GRID INTEGRATED PV FED MODULAR H-BRIDGE MULTILEVEL INVERTER

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Abstract:

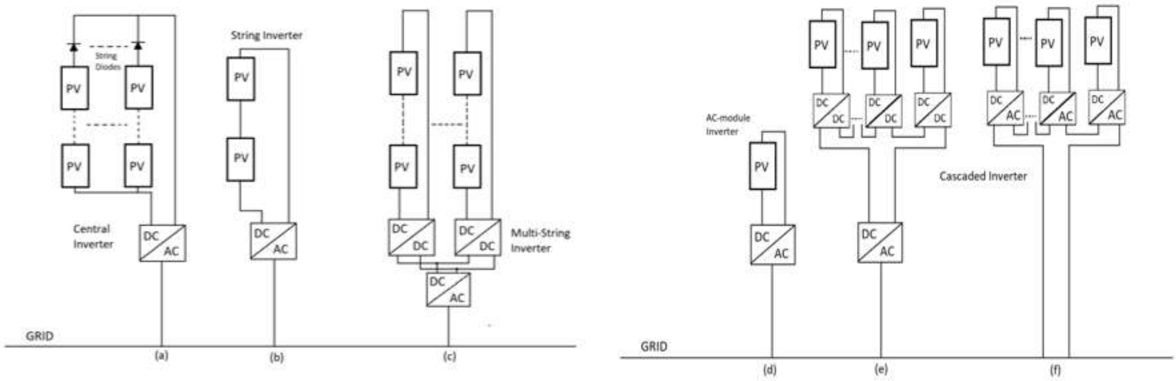
In this article, Grid Integrated Photo-Voltaic Fed Modular MLI (H-Bridge) is introduced for the purpose of three-phase applications. To enhance, the insolation of each PV string, Incremental conductance method is used, enabling independent control which helps in controlling each DC-Link voltage.PV discrepancies could cause the three-phase system.PV discrepancies could cause the three-phase system to receive imbalanced power. To address this issue, a modulation compensation control approach is proposed. The prototype of a grid integrated Photo-Voltaic fed modular-bridge inverter is presented. A 185-W Photo-Voltaic panel is linked to an individual H-Bridge Module. . The Simulink solutions are displayed to demonstrate the runtime environment of Grid Integrated Photo-Voltaic Fed Modular H-Bridge Multilevel Inverter in the MATLAB/SIMULINK.

Key words: Multilevel inverter(MLI),Solar energy, Panel mismatches, Incremental conductance, Modulation Index(MI), Photo-Voltaic PANEL , Fuzzy control Technique.

1.Introduction:

Day-by-day the amount of fossil fuels are gradually reducing and many environment problems due to non-conventional power generation, solar energy, one of the types of renewable energy, has gained popularity. Over the past 20 years, the demand for solar electric energy has been gradually rising at a pace of 20 percent to 25 percent each year and most of the advancements are occurring in grid-connected applications. Grid-connected photovoltaic (PV) system industry growth has been tremendous and the PV designs are gaining popularity. Here are five different inverter families that correspond to different PV system configurations.The high voltage generated by the combination of numerous modules would favour this architecture in medium and large grid-connected PV systems since cascaded inverters are made up of several converters connected in series [8]–[10].Cascaded inverters fall into two main categories.The connection of , DC/DC converter connection of Photo-voltaic converter is shown in Fig.1(e). Every PV module has its own dc/dc converter, which is still connected in series to produce a high dc voltage that is supplied into a dc/ac inverter that is less complicated.This method offers the advantages of individual module MPPT while being more economical and efficient than ac-module inverters.

It combines elements of string inverters and ac-module inverters. This arrangement, however, has two power conversion stages. A cascaded inverter is depicted in Figure 1(f), in which each PV panel These inverters are then connected in series connection to achieve a high voltage level [13]–[16].The benefits of "one converter per panel," such as improved PV module utilization, the ability to combine numerous sources, and system redundancy, would be maintained by this cascaded inverter.
Additionally, this DC/AC cascaded inverter reduces the need for a central DC/AC inverter and a per-string dc bus, increasing overall efficiency even more. The modular cascaded H-bridge multilevel inverter is one type of dc/ac cascaded inverter that needs a separate dc supply for each H-bridge. Individual dc links in the multi-layer inverter provide independent voltage adjustment. The energy harvested from PV panels can be increased by giving each PV module its own MPPT control. The future generation of effective, durable, and dependable grid-connected solar power electronics will likely include multi level converters due to their versatility and affordability. For single-phase or three-phase grid-connected PV systems, this research provides a modular cascaded H-bridge MLI topology.



