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Performance Analysis of Hybrid Multi-Port AC-DC/DC-DC Embedded Based Energy Flow Optimizing Using Resilient Power Flow Control (RPFC) Technique

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***Abstract* - In recent decades, the utilization of renewable power sources has proven to be a reliable and clean vitality more universal, and with specific ultimate goals to achieve efficient and renewable energy power generation. The proposed system is improve the stabilize energy flow between micro grids and the main grid. The power generation of the each and every renewable sources are monitored and controlled by the proposed Resilient Power Flow Control (RPFC) system and also the energy flow variation of the grid system is analyzed and presented in this paper. This work demonstrates the role of energy routers in optimizing the efficient and flexible way of energy stabilization in grid system. This analysis model establishes the entire system, including power routers, interconnected microcircuits, and the main grid. Interconnected microcircuits were analyzed by various controller facilitated by power routers, and corresponding control strategies were developed. The proposed system shows the effectiveness and reliability of the control strategy for micro-grid interconnection and flexible energy flow correspondence.**
***Keywords:* Deferrable Load, Hybrid Energy Management, Energy Storage System, Resilient Power Flow Control (RPFC)**

I. INTRODUCTION

The Renewable Energy Sources (RES) are natural dependent, due to this there is no stability power generation in the system. The energy router based grid connected hybrid system power flow management control is introduced in this system for energy stabilization. The purpose of the energy router is to meet the load requirement, and improve the power flow from sources and to the grid system. Due to this condition the DC-DC converter are utilized to improve the renewable energy generation.

Based on the proper Pulse Width Modulation (PWM) strategy the convert efficiency will be determined. Due to technological advances in intelligent, multifunctional energy converters and router energy (ERS) are analyzed energy flows in the renewable energy system also improving the energy in the grid system (or) load. The improvements of energy AC-DC Hybrid Multiport system for stability in the proposed system, it needs to identify the drawback in the conventional methods that is given below.

The purpose of a generic configuration based on hybrid AC/DC Multi-Port and Multi-Function Grid and equivalent circuits and mathematics modeling in MPMF-PET [1]. The purpose of enhancing the power in the grid system, they are two-stage of compensation is process [2] further stage the Zero sequence Voltage vector is used in the cascaded H-bridge based grid interconnected with hybrid AC/DC multi-port system for stabilize the power flow[3-4]. Multi-port power electronic transformers are used to achieve high-speed hybridization of Alternating Current (AC) and DC multi-stage and various distributed renewable energy sources. In detail, the functions of the reliable and AC/DC hybrid power system are analyzed, and the simulations are carried out by computer and power reliability calculations [5].

Multi-port DC-DC-AC (MP-DC-AC) converters offer the ability to convert power into a single converter configuration between two DC systems and AC systems. Possible benefits include reduced energy conversion levels [6-8]. The Very Large Scale Integration (VLSI) technology enabled to develop reliable Low Voltage Direct Current (LVTC) [9] supply network competitive power converters. In terms of traditional dual-loop control, the three-stage AC/DC converter with its bilateral power flow and a unit power factor on the AC side can act as a link bridge in a hybrid micro grid [10]. Research on conventional optimization planning almost all AC/DC hybrid power systems are Voltage Source Control (VSC)-based this is the most efficient control strategy for hybrid system [11-12]. Multi-input converter rendering it integrates actively controlled Hybrid Energy Storage System (HESS) [14] and front-end AC-DC power factor correction (PFC) converter [13]. An integrated power Load Flow (LF) model For the AC-DC Hybrid Distribution System (DSS). Proposed Models can be used in hybrid Distribution System (DS) and hybrid configurations AC/DC bus and AC/DC lines. A new assortment of DS and LF analysis is also introduced [15-17].

The converter can connect multiple DC buses to different voltages and enable port voltage to control power flow a new resonant ZCS multi-input/multi-output converter is provided. Each of the desired power input ports is sent to each of the output ports independently of the converter [18-20]. The system is also given the ability to operate in both directions.

The proposed system describes the use of micro grids in a novel and flexible interconnect framework. The Resilient Power Flow Control (RPFC) technique proposes increasing the penetration and need for renewable energy to reduce dependence on energy storage equipment. This proposed system a new model using direct energy consumption to mitigate the impact of Distributed Energy Resources (DER) output fluctuations on the stability and reliability of power systems. In the remainder of this work, it will be organized as follows: The entire system is structured including an interconnected micro grid and main grid, and a power router, analytical model of the DC-DC converter and the Inverter are performance are evaluated. The simulated Mat lab / Simulink Simulation 2017b platform demonstrates the effectiveness and reliability of the presented interconnected framework and its associated energy control strategy.

From the analysis of the conventional techniques the different parameter like Execution time (sec), Steady state error (%), THD (%) and Efficiency in (%), are needs to be improved, the proposed hybrid multi-port converter system will improve the performance system also considering the above parameters improvements.

II. PROPOSED RPFC SYSTEM

The proposed hybrid converter is designed to integrate DC / DC converters with DC / AC inverters operating on any dynamic condition to provide a Stabilized power the grid and load system. The additional benefits interconnected structure it is used to increase the rated power reduces input current ripple, output voltage ripple, power loss and efficiency. By switching the proper pulse to the proposed converter efficiency of the system is enhanced by the use of energy-saving inductors also the bi-directional converter save the energy during normal condition and it provides a power during uncertainty state. The proposed RPFC technique improves converter performance, and provides stability under critical conditions. The energy routers will analyses the power flow operation of the proposed model. The detailed Operating principles and design considerations have been proposed system shows in Figure 1.

