

EFFECTIVE GRID SYNCHRONIZATION WITH FAULT RIDE THROUGH CAPABILITY

Poornima.P.U¹ EEE Department, SRM University, Kanchipuram dist, Tamilnadu, India, 603203.

poornimakandati@gmail.com

Subhakanta Sahoo², EEE Department, SRM University, Kanchipuram dist, Tamilnadu, India, 603203

Dr.S.S.Dash³, EEE Department, SRM University, Kanchipuram dist, Tamilnadu, India, 603203.

munu_dash_2k@yahoo.com

Abstract—A Grid Synchronization(GS) algorithm is required to allow a smooth transfer from islanded mode to grid tied mode . In this proposed system, reliable GS technique is analyzed based on Synchronous Reference Frame Phase Locked Loop(SRF-PLL) and Space Vector Pulse Width Modulation(SVPWM) technique for faster synchronization process and data analysis. Dynamic Voltage Restorer(DVR) with the SVPWM technique is analysed. Objective of proposed scheme is to connect a 10KW load 10kw is fed from a PV source of 5kw & a Fuel Stack of 6kw as back up source during islanded mode. After disconnecting PV source load is connected to Grid with Fuel Stack as main source . Within grid when 3phase fault is included voltage is dropped and DVR is used to provide voltage support. The synchronization process is carried out using SVPWM and SRFPLL. A proton exchange membrane fuel cell (PEM-FC) with photovoltaic system is included .In the proposed system PV will be the primary source to satisfy the load and Fuel Cell will be used as backup source in islanded mode or main source in grid connected mode. A control strategy is developed by integrating these sources. A simulation model will be designed for the above system under MATLAB SIMULINK environment. Power quality improvement using DVR will be done through simulink.

Index Terms—fault ride through capability, grid synchronization, Synchronous Reference Frame Phase Locked Loop, Space Vector Pulse Width Modulation, Dynamic Voltage Restorer.

I. INTRODUCTION

Now a days Renewable energy technologies can be used to meet the load demands. Presently challenges faced such as environmental pollution, climate change, energy crisis, global warming etc which can be reduced by appropriate use of renewable energy sources like Solar, wind and fuel cells to overcome above problems. Solar system is the most important source as there are no moving parts, compact design, no emission of harmful gases, minimal maintenance etc.,. Main disadvantages of solar system is that it cannot operate during night time and cloudy environment so the efficiency and reliability of the system will be decreased and output will vary[1]. Because of the environmental impact and intermittent

nature single renewable source will not be able to supply the power all the time. To overcome the problem more numbers of Renewable Energy Sources can be integrated to meet the critical loads and normal loads. It is more reliable to connect more no of renewable sources to make the whole system efficient. Such integrated system is known as Microgrid in which solar system will be primary source to supply the load then after some time fuel will be connected to fulfill load demand[2-3]. Along with the fuel cell grid is connected to supply the load and here grid is infinite bus system from which we can extract any amount of power required depending upon the load. Here Fuel cell can be taken as a primary or backup source. We can use battery also to store the required energy[4-6]. This is the most effective combination. The advantages of PEMFC are excellent load following capability, compactness, low working temperature etc[7-8]. In the proposed system initially solar system will supply the load in islanded mode then after some time using breaker grid connected mode will be introduced, this breaker is connected that will be on for some period and during that period grid will be connected along with the fuel cell. Here grid synchronization is performed using SRFPLL and SVPWM by taking magnitude and angle. Both the synchronization process are analyzed and results are compared by taking a three phase fault with Dynamic Voltage Restorer(DVR). In this system during grid connected mode one three phase fault is included and during that period voltage reduced which is being supplied by DVR. This entire system will be useful if grid will be disturbed as it can be worked as a islanded mode or grid connected mode and also if in grid connected mode some disturbances will be there then DVR will be there to support. Hence by combining all these systems uninterruptable power can be fed. Matlab Simulink environment is being used to develop the system.

II. SYSTEM DESCRIPTION

The block diagram of effective grid synchronization is shown in the figure 1. The system consisting of PV system with maximum power point tracking (MPPT), and Fuel Cell system. Here fuel cell is used as a backup source and PV as a primary source. FC will supply the power if PV system fails. This

system describes grid synchronization using synchronous reference frame phase locked loop(SRFPLL).

