A
Project Report
on

Simulation of power management strategy for grid connected system

Submitted in partial fulfilment of the requirement for the award of the Degree of

BACHELOR OF TECHONOLOGY

in

ELECTRICAL ENGINEERING

by

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DECLARATION

We declare that the work presented in this report titled "**Simulation of the grid connected hybrid system**", submitted to the Department of Electrical Engineering, Galgotias University, Greater Noida, for the Bachelor of Technology in Electrical Engineering is our original work. We have not plagiarized unless cited or the same report has not submitted anywhere for the award of any other degree. We understand that any violation of the above will be cause for disciplinary action by the university against us as per the University rule.

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Signature of the Student

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CERTIFICATE

This is to certify that the project titled **"Simulation of the grid connected hybrid system"** is the bonafide work carried out by Vipul Kumar, Bhupesh Yadav students, during the academic year 2020-21. We approve this project for submission in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Electrical Engineering, Galgotias University.

Dr.Gitanjali Mehta

Project Guide(s)

The project is satisfactory/unsatisfactory.

Internal Examiner(s) External examiner

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ABSTRACT

In this paper the author is trying to give a method in which a grid connected hybrid system is designed to operate. The hybrid system is consisting of a photovoltaic array and a proton exchange membrane fuel cell (PEMFC) which is being taken into the consideration .The PV array basically using a maximum power point tracking (MPPT) technique for the continuous delivery of the highest power to the required load when the variations such as irradiation and change in temperature takes place which make it a uncontrollable source .In coordination with the FUEL CELL, the output power of the hybrid system is controllable .This entire system basically operates in two modes, the unit- power control (UPC) mode and the feeder – flow control (FFC) mode and can be given to the hybrid system. The coordination between the two control modes ,the inter coordination between the PV array and the FUEL CELL in the hybrid system and the determination of reference parameters used are presented .This proposed techniques with a flexible mode of operation change always operates the PV array at the maximum power in the output and a high efficiency performance band in the PEMFC .This results in better performance of system operation, making the system more stable and reducing the overall number of operating mode of changes.

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GLOSSARY

DG	Distributor generators
UPC	Unit-Power Control
FFC	Feeder Flow Control
MPPT	Maximum Power Point Tracking
INC	Incremental Conductance
CCP	Common coupling point
PEMFC	Proton Exchange Membrane Fuel Cell
CV	Constant Voltage
P&O	Perturbation And Observation
PWM	Pulse Width Modulation
FC	Fuel Cell
PV	Photovoltaic Cell

1. **INTRODUCTION**

With increase in the demand of power the **renewal energy is used on large scale** these days .Aim to deliver the maximum demand from the load the photovoltaic cell (PV) generally works at the point of maximum power technique whenever there is any slight or even more change in temperature and irradiation takes place .The limitation PV array is that, It's becomes uncontrollable source as, it's output power is dependable on the atmospheric Condition and temperature. To overcome this issues alternatives ways, like Proton exchange membrane fuel cell must be installed along PV array in the proposed hybrid model. By varying output power of the fuel cell .The system source output becomes easy to manage and controllable to wide range .But the Fuel cell generally functions at highest efficiency level in a specified range of power. Now the proposed hybrid model has different configuration with the main grid as shown in the diagram .When the load demand changes take place the hybrid model and the main grid must coordinate properly .The hybrid system basically operates in two modes that is UPC and FFC mode .In the UPC mode of control the change in load demand is basically communicated by the main grid and the hybrid system output power is revised to constraint value of power. Thus, it's important to determine the value of it. On the other hand in FCC mode,power of the

feeder flow is revised to minimum value and the demand is fulfilled by the hybrid system and therefore the reference value is determined. This proposed techniques will improve the functioning of the system, makes the system operation better and will reduces the number of mode of operation. This technique of power management can play a vital in achieving the target to fulfill the demand of the power in each and every sector, to each and every corner of the globe. In order to make the power affordable and accessible to all the communities of society in this era where the technology has to play a very important role. Different techniques or strategies must be adopted to enhance the generation, effective management and reduce the loss of the power. Keeping this point in mind we have come across with power management strategies. This power management strategy basically constitutes three parts, the MAIN GRID, FUEL CELL(PEMFC) AND THE PV ARRAY .Apart from this converter like DC-DC, DC-AC converter are also used for the conversion of the power.In the PV array the P&O algorithm which has it's own better features over the others.The main task is of controlling the PV ARRAY and the FUEL CELL. For that different strategies have been proposed in the below sections.The main purpose of proposing the algorithms and the strategies is to investigate the equations in order to determine the references values and to satisfy the constraints.The

strategy is basically divided in two parts, one part deals with the operation of the hybrid system in the UPC and the second deals with the overall operation of the hybrid system.

2.LITERATURE REVIEW

A Algorithm to represent hybrid Model connected to a grid .The hybrid Model consists of of a photovoltaic (PV) array operating at maximum power point tracking (MMPT) algorithm for continuous supply of the highest power to the required load when irradiation and temperature plate occur ,it becomes uncontrollable source.

With the Introduction of the PEMFC,the hybrid system output power becomes uncontrollable.Two different operation modes,the unit power control(UPC) mode and the feeder flow control(FFC) mode, can be supplied to the hybrid model. The coordination of the Photovoltaic cells and the PEMFC in the hybrid system,and the determination of the reference values are proposed

3.SYSTEM AND CONTROL DESIGN

3.1 Model description of the Hybrid Model Connected to the HYBRID MODEL

The Model is basically consisting of the two main part as PV Array and the FUEL CELL Source

