Power Control Modes for PV Generation System under Non-Uniform Insolation for DC Microgrid

AE15433 Muhammad Syahir Bin Turiman Supervisor Prof. Dr. Fujita Goro

1. Introduction

Direct current (DC) microgrid is a locally controlled energy networks that involve dispersed renewable energy sources (DRES) and dispersed energy storage systems (DESS), and powered mainly in DC mains. DC microgrid system can disconnect from the power grid when there is fault at the main grid, and continue to supply a portion of their local loads in a so called "islanding mode". The purpose of this paper is to analyse the behaviour of the photovoltaic (PV) system, as one of the DRES, based on the condition of the DC microgrid system. Improvement of perturb & observe (P&O) method is also suggested in order to track the global maximum power point (MPP) during operating under non-uniform insolation. All analysis to prove the results were done by using PSIM software.

2. Direct current (DC) microgrid system

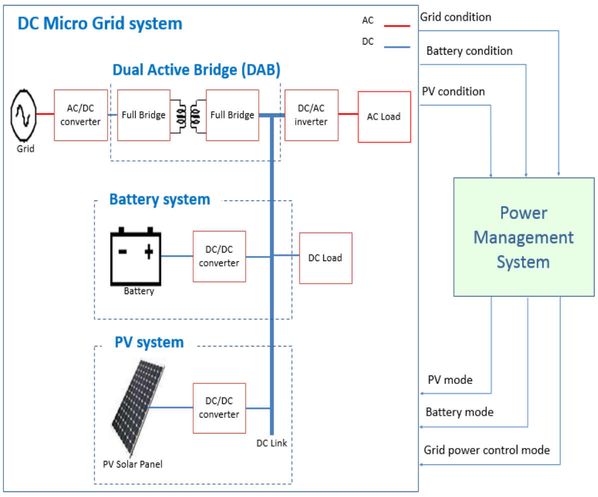

Fig. 1 DC microgrid system

Fig. 1 shows a model of DC microgrid system where the main focus is to balance the power between the power supply side such as the supply from power grid, battery or PV panel, and the power consumer side which is the DC load and AC load. In order to achieve the power balance, the voltage of the DC link must be constant. The components of DC microgrid with their main function are shown in table 1 :

Table 1 : Components in DC microgrid

Components	Function
Dual Active Bridge (DAB) system	to keep and maintain the stability of the DC link.
Battery system	to optimize the battery utilization.
Photovoltaic (PV) system	to regulate the photovoltaic power generation.
Power Management System (PMS)	to control the operation of the entire system of the DC microgrid.

3. PV system connected to DC microgrid

A DC-DC boost converter is used as the interface between low voltage PV panel and high voltage DC link, as shown in Fig. 2. Switching signal of MOS-FET switch is done based on the power control modes of the PV generation system. There are two types of power control modes that will be used in this system based on the condition of DC microgrid, which are maximum power point tracking (MPPT) mode, and power tracking mode.

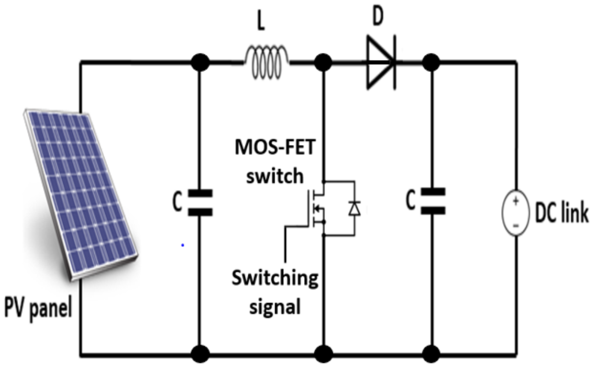

Fig. 2 PV generation system circuit

4. Power control modes for PV system

(a) MPPT mode

This mode is used when DC microgrid operates in the grid connection mode. In this mode, MPPT algorithm technique, Perturb and Observe (P&O) method is being used to achieve maximum power to be supplied to the DC link. This algorithm is chosen because it uses simple feedback arrangement and little measured parameters. In this approach, the PV panel voltage is periodically given perturbation and the corresponding output power is compared with that previous perturbing cycle until the maximum power point (MPP) is achieved. [1] During operating under non-uniform insolation, improvement of perturb & observe (P&O) method becomes necessary in order to do the global maximum power point tracking (MPPT).

(b) Power Tracking mode

This mode will be used when power supply from grid is disconnected from DC microgrid and battery system already reached the limitation of charging rate or state of charge (SOC). In this condition of the DC microgrid, PV system has to balance the power within the system by assuming that the power demand at the load side is lower than maximum power that the PV system can deliver. [2] For power tracking mode, the desired value of power required by the load side is set in the control system. Next, the PV panel voltage is periodically given perturbation and the corresponding output power is compared with the power reference set in the control system until the value of power reference is achieved.

