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Power Quality Improvement in Three-Phase Grid Connected Photovoltaic Cells using MMC with Fuzzy Logic Controller

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ABSTRACT: In modular multilevel converter (MMC), the sub modules which perform switching actions, it may produce higher order harmonics when involved with fluctuating capacitor voltages and when it gets superimposed with the circulating currents, it will increase their magnitude which results into increased system losses. In this research work, we have implemented a repetitive control scheme which consists of three components: PI controller, moving average filter and repetitive controller. It is applied to MMC equipped with fuzzy controlled logic, which controls the harmonics by suppressing them up to a significant level. The proposed model is designed for three phase applications and the simulation results clearly define the effectiveness of the control mechanism. Photovoltaic's (PV) is a method of generating electrical power by converting sunlight into direct current electricity using semiconducting materials that exhibit the photovoltaic effect. A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar power. Power generation from solar PV has long been seen as a clean sustainable [1] energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source – the sun. The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation.

KEYWORDS: MMC, Fuzzy Logic, Harmonic Suppression, Three phases, Repetitive Control, SIMULINK

I. INTRODUCTION: Photovoltaic's (PV) is a method of generating electrical power by converting sunlight into direct current electricity using semiconducting materials that exhibit the photovoltaic effect A photovoltaic system employs solar panels composed of a number of solar cells to supply usable solar Power generation from solar PV has long been seen as a clean sustainable [1] energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source the sun. The direct conversion of sunlight to electricity occurs without any moving parts or environmental emissions during operation many investigations in the field of MMC have led to successful operation in HVDC systems. In recent times, for very long distance HVDC transmission lines based on voltage source converters (VSCs) offered more economic and cost-effective power transmission. Conventional two-level VSCs generates large quantity of harmonics and cause higher power losses due to the high speed switching of IGBTs during its working. This converter is composed of several identical power cells connected in series, each one build up with standard components, enabling the connection to high voltage poles. Although the MMC and derived topologies offer several advantages, they also introduce a more complex design of the power circuit and control goals, which have been the main reasons for the recent and ongoing research. Furthermore, Medium Voltage Converters are an interesting area for the application of MMCs such as STATCOMs and drives etc. The evolution of MMCs over the last few years has been used in several commercial applications such as HVDC and flexible alternating.

II REVOLUTION IN VSC TECHNOLOGY: The Insulated Gate Bipolar Transistor (IGBT) was introduced as the main building block of the HVDC converter valves in the late 1990s. In contrast with thyristors, the IGBT is capable of "turning-off" whenever it is required to do so, independently of the AC voltage of the system. This seemingly small difference has completely revolutionized the world of HVDC, announcing the start of a new era in HVDC technology [09]. Furthermore, the IGBT required a complete change in the way that HVDC stations were designed and controlled, as the implementation of a Voltage Source Converter (VSC) HVDC station was now possible. VSCs have gone through a distinct series of transformations. The first generations of VSCs were based on two-levels (+vdc/2, — vdc/2) using Pulse Width Modulation (PWM) techniques with high switching frequencies as depicted in in large converter losses (3%) the two levels PWM-based VSC topology, was first commercialized by ABB under the name "HVDC-Light 1rst Generation" in 1997.

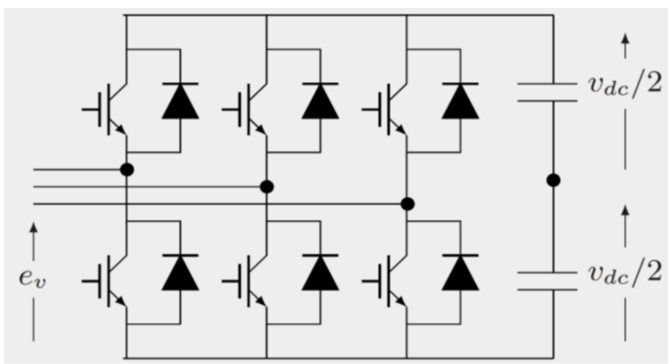

Figure: 1. A 2- Level VSC topology

III. TOPOLOGY EVALUATIONS:

The conceptual background of the MMC comes back to the two-level voltage source converter when there are top and bottom switches in each arm of the converter. The problem with the two-level converter in medium and high power applications is extremely high converter switching losses, as achieving a desirable harmonic content in the converter, requires a high switching frequency. Therefore, there needs to be an alternative converter that provides lower switching losses while achieving high voltage ratios.