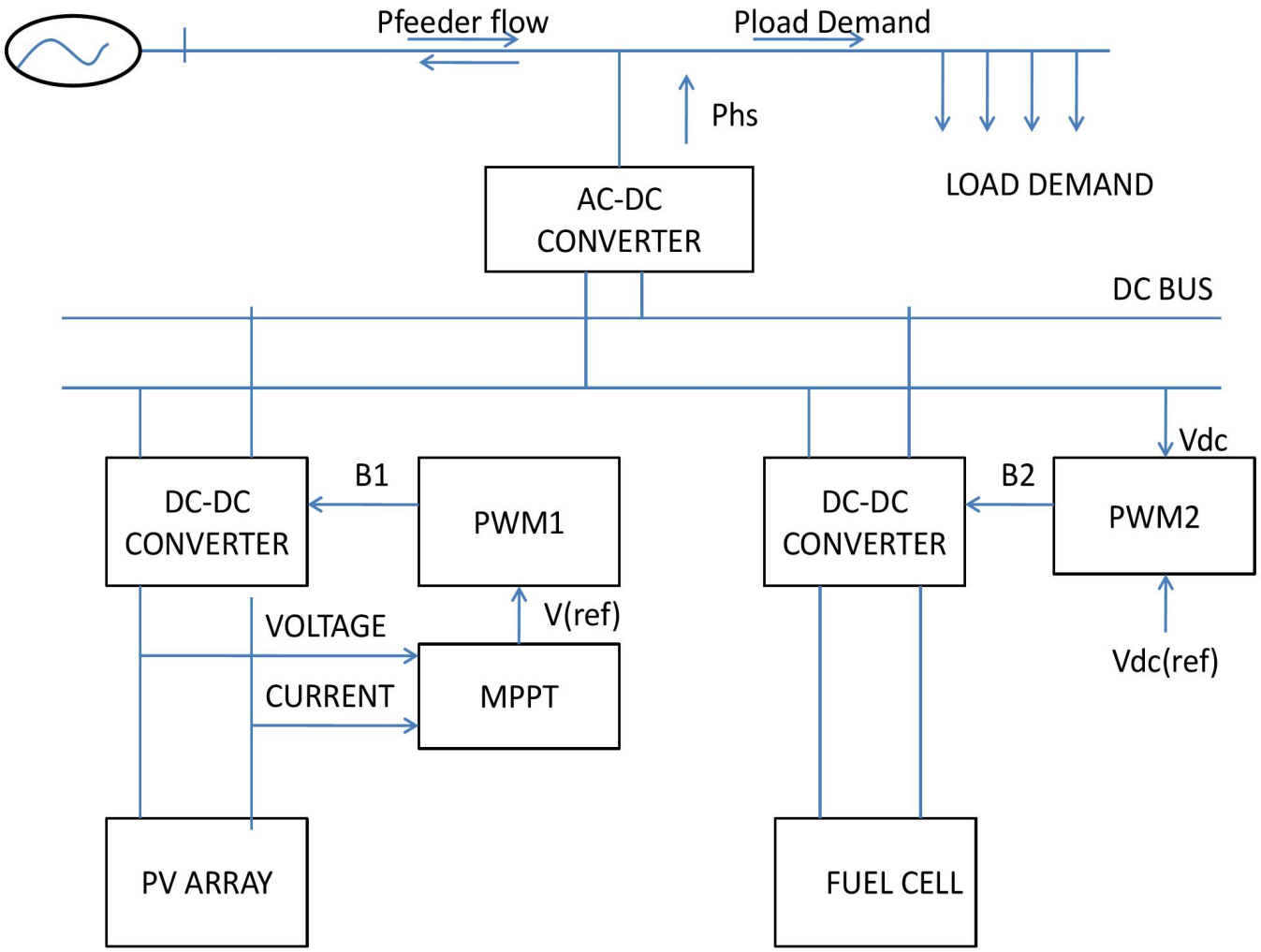

Fig3.1:System Model Design for grid connected hybrid connected

Connecting it to the main grid at the common coupling point as given in above figure. The PV Array and FUEL CELL are designed as source of voltage of nonlinear in nature .Converter1 i.e DC-DC is connected to the source and gain these are coupled to the to the DC portion of the Second

Converter i.e DC-AC Inverter. The Converter1 coupled with PV cells will act as MPPT controller .There have been many algorithms described such as constant voltage, Incremental conductance and Perturbation and Observation .The P&O method has been most popular in use because it's easy to understand ,simpler feedback structure and lesser parameters to measure .The P&O algorithms has been used with power control feedback facility method as given in the figure .The MPP is tracked by determining the voltage ,current and the power .At the point of maximum power, the value of $\partial p/\partial v$ is zero .By varying the reference value of the voltage by small amount of the ∂v(reference),the point of the maximum power can be investigated easily.

3.2 PV Array Description

PV Array is the combination of the PV panels in the proper sequence.They are generally connected in the cascade to obtain the high value voltage and in parallel form to obtain the high value current.A entire photovoltaic system is used as a system to provide the source power.A PV cell generally produces 12V OR 24V is not sufficient to fulfill the required load demand.PV CELL converts the solar energy directly into the DC current.

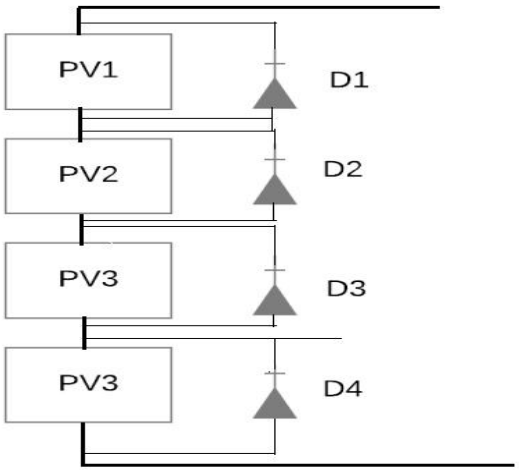

Fig3.2: PV Array

3.3SOLAR ARRAY PARAMETERS

3.3.1 Voc =Open circuit voltage:Under no load Condition or Open short circuit the PV Array offers maximum voltage.This value depends upon the numbers of the cells connected in the series.

3.3.2 Isc=Short circuit current:The maximum current offered by the PV cell when external terminals are short circuited.This value is much higher than the Imax. This value depend on the number of cells connected in parallel.

3.3.3 Pmax=Maximum power point:This refers to the point at which maximum power is delivered to the load by the PV Array when connected to the load(batteries,inverters).The maximum power is calculated in Watts(W) .

3.3.4 FF=fill factor:This fill parameter relates between the value of maximum power offered by the PV Array under normal condition and the product of the Voc and the Isc.This fill factor shows the Sharpness of PV cell.The value usually lies between the 0.7-.08.

3.3.5 %EFF=Efficiency percent:This parameter of PV cell refers to the value of the maximum energy of the electrical output that a photovoltaic cell can offer to the quantity of solar irradiance falling on the Cell plate.This value of cell usually lies between the 10-12%(depending upon the type of material used).

3.3.6 Maximum power point : The V-I characteristics provides the information about the MPP operating under highest efficiency.