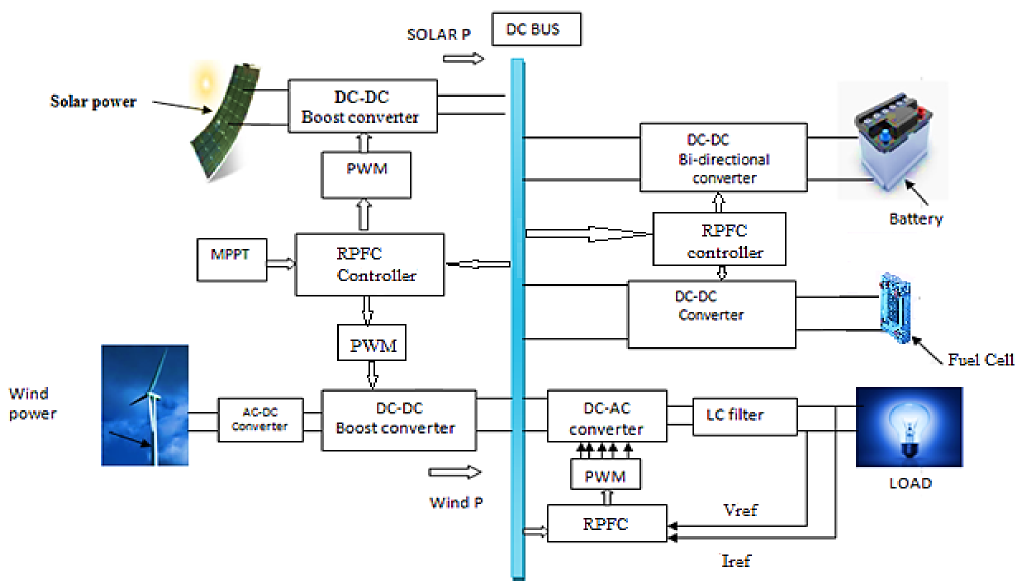

Fig. 1 The block diagram for the Multi-Port Converter

A. Solar PV Array Module and Equivalent Circuit

The SPV system consists of several solar cells, which are connected in series and in parallel to generate voltage. Typically, an SPV frame provides a non-linear voltage. If the solar rays hits the silicon PV cells it will generate the energy according to the irradiance level. The output of each SPV cell is derived from solar radiation and changes periodically. The equivalent circuit based solar power generations are described below. Equivalent circuit model of the photovoltaic module based on single diode model designed for are shown in the figure 2. This model of PV is used for all applications because its structure is simple and more reliable than other multi diode models. The PV module designed using the equivalent circuit must match the real time parameters of a practical PV panel like open circuit voltage, short circuit current, maximum voltage and power rating.

$$I = I_{ph} - I_d \left[\exp\left(\frac{q(V+IR_S)}{KT_C A} - 1\right)\right] - (V + IR_S)/R_P \ldots (1)$$

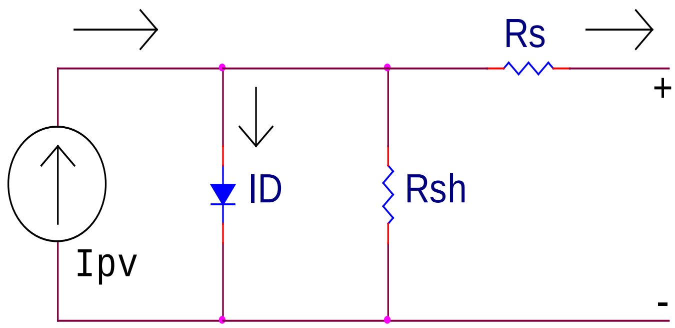

Fig. 2 Equivalent circuit

In order to extract maximum power from a given solar array, a MPPT (Maximum Power Point Tracking) is employed widely in modeling and for serving as standalone applications. Nominal voltage and current in equation (2) is replaced by V_{MPP} and I_{MPP} is performed by using proposed MPPT method as,

$$I_{MPP} = N_P \left\{ I_{ph} - I_0 \left\{ exp\left(\frac{qV_{MPP}}{nN_sKT} \right) \right\} \right\} \ldots (2)$$

$$V_{mpp} = K_1 * V_{oc} \ldots (3)$$

$$I_{mpp} = K_2 * I_{sc} \ldots (4)$$

B. RPFC based MPPT Control System

In the proposed work, RPFC based MPPT system is introduced, so that the power change of the PV module is analysed initially. The PV power output is periodically measured and compared with the previously performed power. If the output power increases, the same process will continue, otherwise it will interfere with the reversal. PV module voltage is increased or decreased in order to check whether the power is increased or decreased. When increased power increases, the line voltage, which means the operating point of the PV module will be away from the MPP.

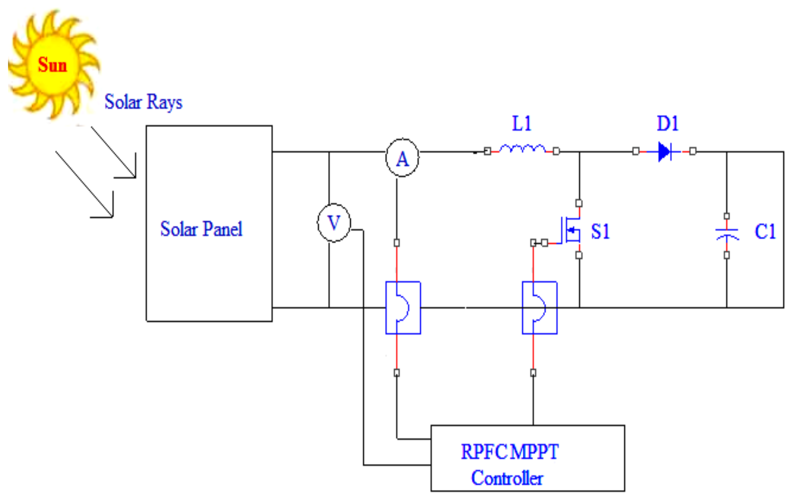

Fig. 3 RPFC based MPPT Control System

Accordingly, a further interference is required to achieve the MPP rights. Conversely, if the voltage is increased to reduce the power supply line, which means the operating point of the PV module at the left and right of the MPP requires further power to reach MPP. Fig 3 shows the block diagram of RPFC based MPPT Control System.

C. Wind Power Generation

Wind energy plays a vital role in creating an environmentally sustainable low-carbon economy. This work observes the process of wind energy technologies for wind energy use. The wind stability operation is shown in Figure 4.

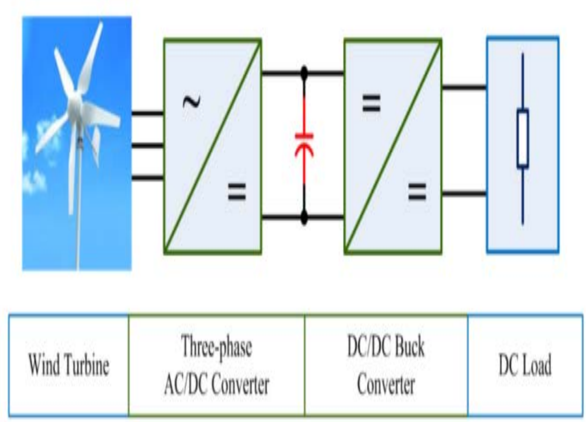

Fig. 4 Overall Block diagram of the wind energy system

According to different aerodynamic characteristics, the wind energy captured by the wind turbine can be expressed as,

$$P = 1/2Cp(\lambda,\beta)\rho\pi R^2 V^3 \qquad (5)$$
$$\lambda = WR/V \qquad (6)$$
$$P_{max} = 1/2\rho\pi R^5 \qquad (7)$$

Output engine power relative to the WEG characteristics of different wind speeds, where the line shows the unique turbine speed relative to the maximum power point characteristic. The various wind turbine rotation speeds and the different wind speeds V. The MPP of each P-W curve is the wind speed. The peak power point of the P-W curve corresponds to DP / DW = 0. The power generated by different wind turbine speed produces optimal target control under the generator.

