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Operation and Control of a Hybrid Photovoltaic-Fuel Cell System Connected as Line Interactive Micro-Grid

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Abstract- *This work presents modeling and control of a hybrid Photovoltaic (PV)- Fuel Cell (FC) system connected to electric grid. A case study on impact of FC operation on the frequency stability of electric grid has been carried out. The model of fuel cell system includes a fuel cell generator, electrolyzer and a hydrogen storage facility. The limits on hydrogen volume due to limited storage capacity have also been incorporated. The modeling of photovoltaic is also presented and analyzed for a time period of 24-hours with varying solar radiation and temperature. Results of simulation indicate that FC system can contribute to frequency stability in both cases when the load increases and also when the load drops. This feature of FC system will be helpful if it is operated along with a hybrid Wind-PV System.*

Keywords- PV (Photovoltaic) solar system, fuel cell System, Inverter, Grid connection, MATLAB

I. INTRODUCTION

Non-renewable sources of energy and fossil fuels are continuously consumed and that cause environmental pollution. Results in shortage of electrical energy in the near future. Thus, it becomes extremely important to think for alternative renewable resources such as wind, photovoltaic (PV), fuel cells (FC), small hydro, bio-fuels etc. This Work is based on modeling and control of a hybrid Photovoltaic (PV) and Fuel Cell (FC) system connected to electric grid. The model of fuel cell system includes a fuel cell generator, electrolyzer and a hydrogen storage facility.FC system can contribute to frequency stability in both cases when the load increases and also when the load drops. This feature of FC system will be helpful if it is operated along with a hybrid Wind-PV System.

Photovoltaic generators which directly convert solar radiation into electricity. Advantages such as pollution free, silent, with no rotating parts, and with size-independent electric conversion efficiency. PV power generation experiences large variations in its output power due to intermittent weather conditions. Which may cause operational problems. One method to overcome this problem is to integrate the photovoltaic plant with other power sources such as diesel and fuel cell (FC).

II. PHOTOVOLTAIC MODULE WITH FUEL CELL SYSTEM

(A) Basic block diagram of PV-FC hybrid system

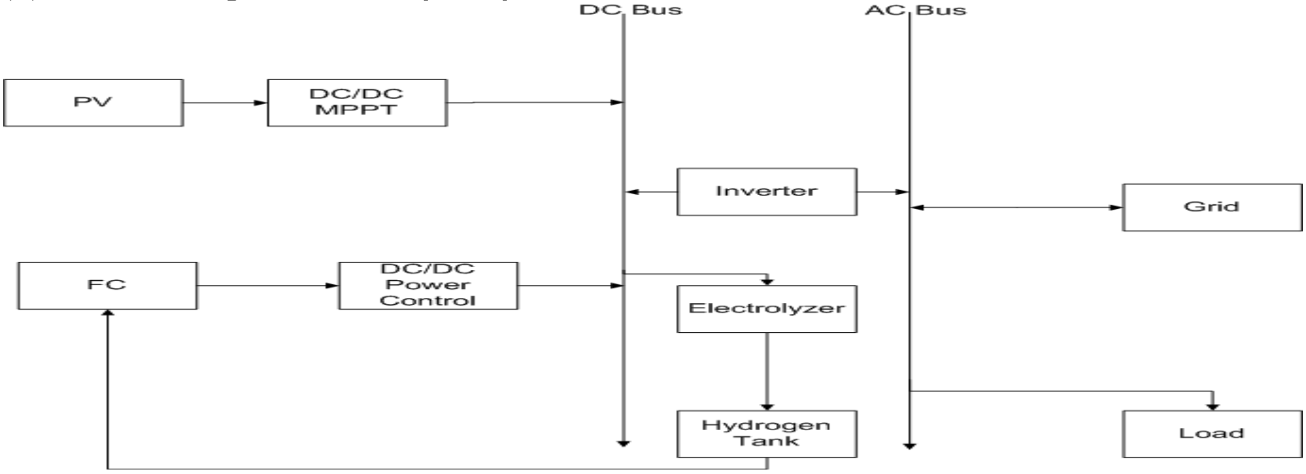
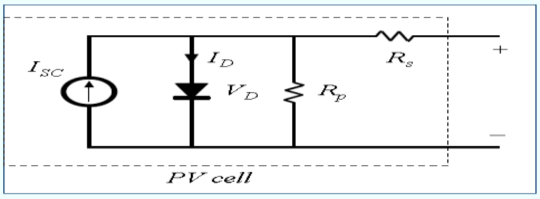


