POWER MANAGEMENT OF PV BATTERY MICRO GRIDS WITH PR CONTROLLER

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Abstract: *In case of solar generation the input quantities, such as solar irradiance and temperature are varies from time to time. Due to these variations, output of solar system unable to provide an accurate and quality power to load sides. So to avoid these situations, use battery systems. Separate control strategies are provided at different places, such as at PV systems, battery and inverter. Especially, PR controller is used in current regulator block of an inverter to reduce harmonics in current waveform. So these control schemes can provide a controlled voltages at both DC &AC buses and control the power flow even in a huge variations in the temperature and loads. With the help of CAPMS and PR controller, switching of Grid connected mode to Islanded mode and vice versa is possible within a less time.*

Keywords: CAPMS, PV, MPPT, Grid and Battery.

1. INTRODUCTION

Generally, the demand of energy is increasing in these days. So to gratify such load demands generate a power with the help of renewable sources. The generation of energy with solar has more scope to gratify the demand of the load. Construction and operation cost of solar system plant is moderate when compared to all other plants.

The one directional power flow exit in Islanded mode i.e. from source side to load side because there is no connection of Grid here. Where as in Grid connected system, both directions of power flow exist, such as source side to Grid side and Grid to source side.

[1] has battery designing idea and its working implementation of vanadium redox battery.

Notable MPPT computations and various kinds of MPPT procedures can be analysed from [2]. [3] has battery size approximation and PV panel dimension estimation of an overlap wind system.

The technique of controlling PV and battery is in [4]. [5] has Inverter design with a conduction of generation. [6] has the procedure of controlling the charging and discharging process of a battery.

A control technology of power in PV, battery, half and half PV/battery in an islanded state is in [7]. [8] has the structure and operation of dc-dc converter for controlling and managing of power in a hybrid systems.

2. SYSTEM DESIGN

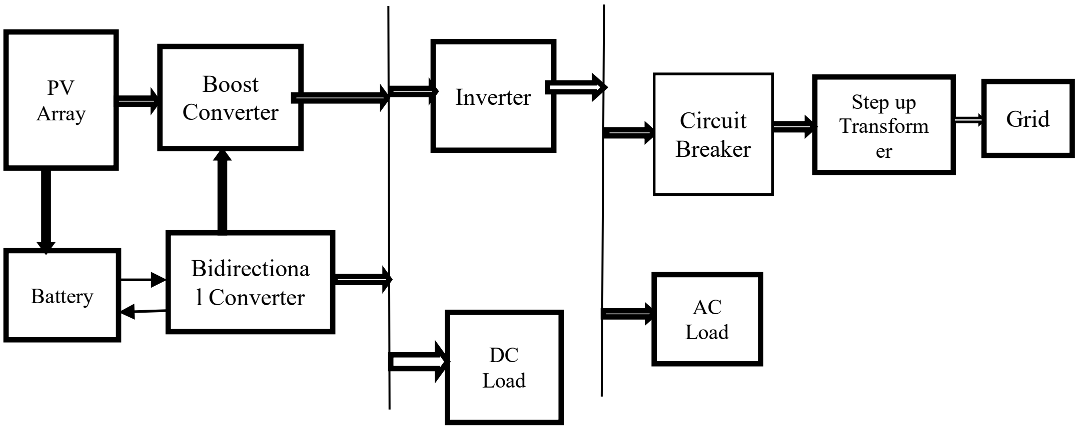

Figure 1. Block diagram of CAPMS

PV System:

PV system is one of the power system come up with solar energy through different photovoltaics. It incorporates with different solar panels to translate solar energy to electrical energy. The solar cell is nothing but the arrangement of different blocks of photovoltaics system.

Modelling of a PV cell:

The equivalent circuit of a PV panel is represented in fig2. Which contain series resistance, parallel resistance, antiparallel diode and ideal current source as solar cell.

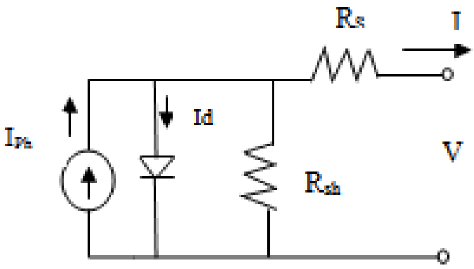

Figure 2. Equivalent circuit of solar cell

Apply KCL in above circuit,

$$I_{ph} = I_d + I_{rp} + I \qquad \text{(i)}$$

$$I = I_{ph} - (I_d + I_{rp}) \qquad \text{(ii)}$$

The equation between current and voltage of a solar cell can be

$$I = I_{ph} - I_0(e^{\frac{q(V-IR_S)}{AkT}} - 1) - \frac{V-IR_S}{R_{sh}} \qquad (1)$$

The total solar panel current formulae is given by

$$I = n_p I_L - n_p I_0(e^{\frac{q(V-IR_S)}{AkTn_s}} - 1) \qquad (2)$$

Maximum power formulae may be written as

$$P_{max} = V_{OC} I_{sc} FF \qquad (3)$$

The total solar Efficiency can be

$$\eta = \frac{P_{max}}{P_{in}} \qquad (4)$$

The efficiency of a solar cell and the maximum power can depends on the intensity of temperature and irradiation of a solar input.

PV Battery with MPPT:

The fluctuations in temperature and irradiance of solar energy does not provide a controlled output voltage. MPPT is one of the approach to extract maximum power point from the fluctuated solar input at each and every situation.

MPPT Incremental Conductance Algorithm Flow chart:

This paper uses the incremental conductance algorithm MPPT to extract maximum power from the solar energy.

