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CURRENT AND VOLTAGE HARMONIC ELIMINATION BY APF IN HYBRID ENERGY SYSTEM

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Abstract: In this work, concerns with power quality resulting from the grid integration of a distributed generating system with several power generators are investigated. The suggested hybrid sustainable energy system (HSES) takes into account a centralized DC bus design, where the power from the DC bus is conditioned by the grid-connected inverter to feed the linear and nonlinear loads coupled at the point of common coupling (PCC). But the PCC is less at risk of voltage and current harmonic pollution because of the presence of several power electronic converters and nonlinear loads. A traditional LC-based passive filter that is attached after the inverter is also useless in reducing the harmonics produced by such a system. In order to build and manage an active power filter (APF), an effort is made.

***Keywords* - Active power filter, hybrid energy system, power quality improvement, harmonic voltage and current compensation.**

1. INTRODUCTION

Due to their ability to reduce greenhouse gas emissions, large-scale photovoltaic (PV) farms and wind turbine generators (WTG) are receiving a lot of attention. However, the production of electricity from WTGs and PV arrays is sporadic and unreliable. It is very likely that a substantial penetration of solar or wind energy will result in voltage and stability issues in power networks. These phenomena have been reduced using a variety of techniques, including the usage of energy storage systems. The unstable nature of such intermittent energy sources has a direct impact on the vital stability between the load linked to the renewable energy source's power supply. As a result, abnormalities in bus voltage and system frequency, system oscillations, and unneeded reactive power production are seen, all of which have an impact on the stability and power quality of the system. With the development of power electronics technology and related Flexible A.C. Transmission System (FACTS) devices, these Renewable Energy Sources (RES) may be used to mitigate power quality problems brought on by their integration. APF can be used in an electric gearbox system or an electric distribution system and is a VAR source and sink. APF is able to control the actual power flow in a power system by including an energy storage technology.

2. Proposed Methodology

The procedures listed below are used in this research to explore how APF maintains voltage under various fault conditions and when harmonic load is applied to the system.

• Prior to powering the load, the distributed generator and the main ac power source were synchronized.

• Create an APF controller based on the voltage received from the power system's source and load sides as well as the current. The reference signal that is sent to the APF for triggering in response to system imbalance is generated based on voltage and current values.

• Produced faults of the unsymmetrical kind, such as L-G, L-L, and L-L-G.

• Captured the voltage and current signal that the APF controller sends out, and this controller generates a signal in accordance with the second step.

• Depending on the amount of voltage and current imbalance in the system, for instance, if a voltage sag condition occurs, the APF will maintain the gearbox line voltage by supplying the proper reactive power, and if a voltage swell condition occurs, the same will be true.

