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Control strategies of a Hybrid Microgrid for grid connected and island mode operation

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ABSTRACT

Microgrid is one feasible and effective solution to integrate renewable energy sources as well as to supply electricity. This paper wind turbine generator as an AC source and fuel cell, solar panel as DC sources integrate and to form a hybrid microgrid in order to decrease the many conversions which are connected through a covverter most commonly seen in DC and AC Grids.The proposed hybrid micro grid is operated in islanded mode V/f control technique is used in order to control the power flow.This paper also includes PQ Control on grid connected mode for variable output power.The performance of proposed method is analysed and validated on Hybrid microgrid operation and control. Simulations are carried out to validate the performance of the proposed method.

Keywords: Distribution Generation, Photovoltaic cell, Fuel cell, Islanding mode

1. INTRODUCTION

Microgrid(MG) has involved collective attention of combiningthe distribution generation (DG) sources into the electrical utilities [1] – [5]. MG is deûnedas an Autonomous medium or low voltage sharing network as well as different alternating energy sources, power-electronic converters,regulated loads. This can be operated in either island or grid mode. In grid side mode, the battery is act as a power buffer. In this mode total demand is balanced by main grid and MG. In island mode, grid is isolated from MG. In this mode, energy storage device is used to supply the power to the loads along with hybrid mcrogrid.

The control schemes for island mode can be categorized into active load sharing, circular chain control and droop control [6] – [8]. The active sharing technique and circular chain control critical inter communication wires are required among modules. The droop control technique, inter communication wires need not required. The Droop control technique which match the operation characteristics of parallel alternators for dispatchable DG sources. The droop control approach has concerned great attention inMG operation because it is more advantageous technique. Either grid mode or island mode can be used this approach, conversions of control strategies are not needed when the changing modes of operation in micro-grid [9]

The objectives of this paper are to regulate the power flow at the busbar which can be realized by the power in power electronic converters in grid mode and to maintain the voltage and frequency are stable of the MG, reasonable power sharing without load shedding.

Respite of this paper is structured as follows. Section II includes the System modelling and description. Section III describes the Operation of Hybrid micro-grid and their controlling blocks. Section IV presents the results for proposed hybrid micro-grid. Section V concludes paper.

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2. SYSTEM MODELLING AND DESCRIPTION

Block diagram for Hybrid grid model:

The proposed hybrid micro grid model is shown in figure 1

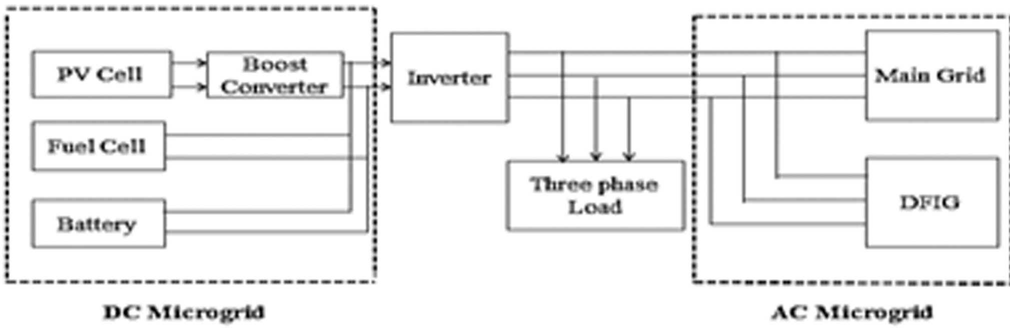

Figure 1: Proposed Hybrid Microgrid

The proposed system consists of doubly fed induction generator of 20 kW as an AC source and fuel cell of 25 kW, solar panel of 20kW as DC sources. In this system the fuel cell and the solar panel are connected to the DC grid using boost converter. By Using AC/DC/AC converter, the DFIG is connected to the AC grid. Energy storage device is connected to DC grid.

2.1.1. Modelling of PV Pannel

Solar cell is basic block of the PV array, which is capable of converting light energy into electricity without prouducing any pollution to environment. The below fig shows the equivalent circuit for PV array.

