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Power Management Techniques For A Grid Connected Hybrid System With Coordinate Control

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Abstract- **This paper presents the methods and strategies of coordinating hybrid system by using their constraints also giving picture about total harmonic distortion values. The system utilizes a photovoltaic system as a primary source and proton exchange membrane fuel cell as auxiliary source. The photovoltaic system is can be operated at maximum power point by using the technique MPPT(maximum power point tracking) and the fuel cell can be operates at its maximum efficiency range. The controller we are using here is fuzzy logic controller with this we can reduce the value of total harmonic distortion when compared to other controllers. Two modes of operation are feeder control mode and unit power control mode. Hence we can achieve the controllable operation, improving system performance with reduced running conditions, enhance system stability and total harmonic distortion can be reduced. The model is designed by using MATLAB software.**

Keywords: **Hybrid System; MPPT; PV System; Fuzzy Logic Controller;**

Nomenclature

P_{PV} =photo voltaic output power

P_{MPP}=PV maximum output power

$P_{FC=}$ FUEL CELL output power

P^{low}_{FC}=FUEL CELL lower limit of high efficiency band.

P^{up}_{FC}=FUEL CELL higher limit of high efficiency band.

P^{max}_{FC}=FUEL CELL maximum output power.

P_{FEEDER}=feeder power flow

P^{ref}_{FEEDER}=feeder reference power

P^{max}_{FEEDER}=feeder maximum power

P_{LOAD}=load demand

I. INTRODUCTION

The electricity is playing a key role in our day to day life and the generation of electrical energy is not a simple issue. So many alternatives are there to compensate the load according to its demand. Renewable energy sources play a key role to generate electrical energy among all the renewable sources the best one is chosen solar energy because of its abundant availability in nature and free of cost. The solar energy is non linear it depends on the solar irradiation and temperature so to make this uncontrolled source to controllable we can use a auxiliary source such as a fuel cell, in our paper we are using proton exchange membrane fuel cell. These two units can be connected to the grid system at the point of common coupling.

The power demand altered from one point to other then the power drawn from the grid and two generating units should be altered properly according to its modes of operation. The two modes of operations we are using here are unit power control and feeder flow control methods. In the case of unit power control the two generating unit works at its reference power point if the load demand increases it can be compensated by the feeder power flow. In case of feeder flow control mode the main grid supply the constant feeder flow and the load demand compensated by the two generating units. The constraints for the system are specified before itself. This way by adjusting automatically the whole system can be satisfy the load demand with reduced number of operating modes with the improved system performance with improved system stability.

II. SYSTEM COMPONENTS

The system arrangement is shown in figure3, the photovoltaic system and proton exchange membrane fuel cell connected to the DC to DC buck boost converter. The output from the DC to DC converter is given to the DC to AC converter and then to the point of common coupling where all the loads are connected, PCC is the synchronizing point between grid and generating units.

a) PV array model

The basic arrangement of the PV array is shown in below figure. A diode connected across the resistor

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will act like a fuel cell and the current equation is given as in the form shown below, from this equation we can say that current from the photovoltaic system is non linear which in turn depends on the irradiation level and temperature.

$$I = Iph - Isat\left\{\exp\frac{q}{AKT}(V + IRs) - 1\right\} \qquad (1)$$

Photo current is given as Iph (Ga) =Isc (Ga/Gs).(2)

From this the photo current is directly proportional to the solar irradiation Gs.

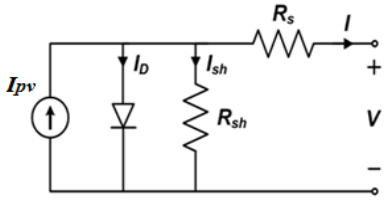


Figure1PV array model

b) FUEL CELL model

The proton exchange membrane fuel cell works on simple principle. Oxygen and hydrogen taken as fuels, anode side hydrogen fuel tank is present this hydrogen fuel passed through an electrolyte and form electrons and protons. The electron transferred to the external circuit where the load is connected hence causes flow of electric current. The remaining protons reach to the cathode side through an acidic medium and form water by combining with oxygen molecules. The basic arrangement is shown in below figure2.

