

Power Management in Hybrid Microgrid System

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Abstract

Objectives: The paper proposes a power management across intermediate grids with power electronic converter. **Methods/Statistical Analysis:** VSC control is done by two techniques which are based on autonomous and communication. **Findings:** Autonomous techniques are applicable for only small scale islanding and communication technique used for large scale. It explains that by controlling VSC so we can manage power both AC and DC sub grids. **Applications:** The proposed method can be applied to Microgrid systems which uses different power generation techniques.

Keywords: Distributed Generation, Hybrid Microgrid, Islanding, VSC

1. Introduction

Distribution Generation (DG) very popular now in these days with this types of DG provide improve reliability of power and integrated resources. DG is the small scale generation. Distributed generation consists of small hydro, small gas, batteries and small solar, diesel and small sources of power generation. DG is AC and DC types. AC generation is easily connected with existing AC power system, on the other hand; DC counterpart picks up the load instantly due to its inherent characteristics. To optimize management of power across hybrid system, interconnection of AC and DC Microgrid is required but for synchronization among two; VSC is incorporated. Figure 1 represents communication by dashed lines and interconnection with utility and sub grids. Intermittent operation across grids are interdependent by (VSC) to combine with wind or solar system form. When islanding conditions occur then we have to control VSC to manage power flow without any interruption.

Power management strategy is used to control power of individual DG, for maintain small signal stability parameters during Microgrid operation. Power management strategies:

- Gathering information about Microgrid , Initial cost, power demand

- stabilizing Microgrid during epidemic from grid tied autonomous operation
- involves exchange between actual and power generated by elements in Microgrid and main grid

Power management classified in two types:

- long term power management: solar ,wind, photovoltaic management system
- Short term power management: RMS voltage regulation, frequency control, optimal power distribution. Real time implementation between AC and DC sub grids by VSC interfacing using autonomous scheme and centralized controller.

Normalised frequency and DC voltage are measured of the terminals of interfacing VSC which point out characteristics of intermediate grids in Autonomous as well as hybrid operation. In AC operation, drooping method is employed where as in DC operation, for determination of small signal parameters like terminal voltage and inter area oscillations; to optimize the system; a controller is used with centralized operation for DG as well as conventional sources¹⁻⁶.

2. Type System

Figure 2 shows islanding mode of distribution generation Islanding is a critical or not safe condition in which

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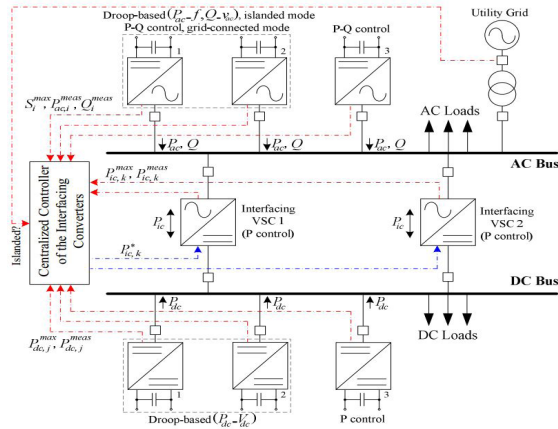


Figure 1. Strategies for Power Management in Grids.

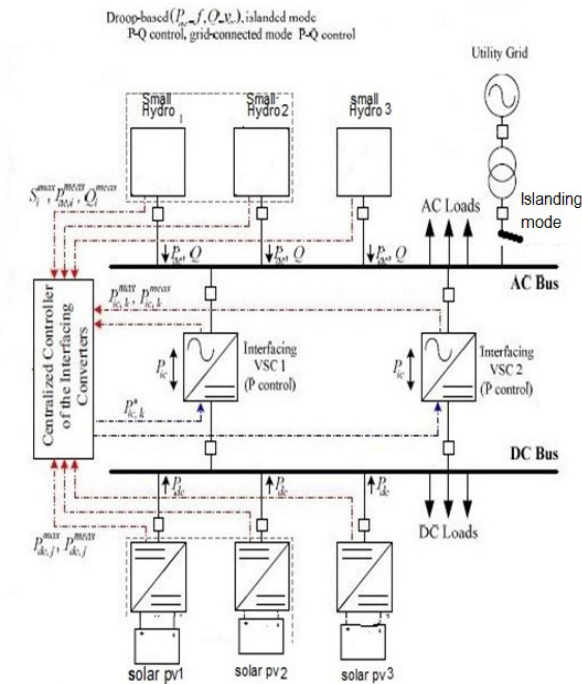


Figure 2. Strategy for DG interconnections with Utility.

distributed generator, such as solar system, photovoltaic system. While continuous supply of power electrical utility grid is down. In islanding mode generator connected in parallel mode with electricity grid. It can independent in case power failure. Islanding gave continuous operation to the photovoltaic generation system. When utility grid power is down, Photo voltaic system does not detect the fault but disconnect with grid⁷⁻⁹. When utility grid failure occurs then islanding mode occurs, after that we get power supply from photovoltaic system or batteries to feed the electrical load.