Here MPPT point will decided by dI/dV and I/V relation. If dI/dV is additive in nature, then MPPT will takes the left path of actual maximum point. When dI/dV is negative in nature, then MPPT will takes the right path of actual maximum point.

The advantages of incremental conductance algorithm MPPT are:

- It deals with high voltages.
- Even when the variations in the irradiation are high, this MPPT approach will extract maximum power point.
- Even it deals with high voltages the power loss in the system will be less.

$$P = VI$$

$$(dP/dV)_{max} = d(VI)/dV$$

$$0 = I + VdI/dV_{max}$$

$$dI/dV_{max} = -I/V$$

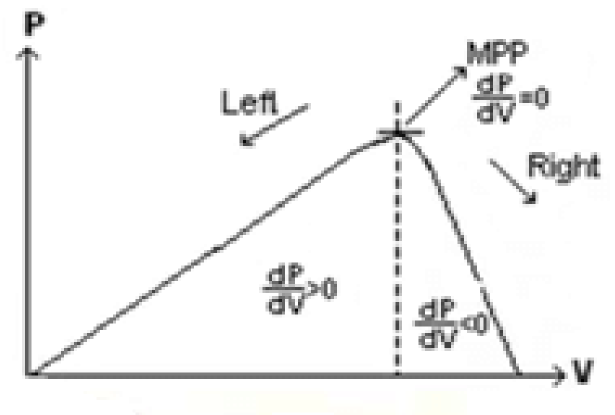

Figure 3. Incremental conductance on PV curve

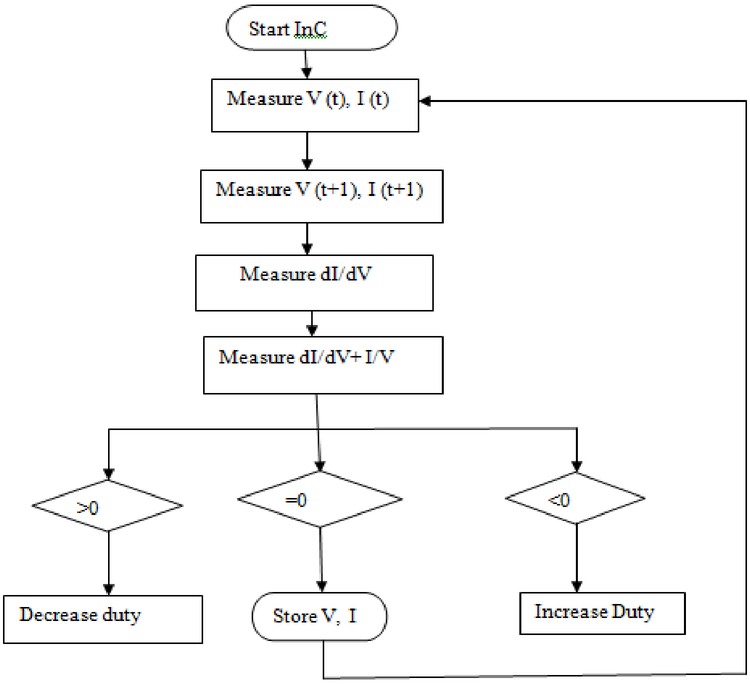

Figure 4. Incremental conductance algorithm flowcharts

Battery:

The controlling of battery depends on its equivalent circuit and which is shown in fig 5. Time constant of RC network is RC.

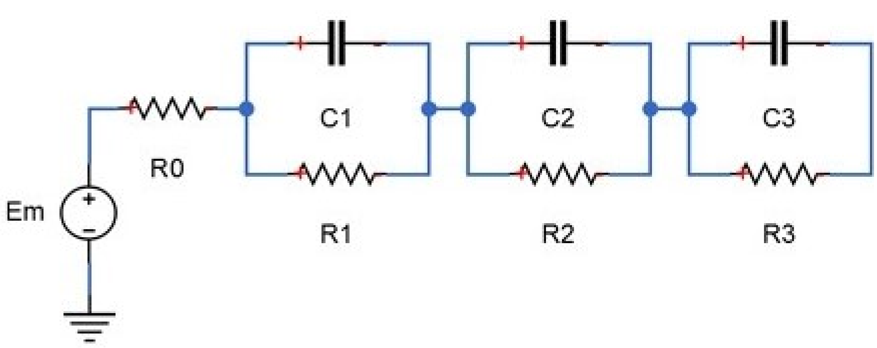

Figure 5. Equivalent circuit of a battery

For designing of battery systems, first design a parameters of equivalent circuit and these shows the nonlinear behavior of battery with respect to SOC, SOH and battery current. To calculate the SOC, the needed parameters are O.C voltage & current and these calculations are done with kalman filtering.

Generally lead acid batteries are most commonly used battery storage system in Grid applications. For solar powered system, valve base lead acid battery was used to regulate the different bus voltages.

Boost converter is one of the power electronic device to boost up the voltage and which is connected between PV and DC bus. This converter is used to control the output voltage of PV system with the help of MPPT. Bidirectional converter is used to control the charging and discharging of a battery.

Inverter:

Inverter is used to convert DC to AC. Generally inverter duty is to construct the sinusoidal voltage with required voltage and frequency. Inverter build with different capacitors and inductors to bring out flat current waveform.

Here in this paper inverter can be connected between DC bus and AC bus. In the current controlled block of an inverter PR controller is used to reduce the harmonics in the current waveform. The inverted AC power from the inverter is given to Grid through PCC and step up transformer.

