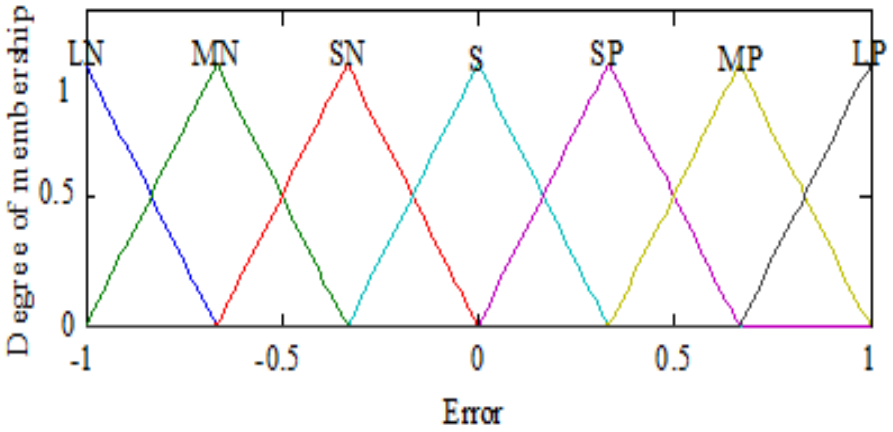

Fig 10 Membership function used for input variable "error"

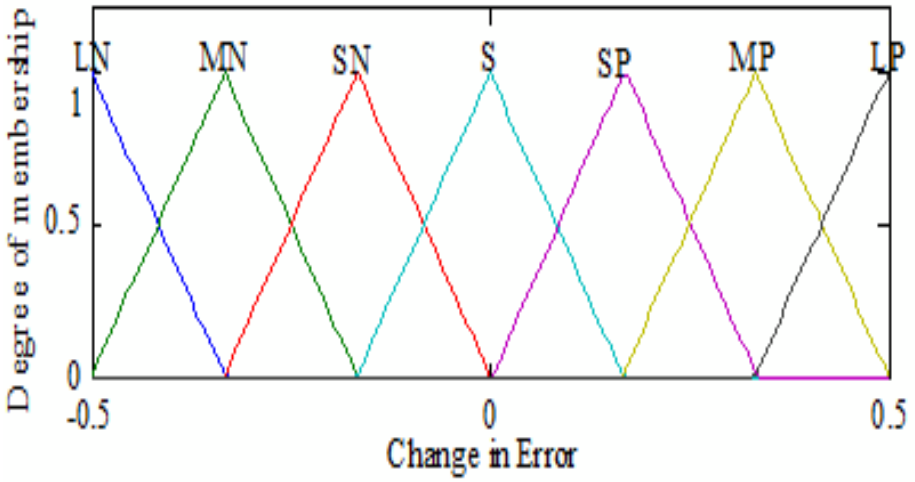

Fig 11 Membership function used for input variable "change in error"

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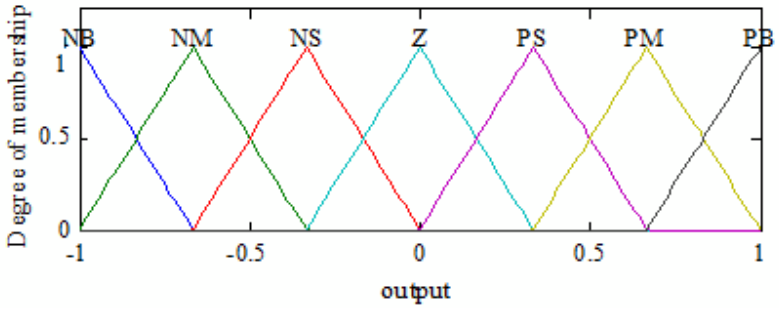

Fig 12 Membership function used for output variable "output"

F. FUZZY RULES

Where, the inputs and output linguistic variables called fuzzy sets are labeled as follows: LN- Large Negative, MN- Medium Negative, SN- Small Negative, S- Small, SP – Small Positive, MP- Medium Positive, LP- Large Positive, NB- Negative Big, NM- Negative Medium, NS- Negative Small, Z- Zero, PS – Positive Small, PM- Positive Medium and PB- Positive Big. The input signals are fuzzified and represented in fuzzy set notations by membership functions.