PV system configurations are shown in Fig. 1.

(**i)**Central inverter (ii) String inverter (iii). Multi-string inverters (iv) An inverter for AC modules. (v)DC/DC converter with cascading. (vi)dc/ac inverter with cascading.

A distributed MPPT control method is then presented after explaining the significance of individual MPPT control in relation to the panel mismatch challenges. Both single-phase and three-phase systems benefit from the distributed MPPT control approach.

Furthermore,the PV mismatches may result in uneven power delivered to the 3-phase MLI, resulting in unevenly injected grid current, if each PV module is operated at its own MPP in the proposed three-phase grid-connected PV system. The control system also features modulation compensation to balance the three-phase grid current. A 3-phase modular cascaded MLI prototype has been developed. Each H-bridge is connected to a 185-W solar panel. Versatility of the system will be increased while also being more affordable thanks to the modular architecture. Utilizing simulation data, the proposed control method is illustrated**.**

2.System Description:

For 1-phase and 3-phase grid-connected PV systems, Figure 2 shows modular cascaded H-bridge MLI. n number of H-Bridge converters are connected in series in each phase and the dc link for each H-bridge can be a single Photo-Voltaic panel or a short string of PV panels.Inductive(L) filters, which are employed to reduce harmonic current, are utilised to connect the grid to the cascaded multilevel inverter. Each H-bridge module has four switches that can be changed to produce one of three output voltage levels: $-V_{dc}$, $+V_{dc}$ and zero.A MLI in cascaded connection with n input sources will produce 2n + 1 levels, which can be used to create the ac output waveform.By the (2n+1) level waveform, harmonics are reduced,indirectly reduces the requirement of large size filters.Other benefits of multilevel inverters include improved efficiency relative to other converter topologies and less voltage stress on semiconductor switches. [17]

3.Panel Mismatches:

In Photo-Voltaic systems, PV mismatch is a serious problem. Due to numerous temperatures, varying received insolation and the age of the PV panels, the MPP of individual Photo-Voltaic unit can vary. If individual PV module is not handled separately, the PV system's overall efficiency will suffer. To illustrate the significance of individual MPPT control.Simulation of a 5-level MLI is simulated in Simulink.Each H-bridge features a 185-W Photo-Voltaic panel that functions as a stand-alone DC source.The PV panel is modelled using the commercial PV panel specification from A strong energy CHSM-5612M.Consider the following operating condition: each panel receives a different amount of sun irradiation; panel 1 receives S = 1000 W/m2, whereas panel 2 receives S = 600 W/m2. As shown in Fig. 3, if just panel 1 is tracked and its MPPT controller estimates the average voltage of two panels, the power taken from panel 1 is 133 W and 70Watts power is obtained from panel 1.The amount of power harvested from the total PV system is 203 W without individual MPPT control.The commercial PV panel specification from A Strong Energy CHSM-5612M was used to model the PV panel. Think about the following operational circumstance: The quantity of sunlight that each panel receives varies;

 ISSN: 2278-4632
Vol-12 Issue-08 No.01 August 2022

panel-1 receives irradiance S = 1000 $W/_{m^2}$, whereas panel-2 receives S = 600 $W/_{m^2}$. The power obtained from panel 1 is 133 Watts, and the power obtained from panel 2 is 70 Watts, If only panel-1 was tracked, the MPPT controller would calculate the mean voltages of the two panels, as shown in Figure 3. The PV system produces 203 W of total power in the absence of individual MPPT regulation.The MPPs of PV panels at various irradiances are shown in Fig. 4.

When the sun's irradiance (S) levels are 1000 $W/_{m^2}$ and 600 $W/_{m^2}$, MPP values here will be 185, and 108.5W respectively. If individual MPPT is successful, this implies that the maximum energy captured from PV system will be 293.5 W. The difference between the two numbers is around 1.45.To increase the PV system's efficiency, separate control in each PV module is required. In a 3-phase grid PV system, a Photo-Voltaic mismatch could lead to further problems. Along with decreasing efficiency, this can lead to an asymmetrical power supply to the 3-phase grid system.If there were PV mismatch differences between phases, the input power of each phase would be different.Changes in input side power,an irregular current flows in the grid, which is not acceptable considering the grid standards, because of the balanced reference voltage.When computing the percentage imbalance, divide the biggest variation from the average current by the phase current. For some utilities, for instance, it is not authorized to have a current per phase imbalance of more than 10%.