2.1 Proposed System

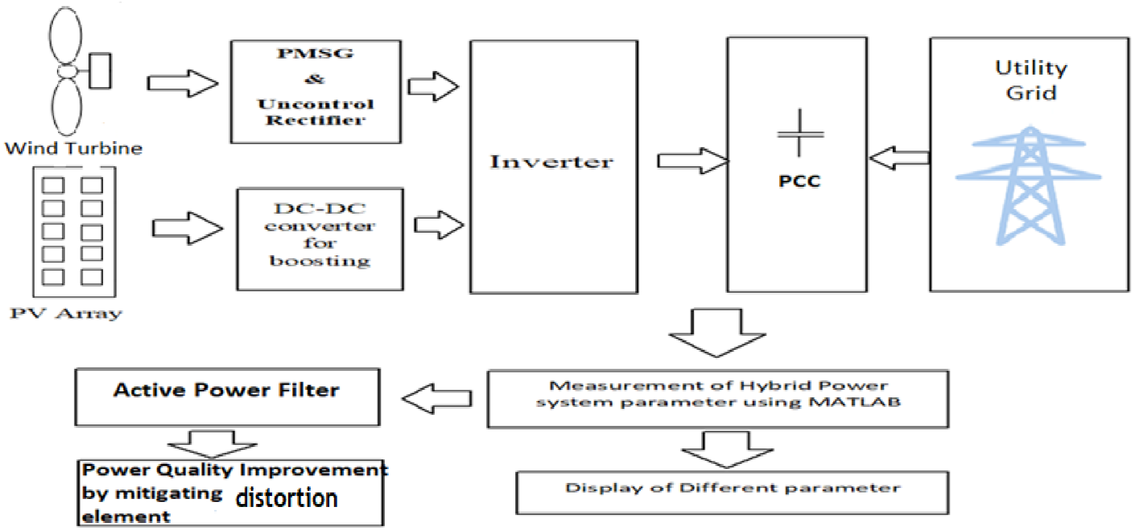

Fig. 1: Block Diagram of Proposed System

2.2 Point of Common Coupling

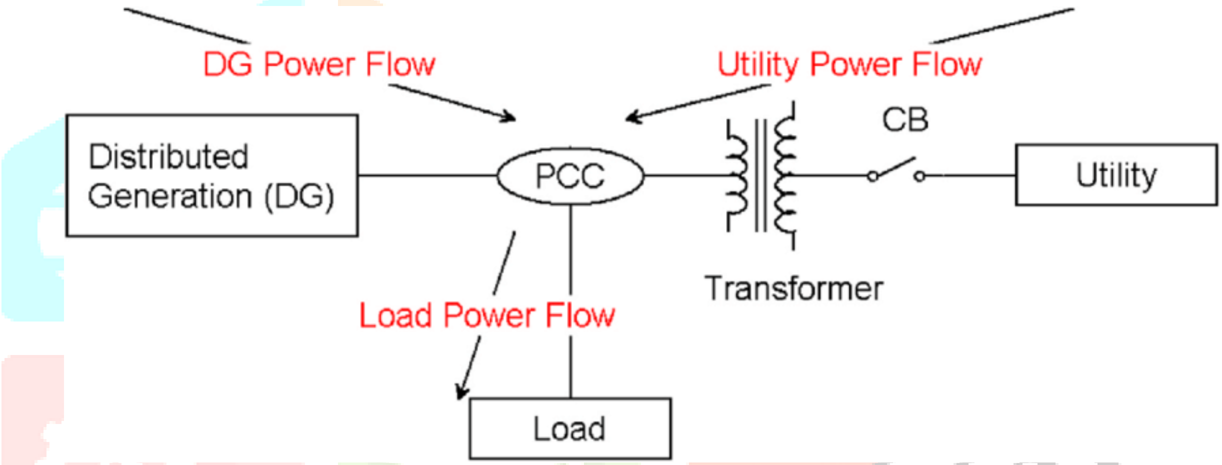

Fig. 2: Power Flow at PCC [1]

According to IEEE, the PCC is the location in the power system where the interaction between the electric utility and the consumer takes place. This location is often the utility revenue meter's customer side. The nearest location in the power system to the user where the owner, operator, or utility of the system might provide service to another user. The PCC is frequently on the HV side of the transformer when providing service to industrial customers (i.e., manufacturing facilities) through a specialized service transformer. The PCC is often on the LV side of the service transformer for commercial customers (office parks, retail centers, etc.) supplied by a shared service transformer.

2.3 Active Power Filter (APF)

Shunt active power filters inject an equal but opposing harmonic compensatory current to reduce current harmonics. The shunt active power filter acts as a current source in this instance, injecting the phase-shifted by 180 degrees harmonic components produced by the load. As a result, the active filter's impact cancels out harmonic current components present in the load current, keeping the source current sinusoidal and in phase with the appropriate phase-to-neutral voltage. Any kind of load regarded as a harmonic source can be used in accordance with this concept. Additionally, the active power filter may correct the load power factor with the right control strategy. Thus, the active power filter and nonlinear load are seen by the power distribution system as an ideal resistor. The primary distinction between active power filters (APFs) and passive power filters (PPFs) is that APFs reduce harmonics by injecting active power with the same frequency but in the opposite phase to cancel that harmonic, whereas PPFs use combinations of resistors (R), inductors (L), and capacitors (C), and do not need an external power source or active components like transistors. This distinction enables APFs to attenuate a variety of harmonics.