Table1 Fuzzy Rules

'e'/' ce'	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NB	NB	NB	NB	NM	NS	ZE	PS
NB	NB	NB	NM	NS	ZE	PS	PM
NB	NB	NM	NS	ZE	PS	PM	PB
NB	NM	NS	ZE	PS	PM	PB	PB
NB	NS	ZE	PS	PM	PB	PB	PB
NB	ZE	PS	PM	PB	PB	PB	PB

IV. SIMULATION RESULT

In simulation Results , The Nine Level Multi Level Inverter, then each part components , simulation diagram and its Results for voltage and current are described below

A.SIMULATION DIAGRAM

In power system networks, reactive power is the main cause of increasing system losses and various power quality problems. Regulations apply in many places, which limit the distortion and unbalance that a customer can inject to a system. The simulation of complete PV system is being carried out without MPPT using MATLAB/Simulink. The simulation model includes PV panel followed by DC-DC boost converter, Modified nine level inverter and PI current control loop.

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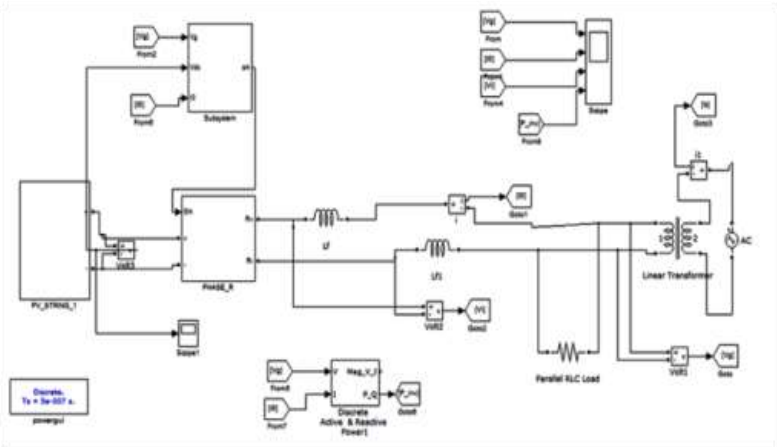

Fig. 13 Simulation Diagram of Modified Nine Level inverter with PV String Module

In a grid connected photovoltaic system, the main aim is to design an efficient solar inverter with higher efficiency and low THD and which also controls the power that the inverter injects into the grid.

The effectiveness of the general PV system anticipates on the productivity by which the direct current of the solar module is changed over into alternating current. The fundamental requirement to interface the solar module to the grid with increased productivity includes: Low THD of current injected to the grid, maximum power point.

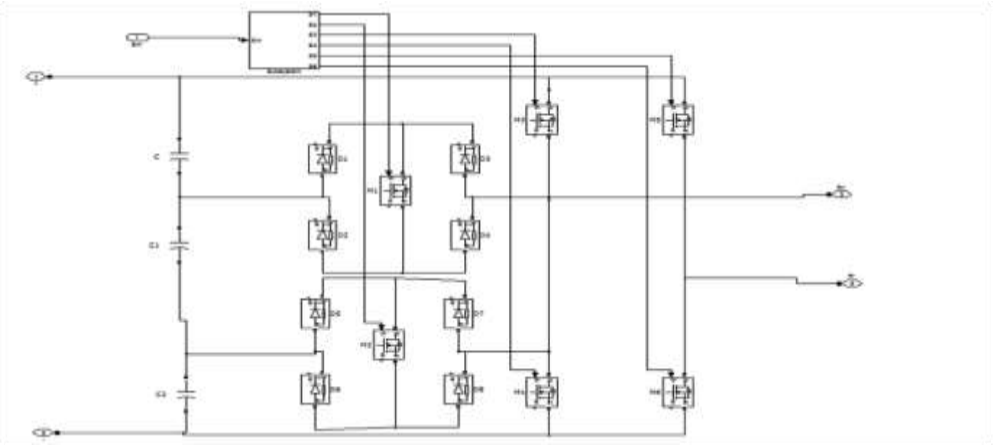

Fig.14 Simulation Diagram of Modified Nine Level Inverter (MNLI) Unit

In this module, a two stage topology is carried out for a single phase grid connected photovoltaic- inverter. The output from the PV panel is given to the DC/DC boost converter, maximum power point tracking (MPPT) control technique is being used to control the gate pulse of the MOSFET of boost converter. The boosted output is fed to the inverter unit in order to convert DC into AC with higher efficiency.

