

CONTROL OF MULTIPLE DISTRIBUTED GENERATORS FOR INTENTIONAL ISLANDING

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ABSTRACT

Due to safety concerns and the risks associated with an islanded system, current legislation has prohibited the islanded operation of distributed generation. However, operation of a temporary island may be a useful support to the main supply. In particular, in the event of an upstream supply outage, the temporary islanding operation of distributed generator (DG) can provide local supplies to critical customers, thus reducing customers' outage cost and improve the power system reliability. Despite all the benefits that an islanding operation can provide to the power system, there are still many challenges and technical issues regarding its implementation that constrain its operation.

The aim of this work is to look into two main challenges associated with temporary islanding operation: frequency regulation and generator control. Several simulation based studies carried out using PSCAD/EMTDC are presented.

INTRODUCTION

The connection of distributed generation into the distribution network has seen a rapid growth in recent years. It is expected that in the near future, DG will become a significant element in the distribution network. However, operating the DG units in a system not designed for them has raised numerous technical challenges. One of the most raised issues is islanding. Due to the safety hazard and complication it poses to the utility network, current legislation, G59 [1] has prohibited the operation of islanding and requires the DG units to be automatically tripped when islanding is detected.

Tripping the DG during a mains failure has limited the benefits offered by DG, particularly when it is capable of supplying the local load within the statutory voltage, frequency and power quality limits. With the expectation of greater use of DG, intentional islanding has created considerable research interest. Different approaches have been investigated in order to operate DG in island mode. [2, 3]

This paper focuses on a multiple DG island, discussing the advantages and disadvantages of different control approaches. Studies will concentrate on synchronous-based generator because of its inherent speed droop characteristic

and ability to sustain an island. Several case studies simulated using PSCAD/EMTDC will be presented and discussed. These case studies simulate the formation of island involving multiple DG units with different combinations of control.

CONTROL FOR GRID CONNECTED AND ISLAND OPERATION

When running in parallel with the grid, DG units are often required to operate in PQ mode, exchanging a predetermined real and reactive power with the grid.

Once disconnected from the main grid, it is obvious that any attempt to continue the use of PQ mode will fail since it is practically impossible to balance the generation and load demand accurately. Besides, the utilities is no longer having control over the islanded system, and hence relies upon the DG units to control the frequency and voltage in the formed island within statutory limits. To achieve this, DG units have to be immediately switched to V-f control mode, supplying the load demand in the island whilst regulating the frequency and voltage of the island within permissible limits. Clearly, there is a need of control switching between the grid-parallel and islanding operation.

This problem is even more complex when more than one DG units operating in parallel in an island. Switching all of them into V-f mode may create problems as all of them will try to control the system frequency to their own setting if they are allowed to operate unregulated. Thus, proper coordination between the DG units is clearly required.

Fundamental Control of DG Units Interfaced Through Synchronous Machines

There are essentially three types of governor control namely

- Droop control
- Fixed power control
- Isochronous mode control (Fixed speed control)

A droop control mode is adopted when more than one unit is operating in parallel. The change in power output for a given change in frequency is determined by the governor's droop characteristic, R which can be expressed as [4]

$$R(\%) = \frac{\Delta f}{\Delta P} \times 100 \tag{1}$$

Where

Δf = per unit change in frequency

ΔP = per unit change in unit output

When running in parallel with the grid, the DG units are not required to participate in frequency or voltage regulation. Hence, a fixed power control mode is adopted, dispatching a fixed amount of real and reactive power to the system. This is done by adjusting the speed droop setpoint, f_0 (refer Fig. 1) of the governor. As the grid frequency fluctuations are very small (essentially constant) throughout the time, the choice of f_0 determines the DG power output.

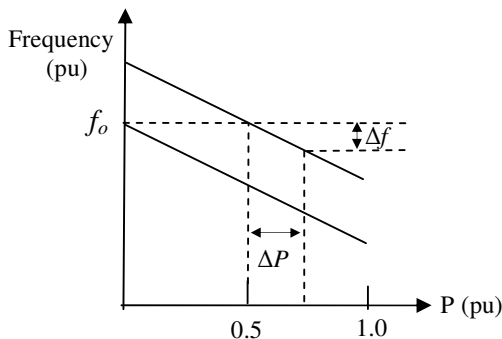


Fig. 1 Speed-droop Characteristic and Speed-changer Settings

Isochronous mode control is often used when generator is supplying an isolated load. This enable the generation to match the load demands while keeping the frequency at a predetermined constant value.

TEST SYSTEM

Fig. 2 depicted the single line diagram of the distribution network used for the distributed generators’ control studies. There are two distributed generators, DG1 and DG2 rated at 4.51MVA and 2 MVA respectively connected to the grid through two parallel 33/11 kV transformers. Both DG units are equipped with an AVR, and the reactive power is shared between them using quadrature droop compensation scheme [4].