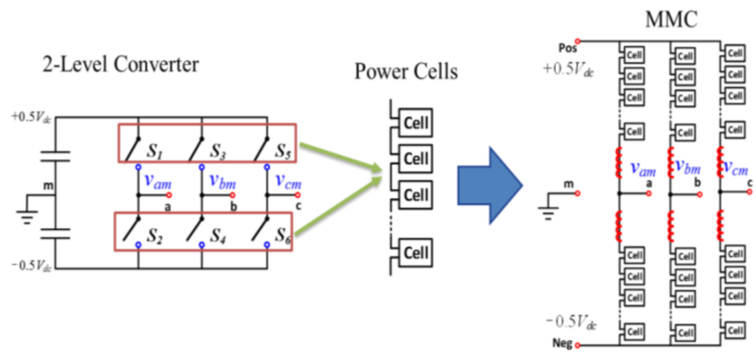

Figure: 1. Modular Multilevel Converter conceptual realizations

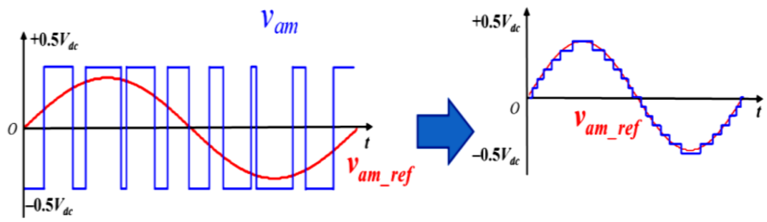

Figure: 3. Waveform in the two-level voltage source and Modular Multilevel Converter

IV. HYBRID MODULAR MULTILEVEL CONVERTERS:

The advantage of the two-level converter is that it contains the smallest total number of semiconductors. The main disadvantage is that it can only have a two-state in the output, and thus requires high switching frequency to obtain a sinusoidal output waveform. The MMC with Half-Bridge power cells provides a solution for the power losses due to high switching frequency in the two-level converter at the expense of having double the number of switches and a very large amount of capacitance. The main disadvantage of the MMC with half-bridge is its inability to block the current path during the DC fault. In contrast, the full-bridge MMC topology permits the ride-through capability of the configuration and suppression of the DC faults, but again, requires twice as many semiconductors.

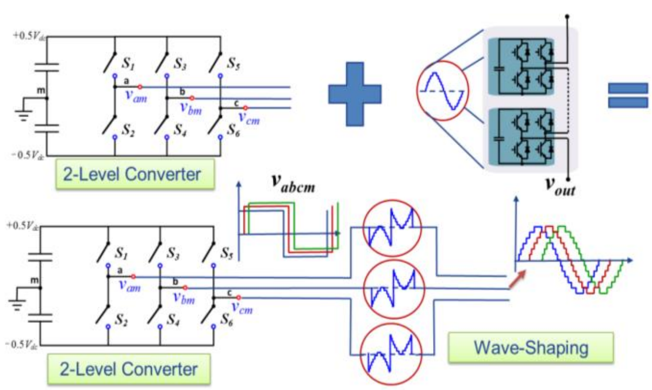

Figure: 4. Hybrid Voltage Source Multilevel Converter with Wave-shaping circuit on the AC side.