Figure 2 describes about the synchronization using space vector pulse width modulation(SVPWM) technique. Here Fuel Cell is used as a source to satisfy the load demand through grid synchronization using SVPWM using circuit breaker and results of both grid synchronization techniques are compared and verified.

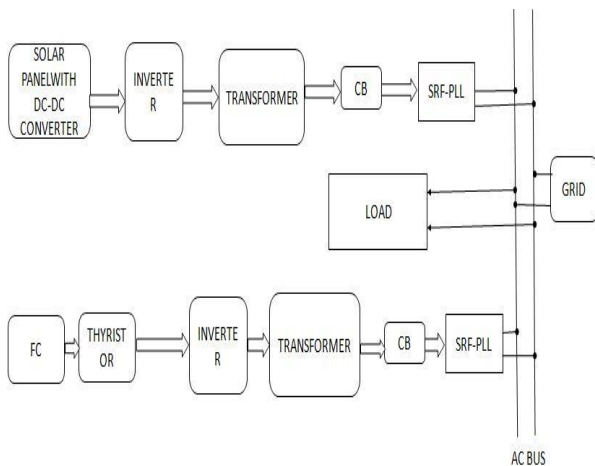


Figure 1 Block diagram grid connected system with SRF PLL

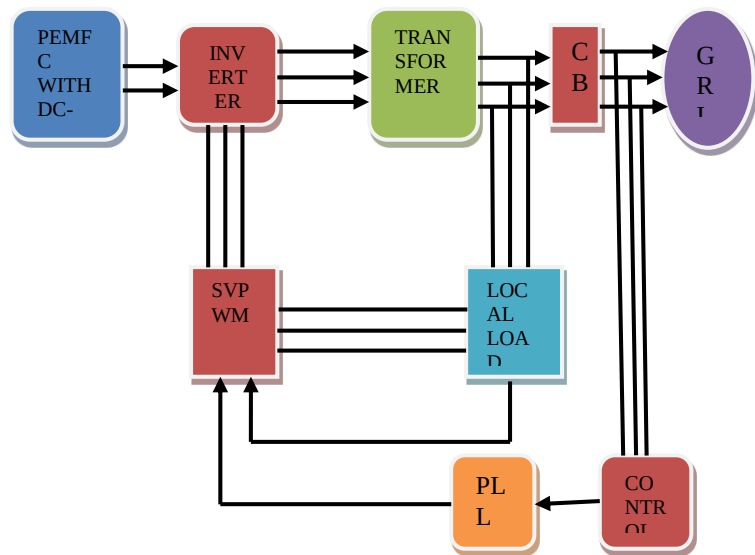


Figure 2 Block diagram grid connected system with SVPWM PLL

III. SYSTEM DESCRIPTION

A. SOLAR SYSTEM WITH MPPT TECHNIQUE

The figure 3 showing equivalent circuit model of single diode solar cell. The model containing one parallel resistance R_{sh} , one current source I_{ph} , and one diode, series resistance R .

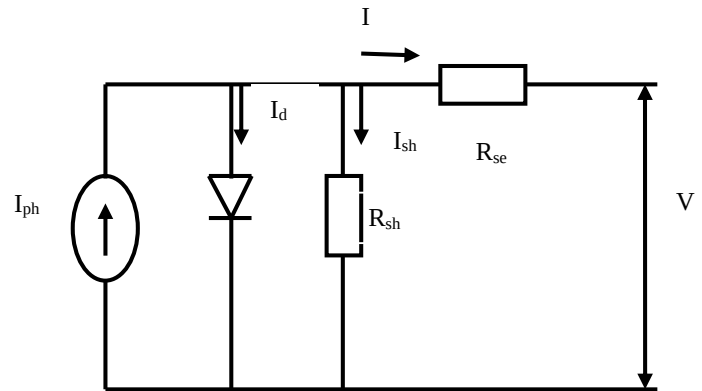


Figure 3 single diode model of PV cell

Where, I_{ph} represents the total current generated by the cell for a given lighting and temperature conditions in Amperes, I_d is the diode current and V is load voltage. Keeping a solar array in the correct position so it will receive the maximum amount of solar irradiance available to produce the maximum possible power. Here to extract maximum power from panel MPPT algorithms are required only because of nonlinear current-voltage characteristic with a point where maximum power is produced. The perturb and observe(P&O) technique observes the array output power and determining the next action, either increasing or decreasing the array operation voltage. This method provides predictive and accurate solutions to maximum power point tracking under partially shaded conditions. This is most commonly used MPPT algorithm and its flow chart is shown Figure 4.