Figure 1. Block Diagram of PVFC System

(B) Modeling of PV module:



KCL:

$$I_{SC} - I_D - \frac{V_D}{R_p} - I_{PV} = 0$$

Diode characteristic:

$$I_D = I_o\left(e^{V_D/V_T} - 1\right)$$

KVL:

$$V_{PVcell} = V_D - R_s I_{PV}$$

Electrical Characteristics	
Maximum Power (P_{max})	150W
Voltage at Pmax (V_{mp})	34.5V
Current at Pmax (I_{mp})	4.35A
Open-circuit voltage (V_{oc})	43.5V
Short-circuit current (I_{sc})	4.75A
Temperature coefficient of I_{sc}	0.065 ± 0.015 %/^{0}C
Temperature coefficient of V_{oc}	-160 ± 20 mV/^{0}C
Temperature coefficient of power	0.5 ± 0.05 %/ ^{o}C

Table 1. PV Module Data Sheet

The PV characteristics from data sheet are used to generate the file necessary for R_s, R_p and other parameters for the maximum power point. The initial setup is used to obtain the I-V curve characteristics of the PV array and show the maximum power point of the PV. The model of the PV is used with the boost converter to determine the performance of the maximum power point tracker.

(C) MPPT

These algorithms are based on the measurement of the PV module output voltage and current. Then, it calculates the PV power and determines if the control parameter needs to be increased or decreased. The control parameter could be a reference signal like voltage or current for a controller or it can be the duty ratio for the switching signal DC/DC converter. The advantage of MPPT with searching algorithm is easy to implement, it does not require previous knowledge of the PV module characteristics. It can be observed that incrementing the PV voltage increases the power of the PV and decrementing the PV voltage decreases the power of the PV when operating on the left of the MPP. On the right of MPP, incrementing the voltage decreases the power and decrementing the voltage increases the power. This process will be implemented in the MPPT controller to extract the maximum power from the PV module. The main purpose of the DC/DC is to convert the DC input from the PV into a higher DC output. The maximum power point tracker uses the DC/DC converter to adjust the PV voltage at the maximum power point. The boost topology is used for stepping up the low voltage input from the PV. A boost type converter steps up the PV voltage to high voltage necessary for the inverter.

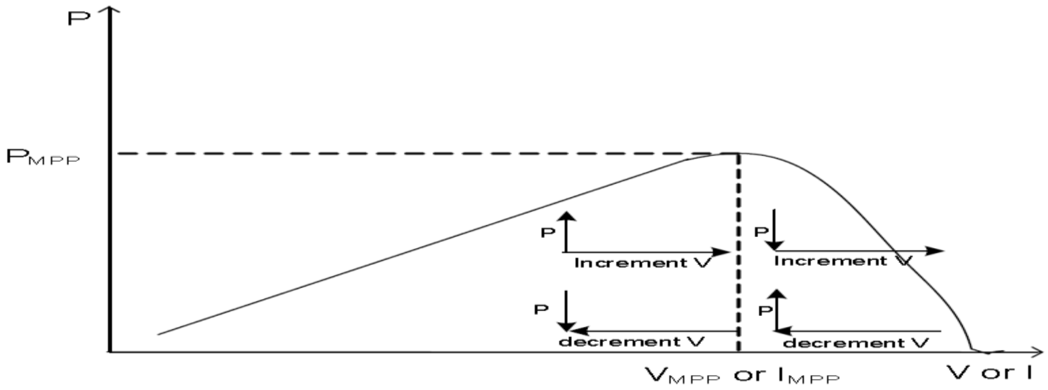


Figure 2. P and V or I curve for MPPT

III. SIMULATION

(A) PV and Fuel cell corresponding simulation data

PV and Fuel cell corresponding simulation data details are given in Table 1.

