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STATCOM Based on Modular Multilevel Inverter Coupled with Smart Detection Technique

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Abstract: *This research studies the multilayer inverter, which uses a novel flexible framework utilizing standard three-phase voltage source inverters to accomplish multilevel operation, and the STATCOM stands for static synchronous compensator. Three different DC wires and an open-end winding configuration are used to link the inverters to a transformer. The inverters in this design will be connected in a cascading fashion. The system stands out not only for its multilayer operation but also for its low blocking voltage requirements for switch ratings. This is because the transformer windings may get twice as much DC capacitor voltage from the proposed STATCOM. Furthermore included is the control system development for the suggested topology. Several simulations and practical experiments will be carried out to evaluate the effectiveness of the current control system and the functionality of the suggested topology. Reactive power compensation in a power system can be used to provide maximum power transfer and voltage regulation..*

Keywords: STATCOM; Modular Inverter; Multilevel Inverter; Detection; DC; Smart detection.

I. INTRODUCTION

A device that changes direct current (DC) electricity into alternating current (AC) power at a set output voltage and frequency is called an inverter[1,2]. Recently, multilevel converters have gained interest as a fascinating field for industrial applications[3]. Only a result voltage that alternates between two different voltage levels can be produced by power electronic converters. The Multilevel Inverter combines various DC voltage levels into its input to obtain the required output voltage[4]. The majority of the time, fuel cells, capacitor voltage sources, renewable energy sources, and other sources provide the input side voltage levels. There are various multilevel inverter topologies, including cascaded H-bridges converter, diode clamped inverter, and flying capacitor multilevel inverter [5, 6]. Multilevel inverters are used in medium voltage, high power applications these days[7, 8].

A flexible ac transmission system (FACTS) technology for generating or absorbing reactive power is a static synchronous compensator (STATCOM) that uses a voltage source converter. Reactive power compensation in a power system[11] allows for maximum power transmission[10] and voltage regulation [9]. Over the past few decades, many STATCOM types have been investigated and implemented in a number of electrical grids [12, 13].

An array of multilevel converters, including diode-clamped, flying capacitor, cascaded H-bridge, modular multilevel converters (MMC), and alternative arm converters (AAC), can be employed in the construction of STATCOM. The layered construction offers scalability as well as redundancy[14,15]. The reduction of harmonics, however, necessitates a large number of H-bridge sub-modules, each of which demands a sizable DC capacitor[16].

The FACTS device, which is shunt-connected and largely controls reactive power, is part of the STATCOM. There are two steady-state modes of operation for the STATCOM: capacitance (leading) and inductor (lagging). Power systems are frequently operated more efficiently with the usage of STATCOMs[17]. One VSC and one shunt-connected transformer make up the STATCOM. The STATCOM capacity is frequently utilized for reactive power compensation for voltage support and is comparable to that provided by a static VAR compensator (SVC) or revolving sync condenser[18].

The STATCOM draws (or injects) a controlled reactive current into the line to do this. By charging and discharging the DC link capacitor, the STATCOM can exchange active power[19] with the line in contrast to a conventional static

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VAR generator. However, until an alternative energy storage device (such a battery) becomes accessible, the active power needs to be actively controlled to a level that is normally zero and only deviates from zero to account for system losses[20].

Through the injection of a variable magnitude current in quadrature as the line's voltage, the STATCOM has the potential to deliver reactive power into the electrical system. In contrast to the SVC, the STATCOM uses a capacitor to maintain a constant DC voltage for converter performance rather than reactor banks or capacitors to produce reactive power[21]. An equivalent circuit to the STATCOM is shown in Figure 1.

