COMPARATIVE ANALYSIS AMONG PID AND MPPT BASED CONTROLLERS IN ENHANCING THE POWER QUALITY IN A MICROGRID

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Abstract – Power quality has become a key factor in present days Power System. It includes several indices which governs the Grid stability. Microgrids are small scale versions of utility grids which can operate independently as well as in conjunction with the main grid in order to satisfy local loads. These involve use of non-conventional energy sources such as Solar, Wind etc, which are intermittent in nature leading to power quality issues. This paper involves application of control topologies such as MPPT-P&O, INC and PID controller in a solar pv based microgrid to enhance the power quality of system being operated both in isolated mode as well as grid connected mode.

Keywords – Microgrid, Power quality, MPPT, Solar PV, PID

1. INTRODUCTION

Now-a-days, with the increase in the population the need for power demand also increasing proportionally. From the recent fossil report, we are well aware about the fact that if the use of fossils grows on increasing at the same rate then very soon the younger generations might not use the non-renewable sources. Not only that, because of excessive use of conventional energy source the environment also getting degraded as per the Environmental research report. So, people are showing interest towards the nature friendly, abundantly available forms of energy i.e., renewable energy sources or non-conventional energy sources. These renewable energy resources include various forms such as solar, wind, biogas, geothermal, tidal etc. Among these most abundantly available and used energy source is solar energy. Solar energy is most abundantly available year long. Approx. we get about 1200-1500 w/m^2 irradiance from the sun to earth depending on the geographical position. This irradiance and temperature from the sun can be made useful to generate power with the help of pv arrays. These pv arrays are made of silicon available in several forms such as Mono crystalline, Poly crystalline, Thin films etc. [1]

But as we know that these non-conventional forms of energies are intermittent in nature. They are not available in the same quantity and same proportion all the times, because of that if these are employed in power generation might damage the connected loads as the loads are designed to operate at certain operating voltage, frequency. So as to minimize such kind of issues several control techniques are employed which make the output from these renewable energy sources as feasible. Among such Maximum power point tracking algorithms are well known. These MPPT algorithms helps to track the input and produce pulses to IGBT corresponding to maximum point. Such that there won't be much loss of energy and always the system will try to operate at maximum points. There are several MPPT algorithms such as constant voltage method, short current pulse method, open voltage method, perturb and observe method, temperature methods, Incremental conductance method etc., among all the most used methods are perturb and observe method as well as Incremental conductance method because of the pros compared to other MPPT methods [2]. Along with this PID controller is also employed as controller to generate pulses to IGBT in a DC-DC Converter.

This paper is all about the implementation and comparison among MPPT methods along with PID controller connected to a DC-DC converter in a solar pv connected microgrid which is made to operate under both grid connected mode as well as isolated mode.

This paper is organised as follows: section II describes about microgrid modelling, section III includes P & O and INC MPPT techniques PID controller, section IV presents the PID controller implementation followed by section V with the simulation and results and finally concludes with section VI.

2. Modelling of Microgrid

A Microgrid is a group of localised loads and sources which are made to operate in synchronism with the macrogrid (traditional electricity grid). These sources may be composed of renewable sources, non-renewable sources as well as combination of both to meet the connected load in the microgrid. A microgrid can operate in two modes i.e., Grid connected mode- it is when the microgrid is in association with the utility grid and Islanded mode – it is when the microgrid alone meets its connected load. Here, in this paper we consider our college as a microgrid with roof top solar pv array are installed as shown in fig1.

Fig .1 Installed PV array and panel ratings.

As shown in the above figure, the panels are arranged to meet a load of 75KW on the roof top of each department. Here in this paper we design 500KW microgrid considering the above panel ratings. A typical microgrid includes Source (PV array), DC-DC converter (Boost), VSI, PLL and utility grid connected to load.

2.1 PV array

The pv array has strings of modules connected either in series or parallel. The combination of these modules is based on the desired output power. The series strings represent the desired output voltage whereas the parallel strings represent the desired output current for the load. [3]

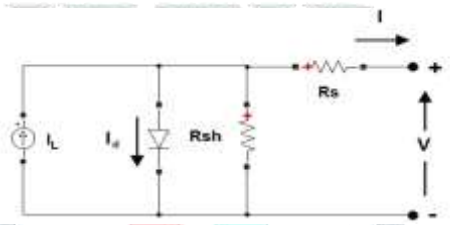


Fig 2. PV array (Simulink model) with internal structure

The above shown is the internal structure of pv array. To the Simulink pv model, two inputs such as Irradiance(w/m^2) and Temperature (^{o}c) are provided. Standard value of Irradiance is 1000 w/m^2 and Temperature is 25 ^{o}c. The IV and pv curves are as shown in fig3.