Photovoltaic System	50 kw
Fuel Cell	30 kw
Electrolyzer	30 kw
Inverter	50 KW
Load	30 kw
Grid Frequency	50 HZ

Table 2. Electrical characteristics data

(B) POWER MANAGEMENT STRATEGY

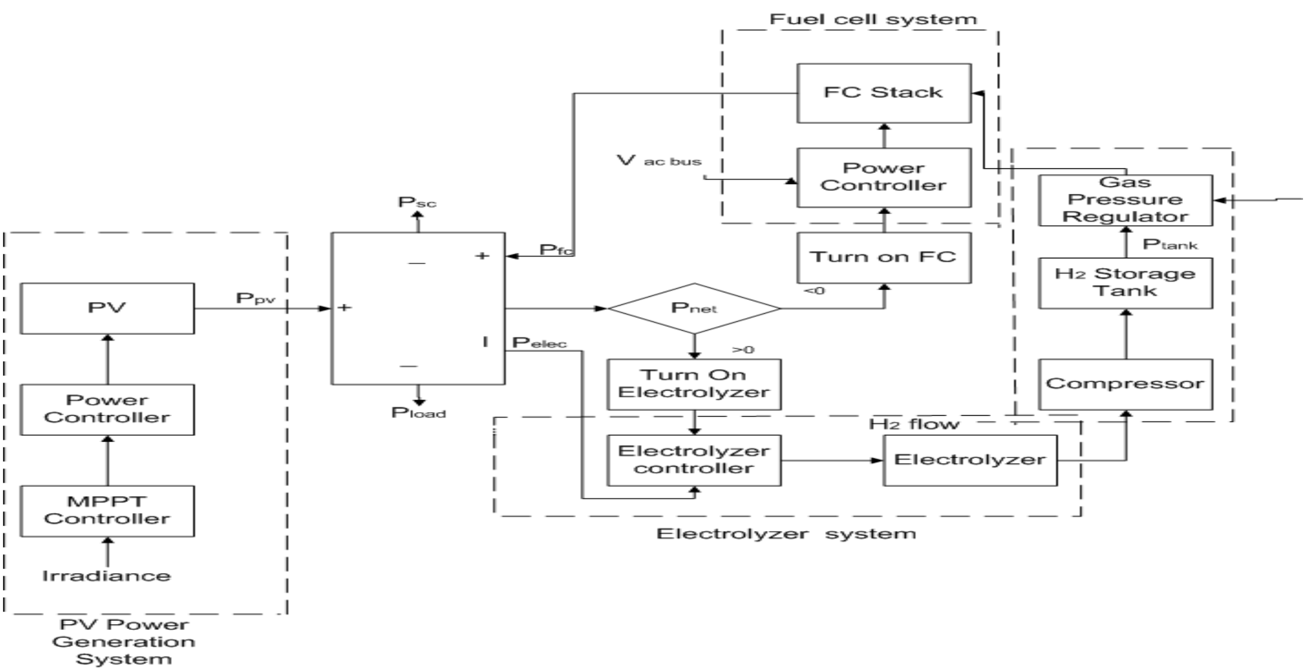


Figure 3. Power management of PVFC System

(C) Control Strategy

In this Control Strategy three cases taken:

- **CASE 1:- PV to feed loads(1000 insolation)**
- **CASE 2:- PV-FC to feed loads(200 insolation)**
- **CASE 3:- FC to feed loads(0 insolation)**

Case 1:- PV to feed loads (1000 insolation)