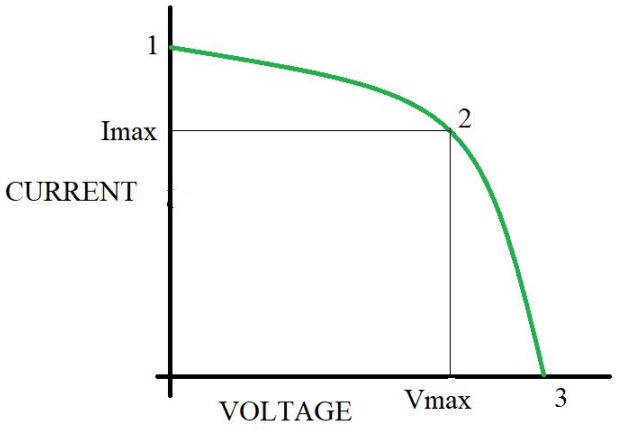

Fig:3.3 V-I Characteristics

3.4PERTURB AND OBSERVE (P&O) ALGORITHM:

Aim to improve the working and the efficiency of the PV cell and to track the MPP easily on varying the solar irradiance.Among all techniques the P&O gives an excellent result and.In this Process a very small perturbation is injected which causes variation in the output power of the PV Array.This output power is regularly calculated and the compared with the last value if the output value is increased then the technique is taken further or else the process of pertubating is reversed.

The mathematical equation is given as

$I=Iph_o-Isa_o\{exp[q1/A_oK_oT(V_o+Irt)]-1$ (1)

Above Equation (1) is showing that the current of the Photovoltaic cell is dependable on the irradiance,Tenperature of the plate and the load value is of nonlinear in nature.

Photo current Iph_o is directly related to solar radiation Ga_o

$Iph_o(Ga_o)=Isc_o(Ga_o/Ga_os)$ (2)

The short circuit current depend on temperature

$Isc_o(T)=Isc_o\ [1+Isc_o(T-Ts)]$ (3)

$Iph_o(Ga_o\ ,T)=\ Isc_o(Ga_o/Gas)[1+Isc_o(T-Ts)$ (4)

Isa is also dependable irradiance and solar plate temperature can be given as

$Isa(Ga,T)=Iph_o\ (Ga_o\ ,T)/exp(Voc(T)/Vt(T))-1$ (5)

3.5 FUEL CELL

A Fuel utilises the chemical energy of the hydrogen like gas or another fuel to produce the current.If the hydrogen is used then H20 and electricity is obtained as the by product.They produces a clean and highly efficient fuel

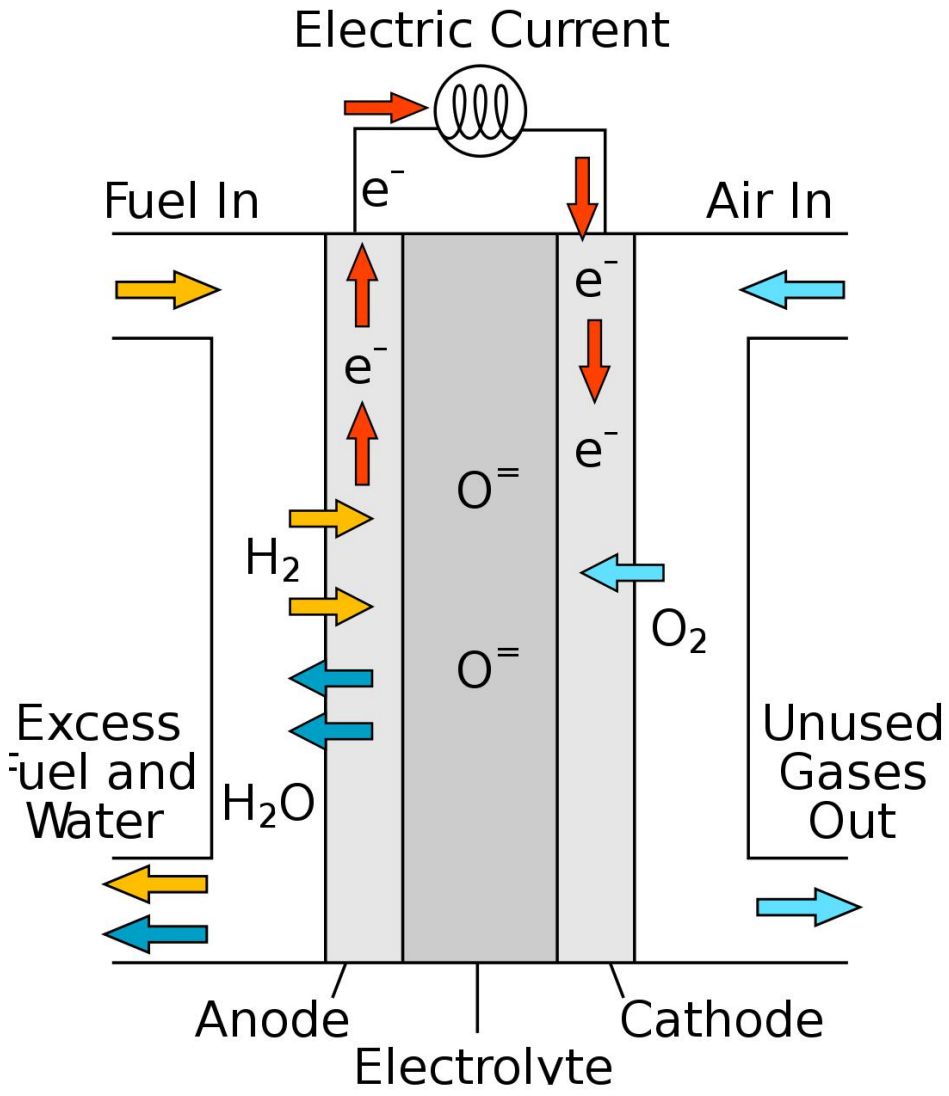

Fig3.4: Fuel Cell

They can provide power to large power station to even the small equipment like the laptops and the cellphones.Fuel cell has better performance and efficiency upto 60% which is far better than many conventional and Non conventional source of energy with low emission than combustion engines.

Fuel cells functions similar like ordinary batteries unlike, they don't break down or need to be recharged as long as the fuel is provided to the cell to produce the electricity.A fuel consists of the two electrodes as anode (negative) and cathode (positive) surrounded by the electrolytes.A fuel like hydrogen is fed to the (-) side and air to the (+) side as shown in the above figure.A catalyst at the (-) side separates the the hydrogen into the proton and the electron. The electron passes through the external circuit producing the electricity and proton reaches to the cathode through electrolyte, thus combining with the air to produce the water and heat.