D. Wind Power Generation Circuit

The circuit diagram based on the proposed wind power generation based AC-DC-DC converter circuit in Figure 5.The wind turbine is considered as a Wind Generation (WG) source. The output voltage of the AC-DC converter is controlled by the "K" in order to maintain a fixed or constant input voltage even when the WG wind-based AC output voltage changes. The purpose of the DC-DC converter is to provide a regulated (boost) voltage to the load of a fixed DC voltage obtained from the AC-DC converter. The DC-DC converter is controlled by "K1". In Figure 5, the dynamics of the current flowing from the source DG to the AC-DC converter is given by the equation (9).

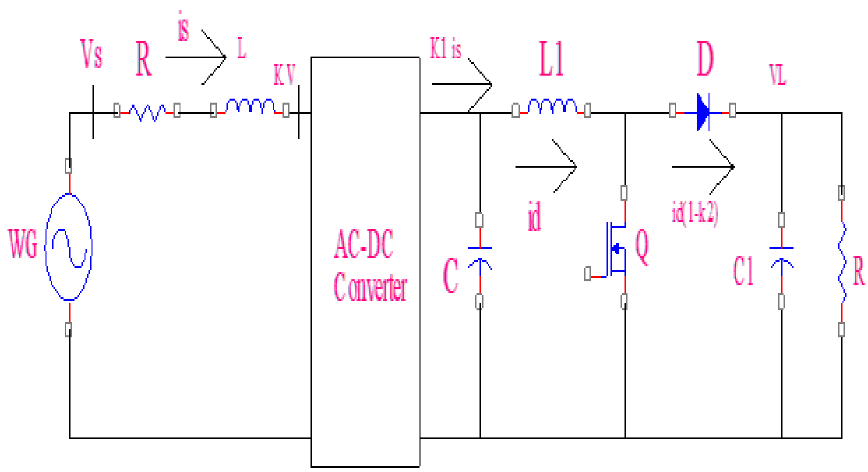

Fig. 5 Circuit diagram for the wind power generation

$$L\,\frac{di_s}{d_t} = V_s - k\,v - i_s R \ldots (8)$$

The dynamic voltage of the capacitor is given in (8),

$$C = \frac{d_v}{d_t} = k i_s - i_s - i_d \ldots (9)$$

The dynamic of current through the inductor "L" and voltage across the load resistance R of the DC-DC converter is given by equation (10) and (11)

$$L_1\frac{di_d}{d_t} = V - V_s(1-K_1) \ldots (10)$$
$$C_1\frac{dV_L}{d_t} = i_d(1-K_1) - \frac{V_L}{R} \ldots (11)$$

Equation sign (8) to eqn. (9) represents the nonlinear mathematical model of the entire system shown in the figure. 5. Linearization of the equation (10) and the equation. (11), Mathematical model of state variable representation in linear system.

$$\begin{bmatrix}\Delta i_s\\ \Delta V\\ \Delta i_a\\ \Delta V_L\end{bmatrix} = \begin{bmatrix}-\frac{R}{L} & -\frac{K_{10}}{L} & 0 & 0\\ \frac{K_{10}}{C} & 0 & \frac{1}{C} & 0\\ 0 & \frac{1}{L_1} & 0 & -\left[\frac{1}{L_1}-\frac{K_{20}}{L_1}\right]\\ 0 & 0 & \left[\frac{1}{C_1}-\frac{K_{20}}{C_1}\right] & \frac{1}{RC_1}\end{bmatrix}\begin{bmatrix}\Delta i_s\\ \Delta V\\ \Delta i_a\\ \Delta V_L\end{bmatrix} + \begin{bmatrix}\frac{1}{L_2} & \frac{V_0}{L_1} & 0\\ 0 & \frac{i_s}{C_1} & 0\\ 0 & 0 & \frac{V_L}{L_1}\\ 0 & 0 & -\frac{i_{d0}}{C_1}\end{bmatrix}\begin{bmatrix}\Delta V_s\\ \Delta k\\ \Delta K_1\end{bmatrix} \ldots (12)$$

Equations (11) it is revealed that the output voltage of the AC-DC converter (connected to the DC-DC converter) can be kept constant by controlling the "K", even though the output voltage of the WG is "V_s".

At the same time, the load voltage across the "R" can be adjusted by controlling the desired value of the duty cycle (designed), i.e. the "K1" of the DC-DC converter.

E. Battery Modeling

The optimum function conditions should to meet the load requirement, when the battery is of sufficient size to provide the required power, then, of course, if the battery charge is large enough to be seen in the optimal setting. This is computed by the following formula

$$B_a(t) = B_a(t-1) + ((B_s(\text{t-1})+B_t(t-1).C_{bat} \ldots (13)$$

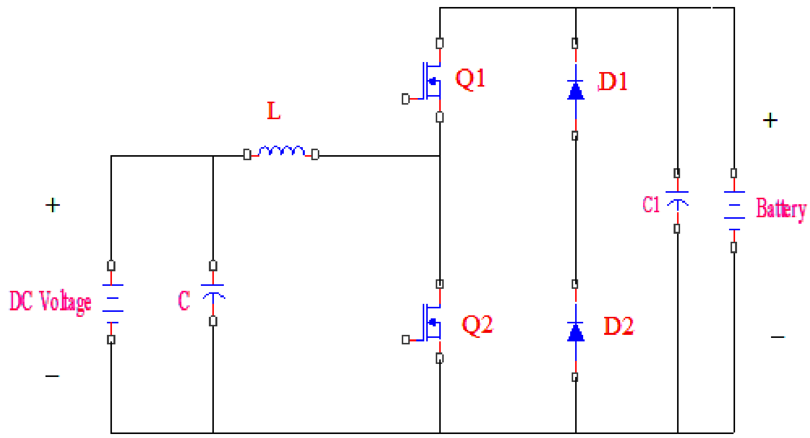

Fig. 6 Bi-directional DC-DC Converter

Where $B_a(t)$ is the battery charging at time t, $B_a(t-1)$ is the battery charge at time t-1, $B_s(t-1)$ is the charge quantity to be stored at the time t-1, p(t-1) is the total energy to provide by the battery at the time t, C_{bat} is the battery charging efficiency. The State of Charge (SOC) depends on the load requirements and the power supplied by the RES, and is calculated using the following equation

(i) For the charging mode,

$$\mathrm{SOC(t)} = \mathrm{SOC(t-1)} + \frac{\mathrm{B_{bat\ (t)}B_{char}}}{\mathrm{PN}}.1\ldots (14)$$

(ii) For the discharging mode,

$$\mathrm{SOC(t)} = \mathrm{SOC(t-1)} + \frac{\mathrm{B_{bat\ (t)}B_{dis}}}{P_N}.100\ldots. (15)$$

Among them, SOC (t) is the state of the battery at time t,$\mathrm{B_{bat\ (t)}}$is the power transfer during the period,$\Delta t\mathrm{B_{char}}$ is the battery charging capacity, $\mathrm{B_{dis}}$ is the battery discharge capacity and $P_N$is the estimated battery capacity.