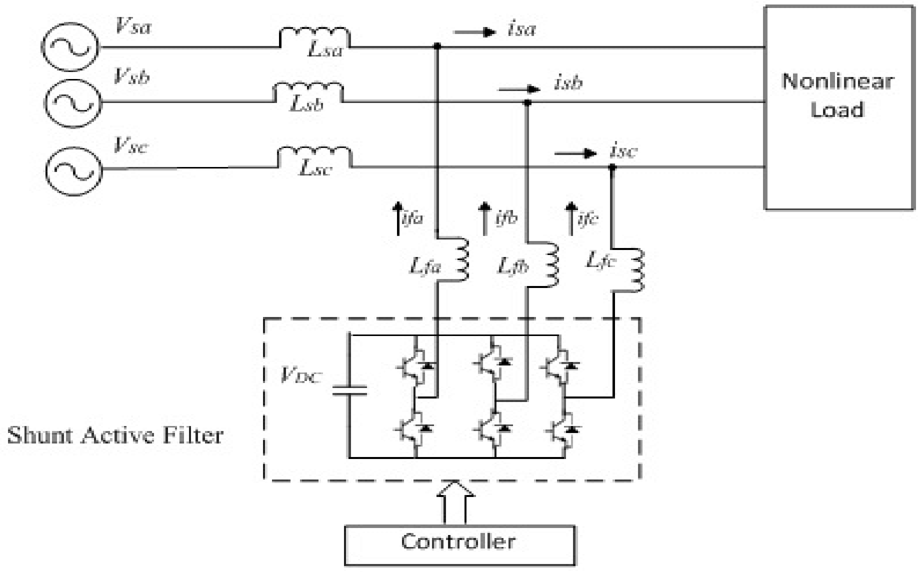

Fig. 3: Shunt Active Power Filter [2]

3. Power Flow Control Devices

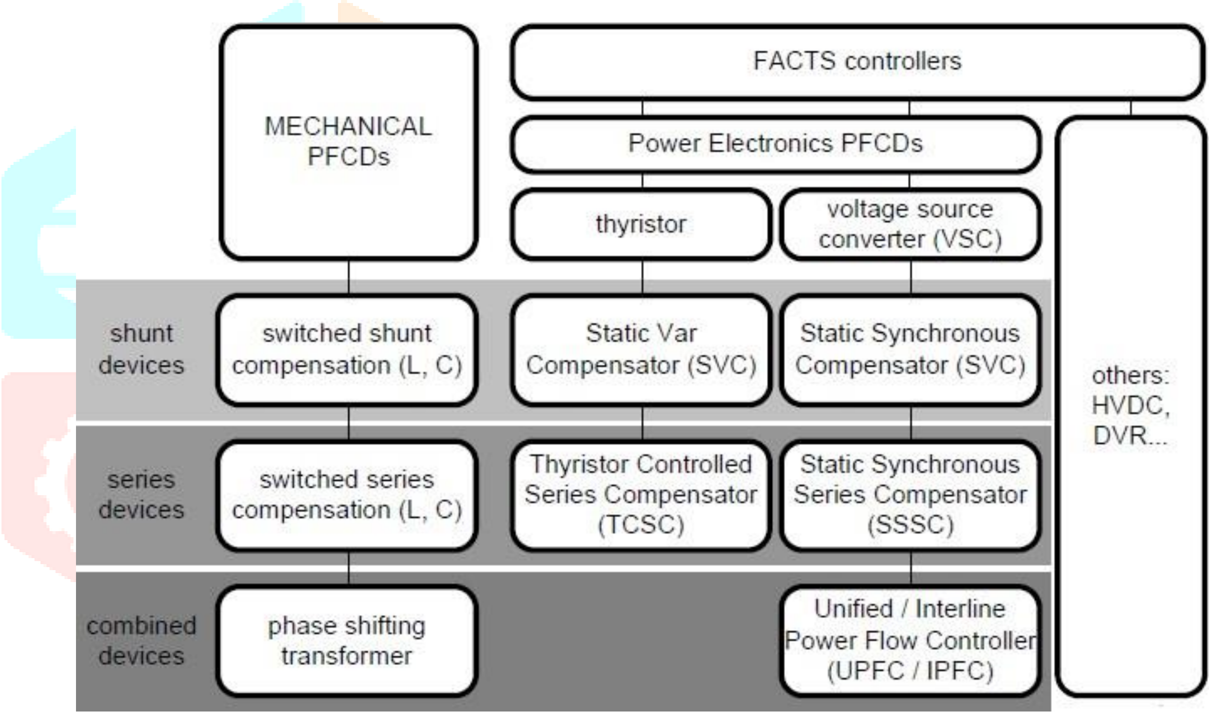

Fig. 4: Categorization of PFCD's [3]