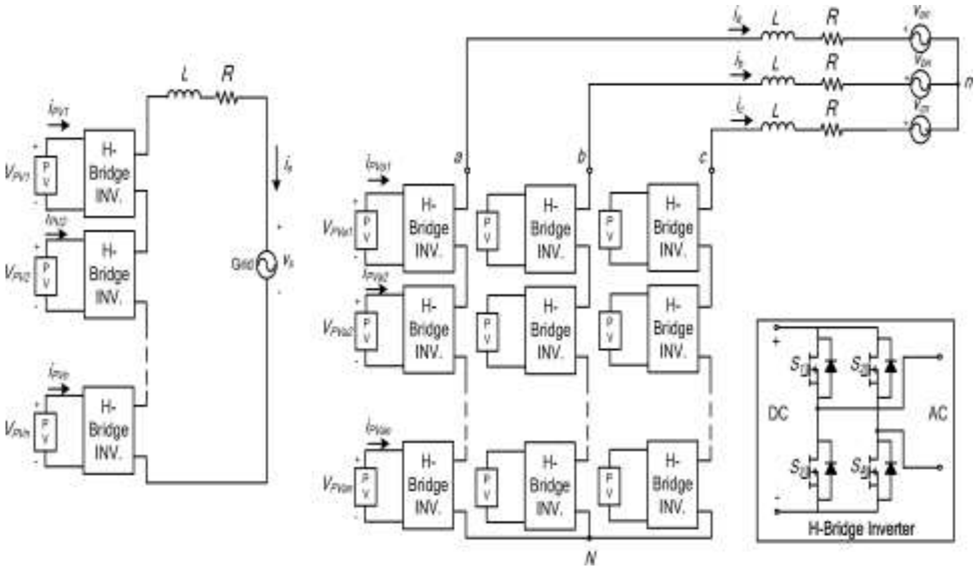


Fig.2 Topology of the grid integrated PV fed modular H-Bridge multilevel Inverter