F. Fuel Cell

Due to fuel cell limitations, including low voltage, low current density and transient power generation, this DC converter has become an important part of fuel cell systems for small or independent applications. With the use of DC converters, are shown in figure 7 these limitations can be solved with modified voltage sources from fuel cells. Various DC converters have been developed to support fuel cell systems, but DC converters are capable of conducting losses and conducting losses. Without adequate conduction and switching losses, DC converters work very efficiently.

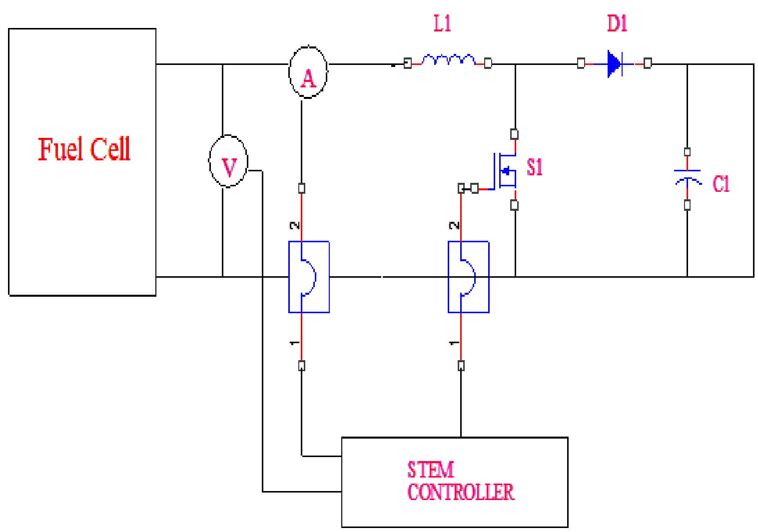

Fig. 7 Fuel Cell Based DC-DC Converter

G. Voltage Source Inverter

A bridge type voltage source inverter, with three-phase connection and square wave pole voltages, is considered and its circuit diagram is shown in Figure 8. The 3-phase square wave inverter's three pole voltage usually is shifted by one-third of the output periods. The considering the way switches are counted, the number series SW1, SW2, SW3, SW4, SW5, SW6, SW1, and SW2 can be found in ON and OFF. At the same time determine the switching time at 360 degrees (2π radians) and see that it is 180 degrees, and the nearby switches can be turned on and off by 60 degrees. Each pole of the inverter holds power in a filler mode with the top and bottom switch. The transition sequence may be reversed by reversing the output phase sequence. Therefore, at any given time the three switches operate as the power is noticeable. This could be the lower group switch connected to the anode DC bus.

The operations of the switches in each leg of the three-phase inverter are found to be in a complementary manner, as in the single-phase square wave inverter. When an upper switch is on the low switch, it will cause the voltage and variation of the entire DC bus. The current distribution between the switch and diode depend on the load power factor only at that operating frequency. The control switch should varying the PWM of the inverter in general. If there is a worst case voltage, the diodes are expected to block the peak reverse voltage equally.

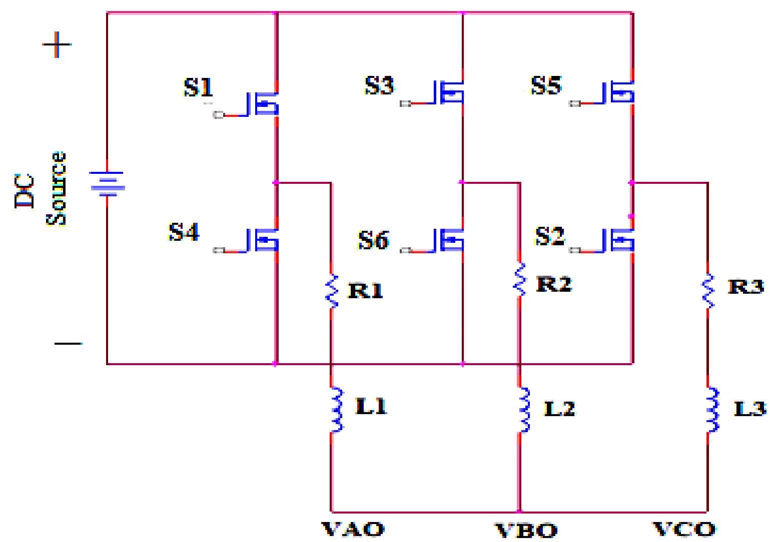

Fig. 8 Three Phase Inverter Circuit

TABLE I INVERTER SWITCHING SEQUENCE

Switching States	V_{AO}	V_{BO}	V_{CO}
S1-S2-S6 On & S4-S5-S3 Off	V_i	0	V_i
S2-S3-S1 On & S5-S6-S4 Off	0	V_i	$-V_i$
S3-S4-S2 On & S6-S1-S5 Off	-Vi	Vi	0
S4-S5-S3 On & S1-S2-S6 Off	-Vi	0	Vi
S5-S6-S4 On & S2-S3-S1 Off	0	-Vi	Vi
S6-S1-S5 On & S3-S4-S2 Off	Vi	-Vi	0
S1-S3-S5 On & S4-S6-S2 Off	Vi	0	-Vi
S4-S6-S2 On & S1-S3-S5 Off	Vi	-Vi	0

H. Energy Router Based Power Flow Analysis

The topology of the energy router considered to find the power flow analysis in the renewable energy system. The circuit diagram of the proposed method is shown in Figure 4.10. In this work, the router will analyze the power flow in a Four-port energy converter, which includes a VSI with Grid power and a shared common DC power line. For the energy flow operation of the proposed system different modes of operation is analyzed by the energy router.

I. Resilient Power Flow Control (RPFC) Technique

A power management policy is a Multi energy generation system designed to optimize the flow of power in a transmission system. Based on the control system, this energy router-based RPFC is generated and then predetermined compared to the value of measure power. Based on the comparative result of energy router-based power flow, RPFC has generated the pulse signal to the inverter to improve the grid power. Figure 10 shows the implementation of an RPFC controller based HRES system. This flowchart describes the operating procedures of a RES with BESS system.