3.1 Shunt Devices

Figure 5 illustrates a shunt device's fundamental operation. The goal is to locally provide the load with the reactive power it needs. The injected reactive current Ish may be changed by adjusting the shunt device's impedance, which thus indirectly affects the line current I. Ohm's law states that the line current I and the voltage drop across the transmission line Vs and Vr are linked. The magnitude of the voltage at the receiving end |Vr| may then be regulated by the shunt devices since it is possible to assume that the voltage at the transmitting end Vs has a constant value.

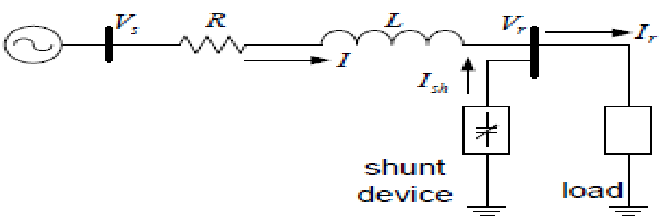

Fig. 5: Shunt Device operating principle [3]

The following equation describes the indirect link between the voltage Vr and the current injected by the shunt device, Ish:

$$Vr = Vs - IZ \quad (1)$$

$$Vr = Vs - (Ir - I_{sh})Z \quad (2)$$

While Z = R + jL. As demonstrated, the shunt current Ish can partially offset the high load current Ir, lowering the line current I under heavy load conditions and causing a little voltage drop. As a result, the shunt device may regulate the voltage by changing its impedance.

4. MATLAB Simulink Model

We have designed a MATLAB model to study the harmonic elements and the system with and without APF to make a comparative study of effect of APF on elimination of that elements.

4.1 MATLAB Model of Proposed System

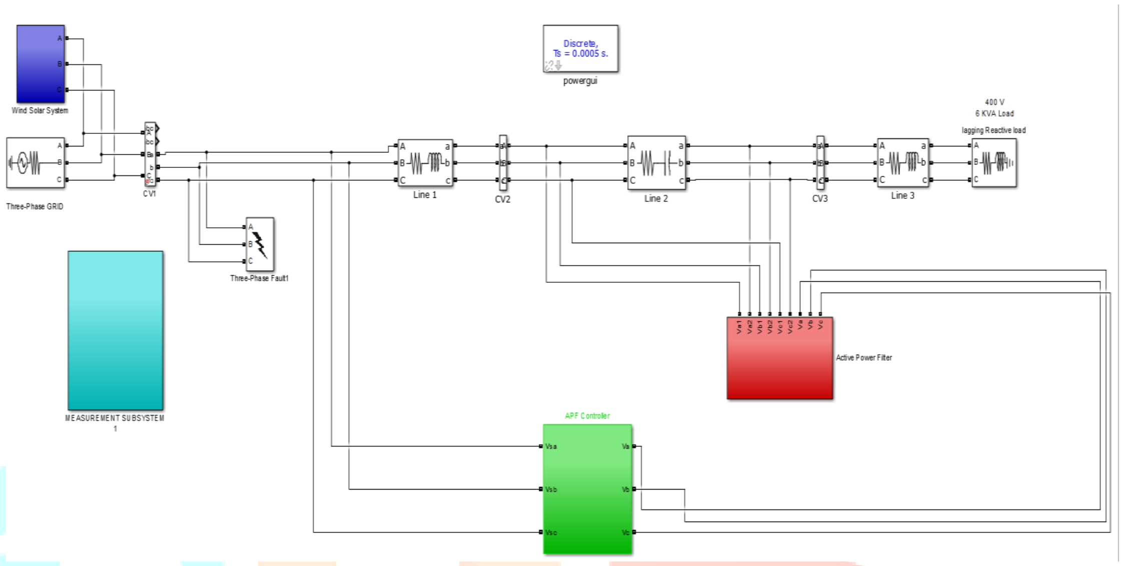

Fig. 6: MATLAB Simulation Model of Proposed System

The MATLAB simulation model of APF-based technology to enhance the power quality of solar-wind hybrid power systems is depicted in the above image. The model shown above includes a solar photovoltaic array, a wind system, a 120-degree inverter, an LC filter, a three-phase power system, a series controller, and a dark green bus bar measurement subsystem that measures the voltage and current of the bus bar three-phases.