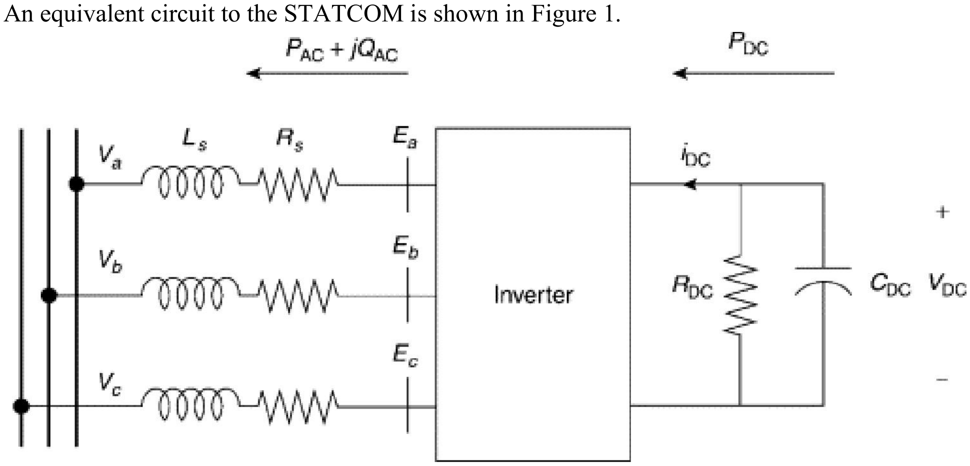

Figure 1- Equivalent Circuit of STATCOM

For multi-level operation, STATCOM is suggested with a completely new modular architecture and conventional three-phase voltage source converters. Force commuted devices like MOSFETs and IGBTs are used in STATCOM power devices.

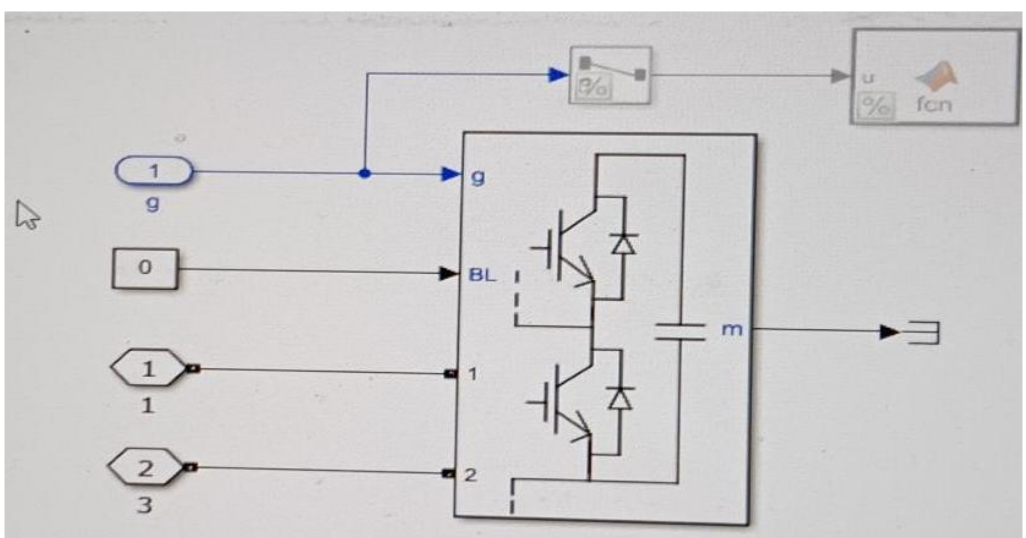

Figure 2- Basic Structure of MMC

A shunt device called STATCOM can produce reactive power or absorb it in order to stabilize the power network's voltage. In the event that a load throwoff causes the power system's voltage to rise, STATCOM lowers its output voltage V1 and absorbs reactive power to bring the voltage back to normal[22]. Voltage Regulation Mode is the name given to STATCOM's previously described mode of operation[23].Multilevel inverters with low distortion voltages and high voltage capacities are preferred by FACTS. A FACTS device that uses multilayer converters is the STATCOM. A variety of topologies are being tested in STATCOMs, the most well-known being cascaded H-bridge multilevel converters, diode clamped multilevel converters, and flying capacitor multilevel converters. Furthermore, a number of

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substitute high-voltage direct current (HVDC) and/or STATCOM solutions, as seen in fig. 2, have been introduced in recent years. These solutions are based on modular multilevel converters (MMC).