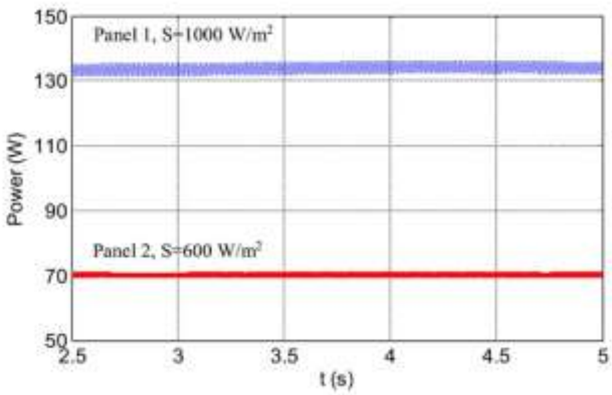


Fig. 3. Energy derived from two Photo-Voltaic panels

 ISSN: 2278-4632
Vol-12 Issue-08 No.01 August 2022

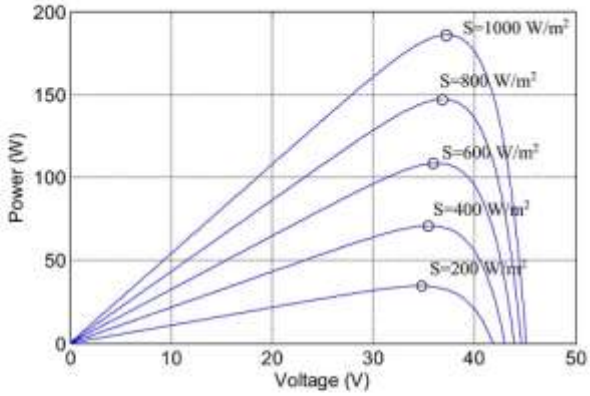


Fig. 4 Characteristics of Photo-Voltaic under the various irradiance levels

4. Control Scheme:

PV modules can be run at different voltages, and usage per PV module can be improved, to increase efficiency and limit the negative impacts of mismatches in the Photo-Voltaic system. The two DC links enable independent voltage control in the cascaded MLI(H-bridge).The control technique provided in [19] is changed for this application in order to understand the unique control of MPPT in each Photo-Voltaic unit.Fig. 5 depicts the distributed MPPT control of the 3-phase cascaded MLI (H-bridge).Individual H-bridge unit now has an MPPT controller to create the DC-link v_{ref}. Each DC-link voltage is compared to the appropriate v_{ref} after the total voltage controller controls the sum of all faults to determine the current reference I_{dref}.With the help of PI controller, the grid currents are converted from abc-dq coordinates in accordance with the traditional control found in 3-phase systems which produce the modulation index in the dq coordinates,and it is converted back to three phases.The Proportional Integral (PI) will provide the active current reference's magnitude, while the PLL will provide its frequency(f) and phase angle(∅). The current loop then returns the MI . By considering the a-phase, the voltages $V_{dca2}\ to\ V_{dc}$are independently controlled.To enable each Photo-Voltaic module to operate at its own MPP, use $n_1$loops. Each voltage controller provides the MI proportion for one H-bridge module in phase an. The modulation index of phase a can be multiplied by the modulation index of phase a to get the $n_1$modulation indices. The modulation index for the first H-bridge can also be calculated using subtraction. The control strategies for phases b and c are remarkably similar. The sole difference is that each phase is given n modulation index proportions, and all dc-link voltages are controlled by PI controllers.Then, a phase-shifted sinusoidal pulse width modulation switching approach is used to regulate each H-switching bridge's components.With the help of PS-SPWM, the switching of each H-bridge can be controlled. Out of the N number of modules,MI is determined by subtraction of one H-Bridge module.N is equal to n in single-phase systems and to 3n in three-phase systems, where n denotes quantity of H-bridge modules per phase. The reason is that n H-bridges require n voltage loops to control various voltage levels, one of which is the total voltage loop that provides the current reference. As a result, n-1 voltage loops can only be used to determine N 1 modulation indices, and one MI must be produced by subtraction. Numerous MPPT techniques have been created and used. The incremental conductance method was used in this study.