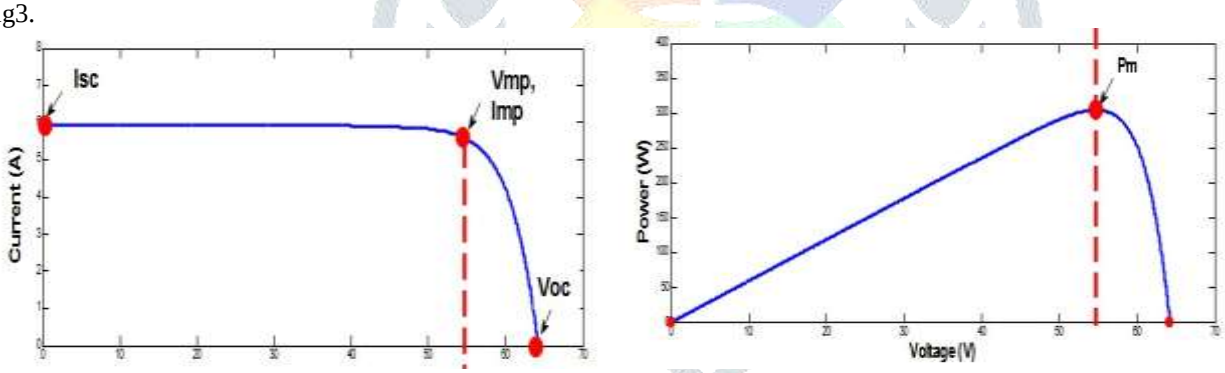


Fig 3. IV and PV curves of a PV array

2.2 DC-DC Converter

A DC-DC Converter is an electronic circuit which is used to transform the voltage to various levels. Similar to the operation of transformer in AC system, this dc-dc converter can either step up or step down the voltage based on the requirement. There are different types of dc-dc converters such as Buck, Boost, Buck-Boost, Cuk converter. Here in this paper we have included a Boost converter to step up the voltage of 300v from the solar pv to 700v. The gate pulses to the Dc-Dc- Converter is fed through the MPPT controller with switching frequency of 5KHz.

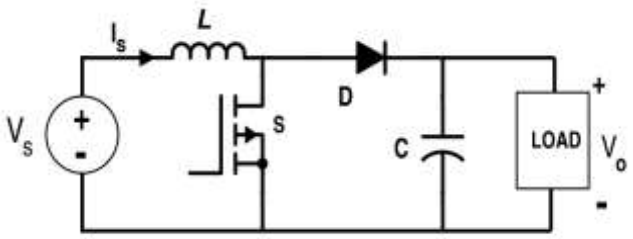


Fig 4. Basic architecture of a Boost converter

2.3 Voltage Source Inverter

The voltage source inverter is the electronic circuit which is used to convert the DC input voltage to AC output. These voltage source inverters are of available for both single phase and three phase configurations. The single-phase voltage source inverters are used for low power ratings whereas the three phase voltage source inverters are used for medium as well as high power rating operations.

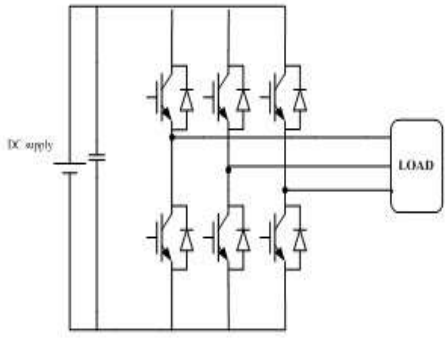


Fig 5. Basic architecture of three phase VSI

In this paper we are using a three phase VSI model connected to the output of DC-DC Converter. The gate pulse to the switches in the VSI are provided from the output of PLL such that the microgrid should always be in synchronism with the utility grid. Passive LC filters are employed at the output of VSI so as to filter out the undesired harmonics.