DC Microgrid have sources like small PV array, wind and Batteries or fuel storage type system while AC Microgrid having only small Hydro generating unit.

Section II describes the test system. Section III consists of modelling of VSC in interconnected microgrids. Section IV elaborated the discussion on results and future scope.

3. Modeling

3.1 Controlling Strategy in Hybrid System and Subgrids

To meet active power on ac Subgrid each ac distributed generation sources have to inject active power into the ac Subgrid according to the active power sharing principal, so that to meet the load power demand. where, $P_{ac1} = P_{ac1} + P_{ac2}$ at common frequency (ω) shows in Figure 3 the load sharing by two ac generating sources^{10,11}. Similarly reactive power sharing is done by sharing terminal voltage of each VSI

Sharing of power in DC Subgrid is shown by drooping based power sharing scheme shown in Figure 4.

3.2 Autonomous Technique Interfaced with Power Electronic Converter in a System

Autonomous operation interconnected VSC in the hybrid AC/DC microgrid shown in Figure 5.

$$P_{ic,dc} = \begin{cases} \frac{V_{dc}^n - V_{dc}}{m_{dc}}, & \text{when } V_{dc} < V_{dc}^{min}, \\ 0, & \text{else} \end{cases}$$

$$P_{ic,ac} = \begin{cases} \frac{[(W)^n - W]}{m_{ac}}, & \text{when } W < W^{min}, \\ 0, & \text{else} \end{cases}$$

$$P_{ic}^* = \begin{cases} 0, & \text{when } W < W^{min} \text{ and } V_{dc} < V_{dc}^{min} \\ -P_{ic,ac} + P_{ic,dc}, & \text{else} \end{cases} \quad (1)$$

Generation capacity on grids depends on the individual droop characteristics on the sub grids it means that com-

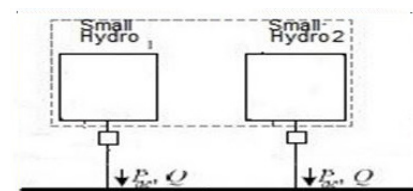


Figure 3(a). Droop based (Pac -F).

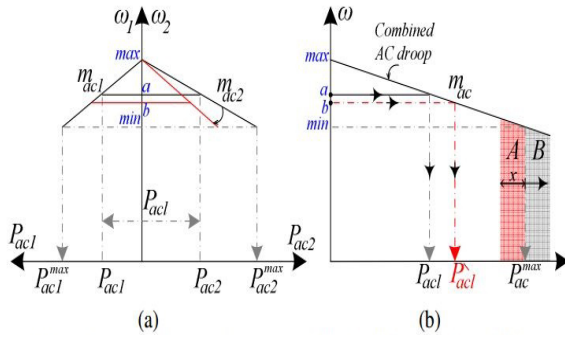


Figure 3(b). $P_{ac} - f$ droop characteristics. (a) individual droop of two DG units. (b) combined droop for the ac subgrid

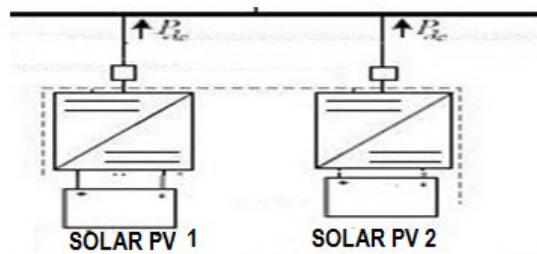


Figure 4. Droop based ($P_{dc} - V$).