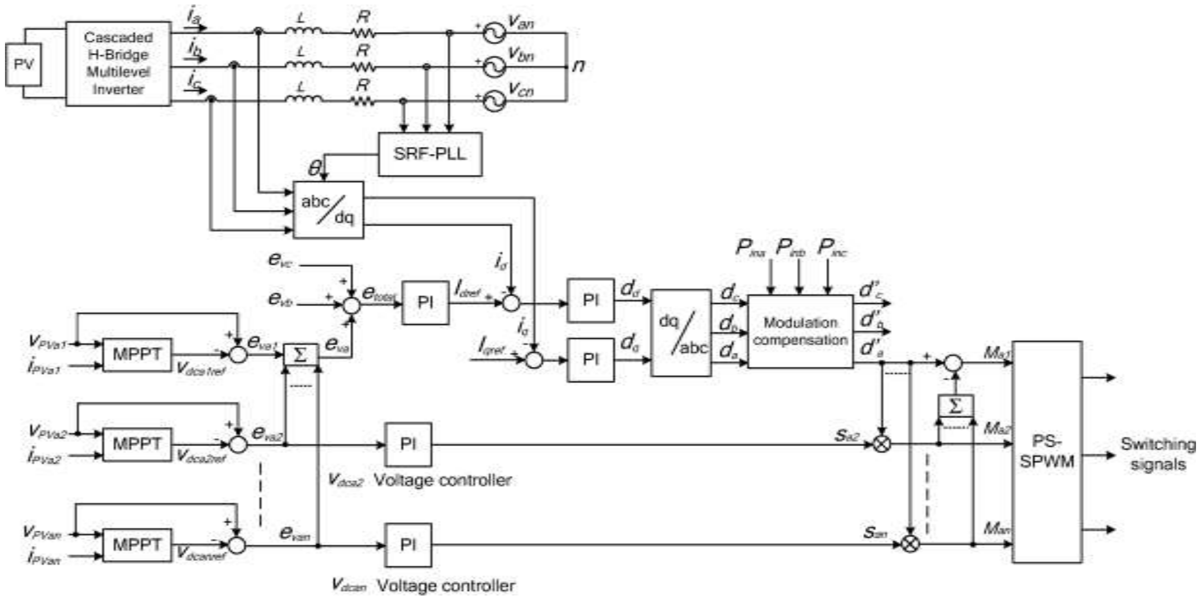


Figure 5 : Control scheme diagram

As previously mentioned, a Photo-Voltaic mismatch may cause additional issues for a 3-phase modular cascaded MLI(H-bridge).If each H-bridge module had its own MPPT control, the input solar power of each phase would be different, resulting in an unbalanced current in the grid.To address the issue, a zero sequence voltage can be provided to the phase legs to alter the current entering each phase[25], [26].If the updated inverter output phase voltage is directly proportional to unbalanced power, the current will be balanced.Consequently, a modulation compensation block is added to the 3-phase modular cascaded MLI(H-bridge) control system, as illustrated in Fig. 6.

The issue is to update each phase's modulation index without adding to the control system's complexity.

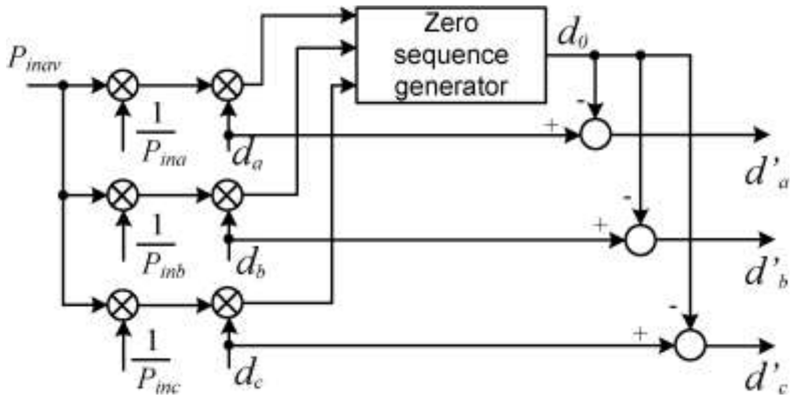


Fig. 6 compensation scheme diagram

By the below mentioned equation(1), the power which is unbalanced is calculated. where P_{inj} is the phase j input power ,where j indicates three phases (a,b,c) and P_{inav} is the average input power.

The injected zero sequence MI can be calculated :

$$r_j = \frac{P_{inav}}{P_{inj}} \qquad (1)$$

The current loop controller determinesd_j, which is the MI of phase j . Each phase's MI is adjusted by

$$d_0 = \frac{1}{2}[min(r_a.d_a.r_b.d_b.r_c.d_c) + max(r_a.d_a.r_b.d_b.r_c.d_c)] \qquad (2)$$

This approach just requires simple computations, which will not add to the control system's complexity.

ISSN: 2278-4632
Vol-12 Issue-08 No.01 August 2022

5.Fuzzy Controller:

The term "fuzzy" refers to ambiguity. When the boundaries of a piece of information is not obvious, it causes fuzziness. It was proposed in 1965. Fuzzy set theory has a lot of potential for tackling problems with a lot of ambiguity. Fuzzy set theory is a powerful tool for dealing with the uncertainty that arises from vagueness. Some common examples of fuzziness include understanding human speech and identifying handwritten letters.Classical set theory is extended to include items with various degrees of membership in fuzzy set theory. Fuzzy logic describes human reasoning by using the entire range of 0 to 1. The input variables in Fuzzy Logic Controller are mapped by "FUZZY SETS," which are sets of membership functions.A membership function that can be defined by parameters makes up a fuzzy set. The value between 0 and 1 indicates the degree of fuzzy set membership. Fuzzificaton is the process of transforming a crisp input into a fuzzy value. The Fuzzier module's output is connected to the rules.The basic operation of FLC is built from fuzzy control rules that use fuzzy set values in general for error and change of error, as well as control action. Figure 6 depicts the basic fuzzy module. This technique is known as "DEFUZZIFICATION," and it involves combining the results to produce a crisp output that controls the output variable.