This Paper proposes the power quality problems such as high reactive power and high THD. Compensation techniques of custom power electronic device were presented.

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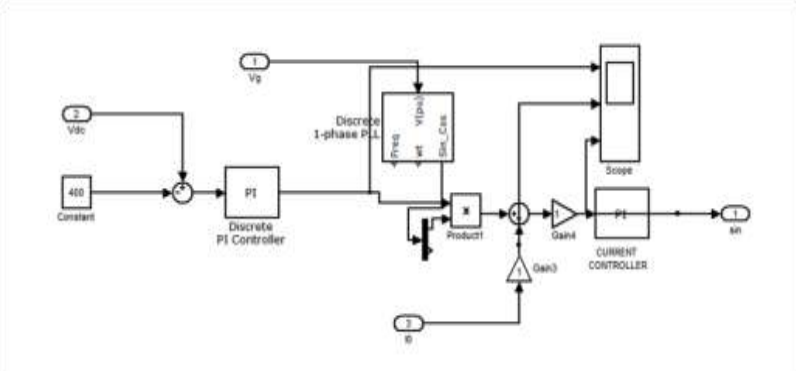

Fig. 15 Simulation Diagram of Modified Nine Level inverter with PV String Module

The main strategy used to control the grid tied PV power converters is the current mode control. This technique consists in calculating an adequate current reference to inject active power into the grid.

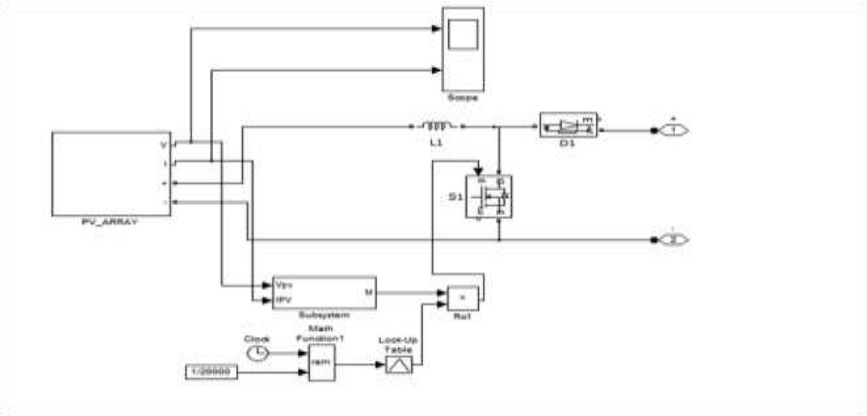

Fig.16Simulation Diagram of PV String with Converter Model

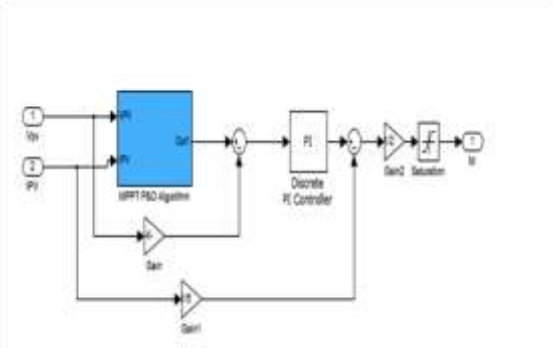

Fig.17 Simulation Diagram of MPPT with P & O ALGORITHM UNIT

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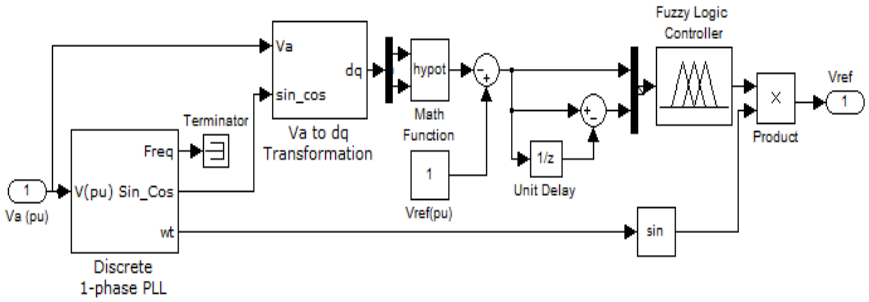

Fig.18 Simulation Diagram of FLC controller.