II. PROPOSED METHODOLOGY

A complete bridge modular multilevel converter is implemented by the full bridge MMC block. The converter is made up of several power modules connected in series. One H-bridge and one capacitor make up each power module's DC side. A three-terminal high voltage direct current (HVDC) grid in configuration was the subject of many simulations. The full bridge MMC was able to handle the grid's reactive power while maintaining constant control over the AC voltage and current. The suggested work is shown in figure 3 by the model that follows. This represents the source or transmission side. The proposed work below has two sides: an input side and an output side, each with two measurement blocks.

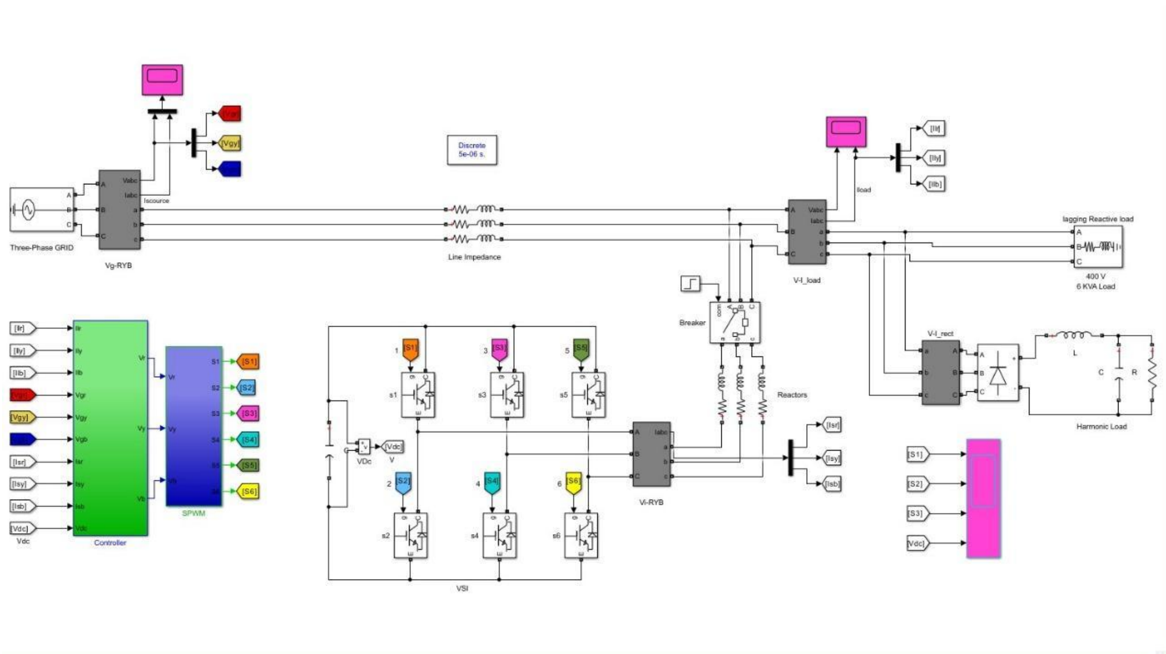

Figure 3- Simulation diagram of Proposed Method at Transmission Side

Typically, the settings are 50 Hz, 11 km, 400 V, and RYB line. As seen in fig. 4, the fault was created in the system by a fault block that took the shape of spikes. From roughly 0.14 seconds to 0.17 seconds, the fault's current rose at a very high amount. When a problem arises, it can be mitigated by employing a system that uses a switch through a breaker to operate a three-phase inverter and converter.

We used the controller, as seen in figure 5 below, to check for the error. The input ABC parameter can be changed into DQ parameters by the controller block. The controller detects this magnitude and outputs signals known as SQWM (Signal Quality Pulse Width Modulation). The value for the inverter block, which transforms DC into an equivalent three-phase AC value, is generated by this SQWM signal. The filter system and reactance system provide the AC value. The output waveform in perfect condition can be seen in the figure below.