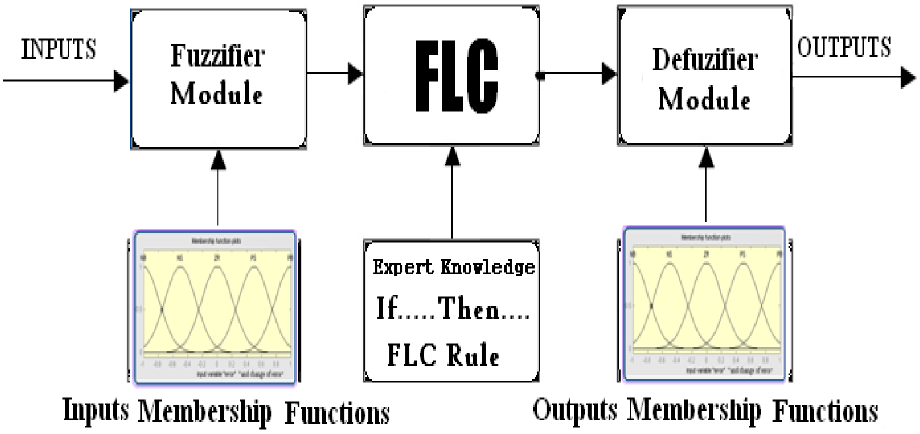


Figure 7 Fuzzy Basic Module

5.1 Fuzzy rules

In fuzzy control, the input and output variables are the size of the form to represent in words, so unique terminology to describe these variables, usually used in "big, medium, and small" There are seven words in all: negative big, negative medium, negative small, zero, positive small, positive medium, and positive big. These fundamental phrases are employed as the prefixes of the English abbreviations NB, NM, NS, ZE, PS, PM, and PB.

Table 1: Rules for implementing Fuzzy

COE / E	PS	NS	ZE	NB	PB	NM	PM
PS	PM	ZE	PS	NM	PB	NS	PM
NS	ZE	NS	NS	NB	PM	NM	PS
ZE	PB	NS	ZE	NB	ZE	NM	NS
NB	NM	NB	NB	NB	ZE	NB	NS
PB	PB	PM	PB	ZE	PB	PS	PB
NM	NS	NB	NM	NB	PS	NB	ZE
PM	PB	PS	PM	NS	PB	ZE	PB

