



Voltage Sag Reduction in a Grid Tied Solar Photovoltaic Plant by Fractional Order Based STATCOM

Nibedita Ghosh*¹, Asha Rani M.A.², Satyaki Biswas³, Rahul Kumar⁴

¹NIT Silchar, Assam -788010, India

²MNNIT Allahabad, Prayagraj, Uttar Pradesh-211004, India

¹gnibedita718@gmail.com

Abstract. An abrupt drop in the electrical system's voltage, known as voltage sag, can be caused by a number of factors, including overloading, line outages, load changes, and system faults. Power system voltage sag can affect the sensitive equipment, cause downtime in specific industries, etc. The 400V supply frequency 50 Hz utility grid connected to the 1KW Solar Photovoltaic plant system integrated Genetic Algorithm (GA) optimized fractional order based STATCOM regulating PWM-VSI has been simulated using MATLAB in this suggested system. A double line to ground (LLG) fault in the 400 V system has been shown to be the cause of voltage sag. The problem has been resolved through the integration of the 400 V system's SPV plant and GA optimized fractional order STATCOM-tied utility grid.

Keywords: Reactive Power Control, Static Synchronous Compensator, Voltage Sag, Double Line to Ground Fault, Solar Photovoltaic Plant, Microgrid, Utility Grid.

1 Introduction

A Dual Vector Controller (DVC) regulating a Series Static Synchronous Compensator (SSSC), is proposed in this research to mitigate weather-induced voltage sag in utility grid connected wind farms and reduce malfunctions and data loss [1]. The work investigates and mitigates voltage sag in a utility grid-connected wind farm using a hybrid GOA-PSO algorithm on a STATCOM controller [2]. Using optimization algorithms on a STATCOM controller to regulate reactive power and voltage during major disruptions, the study discusses the Squirrel Cage Induction Generator (SCIG) wind farm and demonstrates the enhanced performance of Firely Algorithm [3]. The article outlines a STATCOM controller that uses a neural network and simplified SVPWM to effectively adjust voltage profile and power factor correction in a utility grid-connected micro grid [4]. This review paper discusses the use of several adaptive controllers to improve power quality [5]. By adjusting for voltage sag and swell during fault circumstances, D-STATCOM is used by utility grid-connected solar power plants to enhance power quality in micro grid-tied utility grids [6]. A STATCOM controller utilizing Particle Swarm Optimization and the Artificial Hummingbird Algorithm facilitates low voltage ride through (LVRT), resolving the issue of low voltage during disturbances [7]. This study recommends using D-STATCOM and battery energy storage to stabilize the utility grid linked to the

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micro grid in order to mitigate potential instability caused by issues with frequency and voltage [8]. Hydrogen fuel cells are necessary for micro grid systems since they produce electricity steadily and sustainably. They can operate independently of the main grid and in conjunction with renewable energy sources. They are necessary for remote areas, critical infrastructure, and community electricity. D-STATCOM, based on the Fuzzy Inference System (FIS), can be used to minimize voltage fluctuations in utility grids that are coupled to hydrogen fuel cells [9]. The study discusses the optimal placement of a micro grid and D-STATCOM in an IEEE 30 bus radial distribution system to improve voltage profile and power quality [10]. In this suggested system, a MATLAB simulation was used to develop a 1 KW SPV plant connected to a 400 V, 50 Hz electrical grid integrated GA optimized fractional order based STATCOM. The proposed work examined that the voltage dip caused due to the LLG fault when the utility grid is acting alone. This problem has been mitigated by the combinational effect of SPV plant + GA optimized fractional order STATCOM controlling PWM-VSI tied to the 400 V, 50 Hz utility grid system connected to the load. It has been found that SPV + GA optimized fractional order based STATCOM tied 400 V grid works better than the system, 400 V, 50 Hz utility grid without the combinational effect of SPV + GA optimized fractional order STATCOM at lowering the voltage drop that arises from the failure.