V. MODULAR MULTILEVEL CONVERTOR:

Voltage sourced converters can build up a three-phase AC voltage via a DC-voltage. It is used semiconductors such as IBGTs with turn-off capabilities in order to control the DC-voltage into a sinusoidal behaviour [3]. The most common types are two or three level technologies, with two and three voltage levels respectively small increments build a sinusoidal output without similar filtering needs. Modular Realization a converter built up by modules can easily be scaled to different voltage- and power levels multilevel waveform the converter can be expanded to any number of voltage steps. A high number of voltage steps reduce the harmonic distortions**.**

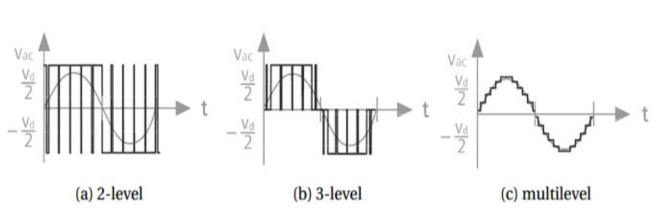

Figure: 5. VSC Output Voltages.

VI. Pulse Width Modulation (PWM)

When choosing a switching scheme for a multilevel converter it is vital to consider the modular and scalable topology, favouring an easily expandable control scheme [8]. There are several types of pulse width modulation (PWM) switching schemes, with these properties. The principle behind a PWM switching scheme. Each time the triangular carrier crosses the sinusoidal reference signal the switch will change position, as is shown in figure below. This idea could be expanded to multiple triangular carriers, each linked to a switch.

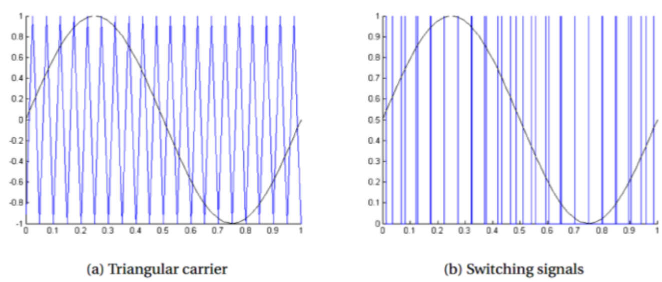

Figure: 6. Principle of PWM switching scheme.

A. LEVEL-SHIFTED PWM: A level-shifted PWM is the different switches are responsible for different parts of the sinusoidal curve. In this case, the switching scheme consists of four levels. At the top of the sinusoidal curve, all the switches will be in on-position, while at the bottom, all switches will be in off-position. The switching output is shown in figure that level-shifted PWM provides a better RMS load voltage than comparable PWM switching schemes, as well as providing a low harmonic distortion.

B. PHASE-SHIFTED PWM: Four carriers phase-shifted PWM is where the phase shift between the carriers is the output of the switches is unlike the level-shifted PWM, the switches can contribute in all parts of the reference signal, as all carriers can cross the reference signal at any point**.**

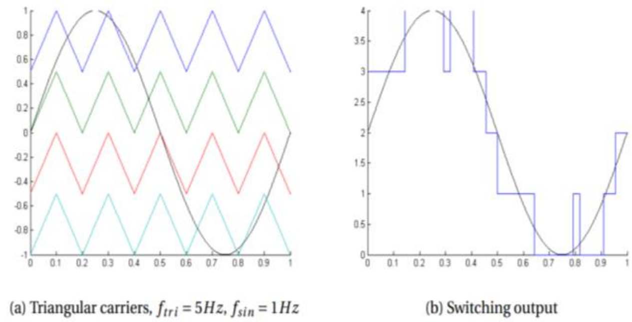

Figure: 7. Level-shifted PWM switching scheme.