The following types of fuel cell

i. PEM fuel cells
ii. DM fuel cells
iii. Alkaline fuel cells

iv. PC fuel cells

v. MC fuel cells

vi. SO fuel cells

vii. Reversible fuel cells

PEMFC design is a complex process that aims at minimizing the cost and maximizing the specific current, voltage, output power and durability PEMFC has current and voltage of non-linear relationship The PEMFC output can be obtained as

$$V_{out} = E_{nrst} - V_{act} - V_{ohm} - V_{conc} \quad (6)$$

Enrst is the " voltage of the thermodynamic "which denotes the voltage value in the open circuit of PEMFC Cell .

The voltage drop in activated form is given as per the equation as

$$V1_{act} = T\{ c + d\ln(I)\}. \quad (7)$$

The resistance voltage drop V_r is given as

$$V_r = IR_r \quad (8)$$

The resistance Rr of FUEL CELL is consisting of resistance offered by the plantinum type electrode and the polymembrane

The voltage drop due to the concentration of the electrolyte is given as

$$V_{conc} = -RT/zFIn(1-I/Ilimit) \quad (9)$$

3.6 Controlling of MPPT

Out the algorithms that have been proposed for the maximum power point The most preferred algorithms are the P&O and INC .The INC gives better result in the fast variations of weather conditions but it requires the four sensors to perform the computations .This algorithms requires takes more conversion time and hence more time for tracking the maximum power point and hence more less will occur and the output power will be less than the maximum power .While the P&O requires only two sensors and has less execution time due to which less loss occurs and the economical affordable and less requirements of hardware.

Two Variant applied controlling techniques are voltage and power control .Out of these two,the algorithms with power control alongwith feedback is given in the diagram .The voltage and current values are obtained and the power is investigated .At a point of maximum power the value of dP/dV = zero .The MPPT can be obtained by varying the constraints voltage value.

A buck-boost converter is deployed for implement the MPPT algorithms .The following parameters L and C must obey the following equation

$$L1> \ (1-D1)^2R/2f_o. \qquad C1>D1/ \ Rf_o \ (\Delta V/Vout). \tag{10}$$

The DC-DC converter is consisting of the one switching device which will turn ON and OFF as per the signal to the gate .The variations of reference voltage obtained by the algorithms of MPPT becomes the input for the PWM . Buck boost converter is controlled by the PWM by generating a signal and thus, MPPT is tracked and passed to the ac side of the DC-AC Inverter.

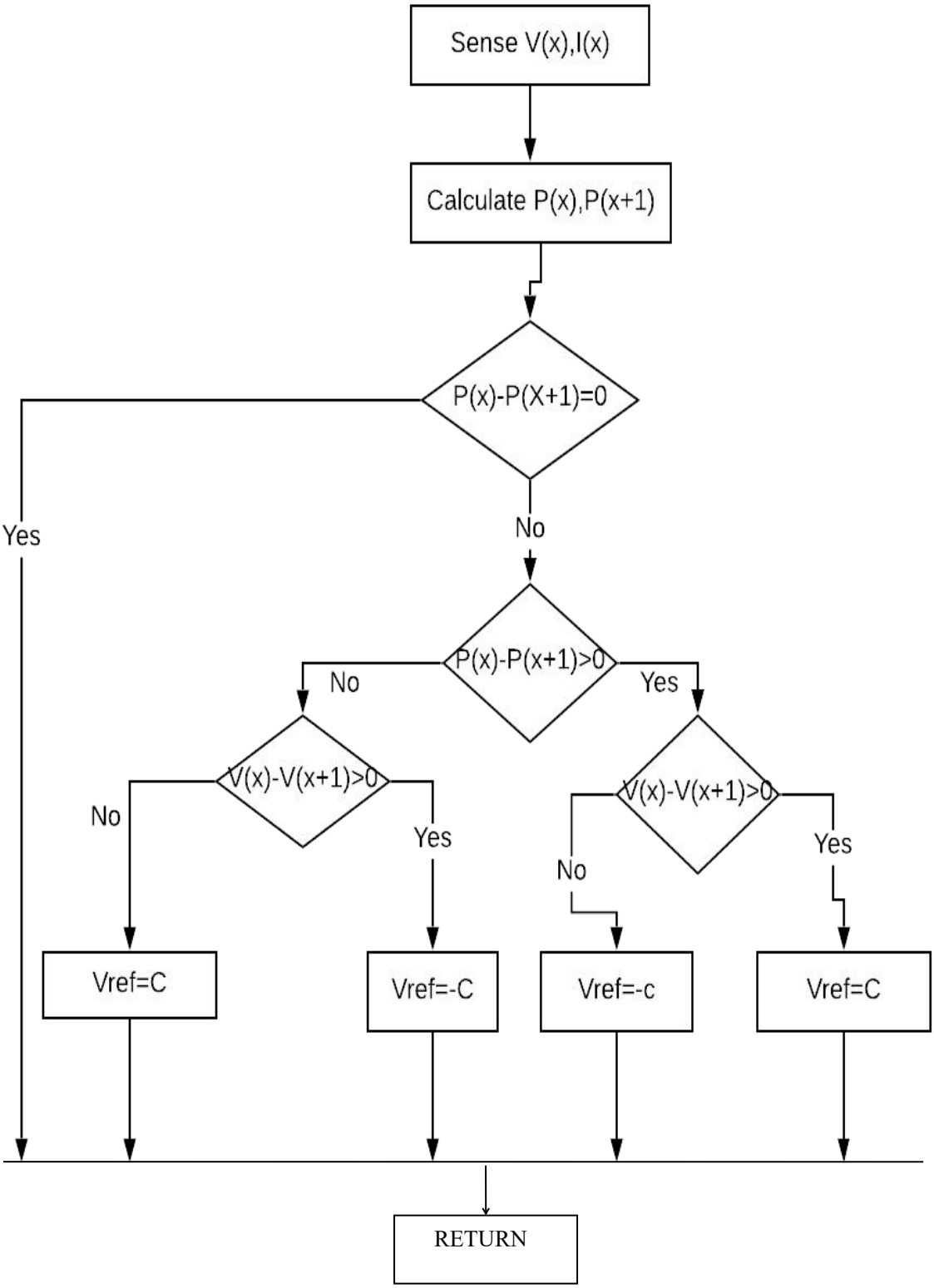

Fig3.5:Flow Chart of the P&O Algorithms

3.7 BUCK BOOST CONVERTER: A buck boost converter is a DC-DC converter whose output power or voltage is either more or less than the input or supplied voltage magnitude.Both of them can provide wider range of output voltage varying from the large value in magnitude to the zero value even.