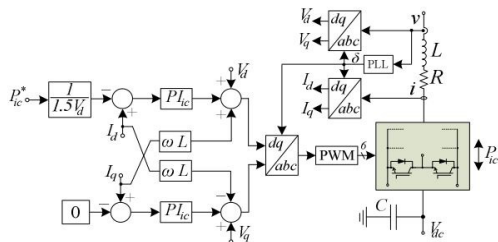


Figure 5. Power Circuit of Current-controlled Interfacings.

bine characteristics voltage on DC Microgrid is measured by calculating of perception DC voltage on VSC and voltage on AC Microgrid measured by calculating frequency of load at the terminals of VSC. If the measured frequency is below the fixed value ($w < w^{\min}$) on ac sub grid it means the sub grid is overloaded then power request to the VSC is done. Similarly in case dc sub grid when voltage level is below the fixed voltage ($V < V^{\min}$), it means that the dc sub grid is overloaded then power request to VSC is done.

3.3 Autonomous Scheme Drawbacks

The combined droop curve characteristics of the distributed generators are depends on assumption of knowledge

about droop curve of individual DGs. Sometime assumption may not be accurate, because

- Some DG units are not connected always due to some problems like faults, scheduled unit maintenance.
- We assume DGs according to their kVA ratings but there are some reasons due to the drooping characteristic are not always same. Like fuel cost, selling prices and other type of running costs also, varies with drooping cost with each other.
- When some new units are introducing.

Drooping curve variation means different loading on all DGs units existing on the same sub grid, more drooping the curve means more lower the frequency than actual frequency which showing loading on the unit more and which is responsible for unwanted starting of VSC to work in inversion mode.

3.4 Communication-Based Control in a System

Centralised scheme for power management is used to interfacing the converters with the both grids. In which power which is coming throw the interfacing converter is acting like an output signal. This signal is act as the reference signal of the current controller, shown in Figure 5. Equations to calculate received signal are given in Table 1.

3.5 Detail Of Islanded AC/DC System and Theory of Islanded System

- Operation is not done when power flow both the sub grids are over load or when both sub grids are under load¹².
- Operation of power flow is automatic from under load to overload and reduced also when sub grid load is increasing from under load.

Table 1. The Received Signal by Centralized Controller

AC Subgrid	DC Subgrid	Interfacing VSCs
$S_{tot}^{max} = \sum_{i=1}^{ni} S_i^{max}$	$P_{dc,tot}^{max} = \sum_{j=1}^{nj} P_{dc,j}^{max}$	$P_{ic,tot}^{max} = \sum_{k=1}^{nk} P_{ic,k}^{max}$
$Q_{tot}^{meas} = \sum_{i=1}^{ni} Q_i^{meas}$	$P_{dc,tot}^{meas} = \sum_{j=1}^{nj} P_{dc,j}^{meas}$	$P_{ic,tot}^{meas} = \sum_{k=1}^{nk} P_{ic,k}^{meas}$
$P_{ac,tot}^{meas} = \sum_{i=1}^{ni} P_{ac,i}^{meas}$		

$$P_{ac}^{cap} = ((S_{tot}^{max})^2 - (Q_{tot}^{max})^2)^{0.5},$$

$$P_{ac}^{tot} = P_{ac,tot}^{mean} - P_{ic,tot}^{mean},$$

$$P_{dc}^{tot} = P_{dc,tot}^{mean} + P_{ic,tot}^{mean}.$$

Where, superscript “cap” showing the power capacity of every

Sub grid. when $P_{ac(or\ dc)}^{cap} < P_{ac(or\ dc)}^{load}$ then system is overloaded but when $P_{ac(or\ dc)}^{cap} > P_{ac(or\ dc)}^{load}$ the system is under loaded,

$$P_{ic}^* = \begin{cases} \min \{ |P_{dc}^{cap} - P_{dc}^{load}|, |P_{ac}^{cap} - P_{ac}^{load}| \}, \\ \text{when } (P_{dc}^{load} > P_{dc}^{cap}) \text{ and } (P_{ac}^{load} < P_{ac}^{cap}) @ -\min \{ |P_{dc}^{cap} - P_{dc}^{load}|, |P_{ac}^{cap} - P_{ac}^{load}| \}, \\ \text{when } (P_{dc}^{load} < P_{dc}^{cap}) \text{ and } (P_{ac}^{load} > P_{ac}^{cap}) \\ 0, \text{ else} \end{cases} \quad (4)$$

P_{ic}^* has three modes of operations.

In first mode, which is rectification, in which P_{dc} sub grid is overloaded ($P_{dc}^{cap} < P_{dc}^{load}$) and P_{ac} sub grid is under loaded ($P_{ac}^{cap} > P_{ac}^{load}$). P_{ac} sub grid has surplus power deliver to P_{dc} sub grid.