VII. VOLTAGE MODULATION METHODS:

Linear current control systems separate controller and modulator so that the voltage modulation methods can be used, which mainly including space vector modulation and carrier based PWM methods i.e. sinusoidal PWM modulation. These modulation methods can achieve the advantages like: constant switching frequency and low harmonic in output current. Sinusoidal PWM Modulation

The sinusoidal PWM modulation is achieved by comparison a triangle carrier signal with three reference sinusoidal signals. If the reference signal is larger than carrier signal, the corresponding output gate signal will be positive, otherwise it is negative. Because of the change of pulse width and high frequency, the output voltages will be nearly sinusoidal.

VIII. SIMULATION MODEL:

The proposed model for the power controller system modular multilevel converter there are number of subsystems are used as demonstrated in figure are subsystem, subsystem 1 ,subsystem 2 and so on subsystem 11 cascaded subsystems are act as level for modular converter connected with number of inductor coils are L, L1 and so forth up to L5 and a series RLC three phase load is connected with the proposed model in figure 4.1 where A, B, C are three phases of the power supply. Case A of proposed work having PI controller with fuzzy logic control controller function of the fuzzy logic controller has already discussed. a fuzzy controller is a powerful tool used in a Matlab Simulink.

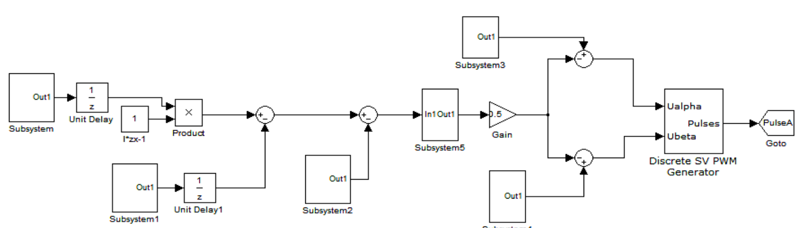

Figure: 8.1 Cases A: PI Controller with Proposed Fuzzy Logic Controller

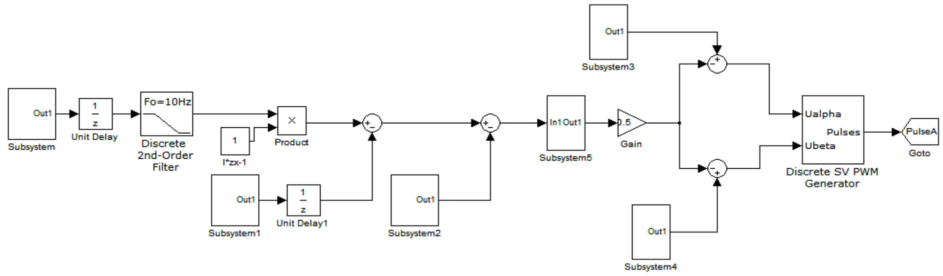

Figure: 8.2. Case B: PI Controller, Moving Average Filter with Proposed Fuzzy Logic Controller.

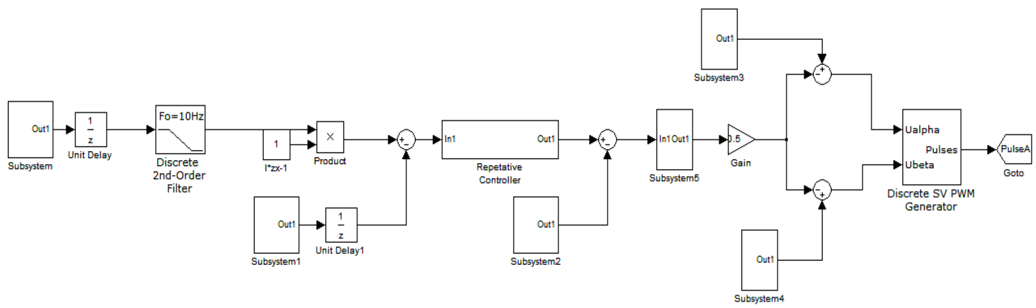

Figure: 8.3. Cases C: PI Controller, Moving Average Filter Followed By Repetitive Controller with Proposed Fuzzy Logic Controller.