Fig.19 Prototype model of PV based 9 level inverter

B. SIMULATION RESULT

A single phase grid connected modified nine level inverter with six power switches is being analyzed. The operation mode of the topology is analyzed through simulation and its results are given below.

The results given below shows that our proposed system works in excellent way and improves the system efficiency and reduce the total harmonic distortion within the prescribed value set by IEEE standard.

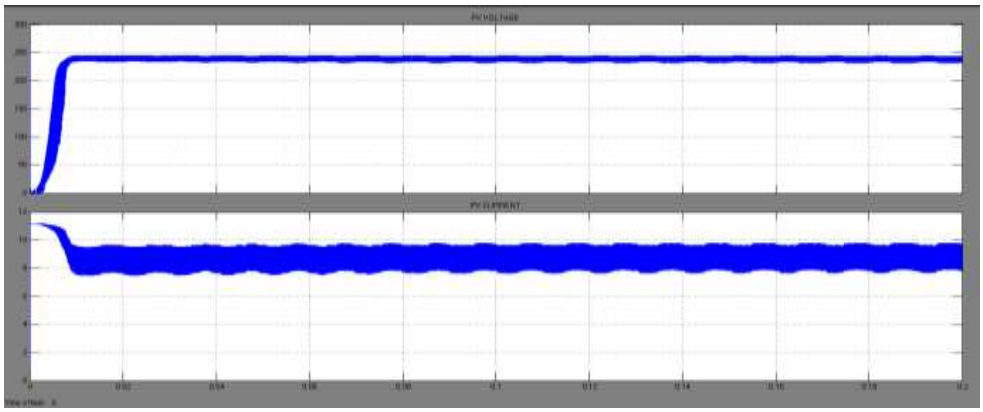

Fig.20 Simulation Output ofPV Voltage/Current

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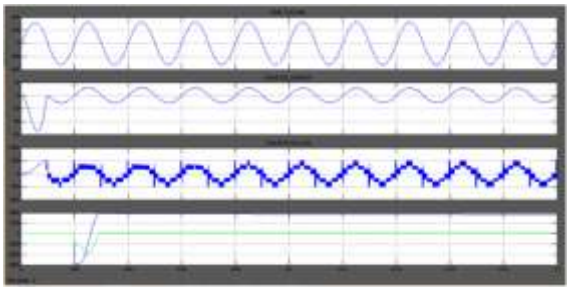

Fig.21 Simulation Output of Grid Voltage/Inverter Current/Inverter Voltage/Real & reactive Power

Although terms of power quality are valid for transmission and distribution systems, their approach to power quality has different concerns.

An engineer of power system deals with the control of active and reactive power flow in order to maximize both the loading capability of the power system and the stability limits of the power system.

On the other hand, an engineer of power system deals with load compensation (by means of individual or group compensation) in order to maintain power quality for each load in the power system, for example achieving nearly sinusoidal bus voltage at rated magnitude for every load. These interests on power quality have also brought the solution by utilizing power electronic based power conditioning devices.