2 Materials and Methodology

2.1 STATCOM-controlled Voltage Source Inverter based on Pulse Width Modulation

A PWM-VSI STATCOM is essential in enhancing power system output quality, efficiency, and precise control, especially in micro-grid integration. Its output voltage and frequency are controlled as it transforms DC into AC.

Figure 1 shows, how the reference signal produced by the STATCOM controller has been compared to a high frequency triangular carrier waveform of 5 KHz in order to create operating signals for the VSI. Along with managing real power (P) and reactive power (Q) in the proposed system, the STATCOM has been in charge of controlling the PWM-VSI.

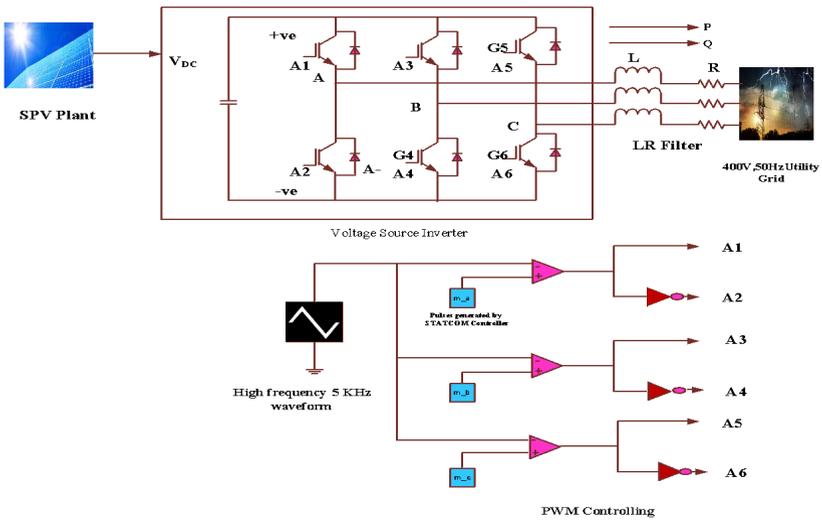


Fig. 1. 400 V, 50 Hz utility grid interfaced with PWM-VSI.

2.2 Computational Model

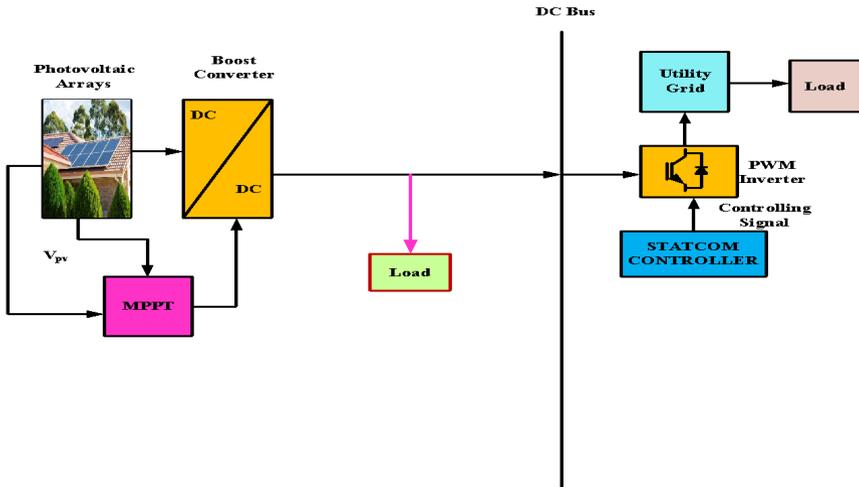


Fig. 2. Utility grid-tied SPV micro grid integrating fractional order based STATCOM.

Table 1. Details of load connected in this proposed system.