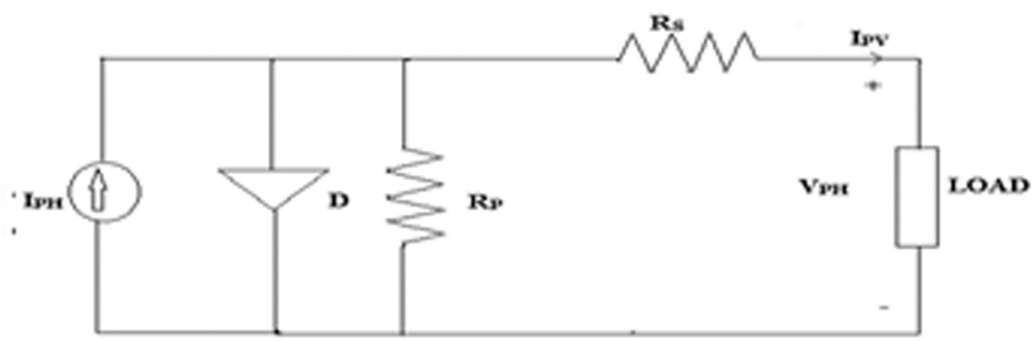

Figure 2: Equivalent model circuit of PV pannel

The figure 2 consists of a diode, photocurrent, parallel resistor, series resistor. In that Series resistor represents an internal resistance of current flow and Shunt resistor represents resistance of the leakage current. The PV solar cell of current equation is

$$I_{PV} = I_{PH} - I_S \left[\exp\left(q\left(\frac{V_{PV} + I_{PV} R_S}{kT_C A} \right) - 1 \right) \right] - \left(\frac{V_{PV} + I_{PV} R_s}{R_P} \right) \tag{1}$$

The equation of saturation current it is varies depending on cell temperature is

$$Is = I_{RS} \left(\frac{T_C}{T_{ref}} \right)^3 \exp\left[qE_G^{'} \left(\frac{1}{T_{Ref}} - \frac{1}{T_C} \right) / k_A \right] \tag{2}$$

The shunt resistance is inversely proportional to the leakage current. There is no effect due to the change in the shunt resistance, where as a small change in the series resistance will greatly affect the PV cell output power. The modified photo current equation is

$$I_{PV} = I_{PH} - I_S\,[\exp\,(q(V_{PV} + I_{PV} R_S)/\,k\,T_C\,A) - 1] \quad (3)$$

After substituting PV solar cell values are $R_s = 0$ and $R_p = \infty$□. so the equation(3) can be modified as

$$I_{PV} = I_{PH} - I_S\,[\exp\,(q\,V_{PV}\,/k\,T_C\,A) - 1] \quad (4)$$

The efficiency of the solar cell is mainly effected by series resistance only, So the shunt resistance can be assumed to be open [10]. The characteristic equation by considering N_P and N_S is given by

$$I_{PV} = N_p I_{PH} - N_p I_S \left[\exp\left(q\left(\frac{V_{PH}}{N_S} + \frac{I_{PV} RS}{N_P} \right) / kT_c A \right) - 1 \right] \quad (5)$$

The equation(5) can be simplified as

$$I_{PV} = N_p I_{PH} - N_p I_S \left[\exp\left(\frac{qV_{PH}}{N_S kT_c A} - 1 \right) \right] \quad (6)$$

2.1.2. Modeling of Fuel Cell

Solid oxide fuel cell(FC)[11] voltage equation is

$$V = N_0 \left[E_0 + \frac{RT}{4F} \left[\ln\left(\frac{P_{H2} P_{02}^{0.5}}{P_{H20}} \right) \right] \right] - rl - A\ln(i) + me^{ni} \quad (7)$$

$$P_{fc} = N_0 VI \quad (8)$$

P_{fc} - fuel cell power

N_0 - number of FC stacks

V - voltage of FC

I - current of fuel cell

2.1.3. Modeling of Battery

By Considering the state of charge and terminal voltage as parameters, battery is modeled [12]. The equations for state of charge and terminal voltage is given by

$$V_b = V_0 + R_b I_b - \frac{KQ}{\left(Q + \int i_b dt\right)} + A\ \exp\left(B \int i_b dt\right) \quad (9)$$