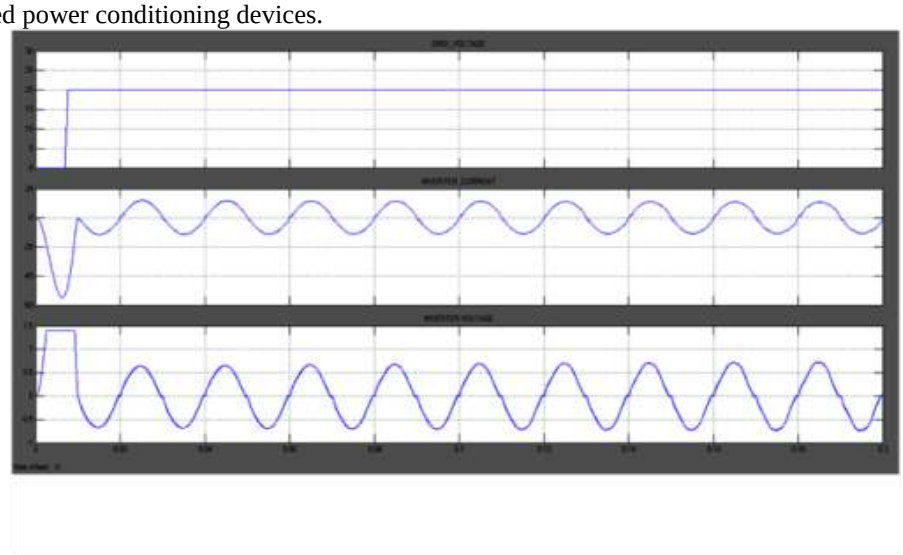

Fig.22 Simulation Output of Grid Voltage/Inverter Current/Inverter Voltage.

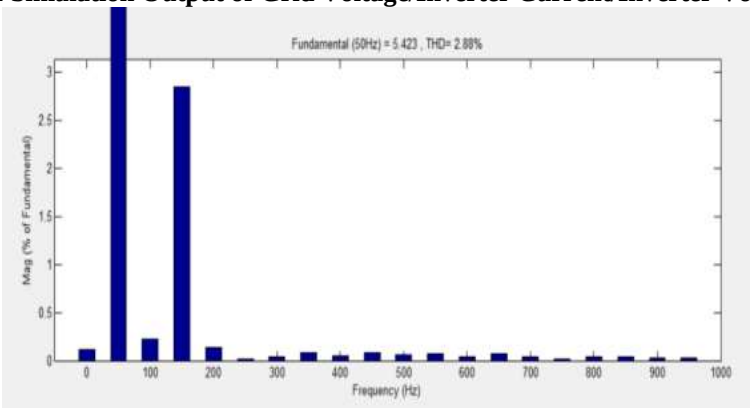

Fig.23 Simulation Output of Proposed MNLI THD Value after compensation period(2.83%)

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Minimization and reactive power compensation and the comparison THD between conventional and multilevel inverter as follows satisfactory in the case of power quality problem and offer efficiency as well reduce the THD).The simulation results show that the performance of the system has been found solutions to the harmonics during nonlinear load condition

V CONCLUSION

This proposed method describes, the systematic procedure of the modeling and simulation of a single phase grid connected PV multi string using novel PWM control scheme for power quality problems, based on proposed MNLI, Phase locked loop technique. Power quality is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end use equipments. To solve this problem, custom power devices are used. One of those devices is our proposed inverter module, which is the most efficient and effective modern custom power device used in power system networks. Current control loop injects a current in to the system to correct the power quality problems (reactive power compensation and improves the system performance, and prevent them from feeding back into the utility grid. It leads to power quality improvement such as THD

Tab1e . 2 Comparison table between Conventional and Multi string inverter

PARAMETER	CONVENTIONAL INVERTER	MULTI STRING INVERTER
THD	4.63	2.82
EMI	Since dv/dt is high. The EMI from the system is high.	Since dv/dt is low. The EMI from the system is low.
SETTLING TIME	3.00	2.91

VI FUTURESCOPE

The Paper work presents the design, simulation, analysis and implementation of hybrid multilevel inverter. Many Papers are implemented with this theory and circuit but in this research work, DSP 28335 with MATLAB/SIMULINK, CCS 3.3 and emulator C2000 series is used to obtain control signals along with DC regulated power supply. The DSP based z-control unit reduces the system hardware and makes it more flexible in comparison with conventional digital control. Hybrid multilevel inverter has many merits such as: ability to synthesize waveforms with better harmonic spectrum, an output voltage level that is higher than those of the power semiconductor switching devices, reduced THD, dv/dt stress and common mode voltage and different approaches to achieve the goal of multilevel output.

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