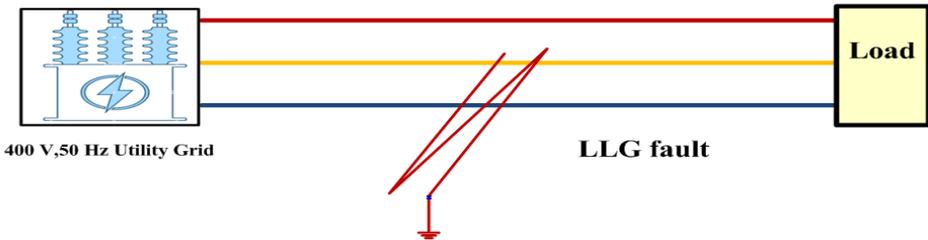
Load type connected in utility grid	Value
R-L	2 Ω , 20mH
Extra R-L linked	2 Ω , 60mH
Extra resistive load connected	10 KW

Table 2. Parameters for STATCOM controller.

Parameters	Values
Interfacing resistance	0.02
Interfacing inductance	10mH
Capacitance of DC linked	4000 μ F
Voltage of DC linked	863.9 V

2.3 A system malfunction causes a voltage dip

The voltage sag that occurs in the 400 V, 50 Hz electric grid system during double line to ground fault (LLG) lasting for 0.5 to 0.7 seconds has been depicted in Figure 6's simulation result.

**Fig. 3.** The system experiences LLG fault.

2.4 Role of reactive power control to mitigate voltage sag

The proposed system uses a PWM-VSI controlled by fractional order STATCOM to prevent fault-induced voltage sags and regulate reactive power. This technology offers enhanced fault ride-through capabilities, particularly for renewable energy sources that are connected to the utility grid. The controller is working on the active and reactive power references to regulate the power flow. The formula explains the effects of voltage and current on the active and reactive power flow in the d-q frame. It has been demonstrated that in order to regulate the active power denoted by $P_s(t)$ in Equation (1), I_d is necessary. Equation (2) makes it clear that I_q is necessary to regulate the reactive power denoted by $Q_s(t)$.

$$P_s(t) = \frac{3}{2} [V_{sd}(t)I_d(t) + V_{sq}(t)I_q(t)]$$

(1)

$$Q_s(t) = \frac{3}{2} [-V_{sd}(t)I_q(t) + V_{sq}(t)I_d(t)]$$

(2)

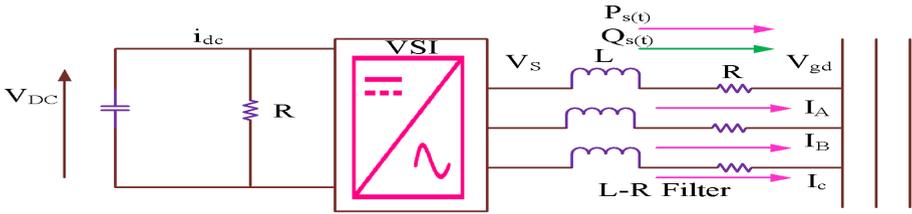


Fig. 4. Basic structure of the STATCOM.