$$SOC = 100 \left(1 + \frac{\int i_b dt}{Q} \right) \quad (10)$$

2.1.4. Modelling of boost converter:

Mathematical modeling equations of boost converter is

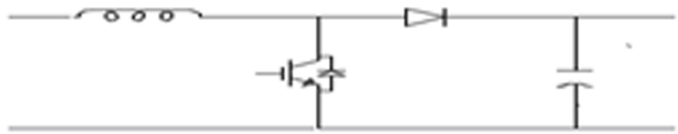

Figure 3. Boost converter

$$V_{PV} - V_T = L_1 \frac{di_1}{dt} + R_1 i_1 \tag{11}$$

$$I_{PV} - I_1 = C_{PV} \frac{dV_{PV}}{dt} \tag{12}$$

$$V_d = V_d(1 - d_1) \tag{13}$$

3. OPERATIG MODES OF MICROGRID

The main grid and hybrid micro grid are connected in grid mode, power is controlled by PQ control technique. The Simulink PQ Control block model is shown in figure 4.

In this the power is controlled by giving gate pulses to the main converter. In order to generate the gate pulses, have to get reference i_d and i_q values. For this the grid voltages and currents should be given to the power regulator block. The Simulink block model of power regulator is shown in figure 5.

The three phase current of the grid is converted into two phase orthogonal stator axis currents by means of Clarke transformation. Then, these currents are converted into direct axis and quadrature axis currents by means of Parks transformation. The obtained id and iq are compared with the reference i_d and i_q values which