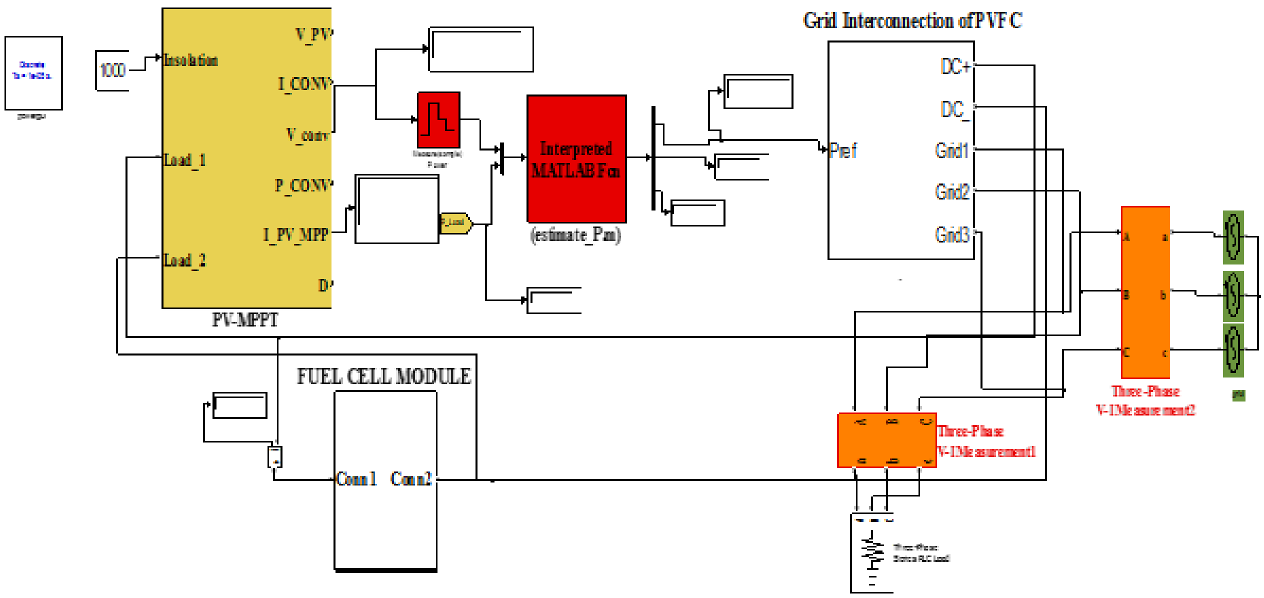


Figure 4. Simulation of PV feed loads (1000 insolation)

Case 2:- PV-FC to feed loads(200 insolation)