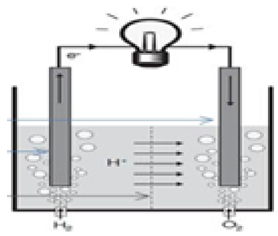


Figure2 Fuel Cell

c)system discription

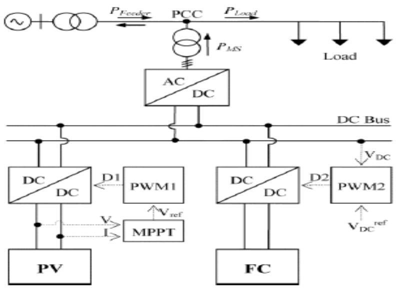


Figure3 PV FC Hybrid system

The maximum power can be achieved by using MPPT techniques in case of photovoltaic systems. Two sensors are arranged to sense the voltage and current and this values given to the MPPT controller. To track the maximum point perturb and observe algorithm is used. It is given in below figure4.

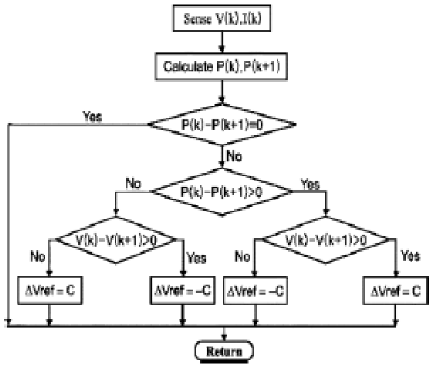


Figure4 MPPT algorithm

After sensing voltage and current values power is calculated this power value is taken as present power value and it is compared with the previous power generated value, if the present power generated is greater than the previous condition then transfer will go to check the condition for voltage values. Present and previous case voltage values compared and adjusted to a reference value. This value is given to the pulse width modulator to generate pulses, this given to the DC to DC converter to generate desired amount of output voltage. This controlled output voltage is given to the DC to AC converter to supply power according to the load demand.

III. OPERATING STRATEGY OF THE HYBRID SYSTEM

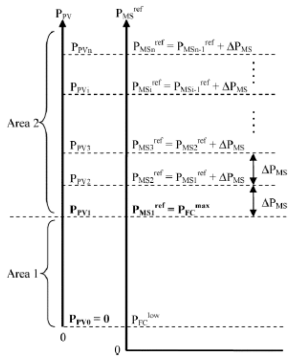


Figure 5 operating strategy of hybrid system

Operating strategy for a hybrid system in unit power control mode is shown in figure5. In this method the photovoltaic system operates at maximum power point and fuel cell operates at higher efficiency range. In UPC mode two generating units operates at its hybrid source reference power level i.e.

$$P_{PV}+P_{FC}=P_{MS}^{ref} \qquad (3)$$

From equation (3) the changes in photo voltaic system output will compensated by fuel cell output power, the total power is taken as or reached to the reference value. The operation explained in two areas.

In area1, the photo voltaic output power is very less then reference power output is equal to the upper limits of the fuel cell, which means total power can be compensated by using fuel cell.

$P_{PV1}= P_{FC}^{UP}- P_{FC}^{LOW}$ (4)

$P_{MS1}^{ref}= P_{FC}^{UP}$ (5)

From the equations (4) and (5) we can say that if the photo voltaic system generating very negligible amount of power then the reference power value will be equal to the upper limits of the fuel cell output power.