Prior to islanding, both DG units operate in fixed power control mode (DG1 – 0.5 pu and DG2 – 0.8 pu; based on their respective generator rating). Islanding is simulated by opening breaker B1 at $t = 0.5s$. In this study, it is assumed that both DG units have the capability of detecting islanding. As soon as they detect the occurrence of island event, their governor control mode is switched. Three different governor control combinations considered are:

- i) DG1 in isochronous mode while DG2 in droop control mode
- ii) DG1 in isochronous mode while DG2 remains in fixed power control mode
- iii) Both units in isochronous mode

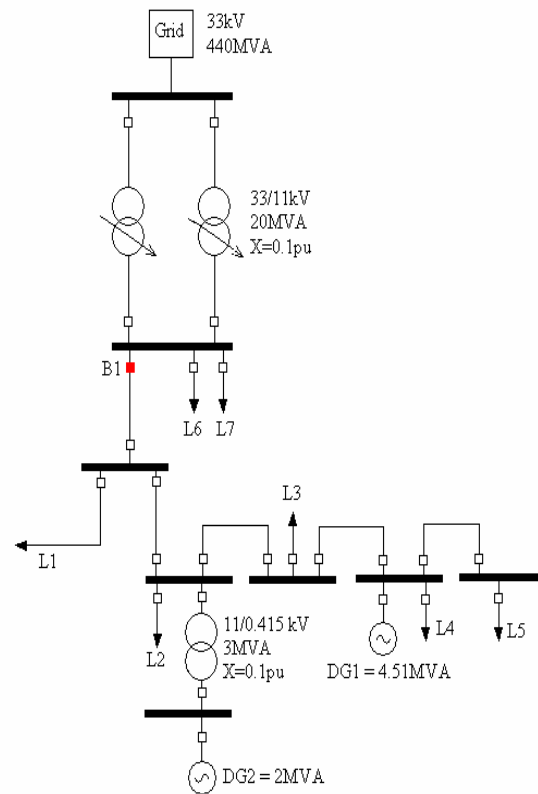


Fig. 2 Single Line Diagram of Distribution Network Model

Case 1: DG1 in isochronous mode while DG2 in droop control mode

Immediately after islanding, DG2 changed its governor control to droop mode by resetting its governor frequency setpoint. It can be observed from Fig. 3 that DG1 (isochronously-governed unit) supplied the entire load demands within its machine rating in order to keep the frequency constant.

Load increment is then simulated at $t=25s$ and $t=41.5s$. As DG1 has now reaches its machine rating and is incapable of supplying the total load, frequency starts to drop, deviating from the nominal value. As the units slow down, the drooping characteristic of DG2 acts to increase its output.

Clearly, it is seen that in this case study, droop-mode unit may not get to deliver any real power if the load demand stays within the isochronous unit’s rating. Even when it gets

to deliver, it is at the expense of frequency drops. Note that the new operating frequency is proportional to the generator's droop characteristic as well as the load frequency's characteristic [5].

A change in frequency may be undesirable for frequency-sensitive loads, i.e computers and motors [6] and without proper coordination; underfrequency relay may be activated to trip loads from the islanded system in some cases. [6]

Transfer of load from the isochronous unit to the other unit may be favorable so as to shed load from the former unit. This can be done by altering the speed changer setting of the droop governor.

Obviously, the main disadvantage of this scheme is its inability to regulate the island's frequency close to nominal value, unless a signal command is constantly being sent to the droop-mode generator to vary its droop speed setting. Clearly, this option requires communication availability.

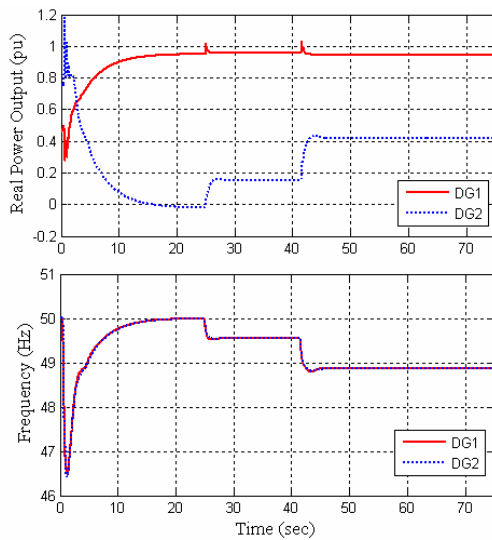


Fig. 3 Real Power Outputs and Frequency Response of DG1 and DG2 for case 1

Case 2: DG1 in Isochronous mode while DG2 remains in fixed power control mode

Again, islanding is simulated at $t=0.5s$. In order to study the frequency response of both generators during load transient, a 240kW with 0.9 power factor load was switch in at $t=25s$ followed by a switching out of 150kW with 0.95 power factor load at $t=41.5s$.

As depicted in Fig. 4, all load changes are absorbed by DG1 while DG2 provides constant real power output (0.8 pu). In this example, it is observed that this scheme is able to control the island's frequency at the nominal value.

Nonetheless, this scheme also suffers the main drawback as the previous scheme. Once the isochronously-governed generator hits its output limit, the frequency will drift from the desired nominal value.