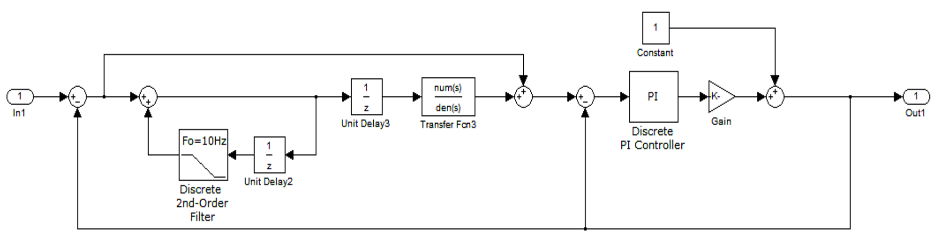

Figure: 8.4. Repetitive Controller

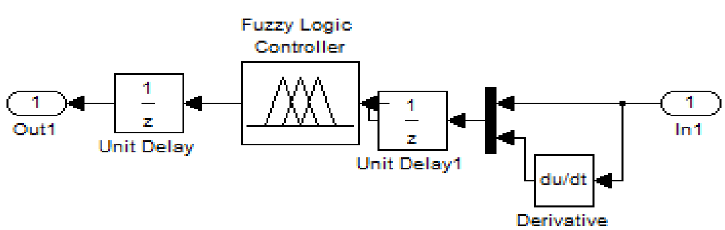

Figure: 8.5. Fuzzy logic controller

IX. SIMULATION RESULT OUTCOME: The modelling of the proposed system has been implemented and simulated on Matlab Simulink. The synthesis outcome of the proposed system has given in Figure Case A: Figure demonstrates the simulation waveform of PI Controller with proposed Fuzzy logic Controller.

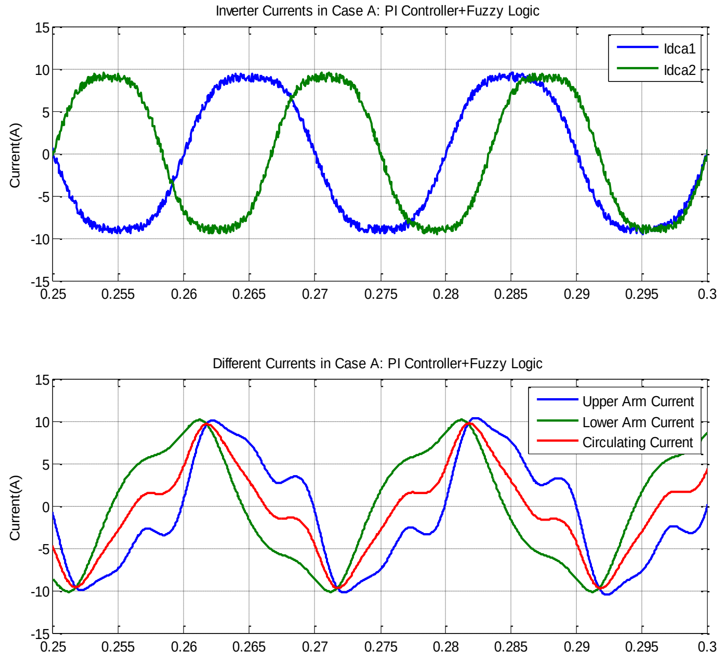

Figure: 9.1 Simulation Waveforms of Case A: PI Controller with Proposed Fuzzy Logic Controller.