4.2 Solar PV Array Subsystem Model

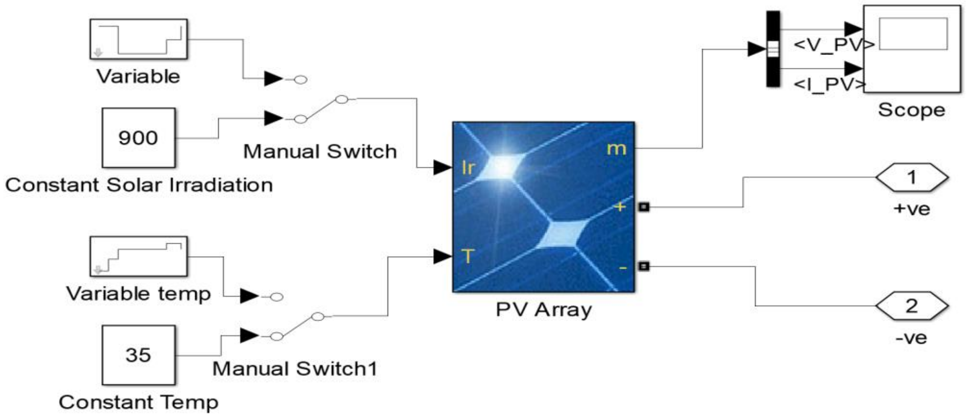

Fig. 7: MATLAB Simulation Model of Solar PV Array Subsystem

The solar PV subsystem model is shown in the above picture, together with the many corporate solar models that are accessible along with sun irradiation and temperature adjustments. 4.5 KW solar pv array system is what we designed in this instance. Despite the fact that there are many different types of solar cell materials, silicon is now the most widely used material in solar cells because of its scalability, momentum, and efficiency in light absorption. A minimum array size of 6.84 kW is provided for the fixed PV array. This PV array has 24 modules total, with 2 strings of 12 modules each linked in parallel and series. There are 36 PV cells arranged in series on each 180W solar panel.

4.3 Wind Turbine Subsystem

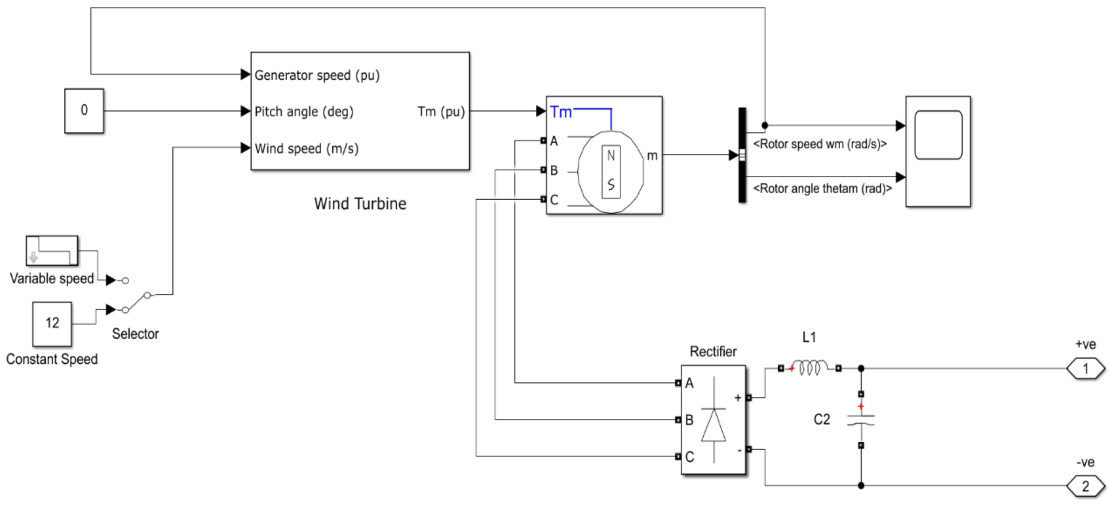

Fig. 8: MATLAB Simulation Model of Wind Turbine Subsystem

A permanent magnet synchronous machine with 3 phase round type rotor is used in above subsystem with base wind speed 12 m/s. Snubber resistance of 100 ohm and forward voltage of 0.8v with 3 bridge arms is implemented.