3.8 CONTROL MECHANISM OF THE HYBRID SYSTEM IN DIFFERENT MODES

The hybrid system basically includes three modes of control as UPC, FFC and mixed control mode of both

In the Unit Power mode of control, the extra load demand is Fulfilled by the Operating grid and the voltage and power of hybrid Model is set to the reference values by the DGs. In the FCC mode of control the extra demand is achieved by the hybrid model and the voltage and power flowing in the feeder is regulated to the reference value .In the mixed control of mode there is coordination of the UPC and FCC mode of control.

In our paper, mixed control mode is taken into the account in order to determine when to apply which mode and to find the reference values for both the control mode .The overall proposed strategy is based on the

minimization of the number of mode changes, enhancing the system operation and making the system more stable.

4. SYSTEM IMPLEMENTATION

4.1 OPERATION OF THE HYBRID MODEL IN UNIT POWER MODE OF CONTROL

In this part, the proposed Strategy investigates the operation of the hybrid model in the Unit power control mode .The algorithms is designed such that the PV operates in MPP and the FUEL cell works in the high efficiency region.

Parameter	**Value**	**Unit**
Pfc(up)	0.06	MW
Pfeeder(max)	0.02	MW
Pfc(low)	0.02	MW
ΔPhs	0.03	MW

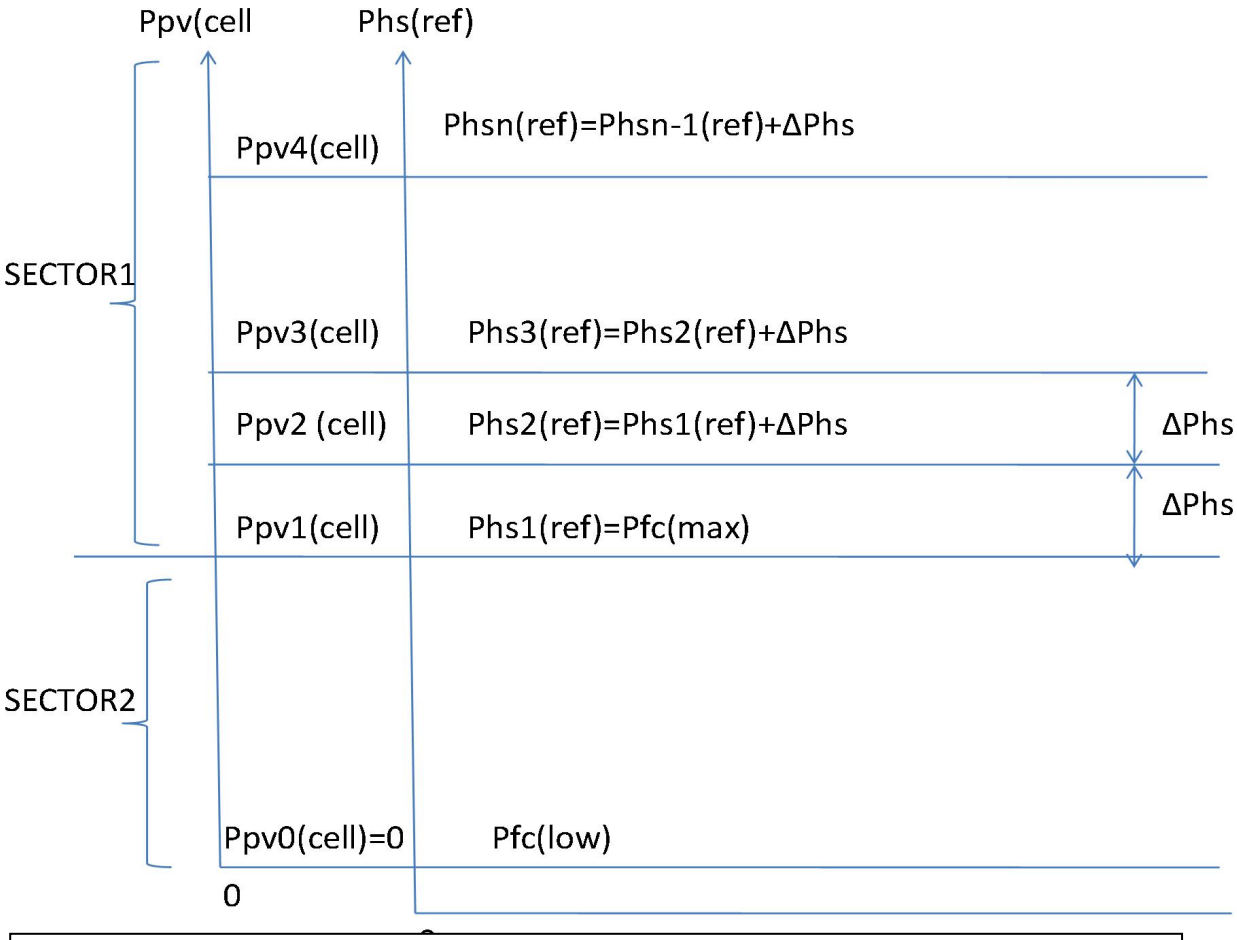

Fig4.1:Algorithms Design For Grid Connected Hybrid Model in Unit Power control mode

In the Unit power mode mode the output of the hybrid system is regulated and is governed according to the following equation

$P_{pv}(cell)+Pfc(cell)= P_{hs}(reference)$ (10)

Equation 12 shows the relationship between the Photovoltaic output and FC output and the FC compensates the variation that occurs in the PV cell .The total output power is set to the constraints value and the constraints of FC system is satisfied .The figure 4 explains the working Technique of the hybrid model in the Unit power mode and in determining the Phs (reference) values .This algorithm shown in the figure basically consists of two Sector ,Sector1 and Sector 2.

In Sector 1, Ppv is lower than the Ppv1, and therefore the constraints value for Phs1(reference) is set at the Pfc(up)

Ppv1=Pfc(up)-Pfc(low). (12)

Phs1(reference)=Pfc(up). (13)

If the Ppv output power is zero then the Pfc gets the Pfc (up).