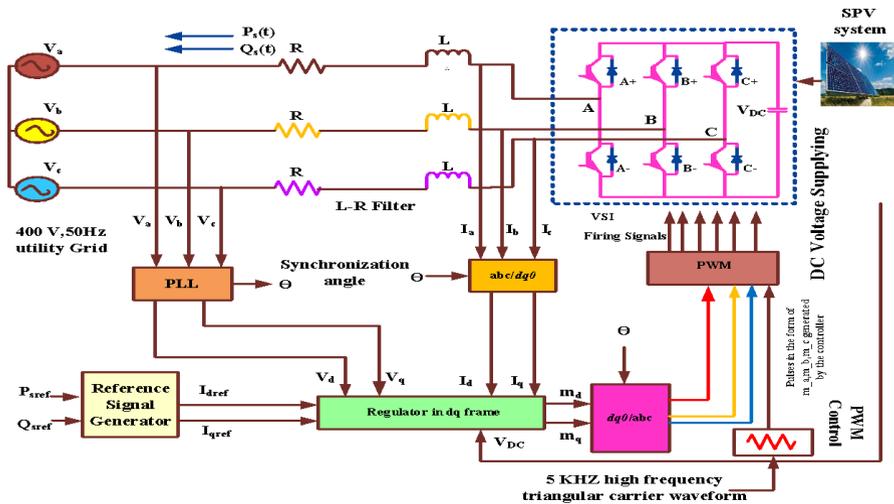


Fig. 5. Control of active and reactive power using PWM-VSI based fractional order STATCOM controller.

Active and reactive power regulation is essential for preventing equipment damage, controlling voltage sag, and maintaining system stability during disturbances. Reactive power $Q_s(t)$ controls voltage, but active power $P_s(t)$ has been used for things like motor power, heating, and lighting. Reactive power is essential because it

increases and injects voltage to keep the voltage level steady during failures. It corrects voltage dip caused by LLG failure for 0.5 to 0.7 seconds with an ohmic-inductive load connected to a 400 V, 50 Hz electric grid. The system employs a SPV plant integrated fractional order based STATCOM regulating PWM-VSI to inject reactive power during disturbances in order to promote quicker recovery and preserve voltage stability.

3 Simulation Results and Discussion

It has been investigated that voltage sag has been occurred in the 400 V utility grid of frequency 50 Hz system when LLG fault occurs in the system for 0.5 - 0.7 seconds and it has been represented in the simulation result of Figure 6. The simulation result of Figure 7 represents that there is a sudden rise of current supplied from the utility grid due to the LLG fault of 0.5 - 0.7 seconds. It has been clearly observed from the simulation result of Figure 8 that there is a sudden increase in active power supply from the utility grid during LLG fault of 0.5 – 0.7 seconds when the utility grid is acting alone. The simulation result of Figure 9 represents that there is a sudden decay in reactive power supply from the utility grid during LLG fault of 0.5 – 0.7 seconds when the utility grid is acting alone. As high current is flowing due to LLG fault in the system, resulting abrupt drop in voltage causes decay in reactive power supply from the 400 V utility grid. The simulation result of Figure 10 and 11 represent that the consumption of active and reactive power when the 400 V utility grid is acting alone. The issue of voltage sag due to LLG fault which has been mitigated by inclusion of the combinational effect of Solar Photovoltaic plant and GA optimized fractional order STATCOM and it has been represented in Figure 12. The active power and reactive power supplied from the 400 V grid integrating SPV + fractional order STATCOM during fault condition are shown in Figure 13 and 14 respectively. The simulation result of Figure 15 and 16 represent the active power and reactive power consumption in a utility grid tied SPV plant integrated STATCOM during LLG fault condition. In this proposed system, using a Genetic Algorithm (GA) to tackle optimization problems is one way to maximize the performance of a grid-tied, STATCOM-integrated solar photovoltaic (SPV) system. The objective may lead to maximize power extraction, optimize reactive power compensation, improve voltage stability, or improve power quality.