In area2 photo voltaic power increases to the certain value then the fuel cell operates at its lower limit range again photo voltaic power increases then the fuel cell operates at below its lower range limits. Hence the PV operates at its maximum power point and fuel cell at its lower limits range, the reference power will increases by the amount of ΔP_{MS}, then the equation we get is

$P_{MS2}^{ref}= P_{MS1}^{ref}+\Delta P_{MS}$ (6)

In same manner, if P_{PV} is greater than P_{PV2} the reference power again increased by the value $\Delta P_{MS,}$ here reference power remains unchanged. Where

$P_{PV2}= P_{PV1+}\Delta P_{MS}$ (7)

It is important to take limited ΔP_{MS} then only new reference power and fuel cell output maintained at less than its upper limit P_{FC}^{UP}, then

$\Delta P_{MS} <=P_{FC}^{UP}- P_{FC}^{LOW}$ (8)

In general we can write,

$P_{MSi}^{ref}= P_{MSi-1}^{ref}+\Delta P_{MS}$ (9)

$P_{PVi}= P_{PVi-1+}\Delta P_{MS}$ (10)

The equations (9) and (10) used to find the reference power when the PV output is taken under area2. The relation between hybrid source reference power and photo voltaic output power is obtained by using the equations mentioned above, then

$P_{MSi}^{ref}= P_{PVi}+ P_{FC}^{MIN}$, i =2, 3, 4… (11)

The photovoltaic output power is in the range of

$P_{PVi-1}<= P_{PV}<= P_{PVi}$ (12)

Also we have

$P_{MSi}^{ref}= P_{PVi}+ P_{FC}^{MIN,}$ i=1, 2, 3….. (13)

$P_{PVi}= P_{PVi-1+}\Delta P_{MS,}$ i=2, 3, 4…. (14)

When i=1, P_{PV1} is given as

$P_{PVi-1}= P_{PV0}=0.$ (15)

The conclusion is hybrid source reference power is determined according to the photo voltaic output power, in area1 reference power always be constant and set to a value of P_{FC}^{UP}.

The algorithm for above discussion is given in below figure 6.

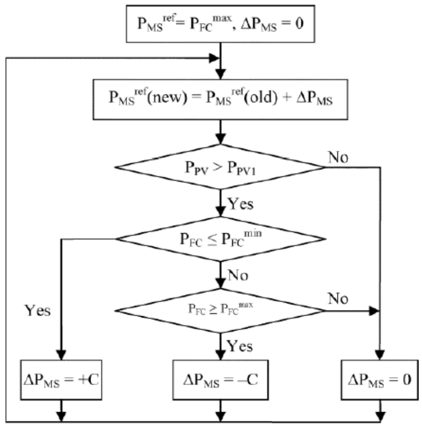


Figure 6 algorithm for UPC mode to set P_{MS}^{ref}

In this control algorithm reference power can set automatically, where C is a constant value. If the value of C increases the number of changes in P_{MS}^{ref} will decrease hence the system performance improved. The selection of C should be very less value so that very many changes in frequency can be avoided (only it takes +/- 5%).

An important control technique we are introducing here is adding a hysteresis control scheme for hybrid source reference power finding algorithm. This is used to overcome the oscillations of the set point of the P_{MS}^{ref}. This is due to the variations in the photovoltaic system output power in the maximum power point technique process the reference power of the hybrid source changes continuously. Here the switching time is lagging without changing instantly. This is given in below figure7.

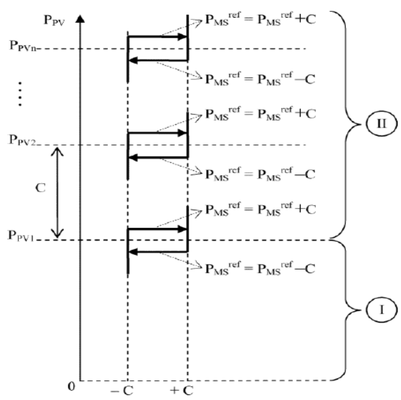


Figure7 Hysteresis control algorithm

IV. OVERALL OPERATING STRATEGY

Here we are using mainly two techniques one is unit power control mode and feeder flow control mode. In UPC mode the hybrid source output power regulated to a constant value and the variations in the load can be compensated by using feeder power flow. On the other hand in feeder flow control mode feeder power is set to a reference value and the load can be compensated by using remaining generating units. The total strategy is given in below figure8