5. Contents of simulation

5.1 PV generation system simulation circuit using PSIM

PV generation system circuit shown in Fig. 3 is the circuit used in the simulations. PV panel is connected to a DC source which act as a constant voltage DC link, through the DC-DC boost converter as the interface. This is because the PV panel only produce low voltage output, so in order to supply enough power to the high voltage DC link, a DC-DC boost converter is used.

There are two control blocks used for switching signal of the MOS-FET inside the DC-DC boost converter. Each block will determine the operating mode of the DC-DC boost converter, either MPPT mode or power tracking mode.

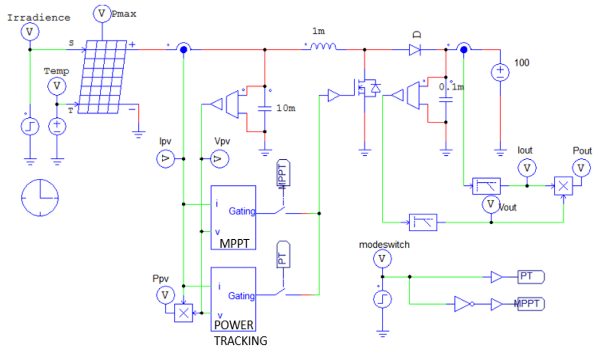

Fig. 3 PV generation system simulation circuit

In order for the PV system to distinguish between the two modes, a signal is received from PMS. A simple switching process is used to change between the two modes. If the signal received from PMS is 0, MPPT block switch will turn on and power tracking block switch will turn off, thus PV system will operate in MPPT mode. If the signal received from PMS is 1, the result is vice versa and PV system will operate in power tracking mode.

5.2 Simulation parameters

In this simulation, as shown in Table 2, four conditions of PV system are being simulated. Each condition is set in the time range of 1 second. PMS signal is sent based on the condition of DC microgrid system, which will later determine the operating mode of the PV system. During MPPT mode, the value of power reference is not set because PV system is expected to produce the maximum power with regard to the temperature of PV panel and irradiance level.

Table 2: Simulation parameters

Time (s)	PMS signal	Operating mode [power ref. (W)]	Irradiance (W/m^2)	Temp (^0C)
0-1	0	MPPT [none]	500	25
1-2	0	MPPT [none]	1000	25
2-3	1	Power tracking [50]	1000	25
3-4	1	Power tracking [30]	1000	25

5.3 Simulation results and analysis

As shown in Fig. 4, from 0 until 2 seconds, it is simulated that DC microgrid is in grid connection mode. The signal received from PMS is 0, and PV system will operate in MPPT mode. During first 1 second, PV system is generating power of 58.95W, and it is nearly to maximum power that PV panel can produce at temperature of 25^0C and irradiance of 500 W/m^2, which is 60.53W. After 1 second, the irradiance level is increased to 1000 W/m^2, and because the PV system is in MPPT mode, the output power is also increasing to 88.42W, nearly to maximum power which is 90.48W.

From 2 to 4 seconds, it is simulated that DC microgrid is operating in islanding mode. The signal received from PMS is changed to 1, and PV system will operate in power tracking mode. In this mode, PV system will generate total load power which is set as power reference. During 2 to 3 seconds, the power reference is set to 50W. At this moment, although PV maximum power is 90.48W, PV system only generate 48.71W. Power reference is then changed to 30W during 3 to 4 seconds. As the result, PV system generates output power of 29.11W.

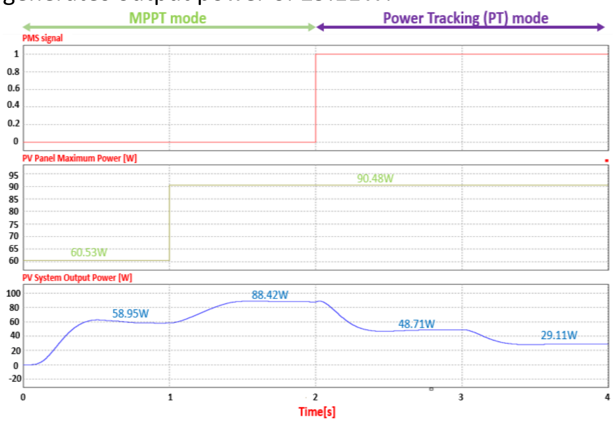

Fig. 4 PV generation system simulation results

6. Conclusions and Future Issues

Through the simulations and analysis, we can understand that the power control modes are used to ensure that PV panel output power is suitable to be supplied to the DC link, thus keeping the stability of DC link.

For future works, simulations of MPPT mode for PV generation system operating under non-uniform insolation will be analysed. Perturb & observe (P&O) method is improved in order to do the global maximum power point tracking (MPPT).

References

[1] Ahmed M. Atallah, A. Y. Abdelaziz, and Raihan S. Jumaah, “Implementation of perturb and observe MPPT of PV system with direct control method using buck and buck-boost converters” EEIEJ, Vol. 1, No.1, February 2014.

[2] Xu She, A. Q. Huang, S. Lukic, and M. E. Baran, “On integration of Solid State Transformer with zonal DC microgrid” IEEE Trans. on smart grid, Vol.3, No.2, June 2012.