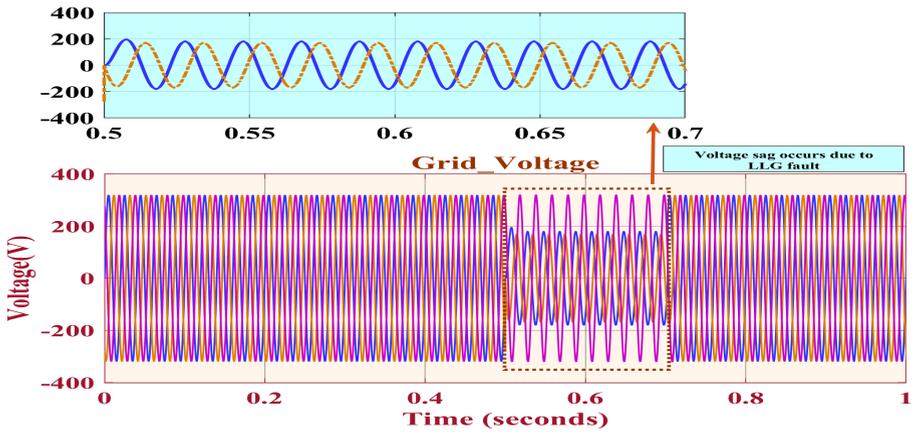


Fig. 6. Without adopting a fractional order STATCOM + SPV micro grid, a utility grid system experiences voltage sag as a result of LLG fault.

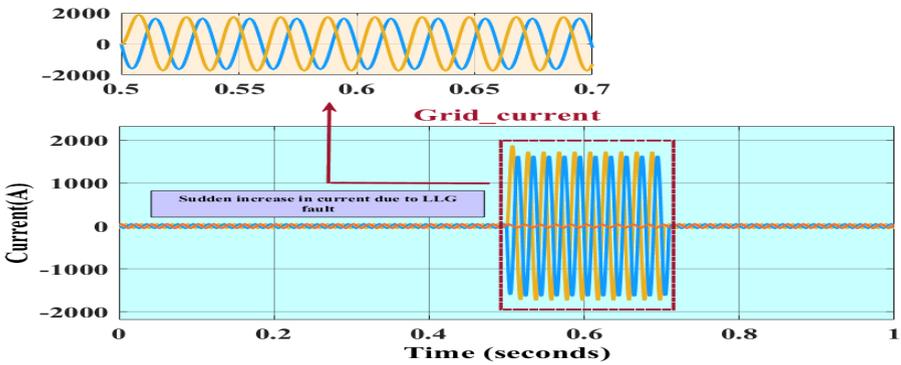


Fig. 7. Without adopting a fractional order STATCOM + SPV micro grid, a utility grid system experiences a sudden rise in current as a result of LLG fault.

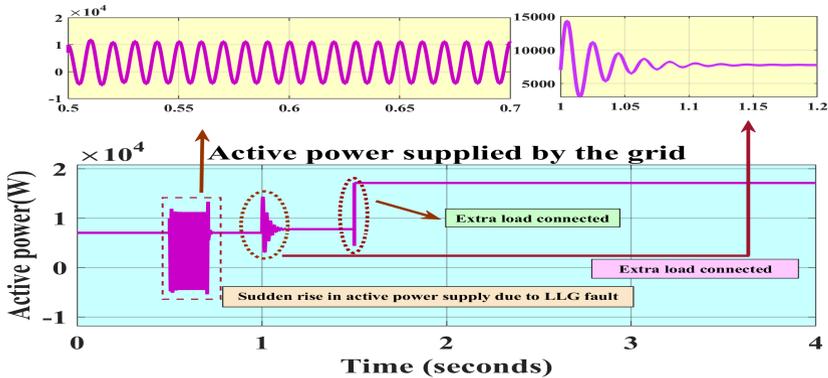


Fig. 8. Without adopting a fractional order STATCOM + SPV micro grid, a utility grid system experiences a sudden rise in active power supply as a result of LLG fault.