III. RESULTS AND DISCUSSION

In Figure 4, the generated fault signal is displayed. As seen in figure 5, the controller checks the fault section. As seen in the figure below, we used the controller to look for the problem. Input ABC parameters can be changed into DQ parameters by the controller block. The controller detects this amount and generates SQWM signals. The inverter block, which changes the direct current (DC) to the matching three-phase alternating current (AC), receives its value from this SQWM signal. The reactance and filter systems provide the AC value. The output wave form is shown without any issues in figure 6 below.

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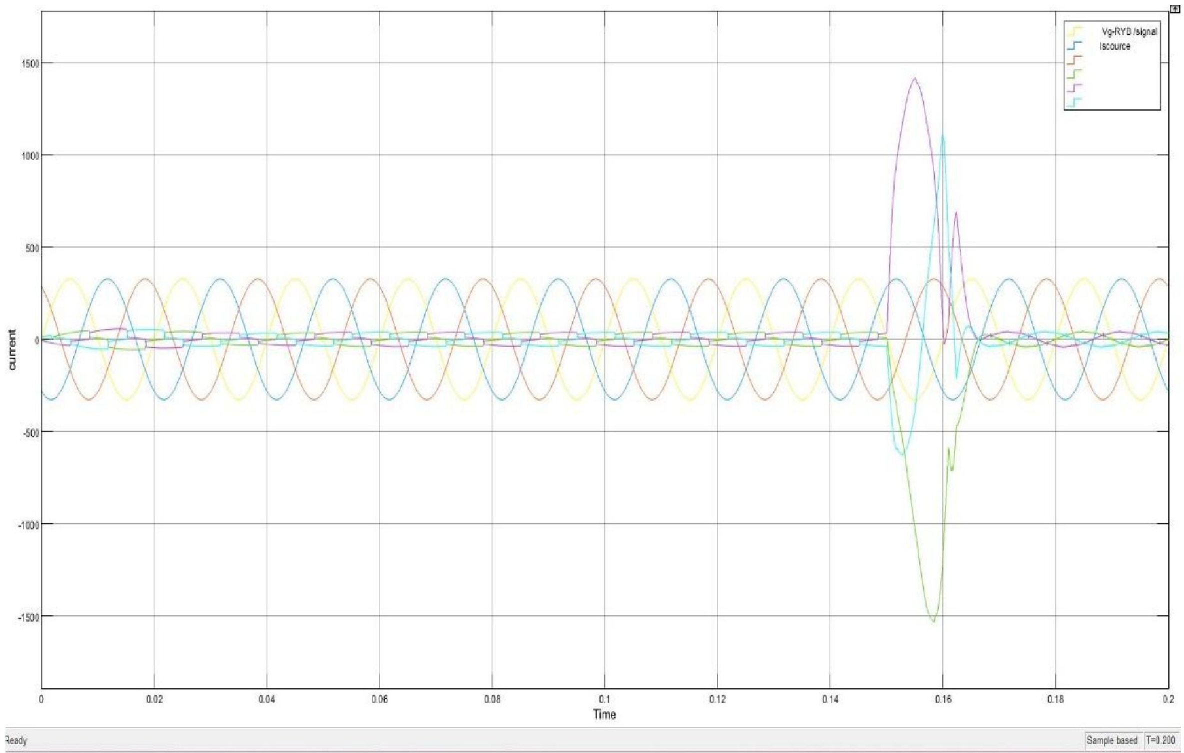

Figure 4- Fault spike is generated in the form of current waveform.