4.4 120 Degree Inverter

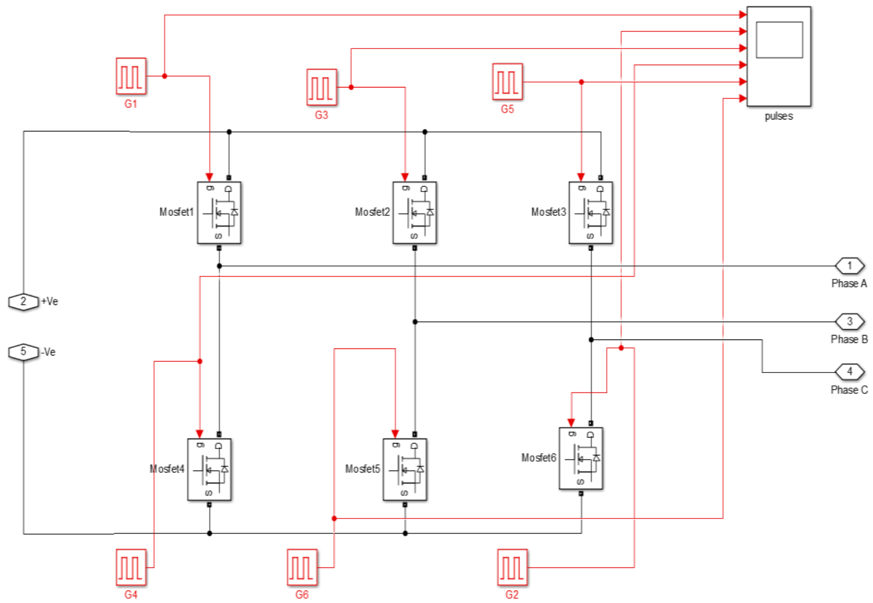

Fig. 9: MATLAB Simulation Model of Inverter

The three phase, six pulse MOSFET-based inverter subsystem is depicted in the figure above. The inverter subsystem's firing pulses were regulated by a 120-degree mode of operation.

5. Simulation Results

We are considering two cases under simulation results where; the first case is system under fault without APF and the system under fault with APF. We will observe the results and check how APF controls the harmonic element present in both voltage and current waveforms obtained at the scope. We are considering LLLG fault condition which is triple line to ground fault and is a common fault experienced on the system and will serve as a good harmonic distortion for voltage and current. The fault is introduced at 0.25 sec and lasts long for 0.05 sec for both the cases. Simulation results for both the cases are shown below and the results will help us analyze the difference that APF will make under this system and prove as a device for mitigation or eliminating the distortion occurred due to voltage and current harmonics.