If the Ppv output power is increased to Ppv1, which results in the Pfc (low)

The constraints of the FC is satisfied at any instant and it reaches to Area1

The reference power is set at Pfc (up) all the time in the UPC mode of control

Now the Sector 2 is for the case when Photovoltaic Output Power is more than the value of Ppv1.As already mentioned in the above paragraph that as PV is increases the Fuel Cell output power will reduced to the lowest limit

Pfc(low).As Photovoltaic cell keeps on changing the Fuel Cell keeps on decreasing and reaches to the lower limit .To Run the Photovoltaic Cell at the Maximum power Point and the Fuel Cell in the limits .The reference value for the output Power must be increased in that proportion .As shown in the figure ,if PV output power increases to PV1,the power will be changed by an amount of ΔPhs and the following equation is obtained

$$Phs2(reference)=Phs1(reference)+\Delta Phs \quad (14)$$

Similarly if Photovoltaic Cell output is more than Ppv2 then the reference power further by an amount of ΔPhs and the FC output becomes lower than the limit value where as if the Ppvis less than Ppv2 and greater them Pv1 then the reference value remains the same

$$Ppv2 = Ppv1+\Delta Phs \quad (15)$$

The value of ΔPhs is confined so that values of then new parameters and Fuel Cell output is not greater than Pfc (up), Therefore we have

$$\Delta Phs \leq Pfc(up)-Pfc(low) \quad (16)$$

The generalized equation can be given as

$$Pmsi\ (reference) = Pmsi\text{-}1(reference)+\Delta Phs \quad (17)$$

$$Ppvi = Ppvi\text{-}1+\Delta Phs \quad (18)$$

The above equations number 17 &18 are used to find the values for the Area2

Using the above equations

Pmsi (reference)=Ppvi +Pfc(min) (19)

The investigating the values Phs (reference) in both the areas 1 and 2 can be generalized as

Now,therefore

Phsi (reference)=Ppvi +Pfc(min) (20)

Ppvi=Ppvi-1+ΔPhs (21)

4.2 OVERALL FUNTIONING OF THE GRID CONNNECTED HYBRID MODEL

It Fact both the system the main Grid and the hybrid system has two mode of control ,UPC and FFC .In the previous section the Phs (reference) in the Unit power mode is designed .Now in this section, Another Algorithm is proposed to corelate the operation of both control mode and to investigate when to apply which mode of control .The purpose of the algorithms is to find the value of reference for the feeder flow power when the feeder flow mode of control is applied .The strategy is proposed in such a way that PV works at MPP ,Fuel system and constraints must be fulfilled by the feeder flow power.