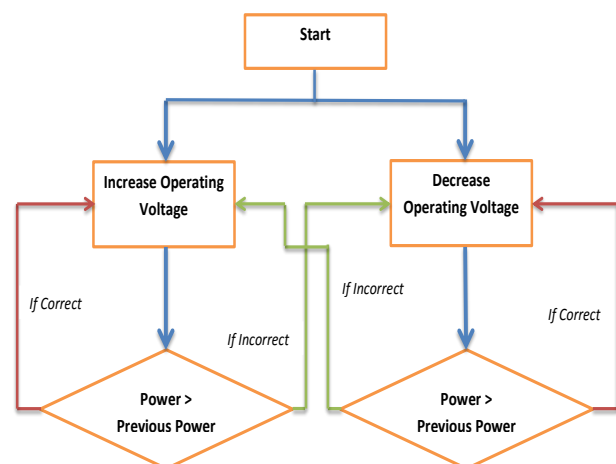


Figure 4 Flow Chart of P&O algorithm

B. FUEL CELL FED SYSTEM

Chemical energy of a reaction directly converted to electrical energy through electrochemical devices like Fuel Cells. Proton Exchange membrane fuel-cell (PEMFC) has reliable Performance under intermittent supply and is commercially available at large industrial scale capacities. PEMFC is widely used device.

Here gas is diffused by gas diffusion layer on either side of membrane electrode assembly. This is having advantages that water is only discharge here. Fuel cells creating electricity chemically hence limiting conventional power plants.

Group of fuel cells are connected in series to get the high value of DC voltage as output voltage of single fuel cell is low.

Table 1 Fuel cell system parameters

Parameters Required	Value
Type of FC	PEMFC(Proton exchange membrane fuel cell)
Rating of Power	5 KW
Rating of Voltage	45v DC voltage

IV. PHASE LOCKED LOOP AND DYNAMIC VOLTAGE RESTORER

Phase locked loop (PLL) is used in the frequency synchronizing applications. It was only proposed for a radio receiver not for radars or frequency synthesis. It is a control circuit. Here information converted to frequency as frequency and phase are linearly related that is rate of change of phase is equal with frequency.

If there is phase locking there is frequency locking. I cannot discuss in terms of frequency change as taking linear system hence taking about change in phase. So once phase lock occurs there must be frequency lock. Invariably if I am putting certain frequency at phase detector output has to track the input frequency. Hence in PLL, there is frequency locking.

In case of Synchronous Reference Frame Phase Locked Loop(SRF-PLL) three phase to two phase conversion of voltage and current towards grid side taking place. Again two phase rotational to two phase stationary frame conversion takes place by considering simple mathematical modeling so that easily we can take constant values from the output of PLL. These constant values again being converted to three phase values and compared with repeating sequence to produce pulses for the inverter as the gate signals. Here in simulation one PI controller is used as loop filter to make the SRF-PLL insensitive to grid voltage variation.

If comparing SRF-PLL with Space Vector PWM(SVPWM) technique, because of less Total Harmonic Distortion(THD) and better power factor SVPWM is the best technique. If upper

transistor is switched ON lower transistor is switched OFF which is the basic principle of SVPWM.

Table 2 modulation index for SVPWM

Modulation Index	THD For Current(%)	Overall PF
0.5	129.62	
0.7	40.71	0.871
0.9	3.42	

Dynamic Voltage Restorer(DVR) is a static VAR device which is used in a variety of transmission and distribution systems. The basic principle of the dynamic voltage restorer is to inject a voltage of required magnitude and frequency, so that it can restore the load side voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted. DC input terminal is connected to energy storage device. Then inverter with pulse generator and filter circuit with transformer of appropriate rating is connected to supply the required amount of voltage that is lost during fault towards grid side. DVR is mainly used to mitigate the damaging effects of voltage swells, voltage unbalance and waveform distortion.