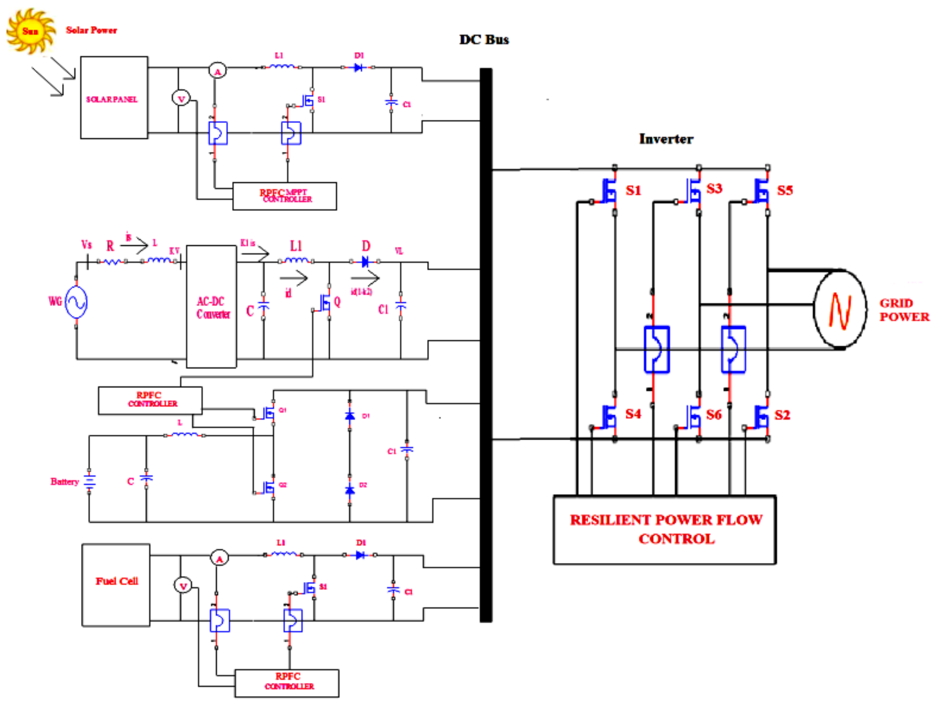

Fig. 9 Circuit diagram of the proposed system

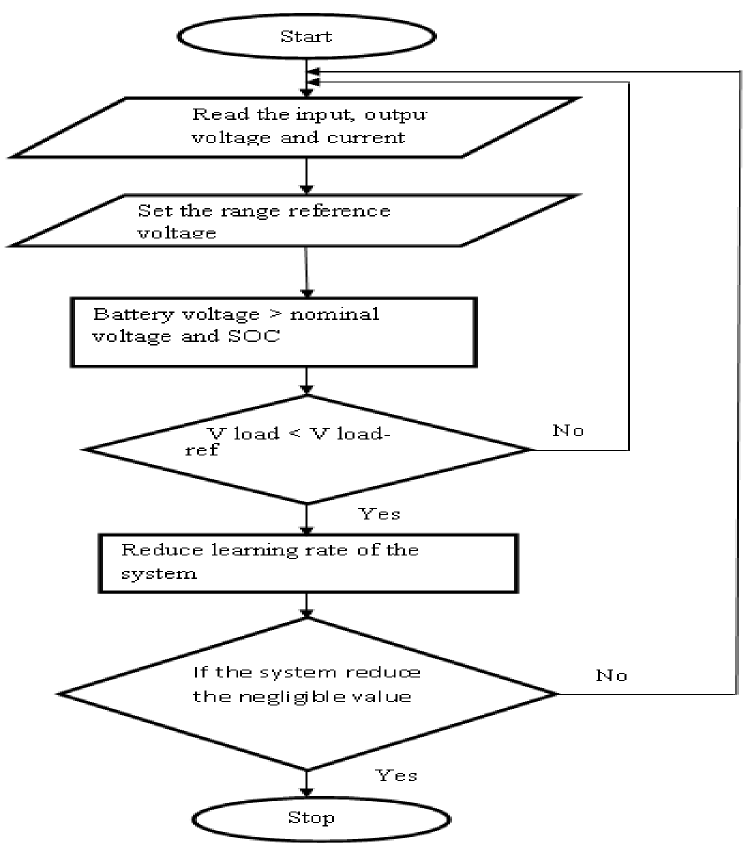

Fig. 10 Proposed RPFC flowchart

III. RESULTS AND DISCUSSION

The present modeling approach of a MATLAB-based toolbox is presented for developing and testing the Resilient Power Flow Control (RPFC) based HRES under various operational conditions. The proposed new RPFC model is designed in a MATLAB environment. The Renewable energy management system produces energy power source of the system which has a different form of power generation. Insufficient sources of energy will be regulated by a converter, which improves voltage in the source side. To optimize, the system power control algorithm is needed for regulating power using the RPFC controller used for optimization. Figure 11 represents the solar power generation with the Converter voltage response, in graph it clearly shows the generated solar voltage is 600 V, also the stability converter voltage using RPFC is represented.