When any fault occur on the Grid side, then separate the healthy system with Grid by opening the breaker contacts. abc to dq transformation technique is use to generate the reference signal for PLL(Phased locked loop) and with PLL switching of grid connected mode to islanded mode & vice versa is possible.

PR Controller:

Nowadays, harmonics created by power system is the considerable power quality issue. So PR controller can be used in current controlled block of an inverter to reduce harmonics in current.

PR controller can generate a gain only at resonate frequency and produce approximate zero gain at other frequencies. Due to nonlinearities present in the system, harmonics can be generated in current waveform. So these harmonics can be reduced by PR controller by taking the references, which is same as the Grid connected references. Generally 3rd, 5th, 7th ------ harmonics present in the current can be neglected with PR control scheme.

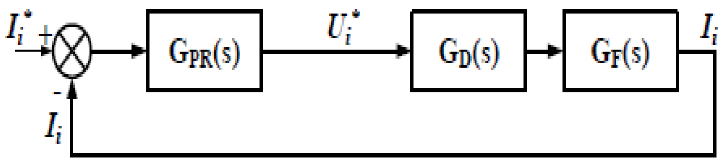

Figure 6. Block diagram of PR controller

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The PR controller equation can be characterized by,

$$G_{PR}(s) = K_P + K_I \frac{s}{s^2 + \omega_0^{\ 2}} \tag{4}$$

GF(s) shows the LCL filter, GD(s) shows the delay of microcontroller used in this controller and this time is approximately equal to sample time.

$$G_D(s) = \frac{1}{1 + sT_s} \tag{5}$$

Equation 4 produced stability issues because of infinite gain and which is avoided by following equation. Because here damping can be neglected and it can make a non-ideal PR controller.

$$G_{PR}(s) = K_P + K_I \frac{2\omega_c s}{s^2 + 2\omega_c s + \omega_0^{\ 2}} \tag{6}$$

PR controller can provide a minimal steady state error when compared to PI controller. That's why in this paper, PR controller is used to reduce harmonics in current instead of PI controller.

3. SIMULATION DIAGRAM AND WAVEFORMS.

To show the performance of the suggested CAPMS, simulation case studies are executed in this sector using the Matlab/Simulink.

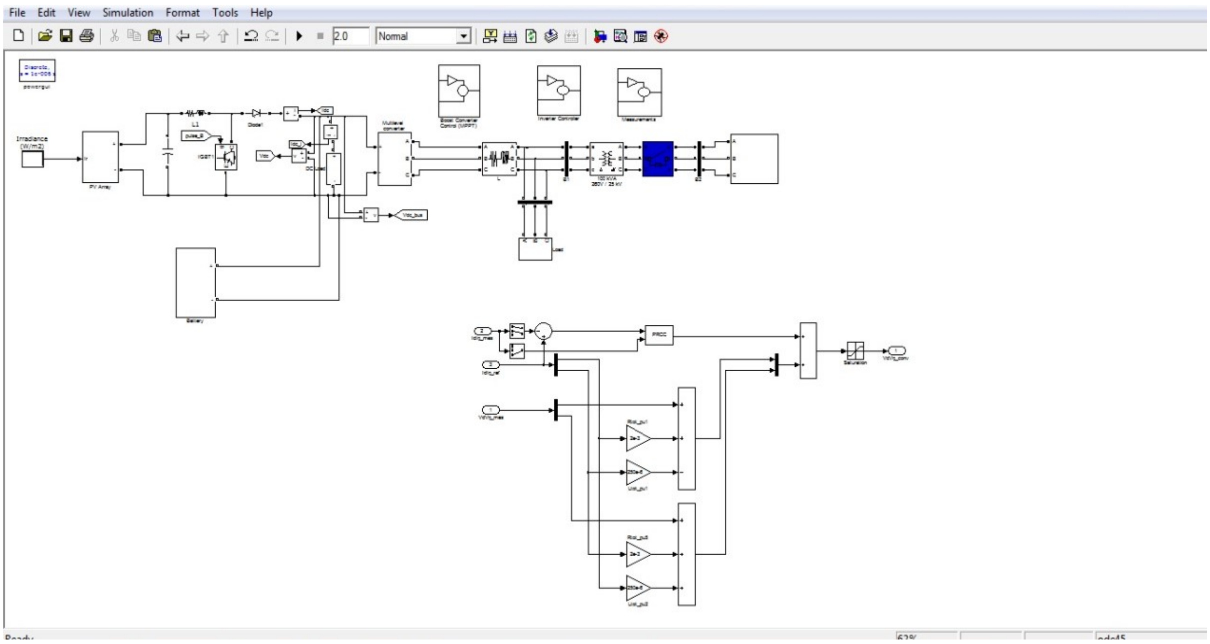

Figure 7. Simulation diagram of a CAPMS with a controller of PR

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The specifications of the system are

MPPT voltage-122V

MPPT power-170kw

Rated voltage of the battery-400v

Voltage of the DC bus-450v

Voltage of the AC bus (L-L)-208V

Grid Connected Mode:

CaseA1:

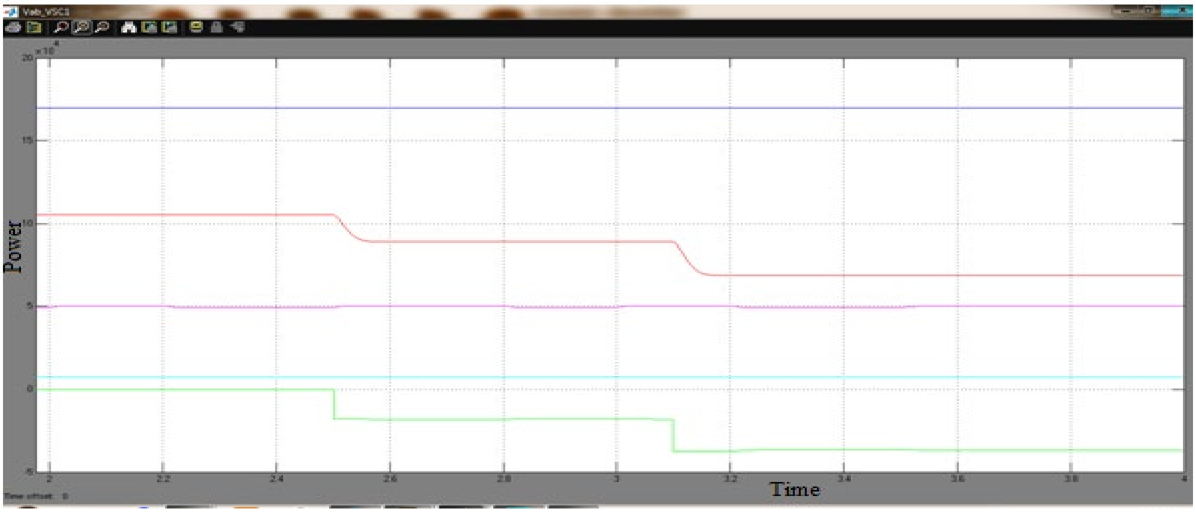

Figure 8. Waveforms of Power - Time

Standard functioning is showed in above waveforms. Here Ppv=170kw, Pdc=50kw,Pac=10kw and Pgrid=110kw.From the above waveform, when Grid order reduces to 85kw then the excess created 15kw energy is collected in a battery and this situation is continues later at 3.5sec. That's why the waveforms of Grid power and battery power are similar in nature.

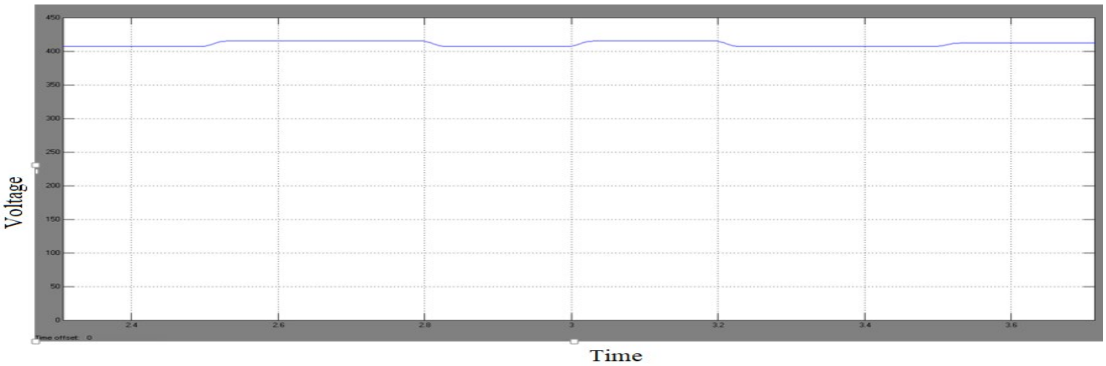

Figure 9. Output voltage waveform at DC bus

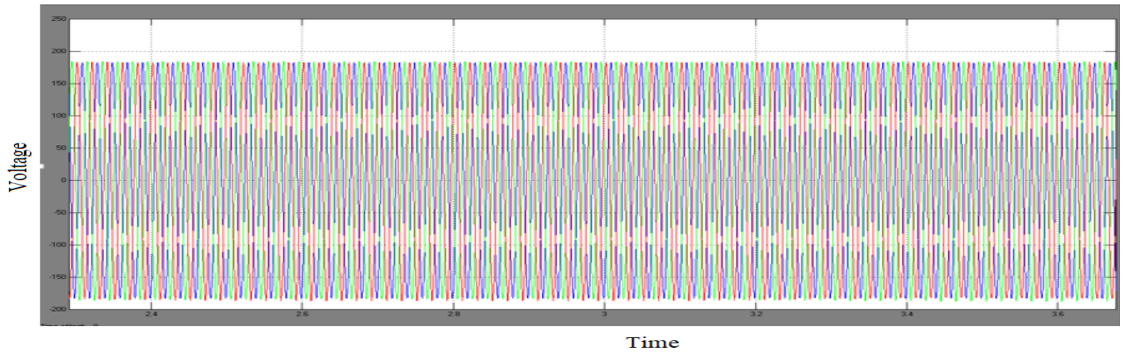

Figure 10. Output voltage waveform at AC bus

Case A2:

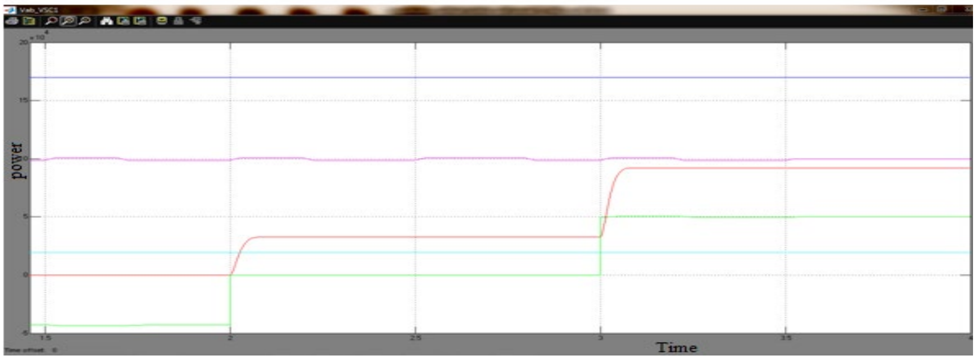

Figure 11. Power waveforms

When battery is fully charged, then handover the excess created energy to the Grid. At 2sec Grid order expanded to 50kw and at 3sec it again extended to 95kw. So the created power of PV (170kw) is shifted to DC, AC and Grid.