2.4 Phase Locked Loops

As the renewable source are varying in nature, it is very difficult to integrate this varying natured microgrid with the utility grid. PLL is the control technique employed in microgrid in order to establish a secure synchronism with grid. Failure of this control results in collapse of entire microgrid.

PLL consists of a phase detector, loop filter, voltage-controlled oscillator. It is provided with the utility grid voltage as reference voltage such that, it can send the signal to the inverter so as to get the desired voltage, frequency and phase from the inverter output. Here the PLL employs abc-dq transformation in which it generates the output pulses depending on the reference.

3. MPPT algorithms

Maximum power point Tracking algorithm is commonly used technique in wind and pv applications to extract maximum power under all conditions. This principle is mainly applicable for varying input system. There are different algorithms developed over the years in MPPT such as Fixed voltage, Open circuit voltage, Perturb and observe, Incremental conductance method. [5]

3.1 Perturb and Observe

Perturb and observe is one of the most commonly used MPPT techniques because of it efficiency. In this method the voltage and current from the solar pv are fed as input to the MPPT. Power is obtained from the product of the fed input. The MPPT stores the previous values and depending on the present input and change between previous values in terms of either voltage as well as power is monitored and corresponding output duty cycle is generated. [5][6]

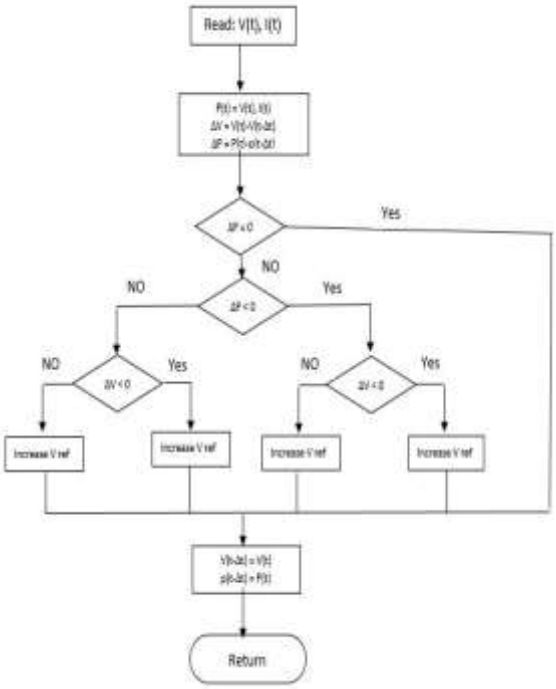


Fig 6 Perturb and Observe flowchart

The MPPT always tries to reach the maximum point. But in practical the input varies every moment and a new maximum point is obtained, Hence, this method oscillates between the previous and present maximum which is the only con of this Perturb and Observe method. [1][5][6]

3.2 Incremental Conductance Method

One of the most well-known method among all remaining maximum power point tracking methods is INC method. This method is most efficient in tracking the maximum point under all conditions. [2][7]