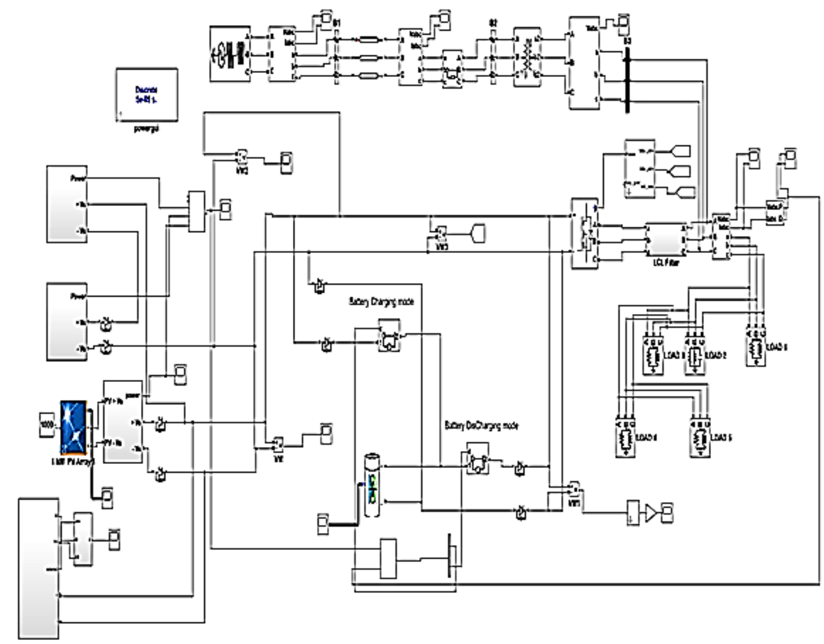

Fig. 11 Proposed Simulink Model

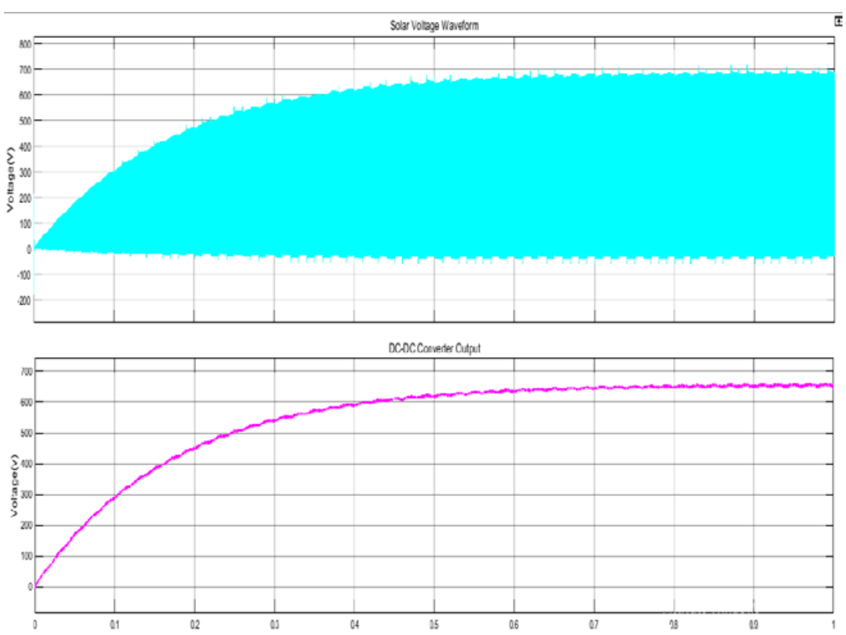

Fig. 12 Solar output power

Fig. 12 shows the solar outpout and Figure 13 demostrates the wind power generation, the above graph clearly shows the stability AC voltage of wind is 500 V with time t = 1 second.

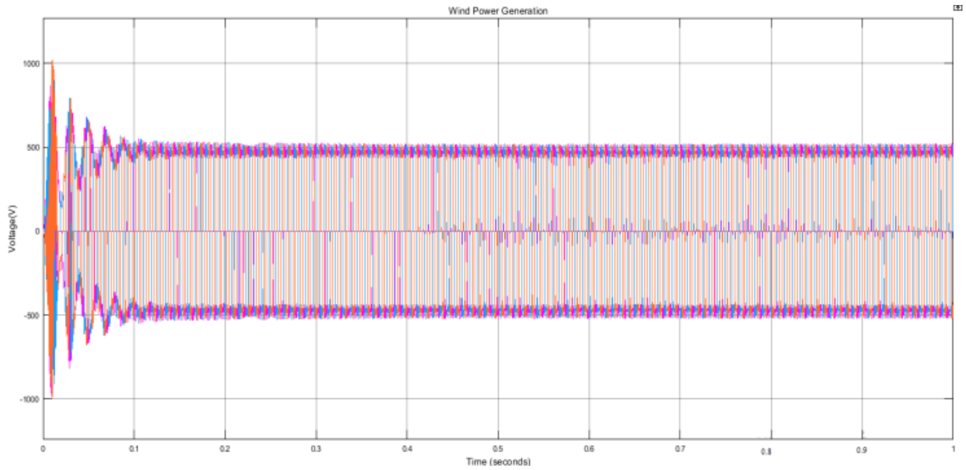

Fig. 13 Wind Power

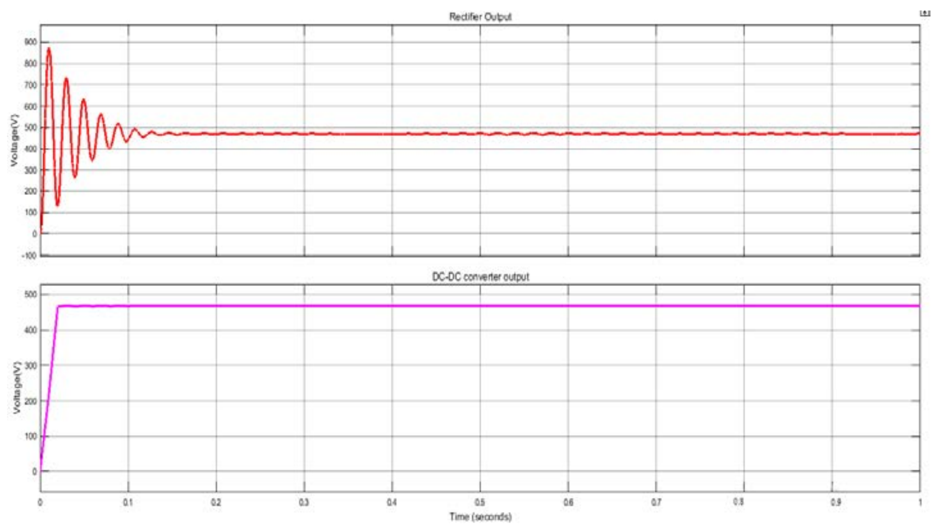

Fig. 14 Wind Energy stabilization waveform

The power variation of the wind is the initial converter to DC voltage, and then the DC-DC converter with output voltage is stabilized, which are shown in Figure 14. The proposed RPFC controller will stabilize the wind voltage at the time of 0.1 seconds. Figure 15 Shows the Fuel Cell power generation, the above are representing the three parameters of the system voltage, current and DC-DC converter voltage.

The energy management is proceeding with the battery system and during the power generation of the renewable energy resources, the battery is in a charging state. If there is energy uncertainty, the battery power is delivered to stabilize the power. By using a bi-directional DC-DC converter, this process is applicable to the charging state of the battery shown in Figure 16.