5. Simulink Model and Results:

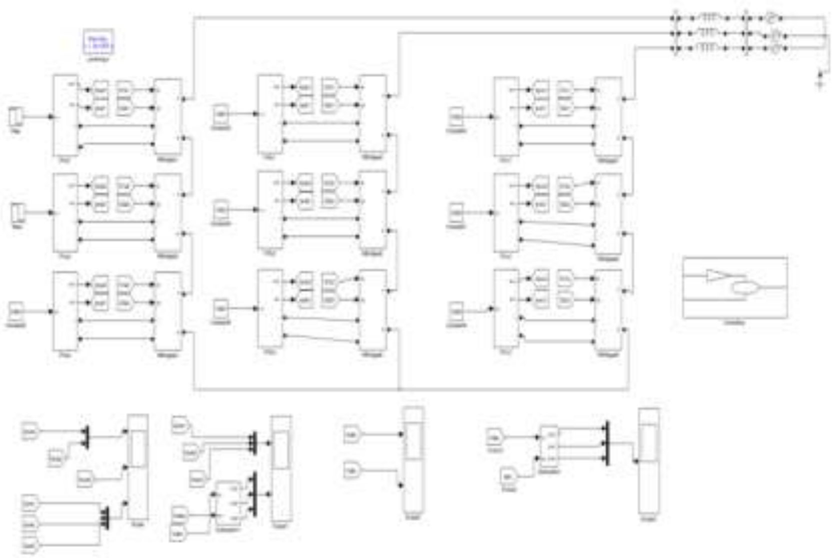


Figure 8 Overall Simulink model

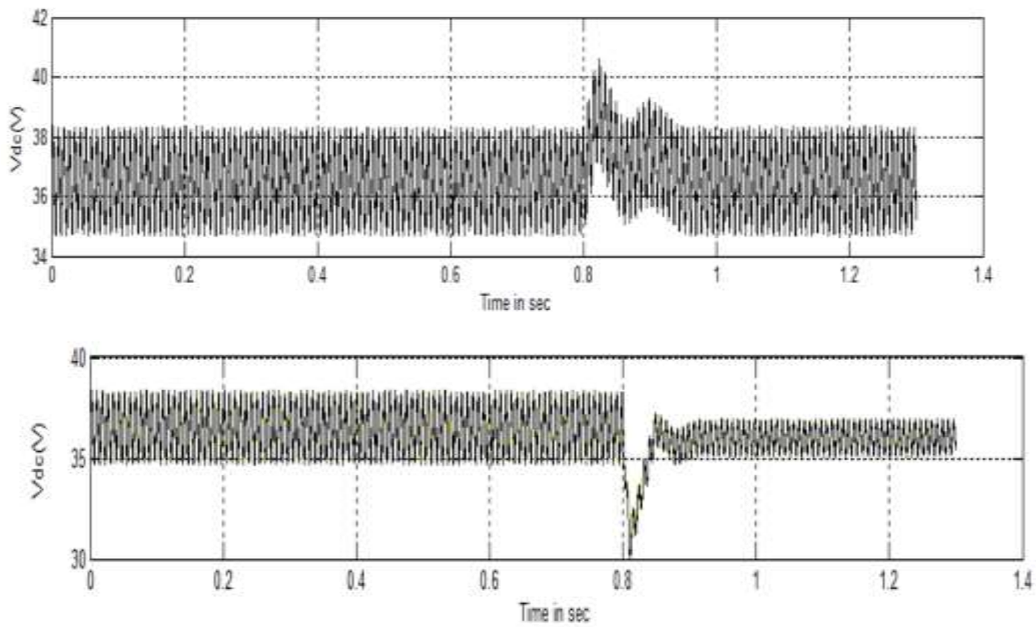


Figure 9 : DC-link voltages of the phase *a*
(a) The DC-link voltages of modules 1 and 2.
(b)The DC-link voltage of module 3.