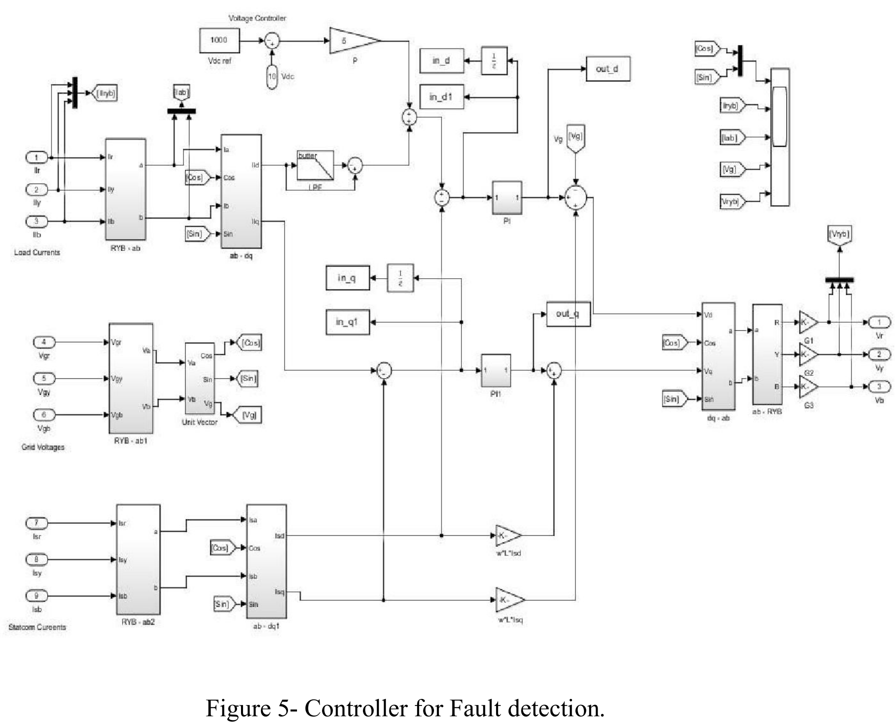

Figure 5- Controller for Fault detection.

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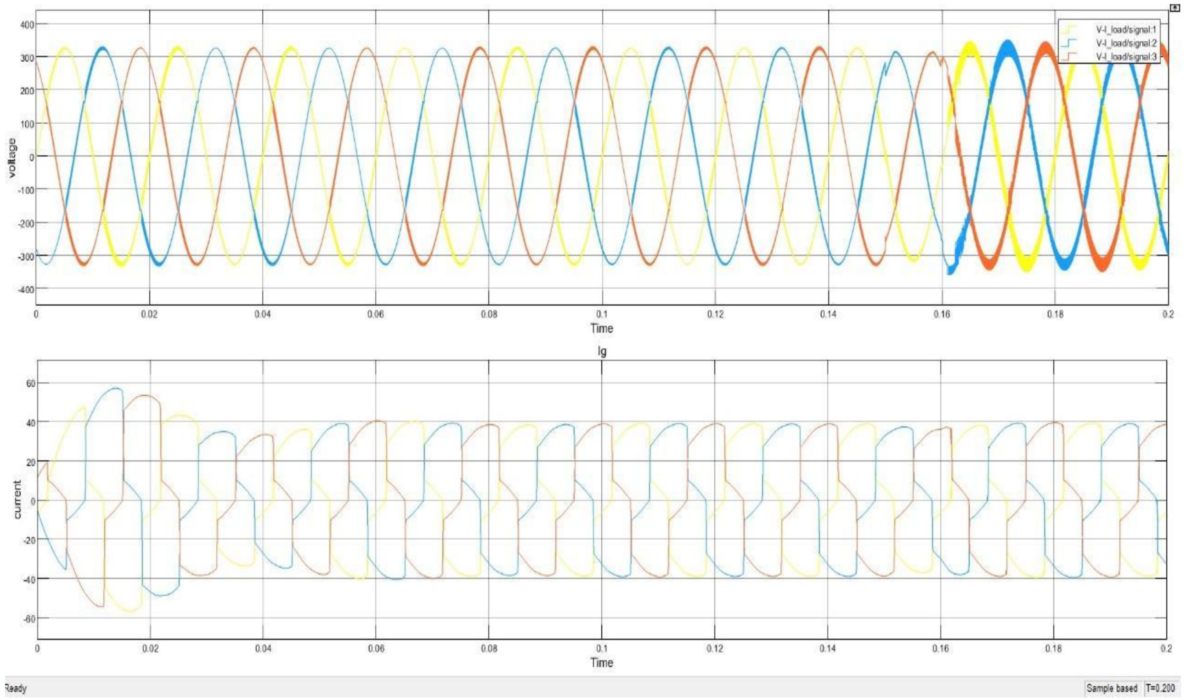