5.1 Without APF under LLLG fault condition

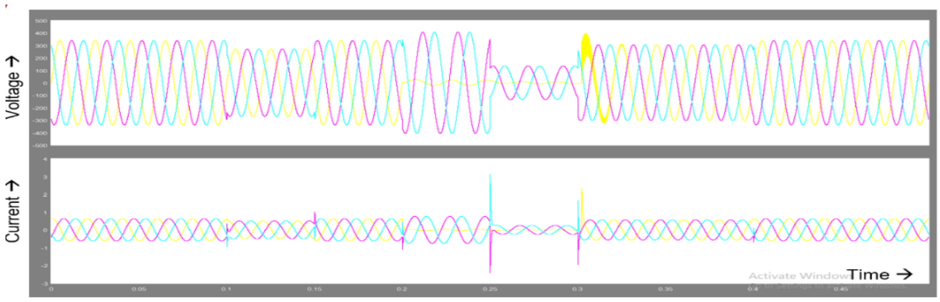

Fig. 10: Sending End Voltage and Current under LLLG fault condition without APF

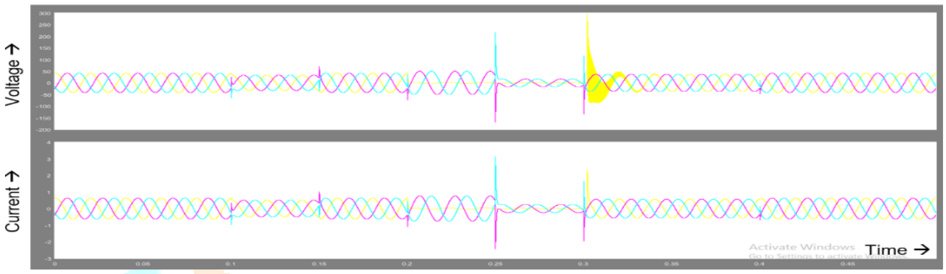

Fig. 11: Receiving End Voltage and Current under LLLG fault condition without APF

As we can see in both the cases the voltage and current is under disturbances or harmonics which are present due to fault as well as the harmonic elements from current due to hybrid energy system. After 0.1 sec we can see the harmonics in both voltage and current waveforms, which is again visible at 0.15 sec. Fault is occurred at 0.25 sec and we can see drop in voltage and current too.

5.2 With APF under LLLG fault condition

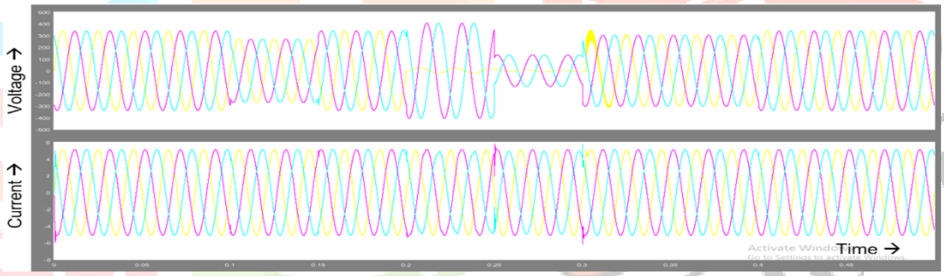

Fig. 12: Sending End Voltage and Current under LLLG fault condition with APF

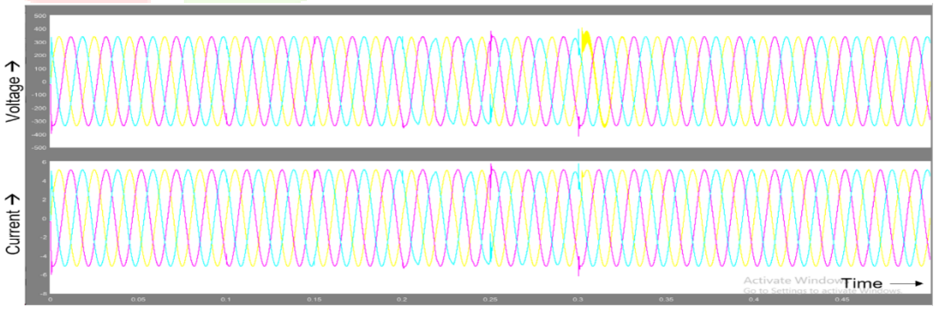

Fig. 13: Receiving End Voltage and Current under LLLG fault condition with APF

Here we introduced a LLLG fault at 0.25 sec for voltage and current harmonics. There is a sudden change in voltage level at 0.25 sec to 0.3 sec. The voltage and current harmonic is cleared within 0.05 sec by APF and the receiving end voltage and current can be seen free from harmonic elements up to 97 % with slight elements present which are negligible.

6. Conclusion

This study examined the function and potential of a series-connected APF installed in a microgrid that was linked to the grid. The PMSG-based wind energy system makes up the generation source. Even with the installation of a traditional passive LC filter after the VSI, the harmonic pollution issue in the grid side current waveform still exists. As a result, the developed APF provided an efficient harmonics compensation control, and at the same time, the APF successfully handled load unbalancing and increased nonlinear loading in the HSES system. The ability of APF to be utilized in the hybrid sustainable energy regime to enhance the present caliber of the supply grid is validated through simulation-based research.

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