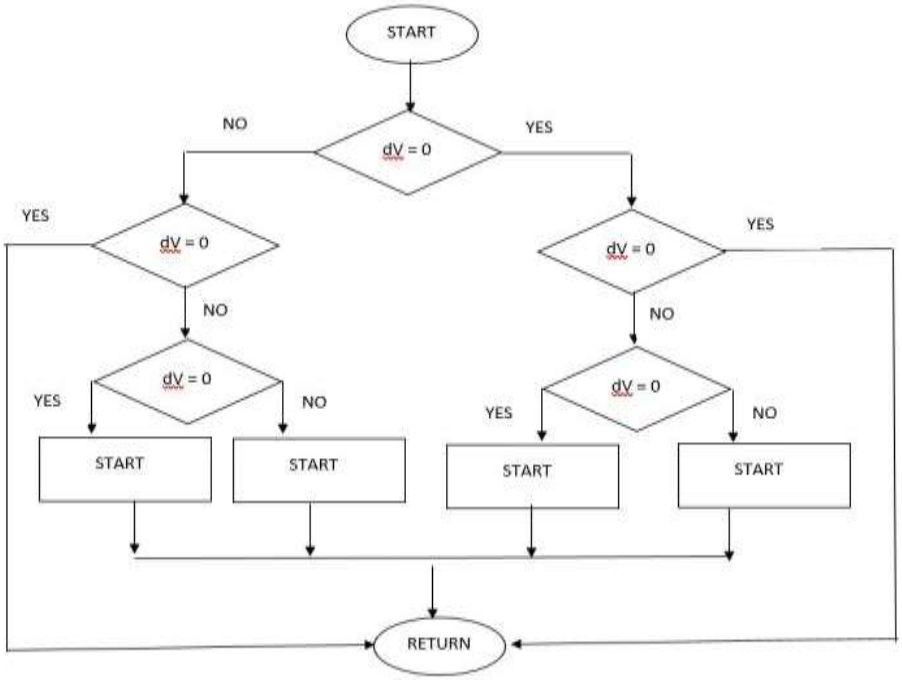


Fig 7. Incremental Conductance Method Flow chart

In this method the voltage and current from the pv array are fed as an input to the MPPT. Further it holds the previous value similar to the P and O method and compares it with the present value and reaches the maximum point. Here, the change in voltage, current and ratio of voltage to current are major factors in production of appropriate duty cycle. The obtained duty cycle is fed to pwm generator which generates pulses fed to switch in a dc-dc converter. [1][7]

4. PID controller

The performance of basically any closed loop system depends on the parameters of the controller. Adjustment of the parameter variable may influence the entire system stability, performance. In such cases, one of the most well-known controller is PID controller. Proper adjustment of Kp, Ki, Kd of the controller results in the improvement of system stability, durability as well as the performance.

Here, in this paper along with different MPPT techniques we have also compared the PID controller performance while connecting it to a DC-DC converter for gate pulse generation mitigating the error and make it to provide desired stable output to the input of VSI. As we have considered Boost converter as a DC-DC converter, we have derived the transfer function of entire converter using state space analysis considering small signal stability. For that closed loop transfer function we employed PID as controller [8].

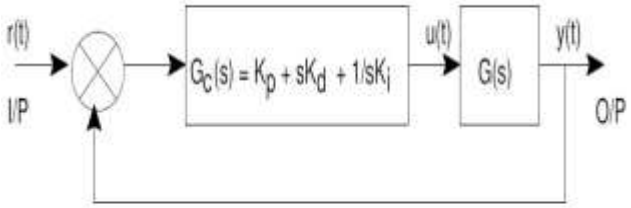


Fig 8. Closed loop block diagram representation of PID based Boost converter

The above shown is the block diagram representation of a closed loop DC-DC converter with PID controller. The parameters of the PID controller are obtained using Ziegler-Nichols first method by providing a step input to the system.

Type of controller	K_p	K_i	K_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

Fig 9. Ziegler-Nichols tuning rule based on step response

Using the tuning rule we calculate the Kp, Ki, Kd values of the PID controller and employ those to the system in order to improve stability of the closed loop system.

5. Simulation and results

The basic block diagram model of microgrid is as shown below:

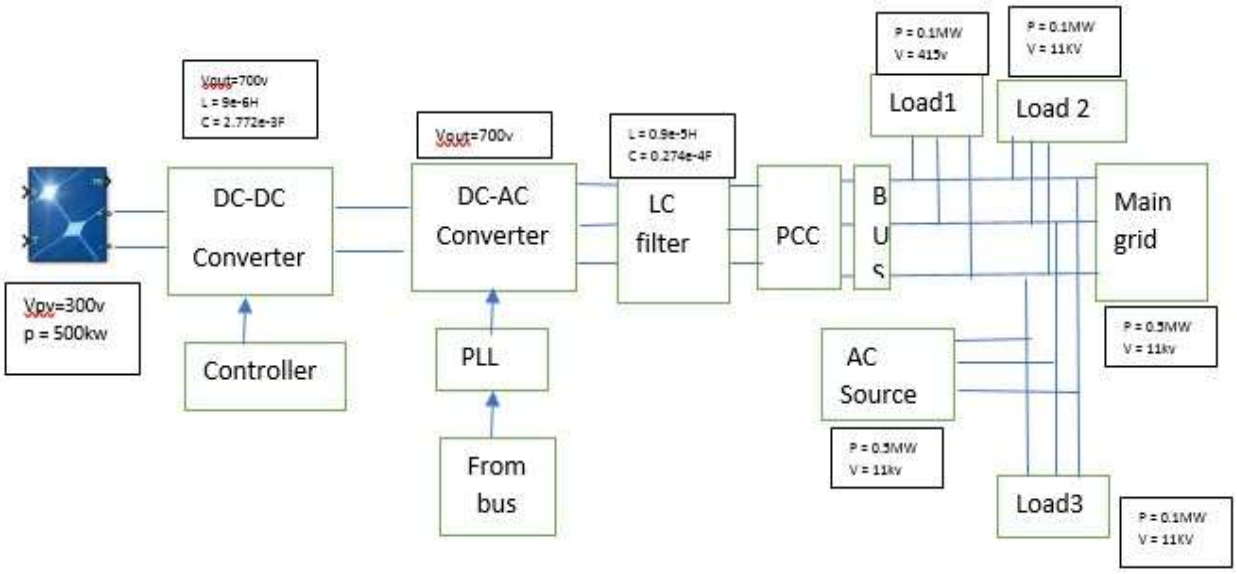
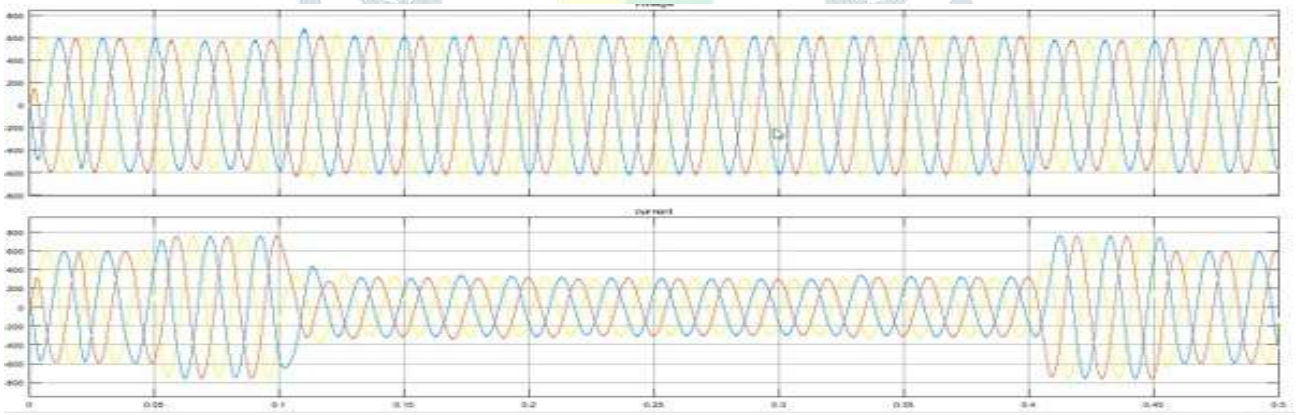
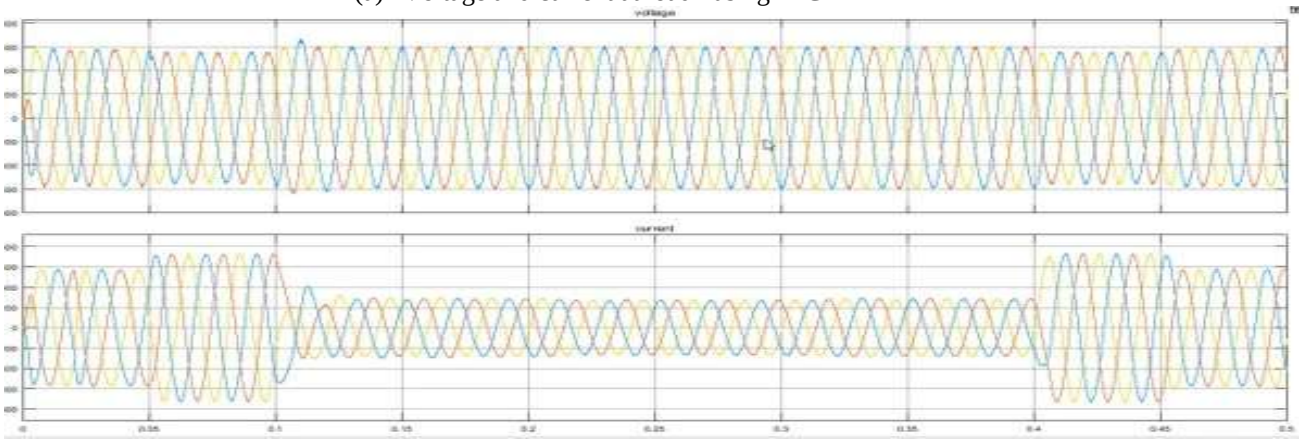