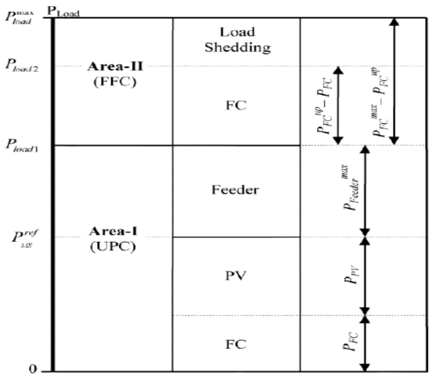


Figure8 Operating strategy of the overall system

The algorithm is explained in two areas. In area-I UPC mode is selected to satisfy the load demand. By adding photovoltaic and fuel cell output power we can get hybrid source reference power. If the load demand is increased above the reference level then the demand can be satisfied by using feeder power.

$$P_{LOAD1}=P_{FEEDER}^{max}+P_{MS}^{REF} \quad (16)$$

The system operating under FFC mode i.e. in area II, the flow is constant and set to a maximum value and the load demand satisfied by the generating units.

$$P_{FEEDER}^{ref}= P_{FEEDER}^{max} \quad (17)$$

$$P_{LOAD2}=P_{FEEDER}^{max}+P_{FC}^{UP}+P_{PV} \quad (18)$$

When the $P_{PV\ OUTPUT\ POWER}$ is zero 0 kW then P_{LOAD2} is minimal.

$$P_{LOAD2}^{MIN}=P_{FEEDER}^{max}+P_{FC}^{UP} \quad (19)$$

From the above equation we can say that load shedding never occurs. If the load is highest and maximum load

$$P_{LOAD}^{MAX}=P_{FEEDER}^{max}+P_{FC}^{MAX} \quad (20)$$

Hence load shedding is avoided, for improved operation number of mode changes should be less. In brief we can conclude that, during light load condition the hybrid source regulates power the power to a constant value and the load demand can be compensated by grid, during heavy load condition grid power maintained as a constant value and the load demand compensated by generating units this is under FFC mode. Hence we are utilizing the maximum efficiency of a fuel cell and the photo voltaic we making it to run at its maximum power.

V. SIMULATION RESULTS

According to the load demand and the changes occur in photo voltaic output fuel cell output power, hybrid source reference power, feeder flow reference power and operating modes can be determined.

Figure9 shows the simulation results of the system operating strategy.

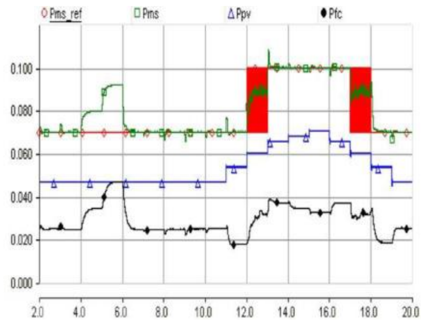


Figure 9 operating strategy of the hybrid source

The $P_{MS\text{-}REF}$, P_{FC}, P_{PV}, P_{MS} values are given in above figure. From 0 to 10 seconds the photovoltaic output power is constant, which means it operates at standard test condition so P_{MS}^{REF} is also constant. From 10 seconds to 20 seconds photo voltaic output power changes in step manner according to this value P_{MS}^{REF} value also changes according to the algorithm explained above. According to changes in P_{PV} and P_{MS} the value of P_{FC} also changes. From 4 to 6 seconds system runs in FFC mode, here hybrid system power changes according to load demand. Remaining time period system works in unit power control mode. If we observe from 12 to 17seconds oscillations can be seen in P_{FC}, P_{MS} and also in P_{MS}^{REF}, this is because of changes in P_{PV} continuously during MPPT process.

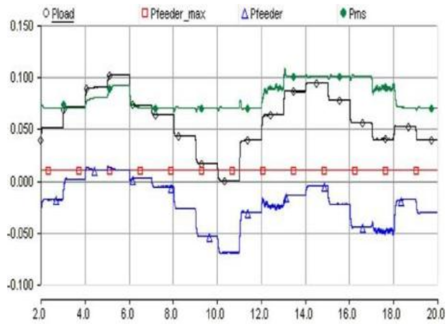


Figure10 overall operating strategies for whole system.

According to load demand hybrid source output power also changes, hence there is a continuous power supply to the load without load shedding.