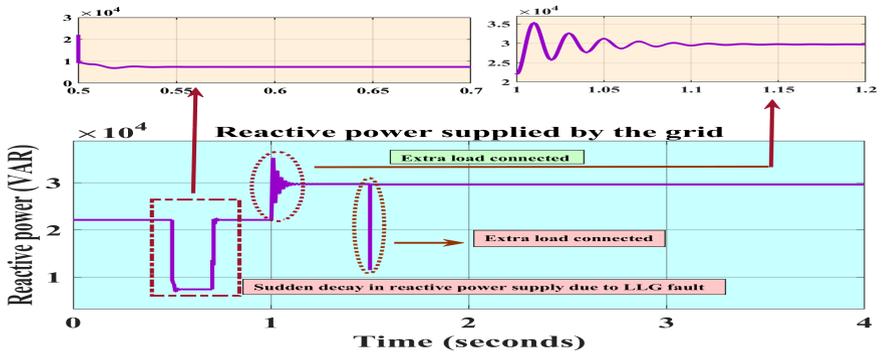


Fig. 9. Without adopting a fractional order STATCOM + SPV micro grid, a utility grid system experiences a sudden decay in reactive power supply as a result of LLG fault.

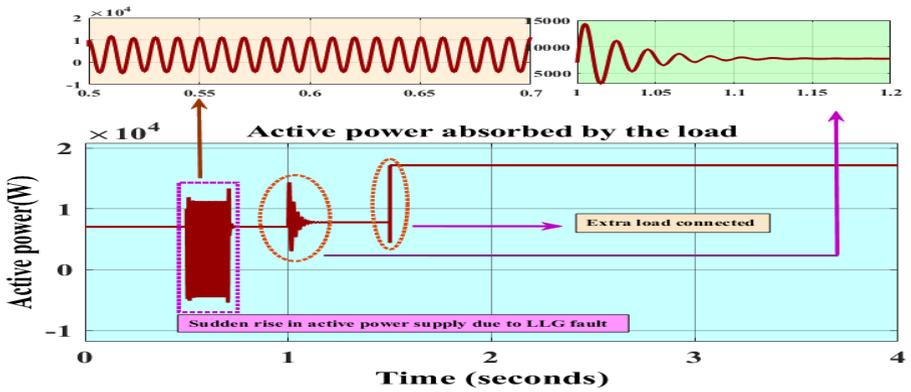


Fig. 10. Consumption of active power when the utility grid is acting alone.

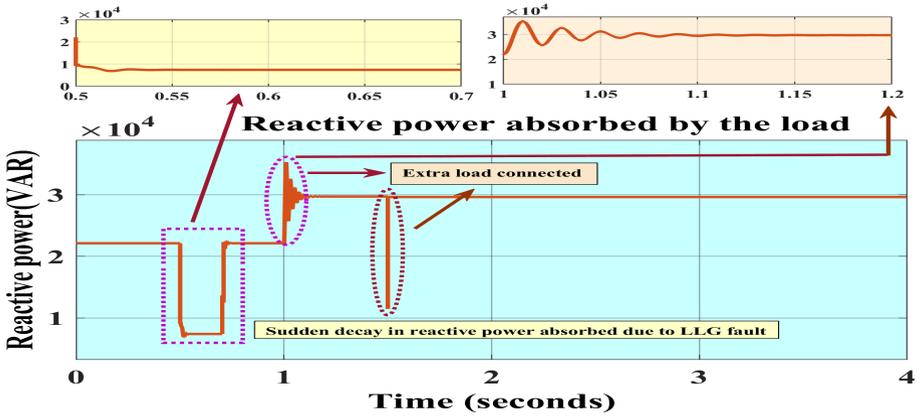


Fig. 11. Consumption of reactive power when the utility grid is acting alone.

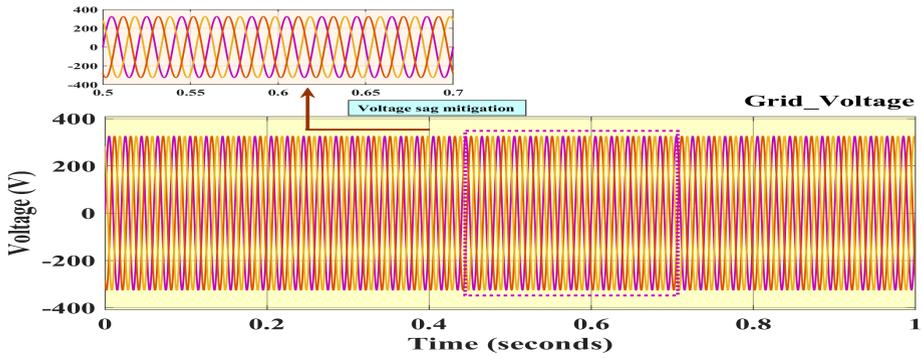


Fig. 12. After the fractional order STATCOM + SPV micro grid is implemented, a utility grid system experiences reduction of voltage sag during LLG fault.