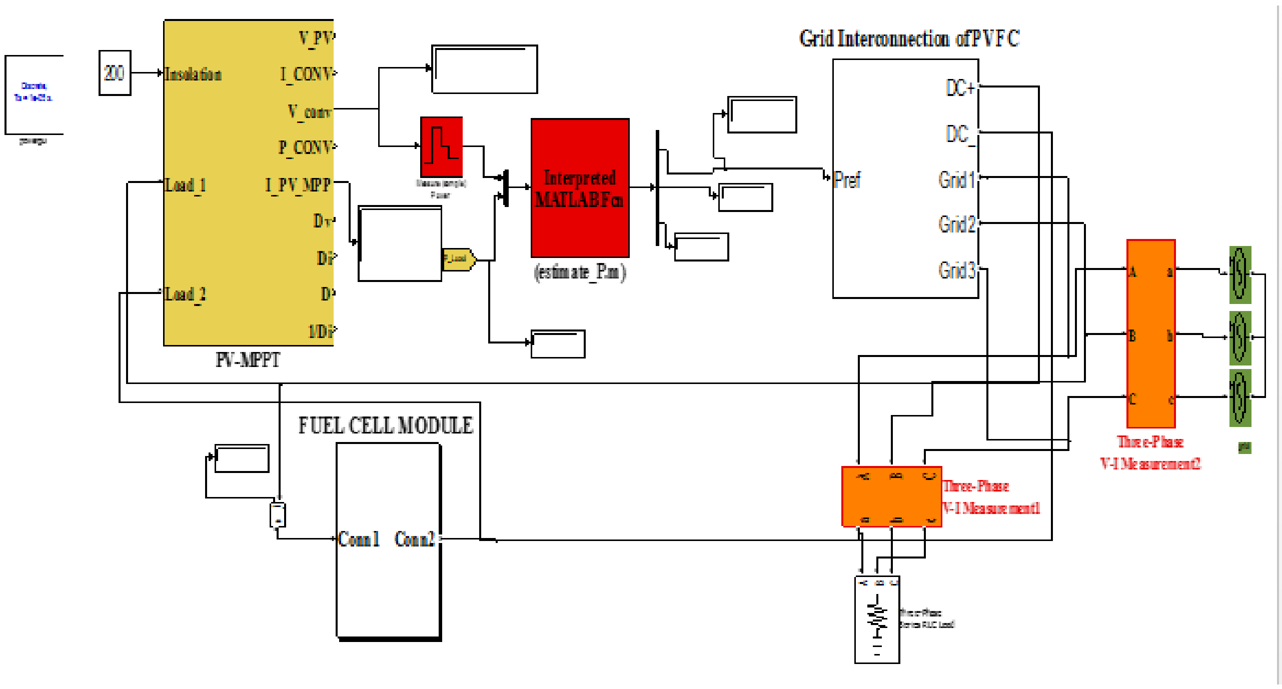


Figure 5. Simulation of PV-FC feed loads (200 insolation)

Case 3:- FC to feed loads(0 insolation)

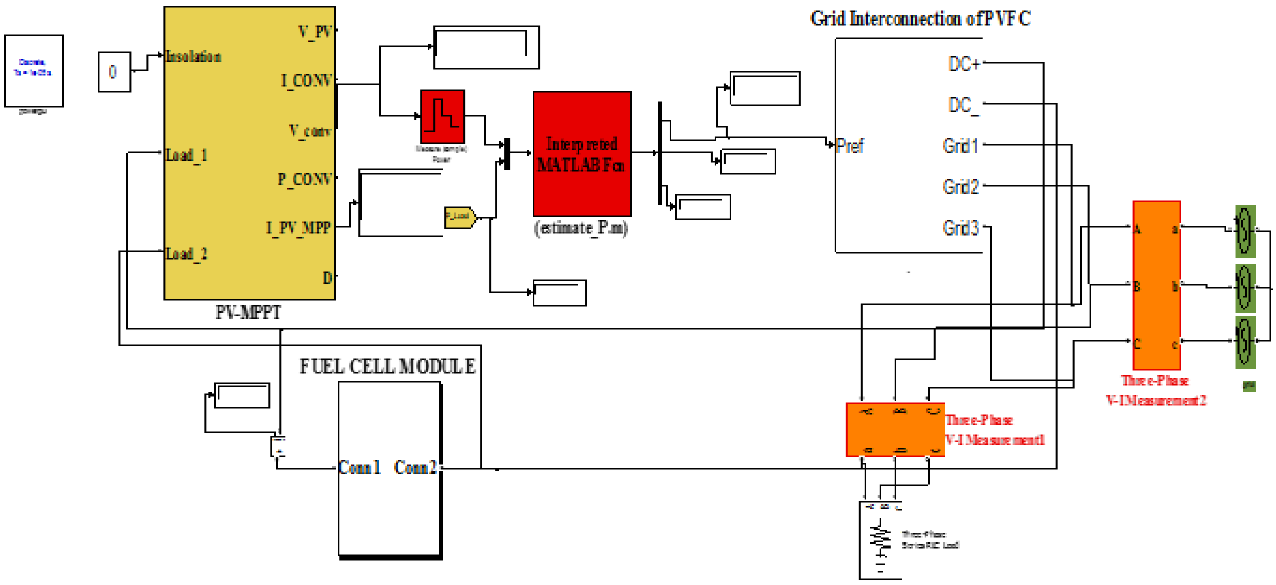


Figure 6. Simulation of FC feed loads (0 insolation)