The oscillations can overcome by introducing a hysteresis controller to the algorithm, with this the switching time is lagged so instantaneous switching is avoided hence distortions also.this is given in below figure11 and figure 12.

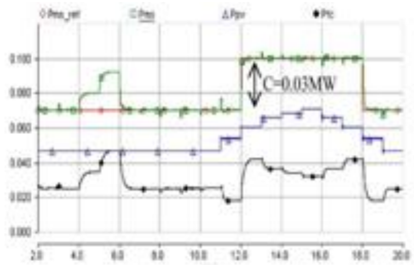


figure 11 hybrid systems by adding an hysteresis control.

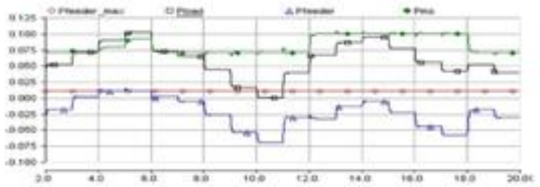
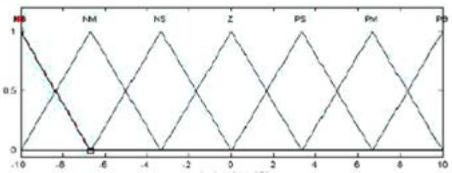


Figure12Overall system strategies by adding a hysteresis control

Total harmonic distortion can be reduced by using fuzzy logic controller instead of PI controller, this is shown in figure 13 below. In this project we are introducing a modern technique that is including a fuzzy controller in the place of PI controller. In PI controller only one input and one output we used as incase of fuzzy logic controller we can use two inputs and one output. Error (e),error change(de) are the inputs and output is a control signal.

CE \ E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB



The total inputs and fuzzy membership functions are shown above figures. The inputs we used here are

NB-negative big

NM-negative medium

NS-negative small

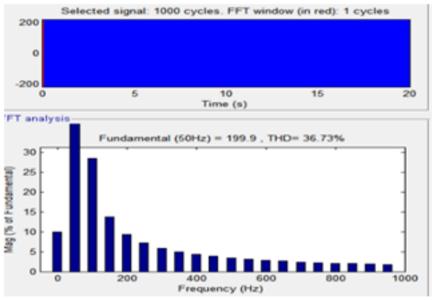
Z-zero

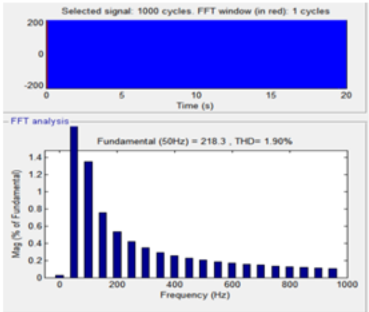
PS-positive small

PM-positive medium

PB-positive big

These are decision making rules. By using fuzzy logic controller total harmonic distortions reduced, which are compared below.





THD analysis With PI controller
THD analysis With FUZZY controller

VI. FUTURE SCOPE

By doing some modifications in my proposed system strategy I can improve the system performance. The one of the best method is providing battery to store generating electrical power, with this we can enhance the system performance. Other method is we can add any other hybrid sources to get more amount of hybrid source output power.

VII. CONCLUSION

The paper which i am presenting is an available topology to operate a PV-FC hybrid which is connected to grid. Here the maximum power point of the PV is tracked by using MPPT technique and hence operates at maximum power also PEMFC runs at higher efficiency range. The feeder flow also we are maintaining below the maximum level by choosing proper operating mode.

With the given algorithm overall system works with flexibility by extracting maximum solar power and operating fuel cell at its higher efficiency band. Hence system performance can be improved.

The load is heavy maximum power can be generated by the system, UPC mode come into existence when the load is light. So hybrid source work more stably. In addition with this by adding a hysteresis to the system we can avoid disturbances in the system and stability can be maintained. Total harmonic distortion is reduced by using fuzzy logic controller.

Finally the proposed strategy is useful to run a system at stable condition, to improve the system operation with the maximization in photo voltaic power output.

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