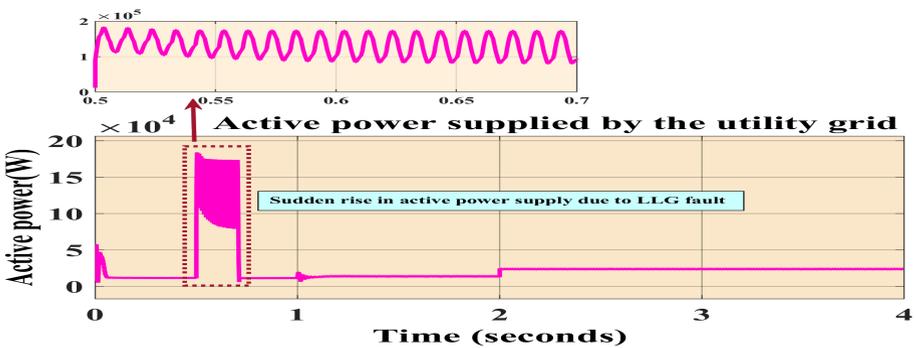


Fig. 13. The integrated PWM-VSI controlled by fractional order STATCOM technology for the utility grid-tied SPV plant provides active power.

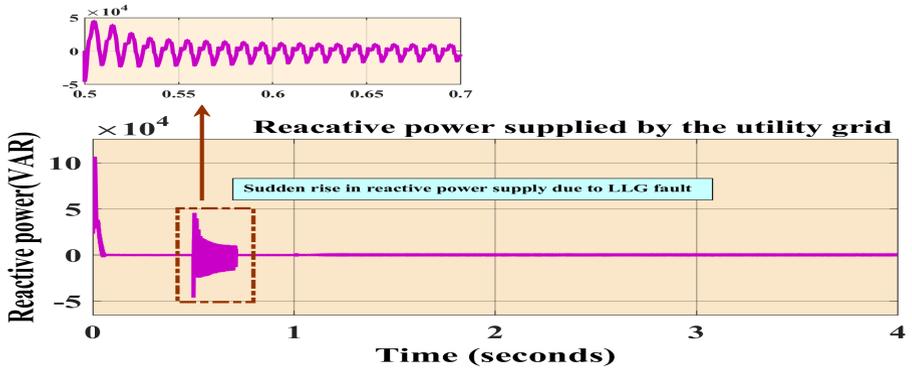


Fig. 14. The integrated PWM-VSI controlled by fractional order STATCOM technology for the utility grid-tied SPV plant provides reactive power.

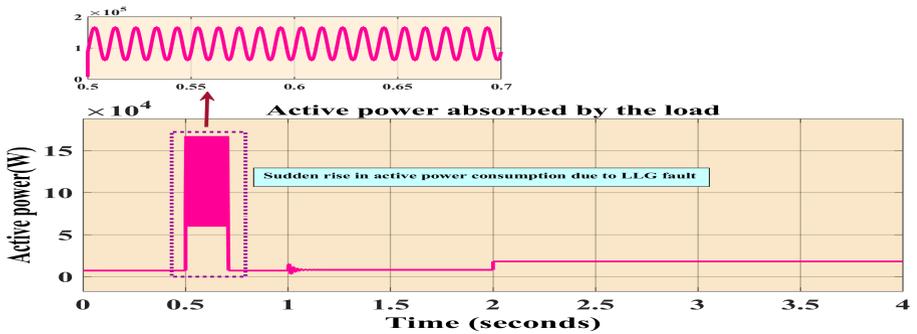


Fig. 15. Consumption of active power in a utility grid tied SPV plant integrated fractional order STATCOM.