CaseA3:

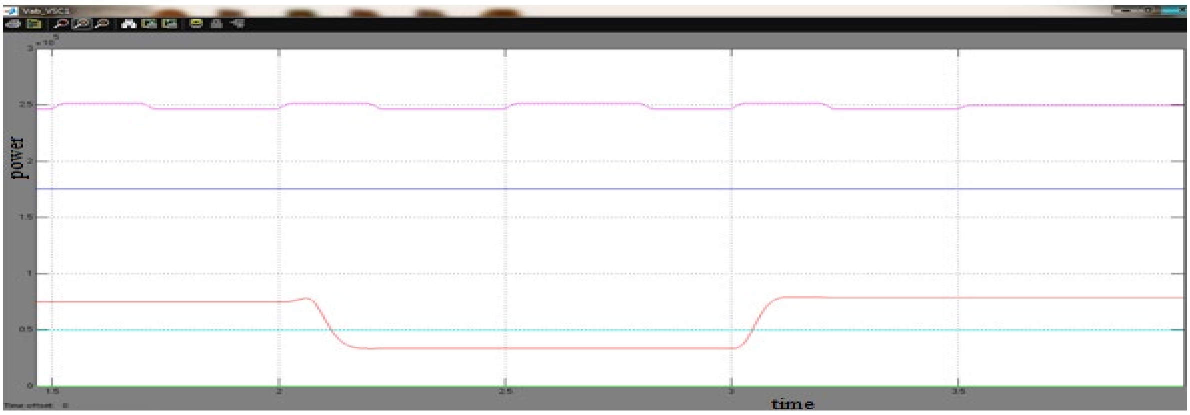

Figure 12. Power waveforms in power reference mode

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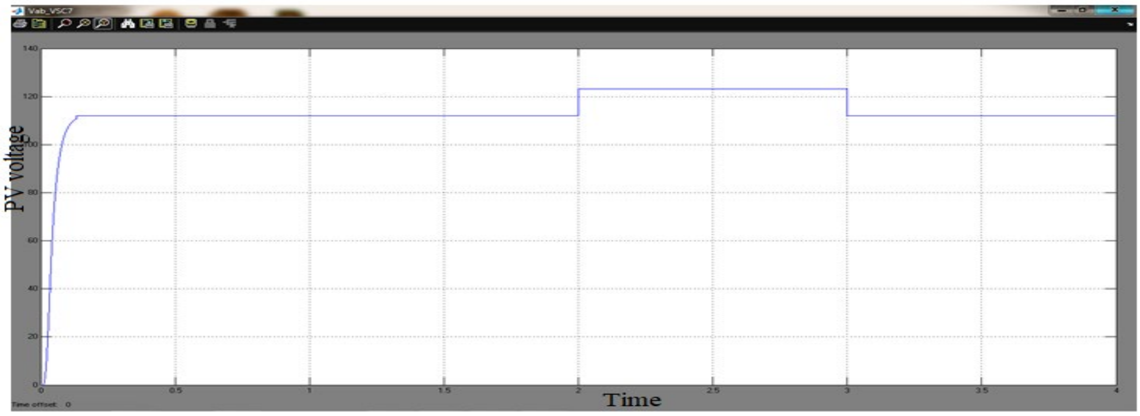

Figure 13. PV array voltage in power reference mode

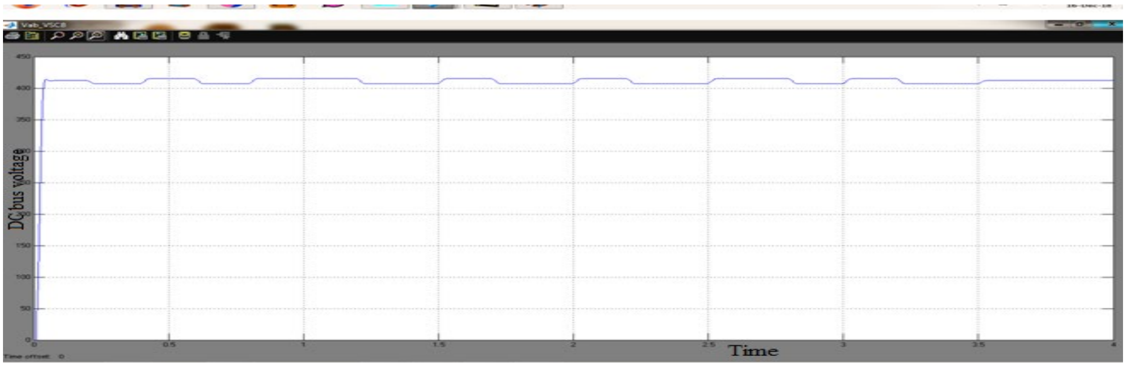

Figure 14. DC voltage in power reference mode

From the above figure, previous to 2sec Ppv=150kw, Pdc=50kw, Pac=25kw and Pgrid=75kw. But succeeding 2sec of time, instantly load order diminished and battery has fully charge. So in this case the created energy may chance to loss. So to keep away from this, decrease the generation by diverting the MPPT state to power reference state.