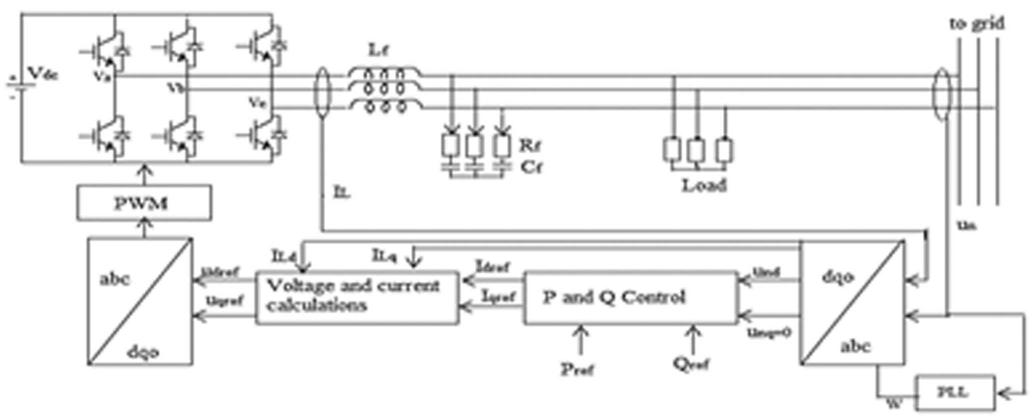

Figure 4: Simulink model of P and Q control block

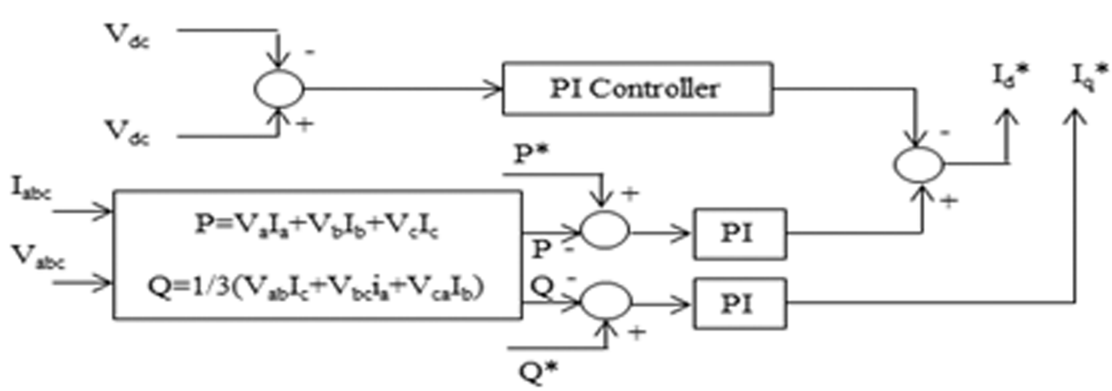

Figure 5: Simulink model of Power regulator block

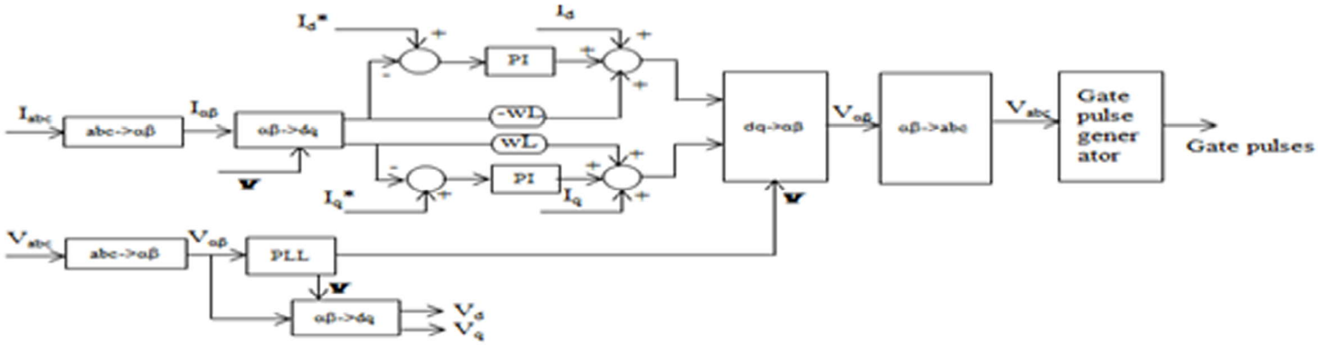

Figure 6: Simulink model of Current regulator block

are obtained from the power regulator block. The error is passed to the proportional integral controller then the obtained voltages are synchronized with the three phase grid voltages with the help of phase locked loop, then the direct and quadrature axis voltages are converted into v_α and v_β by inverse Parks transformation, then these are converted into three phase voltages by inverse Clarke transformation. These voltages are passed through pulse generator to generate gate pulses. The Simulink block of current regulator is shown in figure 6.

In the islanding mode of the MG is disconnected from the main grid. In this mode battery plays an important role. In this the power is controlled by using V/F control technique [16]. When the power in the MG is more than demand then it is stored by using battery.To provide stable and quality AC bus voltage with main inverter in island mode . The power flow is controlled using V/f control technique. As the hybrid micro grid is disconnected from the utility grid there is no synchronism of voltages and currents, so the voltage and frequency is controlling by using the control technique. Active and reactive power values to calculate by using instantaneous values of q and d axis voltages and currents with PQ calculation block. The fallowing equations are