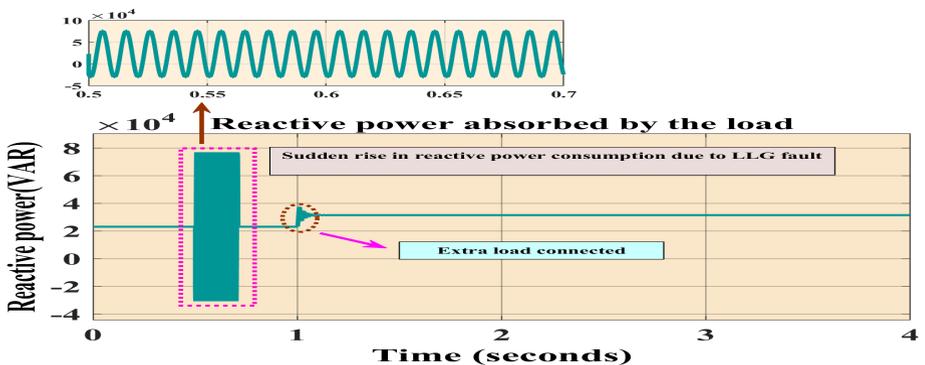


Fig. 16. Consumption of reactive power in a utility grid tied SPV plant integrated fractional order STATCOM.

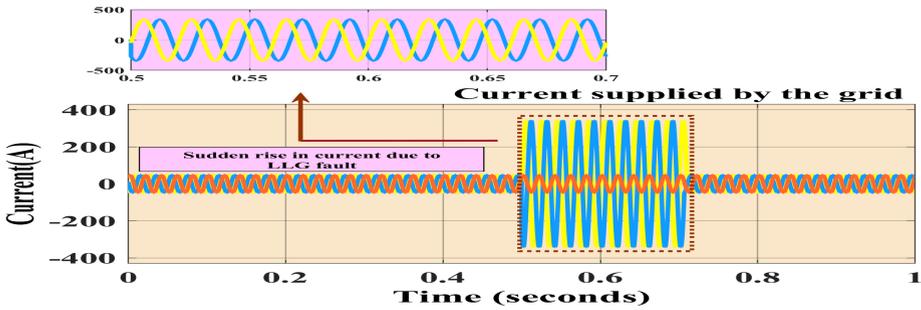


Fig. 17. Current supplied by the utility grid tied SPV plant integrated fractional order STATCOM.

Table 3. Information on the availability of active and reactive power.

When operating independently, the utility grid provides active power	17.16 KW
When operating independently, the utility grid provides reactive power	29.63 KVAR
The utility grid + GA optimized fractional order STATCOM provides active power when tied to the SPV micro grid	23.76 KW
The utility grid + GA optimized fractional order STATCOM provides reactive power when tied to the SPV micro grid	417.2 VAR

Table 4. Specifications of the system's overall active and reactive power load demand.

Active power load demand	Reactive power load demand
18.25 KW	31.51 KVAR

4 Conclusion

Micro grid connected utility grid provides resilience, dependability, cost effectiveness, and integration of renewable energy sources. They offer grid stability, backup power, and seamless power switching. The fast responsiveness of GA optimized fractional order STATCOM guarantees a prompt reaction to fault-induced voltage sag, while

micro grids provide focused support. According to the simulation studies, a utility grid-tied SPV micro grid incorporated GA optimized fractional order STATCOM reduces voltage sag under LLG fault circumstances better than a utility grid with the same rating but without the SPV micro grid integrated GA optimized fractional order STATCOM.

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