CaseA4:

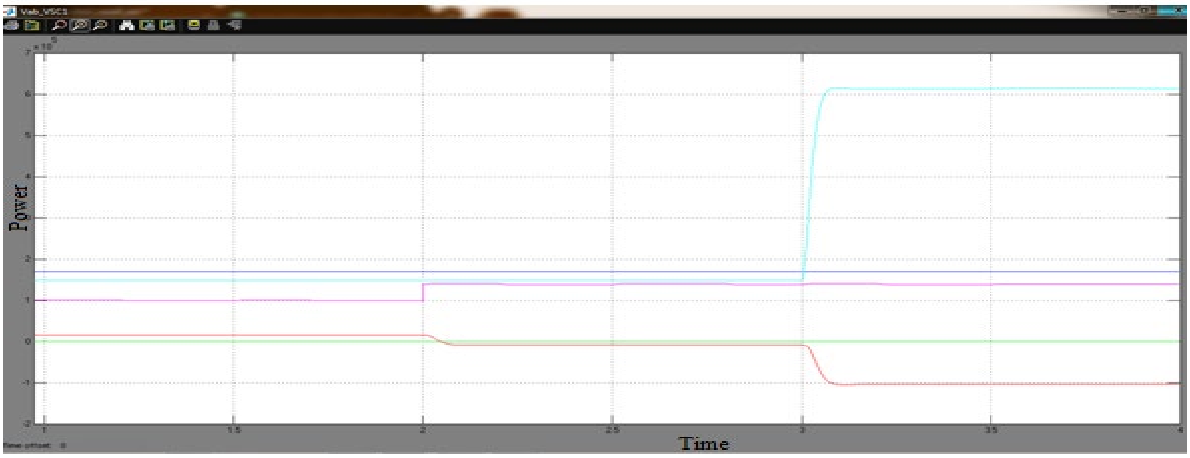

Figure 15. Power waveforms receiving from Grid with PR controller

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In this case, Grid give the power to the demands because here the generation of energy is less which conveyed in above figure. Here the grid is giving power back to loads so the grid power waveform negative in nature. With PR controller the divergences in Grid power is minimum when differentiate with PI controller.

Case A5:

These are the active and reactive powers of a micro Grid system and these waveforms can be managed by Inverter. To stabilize the system, if Grid require any reactive power, then this energy will give by inverter system.

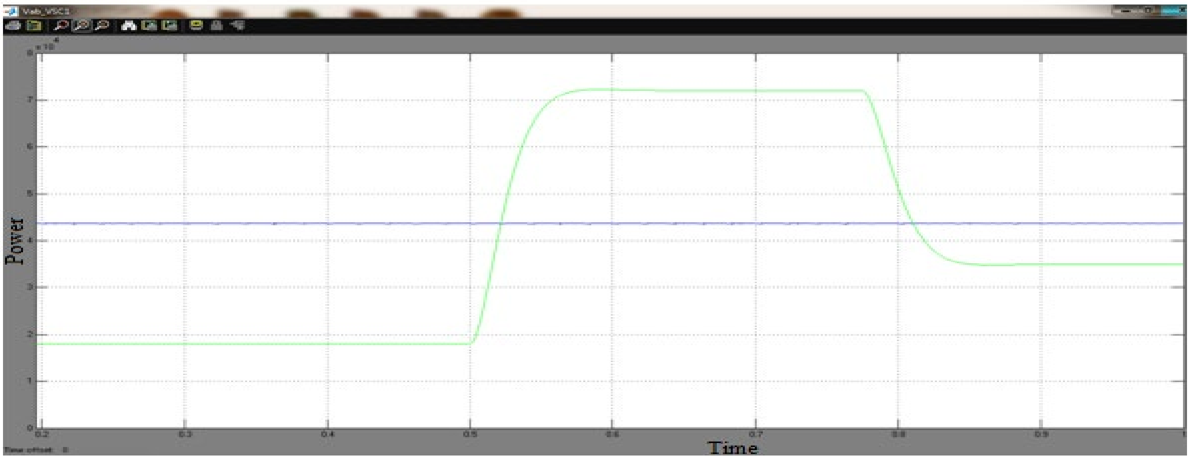

Figure 16. Waveforms of Active and reactive power with PR controller

Case A6:

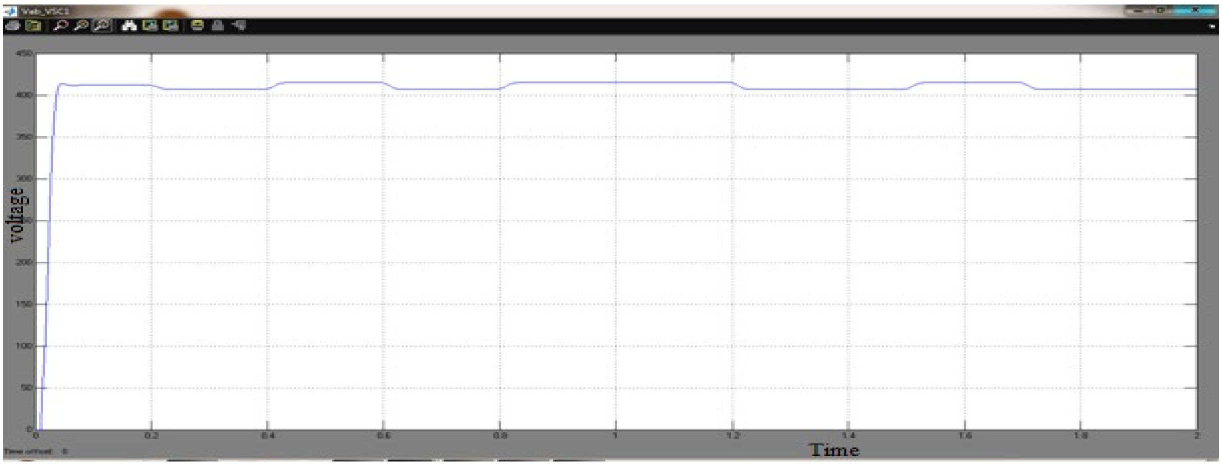

Figure 17. Variation in DC bus voltage, when switching of Grid connected mode to Islanded mode with a PR controller