Case B: Simulation Waveforms of PI Controller, Moving Average Filter with Proposed Fuzzy Logic controller

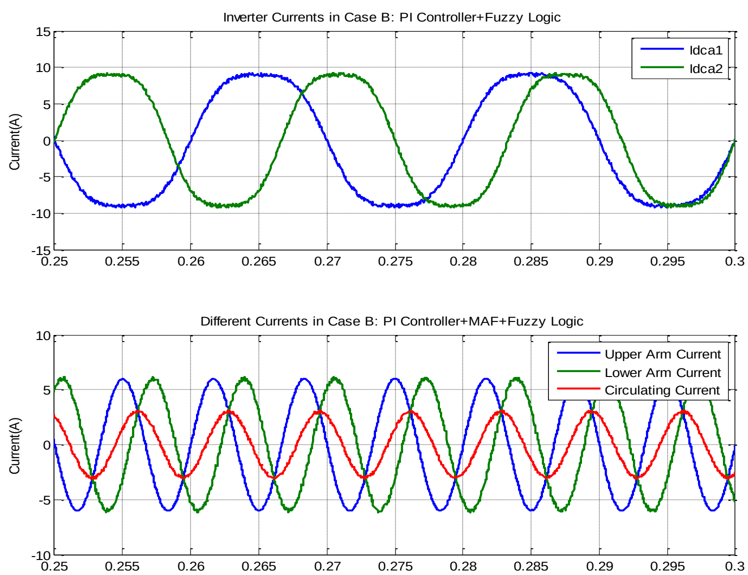

Figure: 9.2 Simulation Waveforms of Case B: PI Controller, Moving Average Filter with Proposed Fuzzy Logic controller.

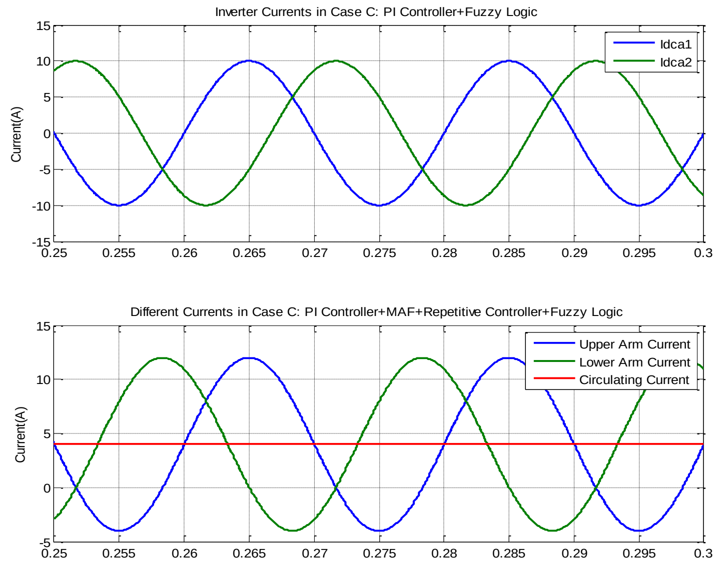

Figure: 9.3. Simulation Waveforms of Case C: PI Controller, Moving Average Filter followed by Repetitive Controller with Proposed Fuzzy Logic Controller.

X. CONCLUSION AND FUTURE SCOPE: In this paper, a PV system is interfaced to the grid via a Modular Multilevel Converter. A fuzzy logic controller is employed to feed the grid by the maximum allowable PV power. A simple predictive current control algorithm is used. The system performance is investigated using a MATLAB/ Simulink model at different cases of load variation, atmospheric temperature variation and solar irradiation variation. The inverter achieves functions of supplying the available power from the PV unit into the loads in addition to improving the power quality in terms of grid current THD and power factor the proposed scheme can be utilized with advanced controllers in which some of them are still in research phase for the purpose of harmonics suppression. Here we have used fuzzy logic, but we may also perform simulation with other soft computing techniques this scheme can also be employed in smart grids which work on advanced automation techniques. Although the modular multilevel converter is an interesting and promising topology, other promising topologies that are still undiscovered may exist. Therefore, the future work should not only be limited to comparing existing topologies but an effort should be made to find new alternatives for high-power applications.

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