Fig 10. Microgrid block diagram model

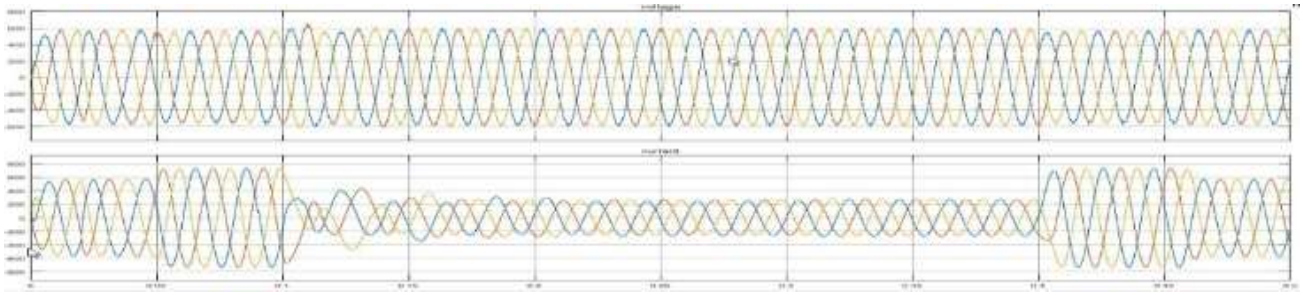
The complete block diagram model of microgrid is as shown in above fig 8. It consists of a solar pv array generating 300v output with output power of 0.5MW. The output is fed to Boost converter with L = 9µH and C = 277µF generating output voltage of 700v which is further fed as an input to Three-phase VSI. PLL is connected to VSI generating gate pulses as per the reference fed from the Grid. The output of VSI is filtered by using a passive LC filter. All the loads are connected as shown in the above figure. The simulation is carried out under varying irradiance and temperature in between 800-1200w/m^2 and 25-35ºC respectively under both grid connected as well as isolated mode. As shown in the fig below the simulation is carried out in different modes. Under mode 1 i.e., from 0secs to 0.05 secs utility grid is connected to microgrid whereas from 0.05sec to 0.1sec standby generator is connected to microgrid by disconnecting utility grid. Again from 0.1secs to 0.4secs all the three i.e., utility grid, microgrid and standby generator are connected. After 0.4sec the vice versa operation is performed. The simulations results are as shown below.



(a) Voltage and current at load1 using INC-MPPT



(b) Voltage and current at load1 using P&O-MPPT



(c) Voltage and current at load1 using PID controller

Fig 11. Variation of voltage and currents under grid isolated as well as grid connected mode using(a) Incremental conductance method as MPPT (b) Perturb and observe method as MPPT (c) PID controller

	Without filter (THD%)		With filter (THD%)	
Location	Voltage	Current	Voltage	Current
Load1	73.62	31.58	1.38	2.23
Load2	0.61	3.64	0.09	2.01
Load3	0.57	2.68	0.09	1.03

(a) Using Perturb and observe MPPT

	Without filter (THD%)		With filter (THD%)	
Location	Voltage	Current	Voltage	Current
Load1	73.48	31.62	1.50	3.16
Load2	0.57	3.45	0.10	2.31
Load3	0.57	2.58	0.10	1.07

(b) Using Incremental Conductance method as MPPT

	Without filter (THD%)		With filter (THD%)	
Location	Voltage	Current	Voltage	Current
Load1	73.53	32.56	1.33	1.59
Load2	0.34	3.14	0.08	0.49
Load3	0.34	2.16	0.08	0.62

(c) Using PID controller

Table 1 THD at different locations in microgrid under mode3 for (a) P&O MPPT (b) INC MPPT (c) PID Controller

6. Conclusion

Microgrids are still evolving technologies, a lot of research and development is being carried out over several issues such as monitoring, control, protection of microgrid. In this paper we have observed the operation of microgrid under both grid connected as well as standalone mode using Perturb and Observe, Incremental conductance as MPPT techniques and also PID controller as gate pulse generator in a DC-DC converter respectively. Although the output THD is less for PID based system, perturb and observe method is simple in implementation and cost point of view compared to other compared techniques. As a part of future work, Artificial Intelligence such as Fuzzy, GA, PSO, Cuckoo search etc can be used as MPPT.

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