V. SIMULATION RESULTS AND ANALYSIS

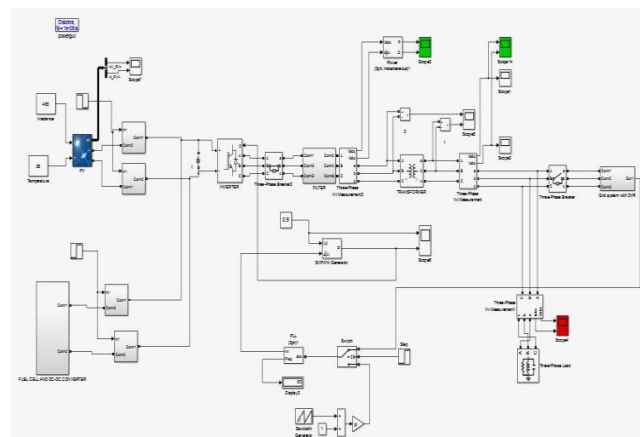


Figure 5 Simulation diagram of PV system and Fuel Cell with SVPWM technique and dynamic voltage restorer

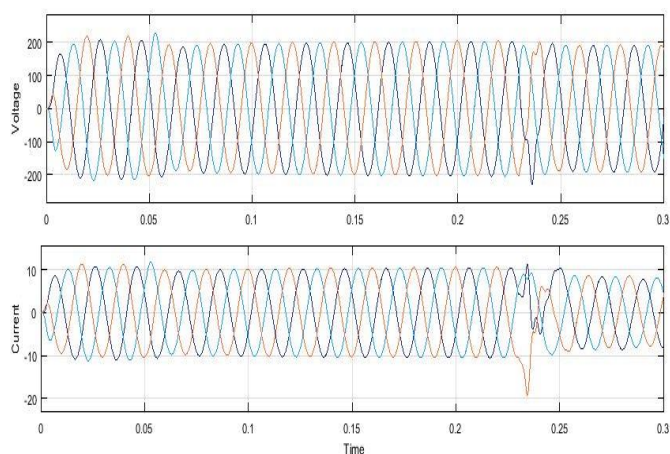


Figure 6 Output waveforms of voltage, current with respect to time respectively of Voltage Source Inverter(VSI)