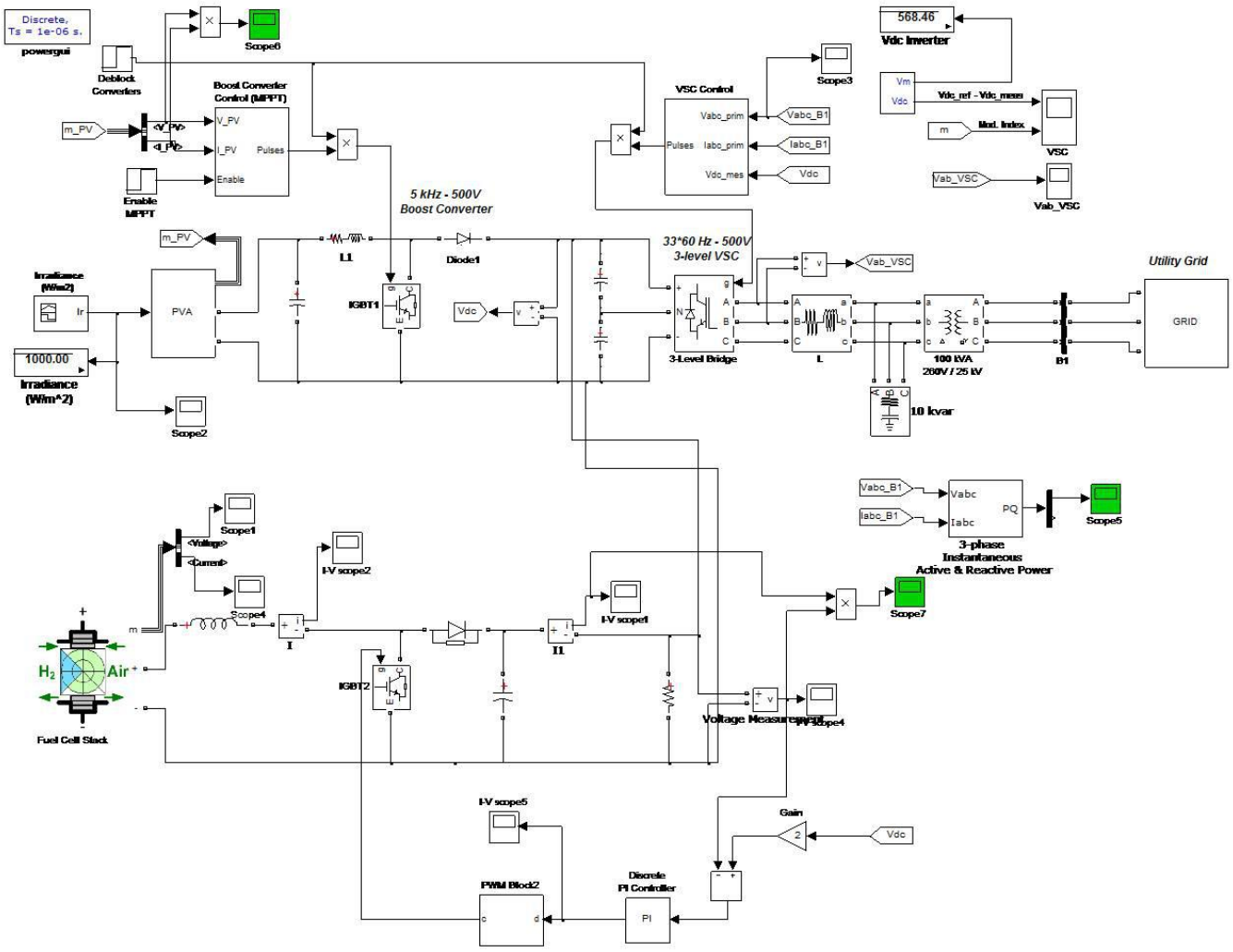

Fig4.2 : MATLAB SIMULINK CIRCUIT BLOCK DIAGRAM

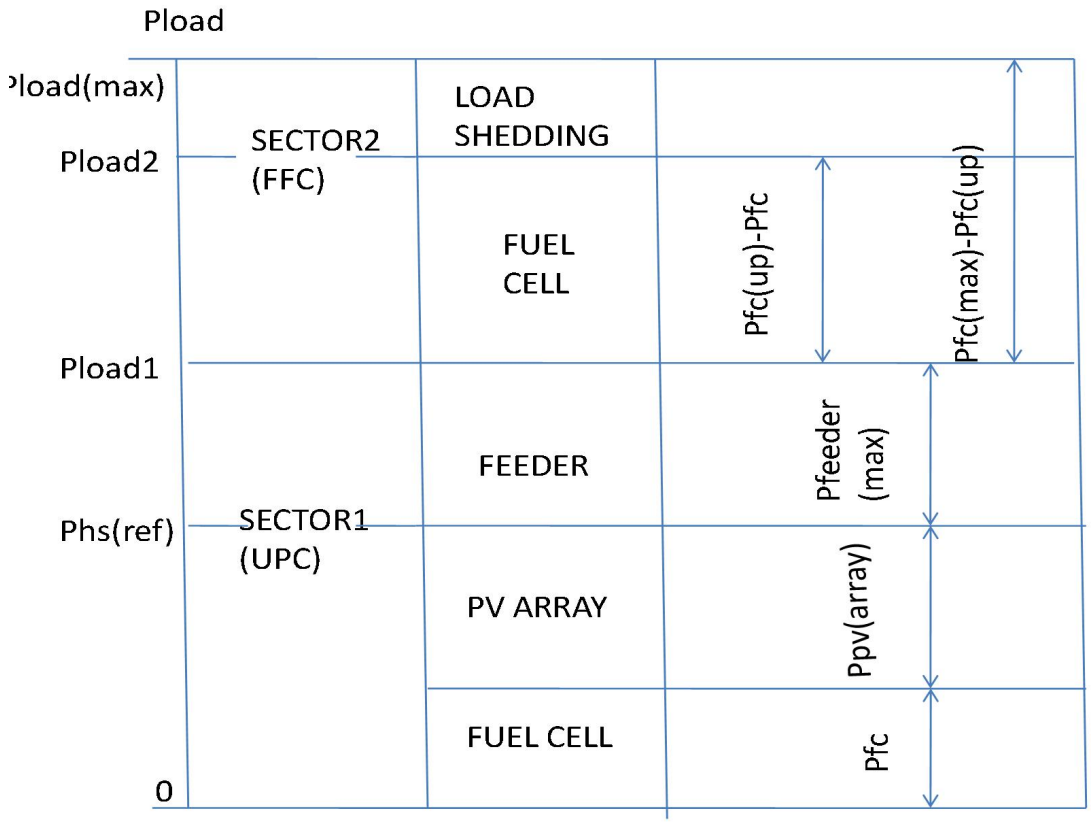

Fig4.3 Algorithm Designed for the Overall Operation

If the hybrid system operates in the Unit power mode , the reference value the hybrid output is set and their constraints are considered in the previous section .Therefore ,only the constraints of feeder flow is considered in this .During the operation of the hybrid system in Feeder flow mode the power flowing through the feeder is regulated to reference value i.e Pfeeder (reference).The hybrid system takes care of the extra demands.Considering all the above analysis and ensuring all the

constraints .The operating strategy is proposed through the diagram as shown in the figure above.

The algorithms shown in the figure above is divided into the two areas Area1 and Area2.The controlling mode is directly dependable on the load. If the load demand is in the Area1 then, he Unit power mode is applied or else it falls under Feeder flow mode.

In the Unit power mode output Power of the hybrid system is set Phs (reference).If the demand is less than this reference value the surplus power is sent to the grid .As the load demand increases the grid will supply the power to match the demand Further increase in the demand the feeder reaches to the maximum value i.e Pfeeder (max). Anything further increase will shift to the Area2 i.e FFC mode of control for achieving the load demand . Therefore the boundary between the areas is Pload1

$$Pload1 = Pfeeder\ (max) + Phs\ (reference) \quad (23)$$

As the mode shifts to the feeder flow, reference value of the feeder must be calculated .In order to have seamless functioning ,the FFC value must not be changed during the shift of control mode And therefore the values of reference set at the Pfeeder(max)

Pfeeder (reference)=Pfeeder (max) (24)

In the FFC control the load demand and the variations in the PV is compensated by the FC Power .The FC reaches it's upper limit value with increase in the demand .If the load demand is higher than the total power generation in combined form ,then the load shedding will occur.

Pload2=Pfc(up) + Pfeeder (max)+ Ppv. (25)

The above equation of 25 reveals, Pload2 is minimum when Photovoltaic power is 0kw.Therefore we have

Pload2 (minmum) = Pfc (high) + Pfeeder (maximum). (26)

From the starting the Fuel cell has worked with highest efficient range and the Fuel Cell output Power is lower than the Pfc (high). Therefore the largest load

Pload (max) = Pfc (max) +Pfeeder (max) (27)

If the load demand and Fuel cell satisfy the above equation then load shedding will never occur and installed capacity for FC system can be determined and the width of Area2 is calculated

PArea2=Pfc (max) - Pfc(up). (28)