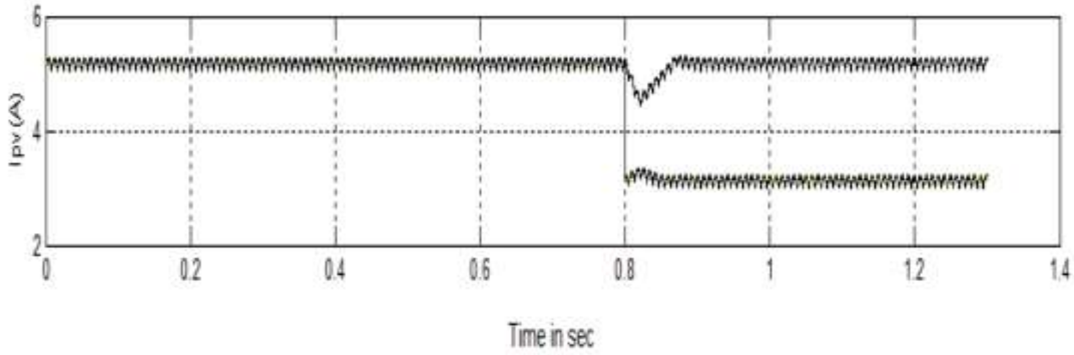


Figure.10 Photo Voltaic currents of phase *a*

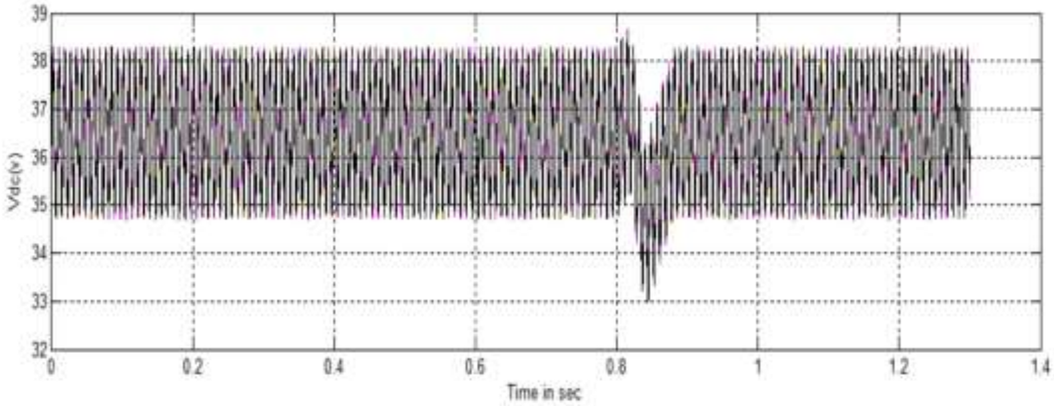


Figure 11. DC- link voltages of phase *b*

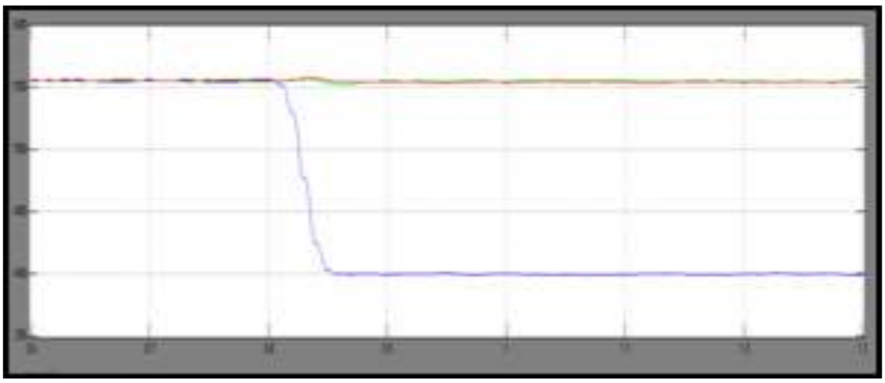


Figure 12 Power derived from Photo-Voltaic panels with MPPT

ISSN: 2278-4632
Vol-12 Issue-08 No.01 August 2022

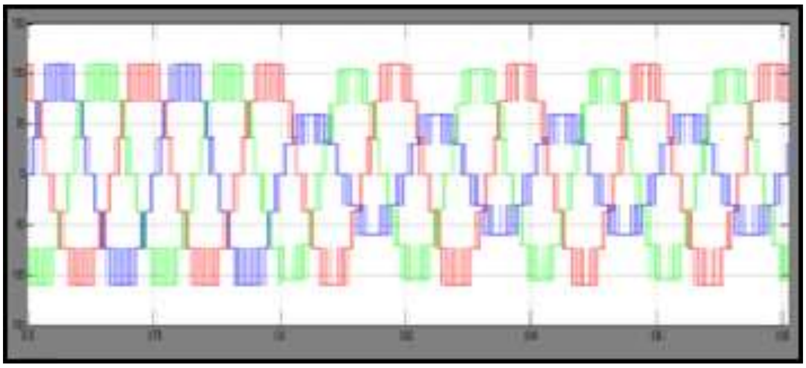


Figure 13 Wave forms of the three-phase inverter's output voltage with modulation improvement.

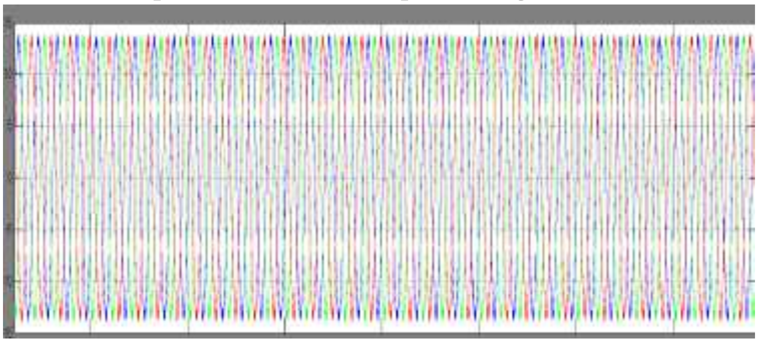


Figure 14. Three-phase grid current waveforms after compensation.

6.Conclusion:

A modular cascaded H-bridge multilevel inverter for grid-connected PV applications is presented in this study. If the voltages of the separate dc links are managed independently, the multi-layer inverter topology will help to optimize the usage of connected PV modules. To improve the overall efficiency of PV systems, a distributed MPPT control technique has been implemented for three-phase Photo-Voltaic application systems.Mismatches caused in PV can cause unbalances in the supplied electricity and result in unbalanced grid current,A modulation compensation technique is offered to balance the grid current and doesn't increase the complexity of the control system or result in additional power loss. In this proposed control scheme , a fuzzy logic controller has been used for better regulation of the MPPT control of the system. Individual Photo-Voltaic unit can be run at its own MPP to harvest as much solar energy as possible, and owing to the suggested control strategy, the three-phase grid current is balanced even with imbalanced supplied solar power.

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