Figure 6- Simulation Waveforms

Table 1- Results of Modulation schemes

Si/ Sic	Modulation method	Power Loss (KW)	MMC Efficiency (%)	THD(%)
Si	***PSC-PWM***	2.5	97.5	23.9
Sic		1.3	98.7	
Si	***PD-PWM***	1.4	98.6	31.3
Sic		1	99.1	
Si	***SAM-PWM***	1.2	98.8	49.7
Sic		0.9	99.1	

Table 1 and Figure 7 show the disparate outcomes of several modulation strategies based on output voltage THD, MMC efficiency, and semiconductor power losses. SiC modules outperform Si devices in Figure 7a,b with respect to power losses and power efficiency in each of the three modulation modes. Furthermore, as Figure 7a shows, the PSC-PWM (Phase Shift Carrier based Pulse Width Modulation) for both Si (Silicon) and SiC (Silicon Carbide) switches has more power losses than the PD-PWM (Phase Disposition) and SAM-PWM (Sampled Average Pulse Width Modulation), which leads to a lower MMC efficiency, as shown in Figure 7b. PSC-PWM does worse in terms of power losses and efficiency than the other two approaches, but it performs better in terms of voltage quality and THD, as shown by Figure 7c.

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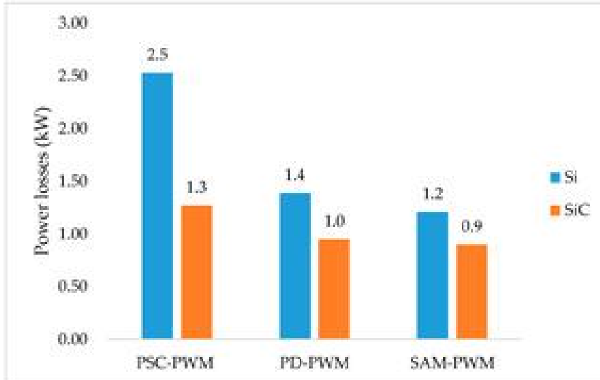
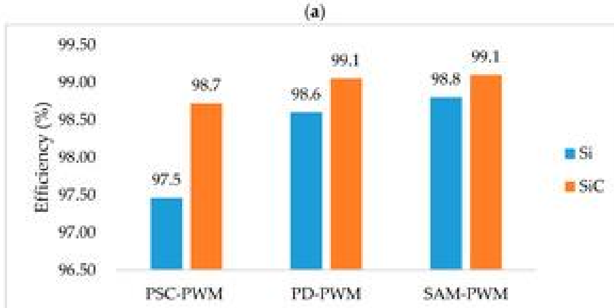
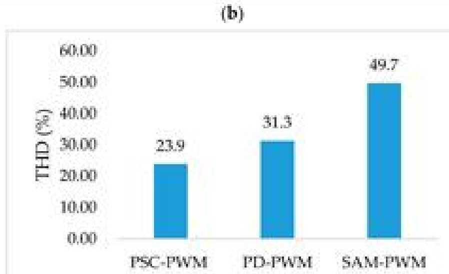


(a)



(b)



(c)

Figure 7- Si and SiC semiconductor performance for various modulation techniques according to MMC: Three factors are involved: (a) Semiconductor power losses; (b) MMC efficiency; and (c) Total harmonic distortion (THD) of the output voltage.

IV. CONCLUSION

By employing the suggested approach, the proposed system detects the fault caused by the line through the use of a controller, and it then assumes control of the fault to prevent an inverter loss. Due to its built-in features, which include an expandable multilayer output voltage, a lower output voltage and output current harmonic content, a modular and flexible design, increased efficiency, and redundancy, the STATCOM-MMC is anticipated to be a better option in medium and high-voltage power applications. As an application-oriented topology, the STATCOM-MMC is expected to be improved in the special purpose domain and become more tailored and well-suited for power transmission. PSC-PWM reduces MMC efficiency for Si and SiC switches since it has higher power losses than PD-PWM and SAM-PWM. When it comes to efficiency and power losses, PSC-PWM performs worse than the other two approaches, but it performs better in terms of voltage quality and THD.

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