Configuration for case 1 and case 2 works on the basis that the generator responsible for the frequency-governing is predetermined. As this generator is responsible for absorbing all the load changes, fast response governor and huge capacity machine are among the factors looked in determining the isochronous mode generator.

If the generator responsible for the isochronous control trips, in this case DG1, the island system may need to be shut down unless there is a signal command given to the other generator to take up the task/responsibility.

As the connection of distributed generator increases, the size of island may vary. To make the matter worst, more than one island may be formed. The generator responsible for the isochronous-mode may be predetermined, but it has to be ensured that this particular generator is within the island and it is online at the time islanding occurs. As such, the communication requirement may be inevitable.

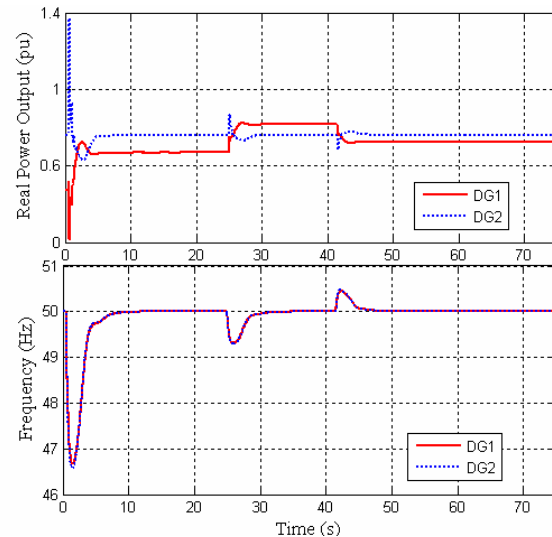


Fig. 4 Real Power Outputs and Frequency Response of DG1 and DG2 for case 2

Case 3: Both units in isochronous mode

It is reported in the literature that no more than one isochronous unit is to be connected to the same system [4, 5, 7]. This is because it is literally impossible to set multiple machines at exactly the same speed when paralleling. The machine which runs faster may absorb all the loads while the slightly slower machine will shed all its loads [4], as shown in Fig. 5. Eventually the frequency will become

unstable and collapse. The rate at which this situation may happen is related to the steady state measurements errors, the difference in the gains and time constants for the governor of each generator [8].

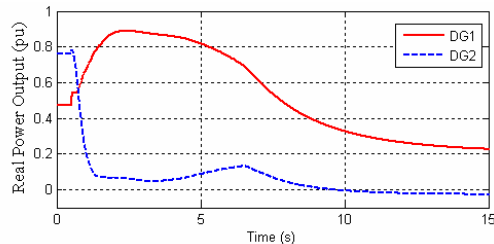


Fig. 5 Real Power Outputs of DG1 and DG2 (both generators running in isochronous mode)

However, communication may be employed to increase the stability of this scheme. Information exchange between generators can help in preventing measurement errors and thus eliminating the conflict between their governor controls.

The same study as case 2 has been carried out, but with both DG with isochronous mode governor. In order to prevent the real power deviation as seen in Fig. 5, communication has been employed to facilitate the load sharing between the generators.

It is depicted in Fig. 6 that the frequency response with all units operating in isochronous mode (with communication) is better than the previous case. The frequency deviation during system transient has clearly reduced. Besides, with this scheme, there isn't a need to appoint any generator responsible for the speed-control. All the generators will switch to isochronous mode once they detect the occurrence of islanding. Even when one of them trips, there is always a backup generator regulating the island frequency. In addition, this method has enabled equal sharing of loads between generators, as shown in Fig 7.

CONCLUSION

Intentional islanding is gaining much attention in recent years as an approach to improve system reliability and service continuity, particularly to 'critical loads'. In addition, it is seen as a way to maximize the benefits brought in by DG technologies. However, only DG units with proper coordination and control can be operated in islanding mode.

With the continually increasing penetration of DG into the network, it is envisioned that more multiple-DG island will be formed. At that point, communication requirement may be inevitable for the proper coordination between generators

in the island. With current technology advancement, it is anticipated that reliable low cost communications will be widely available in the near future.

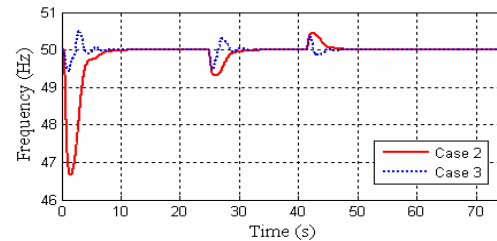


Fig. 6 Comparison of Frequency Response between Case 2 and Case 3

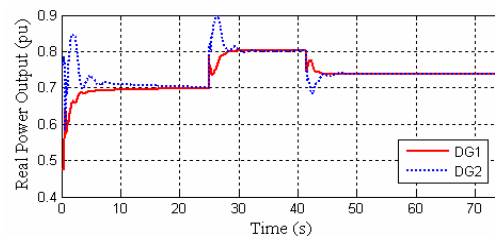


Fig 7 Real Power Sharing between DG1 and DG2

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