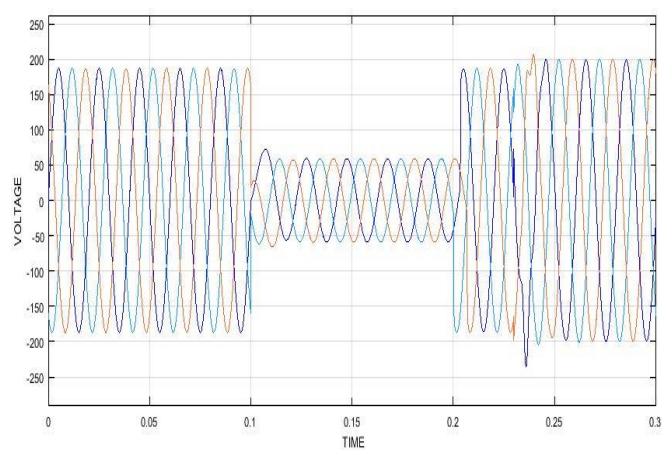


Figure 9 Voltage waveform of Grid during three phase fault

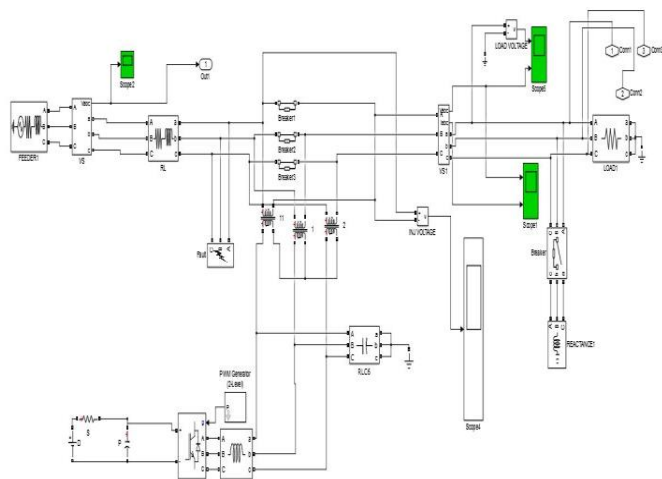


Figure 7 simulation diagram of DVR connected to system towards grid side

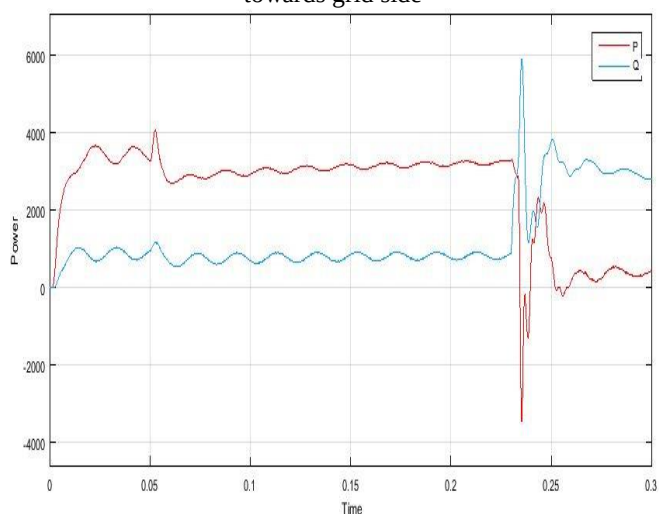


Figure 8 Waveform of Active and Reactive power towards VSI

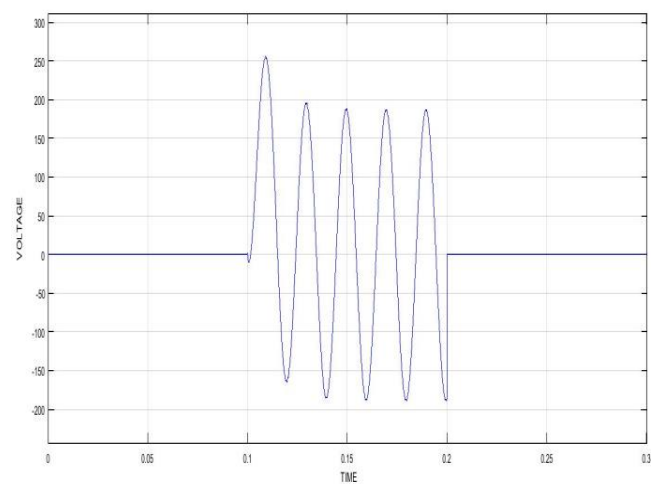


Figure 10 Voltage Supplied by DVR during three phase fault

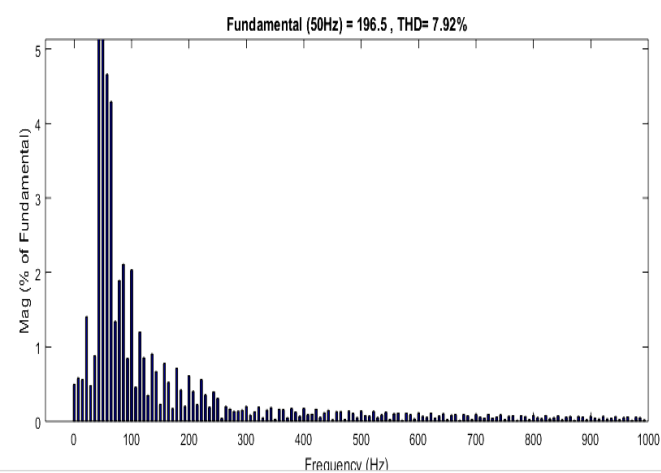


Figure 11 FFT Analysis of Load Current Using SVPWM

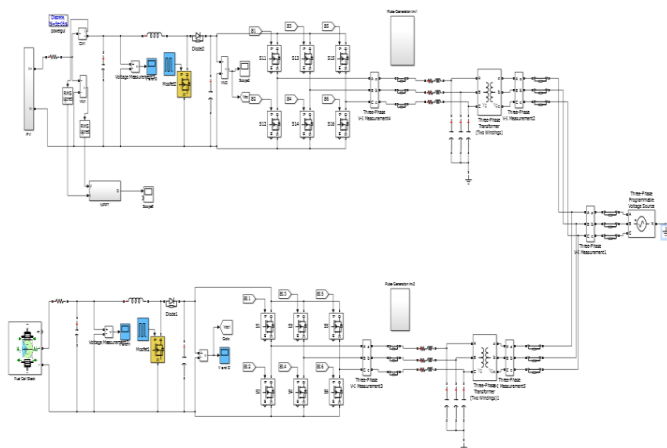


Figure 12 Simulation diagram PV System and Fuel Cell with SRFPLL

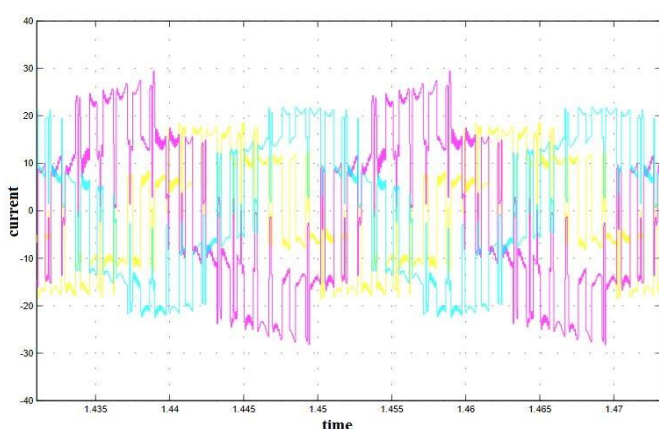


Figure 13 Current Waveform of inverter using SRFPLL

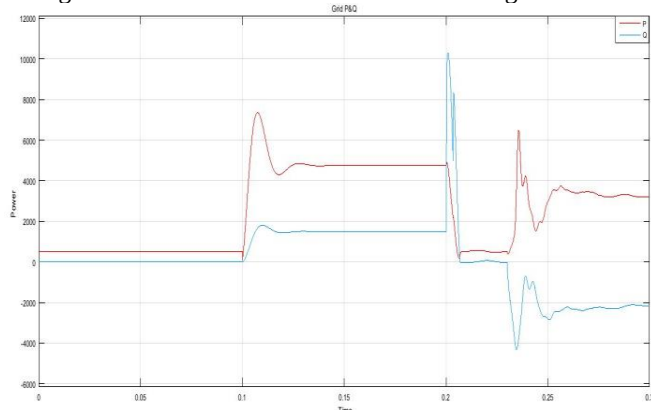


Figure 14 Real and Reactive power waveform of GRID through SRFPLL

Figure 5 shows simulation diagram of PV array with Fuel stack are connected to supply 10KW of load upto 0.1 second during islanded mode. After 0.1 second using SVPWM synchronization technique Fuel Stack is being connected with load in grid connected mode. Here PV array will be disconnected. Within grid one DVR is included to withstand the reduction in voltage during fault generated within 0.1 to 0.2 second.

Figure 6 shows Voltage(v) and Current(amp) with respect to time(sec) graph describes the voltage of 200V and current of 10 amp when PV array and Fuel Stack are in islanded mode of operation supplying grid of 10KW and 440V RMS voltage.

Figure 7 shows simulation diagram of DVR connected to system towards grid side supplying voltage which is absent during fault inside the grid.

Figure 8 shows the voltage source inverter Power with respect to time in sec during the connection of Fuel Stack with Grid to supply load of 10KW.

Figure 9 shows that one three phase fault is considered during synchronization process only to check the fault ride through capability and here during 0.1sec to 0.2 sec fault is there. During that period voltage will be reduced.