5.RESULTS AND DISCUSSION

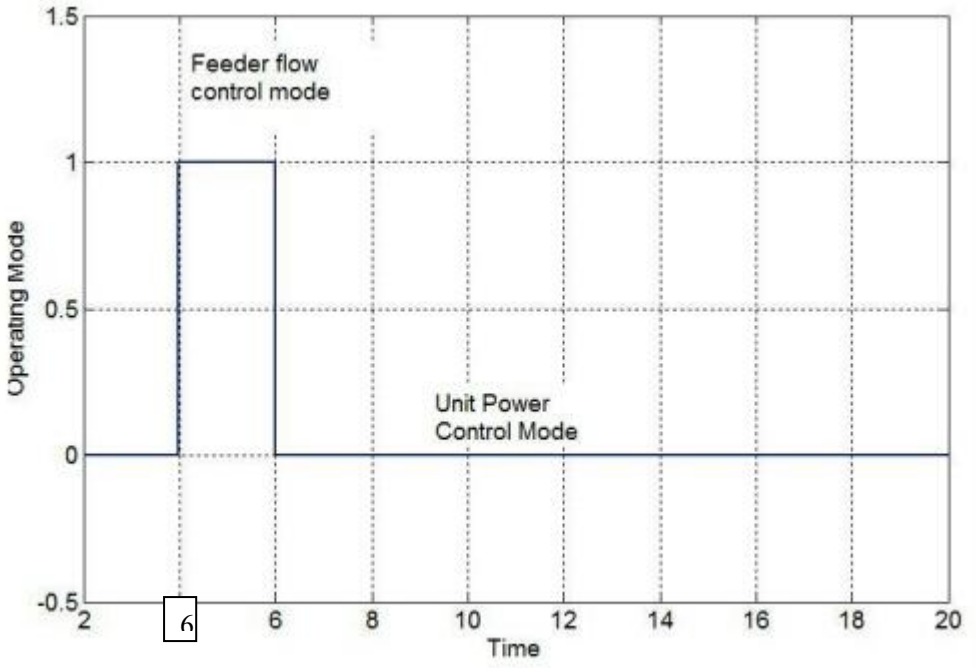

Fig5.1:change of operating mode of operation

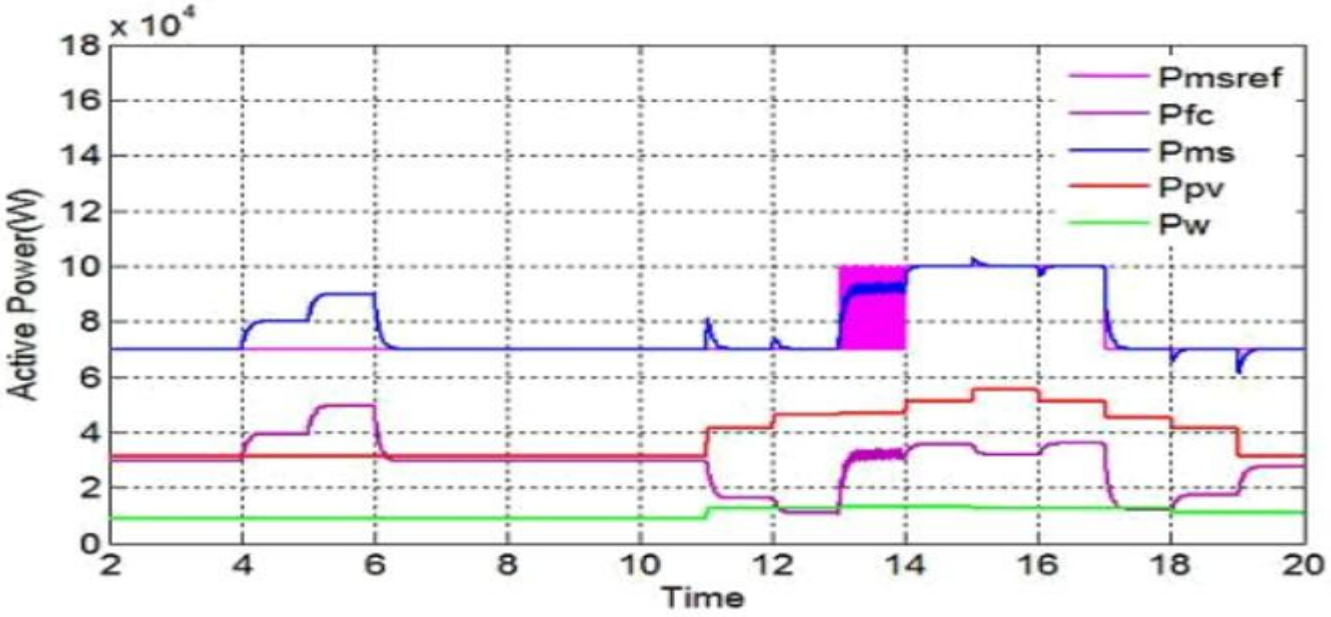

Fig5.2: Result of the proposed algorithms for Grid-Hybrid System

Figure 8(a) (c line). The output power of the fuel cell PFC is shown in the Figure which is varied according to the variations in the Ppv and the Phs(ref).

In the figure 8(c) depicts the operation mode .The UPC mode corresponds to 1 while FFC to 0.As obtained the Fig(c). FCC mode operates for 4 to 6 second while rest of the time it operates under UPC mode .While operating under Feeder flow mode the output of the Hybrid System varies as per the change in load demand .While in UPC mode Phs varies with Phs(ref).It can be clearly observed that system operates in feeder flow mode under high load condition and in less load situation under unit power mode .In practical situations the the microgrids are supposed to work at fixed load from beneficial,economical and stability reasons. In microgrids the Distribustion generators have parallel connections with the feeders . Therefore in unit power mode variations in the output is meet through the hybrid system.In case of a single hybrid source the system must be proposed to operate in the feeder flow mode of operation. This can be achieved by the setting a very high value of Pfeeder(max),Thus hybrid system operates in the FCC .According to this operating strategy the FC should work in the high efficiency mode to match the demand of the varying load at night.From the above discussion it can be concluded that the designed algorithm is highly

useful and sensable to the practical world which has microgrids along with the several Distributions Generators.

6.CONCLUSION AND FUTURE SCOPE

This project has put up an alternate technique of operating a microgrids connected hybrid system with consisting of the Photovoltaic cells and the Proton Exchange Membrane Cell. The controlling and operating algorithms is consisting of the two different modes i.e UPC and the FFC mode which provides an excellent method of operating the Photovoltaic cells at the maximum power point where as fuel cell efficiently at high.The paper has successfully explained the control mode, minimizing the number of changes required in modes for operating the Photovoltaic Cells array at its maximum power point and the PEMFC at the highest efficiency.The system is capable of maximizing the output power When the load is at its peak and minimizing the load shedded area.This strategy is the most simplified and flexible in the operation of the Hybrid System connected either through microgids/grids improving the overall performance of the system with greater stability.

For the future research work taking into the account of the batteries and the microgrids with the large numbers of the feeders and the Distributors Generators must analysed in details and their operating strategies.

One very prominent work which can be achieved under this, the inclusion of the wind system in the hybrid system and proposing its strategy to operate would be quite interesting and exploring even more techniques for managing power.For this a suitable model can be proposed like this:

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