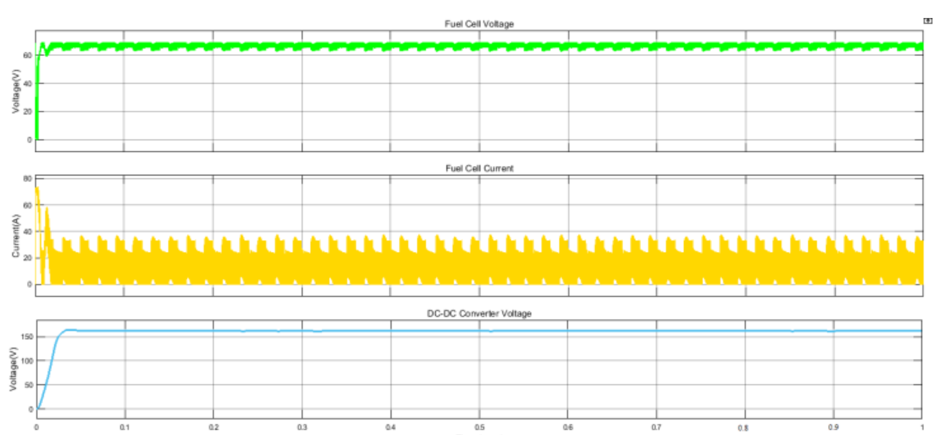

Fig. 15 Fuel Cell Generation with Boost Converter Waveform

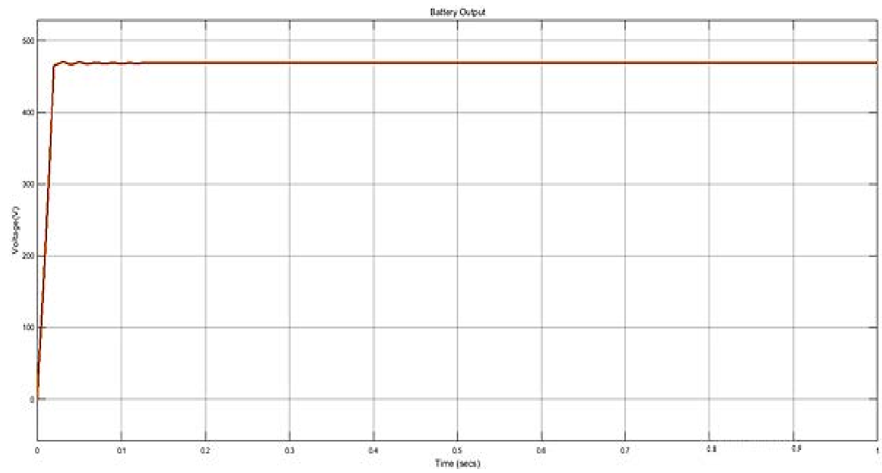

Fig. 16 Battery Output

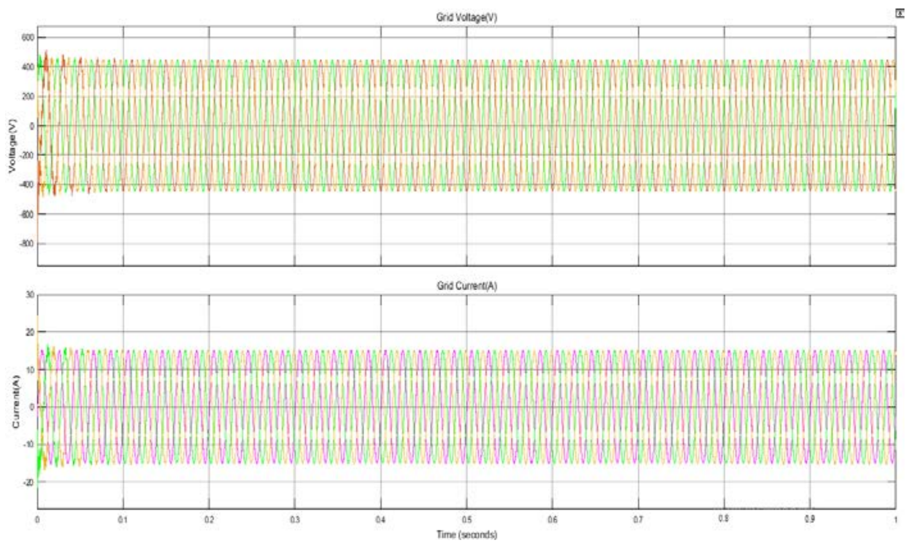

Fig. 17 Grid Power Waveform

Figure 17 shows the grid power waveform of the HRES system**.** The RPFC controller will stabilize the renewable energy generation sources. The stabilize HRES power will be fed to the load system for the performance analysis.

Figure 18 Representing the load voltage, and current waveforms in a differential time period relative to each other. The waveform confirms that the power Factor is almost unity for any load.

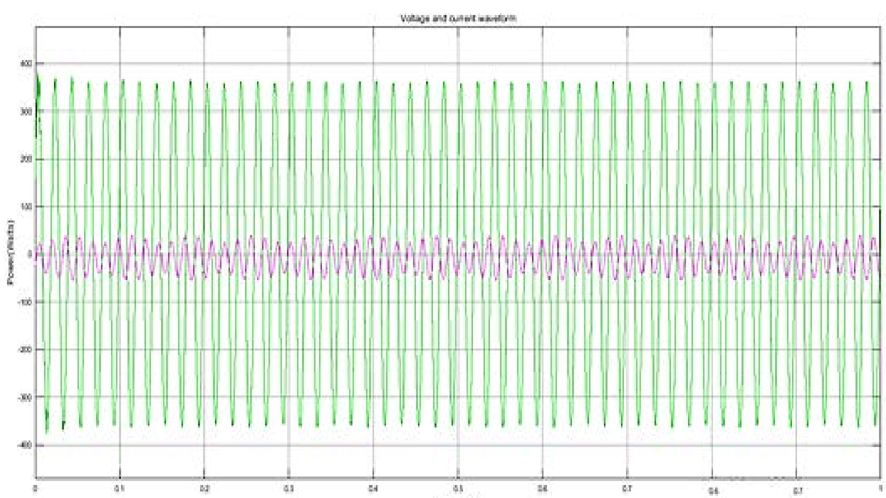

Fig. 18 Load current and Voltage waveform

Figure 19 shows the Total Harmonics Distortions (THD) analysis of the proposed Hybrid Multi port converter model by using the Resilient Power Flow Control. The (RPFC) control strategy will produce the 1.68% of the THD Ratio.