$$P = u_{nd}\, i_d + u_{nq}\, i_q \tag{14}$$

$$Q = u_{nq}\, i_d - u_{nd}\, i_q \tag{15}$$

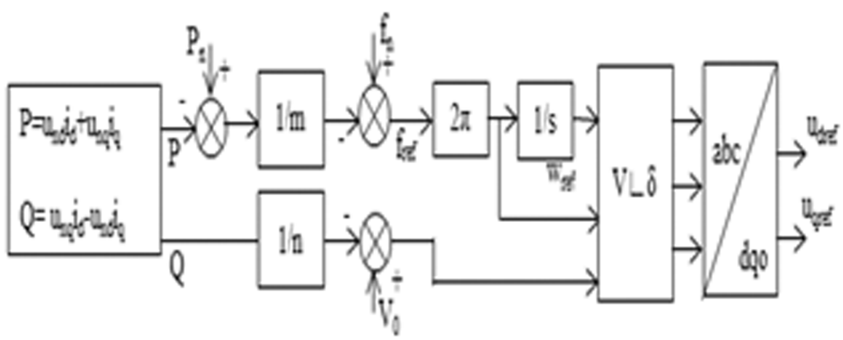

Figure 7: Simulink model of Power control block

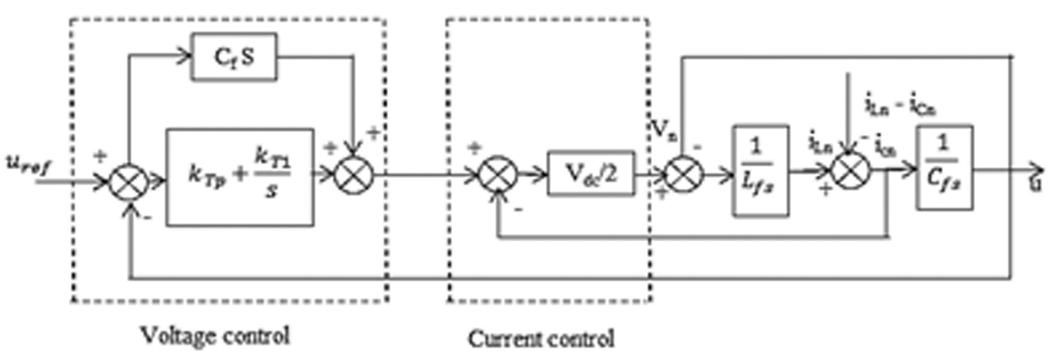

Figure 8: Simulink model of Voltage and Current control block

The Simulink models of power control, voltage and current blocks are shown in figure 7 & 8.

4. RESULTS

The proposed hybrid microgrid is simulated in MATLAB/SIMULINK. The voltage of the PV Panel is shown in figure 9.Output voltage and power of FC is shown in figure 10 &11. The voltage and current waveforms on ac side is shown in figure 12. The waveforms AC side power flow and Reactive and real power Sharing in grid mode is shown in figure 13 &14.