Figure 10 shows During the fault inside the grid to withstand the voltage reduction one DVR is included which will supply the required amount of voltage as reduced during fault. Here synchronization is done with SVPWM technique and DVR also included inside the grid.

Figure 11 shows FFT Analysis of Load Current Using SVPWM.

Figure 12 shows PV array and fuel stack both are being synchronized with grid through SRFPLL technique. This method is being compared with above SVPWM synchronization technique.

Figure 13 shows current waveform of inverter using SRFPLL.

Figure 14 shows the Grid side P&Q with time in sec. when within the grid DVR is connected to supply the required amount of voltage. Here SVPWM technique is used to synchronize the grid with fuel stack to supply load of 10KW.

VI. CONCLUSION

For the power quality improvement of a grid connected system with solar and fuel cell to supply the critical load, the FACTS controller DVR system is used. The issues related to the power quality and its consequences are represented here. The operation of control system is developed for the DVR, SVPWM & SRFPLL in the MATLAB/SIMULINK for maintaining synchronization is to be simulated. It has the capability to synchronize the Microgrid with grid reliably by cancelling the harmonics parts of load current. It maintains and controls source voltage and source current across the entire circuit and supporting both active and reactive power demand for integration of all kind of renewable energy sources at PCC along with the load in the microgrid system, thus it gives a chance to improve better utilization of transmission lines & also gives a better synchronization process with less harmonics. The integrated solar, fuel cell with synchronization technique like SRF-PLL, SVPWM and FACTS controllers like DVR have shown outstanding performance and

it fulfills all the requirements of the power quality enhancement mentioned in the proposed system.

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