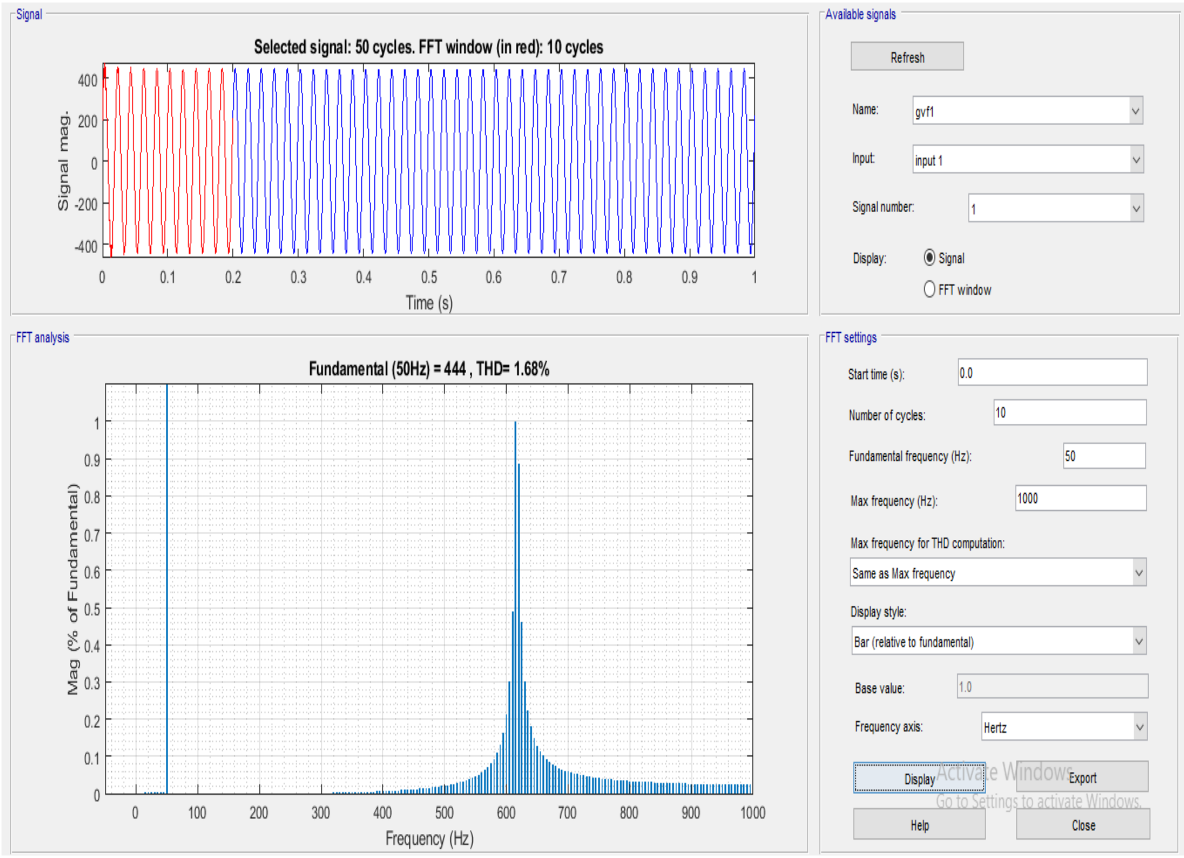

Fig. 19 THD analysis

TABLE II PERFORMANCE ANALYSIS OF THE HYBRID POWER GENERATION SYSTEM

Controller	Steady State Error (%)	Execution Time (Sec)	THD (%)	Efficiency (%)
PI	1.536	0.889	8.9	86.5
PID	1.2365	0.8715	7.23	88.4
Fuzzy	0.821	0.7216	5.06	90.1
RPFC	0.326	0.536	1.68	98.25

Table II represents the performance analysis of the hybrid multi-port converter system based on the parameters, it is clearly shows that the proposed RPFC control strategy produces an efficient result compared with the other conventional controllers.

TABLE III PERFORMANCE ANALYSIS OF THE POWER FACTOR FOR VARIOUS LOAD

Load (W)	PI	PID	Fuzzy	RPFC
0	0.9949	0.9954	0.9958	0.9989
200	0.9945	0.9951	0.9955	0.9972
400	0.9941	0.9948	0.9949	0.9970
600	0.9938	0.9945	0.9947	0.9968
800	0.9934	0.9941	0.9945	0.9962
1000	0.9932	0.9940	0.9941	0.9958

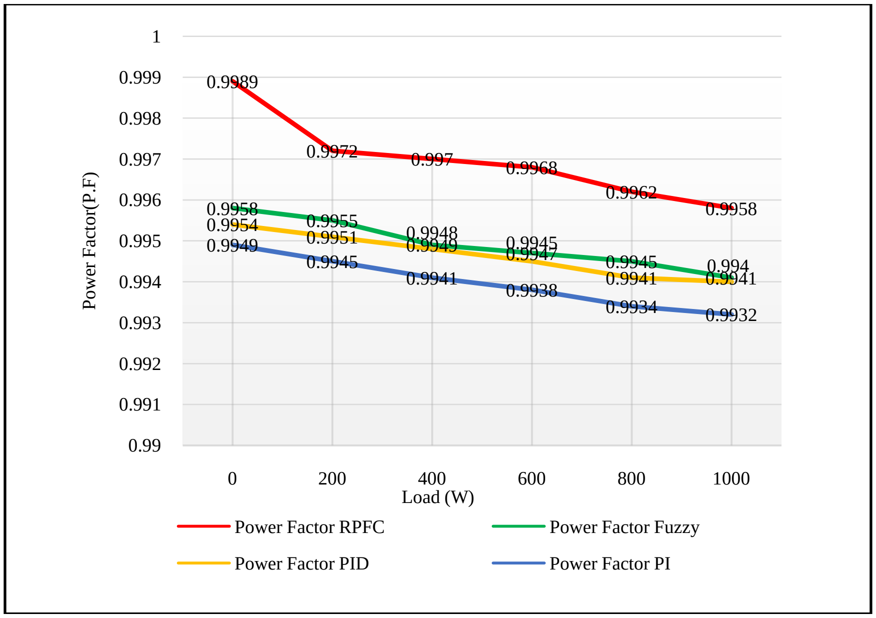

Fig. 20 Comparative analysis of Power Factor under load varying condition

Table III describes the performance analysis of the Power Factor (PF) variation for the HRES system under load varying conditions. Figure 20 shows the comparative analysis of the HRES system for the power factor under load varying conditions. When compared with other conventional controllers, the proposed RPFC Controller will produce efficient results under (0-1000) load varying conditions.

IV. CONCLUSION

The proposed RPFC technique in the hybrid multiport converter system shows the better optimized energy management system in the smart grid application. The simulation is done from the dynamic model of the simulated Hybrid multiport grid system, and from this simulation it is possible to understand how to maintain the parameters of the multi power generation with battery based energy management. The purpose of the proposed smart energy management is to reduce operating costs and reduces impact of micro grids on the environment, while significantly improving the economic and technical efficiency of the power generation system. The proposed control ensures power management between renewable energy generation, energy storage and load during the Hybrid multiport converter to perform it functions. The simulation results clearly show that the proposed controller shows high performance under Steady state condition and efficiency analysis. It produces the least THD of 2.52 (%) compared with the conventional methods.

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