IV SIMULATION RESULTS

CASE 1: PV to feed loads (1000 insolation)

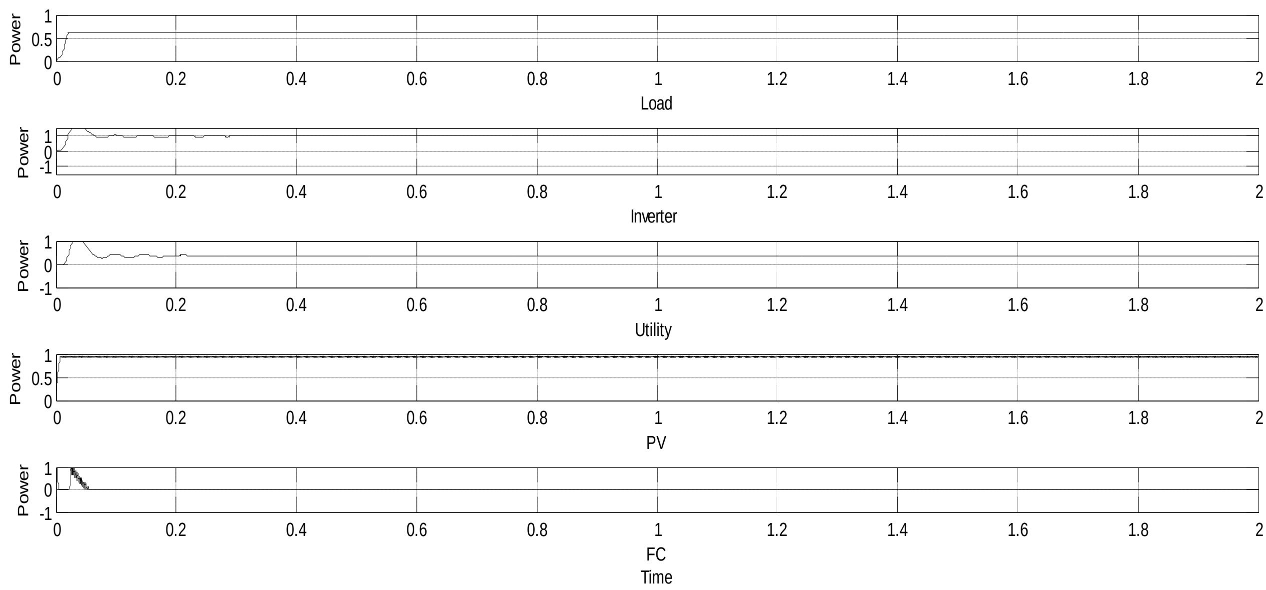


Figure 7. PV to feed loads (1000 insolation)

CASE 2: PV-FC to feed loads (200 insolation)