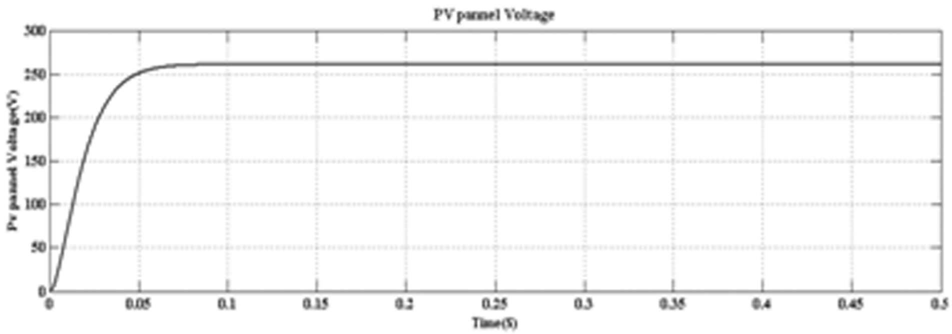

Figure 9: PV panel voltage

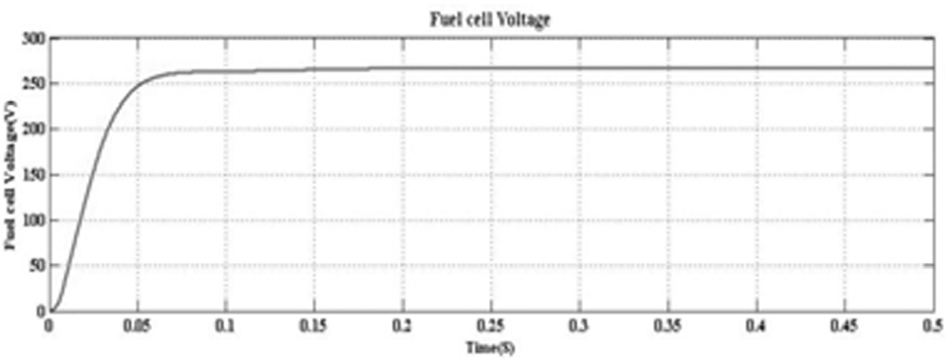

Figure 10: Fuel cell output voltage

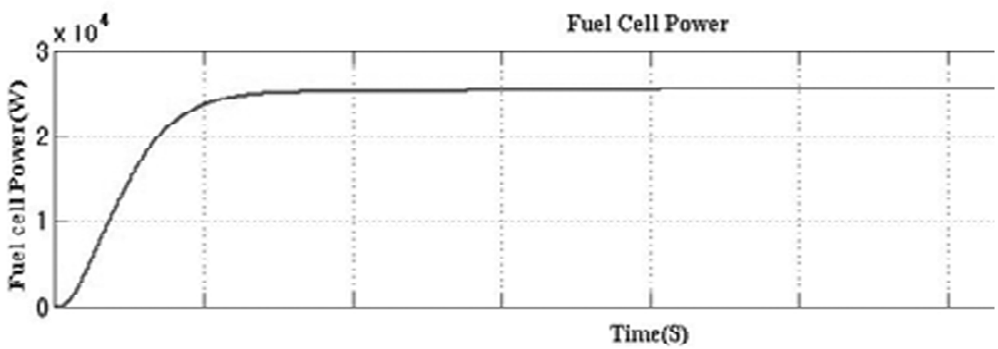

Figure 11: Fuel cell output power

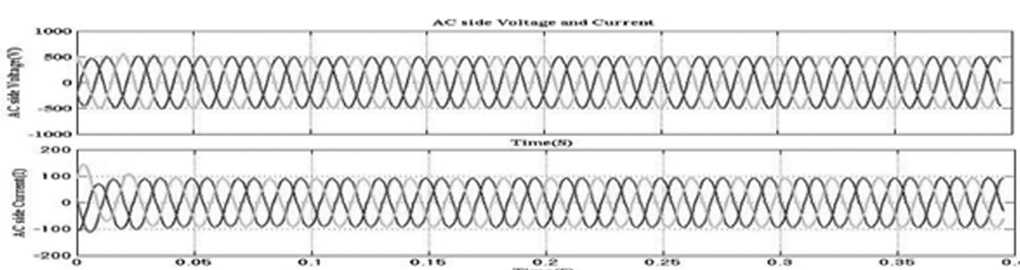

Figure 12: Voltage and Current across AC side

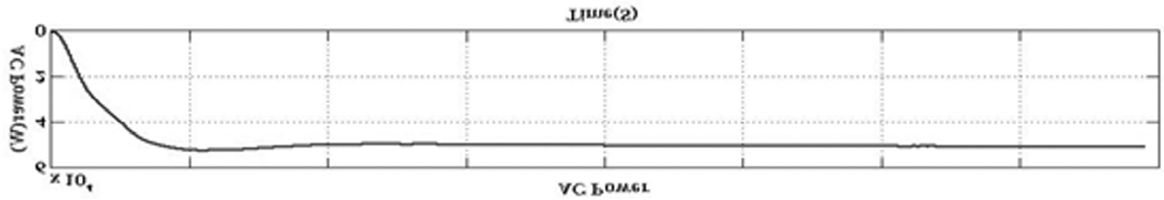

Figure 13: Power flow on ac side

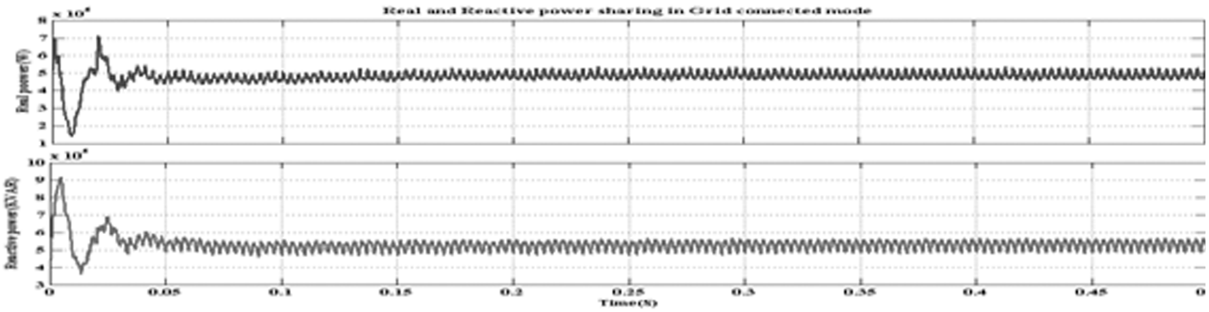

Figure 14: Real and Reactive power sharing

5. CONCLUSION

In this paper, integration of solar,wind and fuel cell has been implemented. Output power is connected to main grid.The proposed system is suitable for india circumstance because solar and wind most abundant in nature. Single renewable energy power generation is not gives continuous power supply is not possible in islanding mode and also increase grid burden in grid mode. The proposed system is able to supply the power to the consumers in all seasons and all operating modes. In islanding mode, the solar and wind energy conversion system will feed the power to the consumers with backup power as FC and battery. And in grid connected mode, hybrid micro grid will supply power to the load. The proposed system reduces the complexity of the electrical system, having reliable operation and control. The power flow is increased due to addition of FC to the hybrid micro grid. Hence, In islanding mode voltage and frequency is maintain at acceptable levels. In grid connected mode, by maintaining the P, Q as constants the power exchange occur between the grids. The obtained results show that the proposed system has the potential to supply the local loads without load shedding.

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