In second mode, which is inversion mode, in which P_{ac} sub grid is overloaded ($P_{ac}^{cap} < P_{ac}^{load}$) and P_{dc} sub grid is under loaded ($P_{dc}^{cap} > P_{dc}^{load}$). Now P_{dc} sub grid has surplus power and ready to deliver power to P_{ac} sub grid.

4. Results

A simulation result of hybrid model same of Figure 6. In which two AC and DC sub grids are interfacing with converter to form hybrid system. Load allowed in each sub grid in (AC and DC) 2MW. load in each sub grid not more than 2MW. If value of load is more than 2MW, this at one side (ac or dc) and if the load is low or equal to 2MW, at the other side to make transition of power transferred from low side to high side with the help of the combine with converter. Firstly we take overload starting load is 1

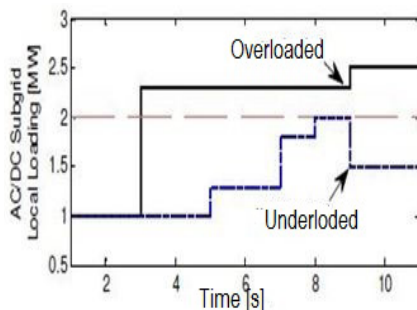


Figure 6. Local Loading Conditions in both Subgrids - the Maximum Generation Capacity 2MW.

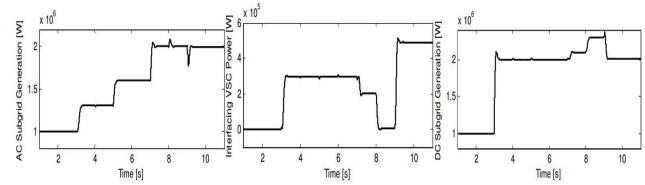


Figure 7. Centralized Control of Interfacing Converter when being operated in the Rectification Mode Stand alone.

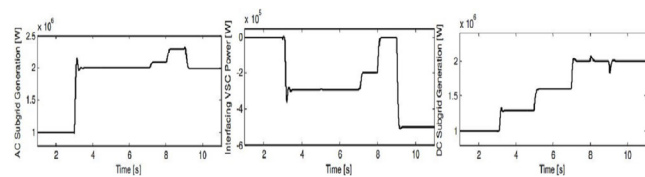


Figure 8. Centralized Control of Interfacing Converter when being operated in the Rectification Mode Hybrid.

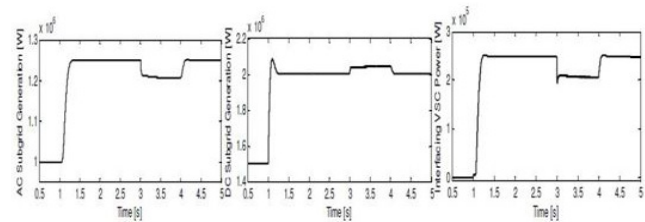


Figure 9. Transition between the Autonomous Operations of Converter.

MW and 2.3 AND 2.3 to 2.5 expand the value when $t = 3s$ and $t = 9s$. In second case is under load when load value 1MW it is expand to 1.3, 1.8, 2MW and $t = 5s$, $t = 7s$ and $t = 9s$ and its value decline to 1.5 MW when

Rectification Mode

When time, $t = 0$ to $3s$: AC and DC are under loaded then it does not combine with VSC converters

When time, $t = 0$ to $5s$: then converter work as a rectifier. Because DC work as an overloaded and AC work as under load

When time, $t = 5$ to $7s$: Interfacing unit still works as a rectifier

When time, $t = 7$ to $8s$: Interfacing unit is not working and some load is completely shed from the dc subgrid because both subgrids are fully loaded.

When time, $t = 9$ to $11s$: The interfacing unit again starts working as rectifier.

Control of interfacing converter when being operated in the rectification mode in Figure 7.

At, $t = 1s$ the dc subgrid is overloaded with under loaded condition in the ac side. At, $t = 2s$ DC distribution

generation unit is decreases to 0.95 with droop quotient. AC and DC convertor combine with VSC centralized controller does not interrupted.

At, $t=3s$ communication process does not work.

These ordered figures are successfully working for autonomous mode. Power transfer in autonomous mode is less due to DC droop quotient. This is disadvantages of autonomous mode .in case of autonomous scheme it can regenerate 1s. At $t=4$ communication controller continuously regenerated. Figure 8 shows centralized control of convertor operating in rectification mode. Figure 9 shows transitions of converter in autonomous operations.

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