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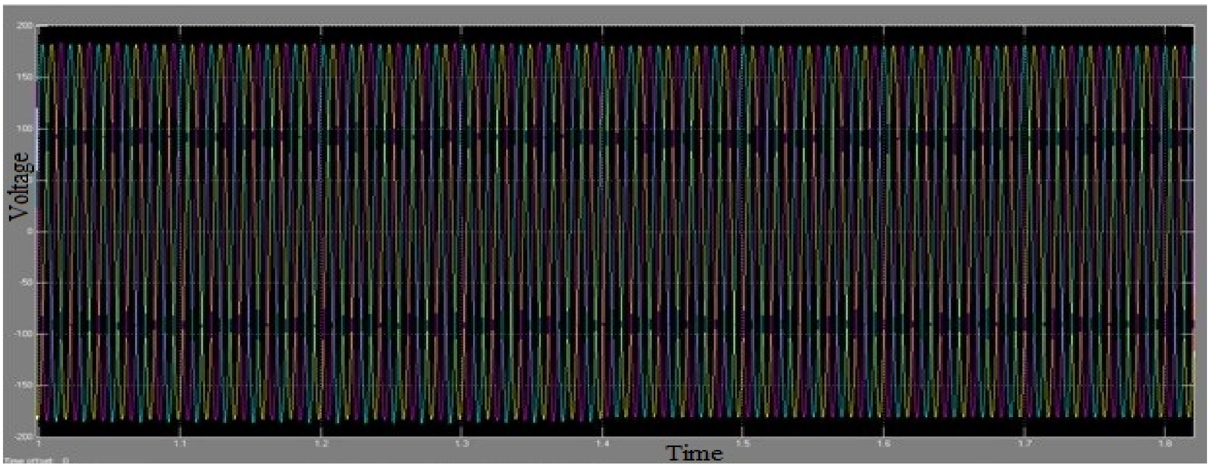

Figure 18. Variation in AC bus voltage, when switching of Grid connected mode to Islanded mode with a PR controller

Here in this case, the waveform shows the variations in voltages while shifting from Grid connected state to Islanded state with a PR controller**.** The PR controller has a capacity to reduce the variations in voltages and can reduces the shifting time when differentiate to PI controller.

Islanded mode:

This means, here no Grid connection. So the power equation is

$$Ppv+Pbat=Pdc+Pac$$

Case B1:

This case shows the stable generation of PV. So the PV with battery will manage the loads requirements.

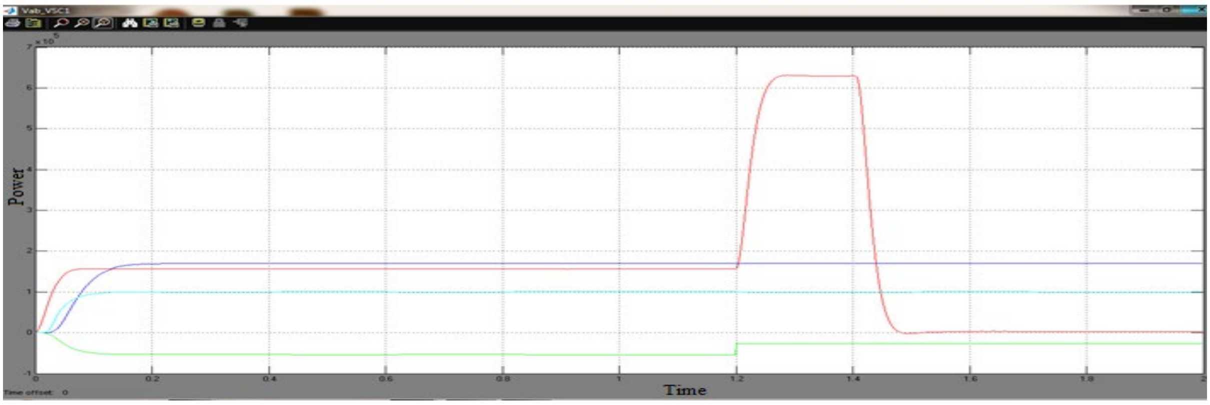

Figure 19. Power waveforms in Islanded mode with PR controller

Case B2:

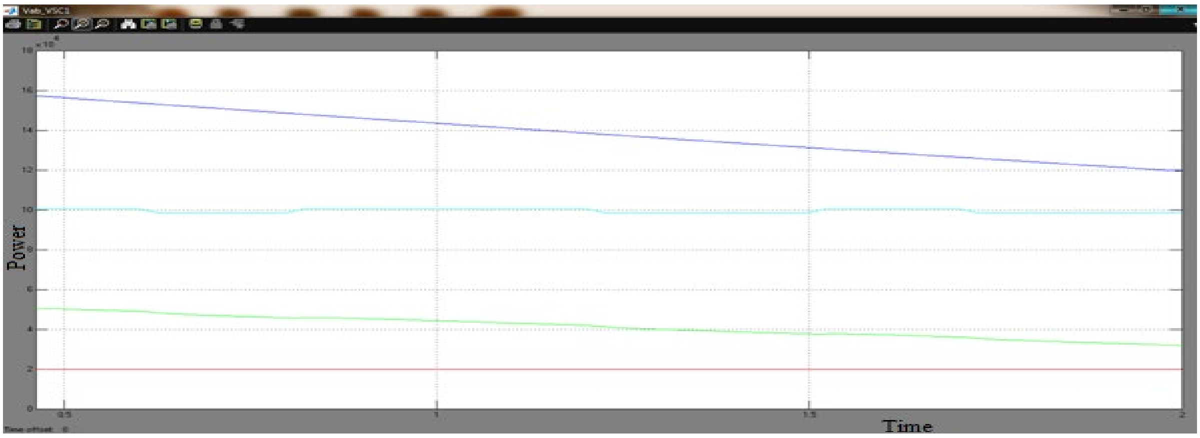

Figure 20. Variations in battery Power waveforms with changes in generation

Generally solar irradiation changes time to time and season to season but to stabilize the system battery can send the charged energy to load demands. The waveforms shows the reduction in PV created power because of the depletion in solar irradiance. So in waveform the discharging dimensions of the battery will expand.

Case B3:

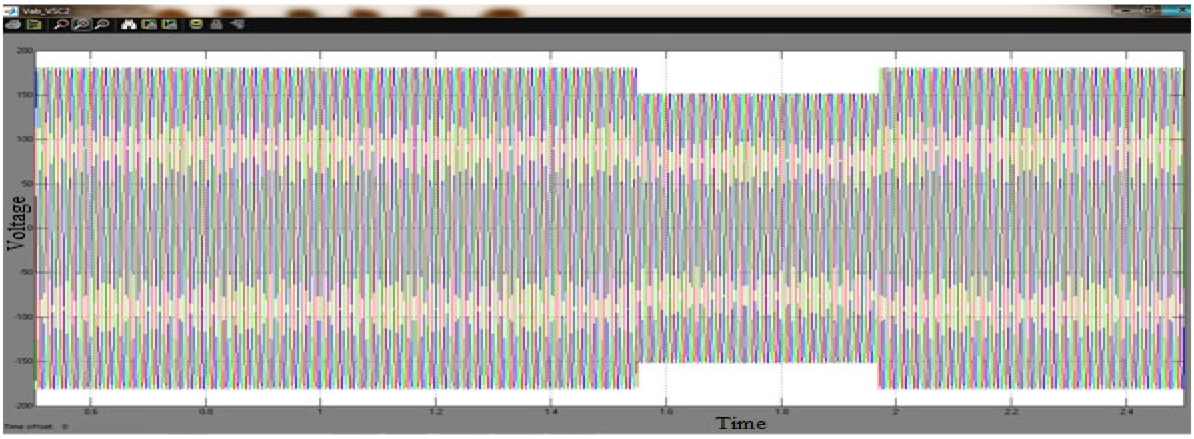

Figure 21. AC bus voltage control with PR controller

Case B4:

These waveforms are conveying the variations in voltage because of shifting islanded state to Grid connected state. So to divert this, synchronization voltage and frequency are important and this operation is finished with PLL.

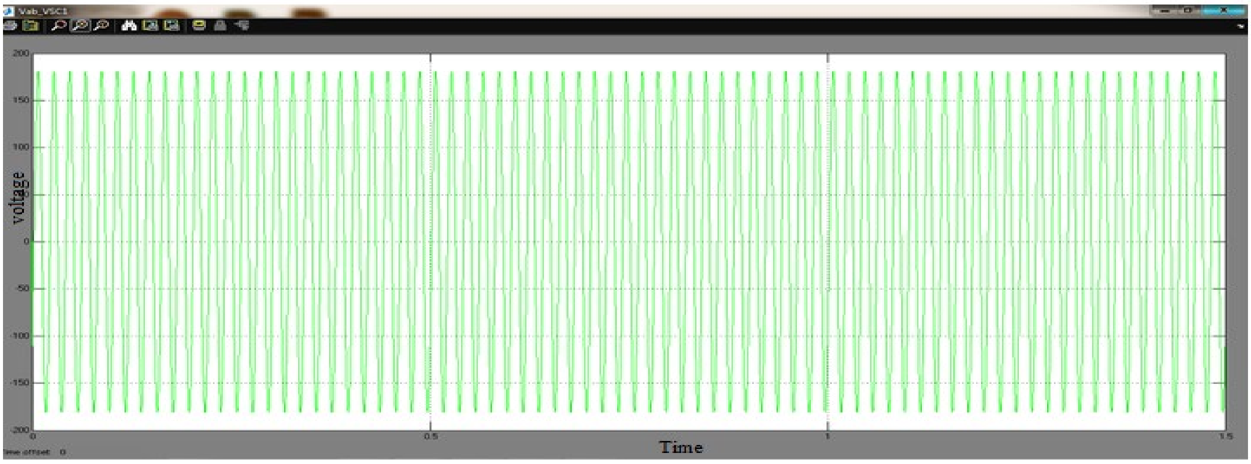

Figure 22. Synchronized AC bus voltage with PR controller

CONCLUSION

In this paper, along with CAPMS, a PR controller is used to reduce the harmonics in current waveform. For power balancing, deviations in the Grid power should be less and this is possible with PR controller along with CAPMS. The time required to synchronise the parameters is less and the time is less than 0.15 sec (approximately equal to 0.05 sec).

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