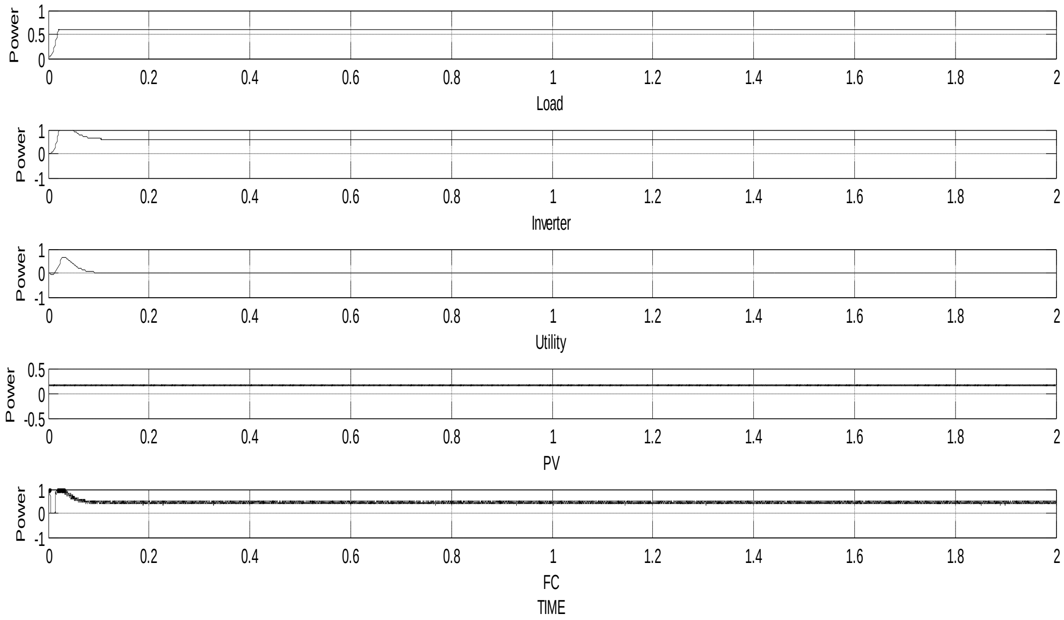


Figure 8. PV-FC to feed loads (200 insolation)

CASE 3: FC to feed loads (0 insolation)

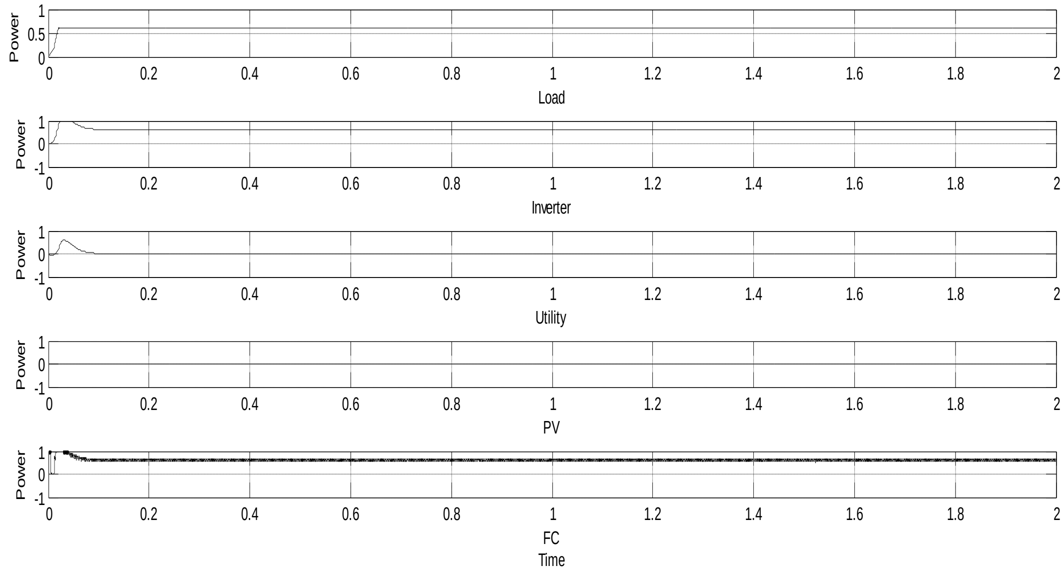


Figure 9. FC to feed loads (0 insolation)

V. CONCLUSION

Photovoltaic and fuel cell hybrid energy system, designed to generate a continuous power irrespective of the intermittent power outputs from the photovoltaic energy sources. The photovoltaic systems are controlled to operate at their point of maximum power under all operating conditions. The fuel cell is controlled so as to maintain a minimum power level of 30 kW. The simulation results show that:The fuel cell controller responds efficiently to the deficit power demands. With photovoltaic systems operating at their rated capacity, the system can generate power as high as 50 kW and the fuel cell does not need to be utilized in such cases.

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