Islanding Operation of Distribution System with Distributed Generations

Mahat, Pukar; Chen, Zhe; Bak-Jensen, Birgitte

Published in:
Proceedings of the Danish PhD Seminar on detailed Modelling and Validation of Electrical Components and Systems 2010

Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

Islanding Operation of Distribution System with Distributed Generations

Pukar Mahat, Zhe Chen, Birgitte Bak-Jensen

ABSTRACT

THE growing interest in distributed generations (DGs) due to environmental concern and various other reasons have resulted in significant penetration of DGs in many distribution system worldwide. DGs come with many benefits. One of the benefits is improved reliability by supplying load during power outage by operating in island mode. However, there are many challenges to overcome before islanding can become a viable solution in future. This paper point outs some of the major challenges with island operation and suggests some possible solutions.

I. INTRODUCTION

Power system functions mainly through synchronized operation of large power plants producing bulk power and transmitting it to the customer premises for consumption. This is mainly due to the cost of production of bulk quantity of electricity being much lower than the cost of producing small quantity of electricity. But, the trend is changing with a renewed interest in the distributed generation (DG) because of a variety of reasons like environment concern, electricity market liberalization etc. Many utilities around the world already have a significant penetration of DG in their systems. This has created lot of operational challenges but at the same time opened many opportunities. One opportunity/challenge is islanding operation of distribution systems with DGs.

Islanding is a situation in which a distribution system becomes electrically isolated from the remainder of the power system, due to a fault upstream or any other disturbance, and yet continues to be energized by the DG connected to it. Islanding can improve the quality of supply indices and reliability [1], [2]. Furthermore, DG owners get additional revenue due to the increased power supplied during network outage, and customers are benefited by the reduction in frequency and duration of interruptions from outages in the distribution network [3]. However, various issues have to be addressed before islanding can become a viable solution. Some of the major issues are islanding detection, control of DGs, load control and protection.

The islanding detection is explained in Section II. Section III deals with the control and operation issues. Section IV shows why under frequency load shedding is required in islanded systems. Section V deals with the protection issues and Section VI concludes the paper.

II. ISLANDING DETECTION

IEEE 929-1988 standard [4] requires the disconnection of DG once it is islanded and IEEE 1547-2003 standard [5] stipulates a maximum delay of 2 seconds for detection of an unintentional island and all DGs ceasing to energize the distribution system. Hence, it is essential to detect the islanding both quickly and accurately.

System parameters (like voltage, frequency, etc.) change greatly when the system is islanded but not much when the distribution system is still connected to grid. Most of the islanding detection techniques make use of this phenomenon to detect islanding. Islanding detection techniques can broadly be divided into remote and local techniques. Local techniques can further be divided into passive and active techniques. Remote techniques use communication between utilities and DGs to detect islanding. Even though, this technique has better reliability, it can be expensive to implement. Hence local techniques are widely used to detect islanding. Passive methods set some kind of thresholds for the system parameters such as voltage, frequency, etc. When islanding occurs, these system parameters exceed the thresholds and islanding is detected. When the load and generation in the islanded system closely match, change in system parameters is small and hence it is difficult to detect islanding with passive techniques. Many common events in power systems, like load change, also result in small changes in the power system parameters. Thus setting lower threshold values will result in nuisance tripping of the DG. Active techniques can detect islanding, even under a perfect match of generation and load in the islanded system, by injecting perturbations. These perturbations will drive the observed system parameter outside the threshold when the system is islanded. On the other hand, these perturbations have negligible impact if the system is still connected to grid. But they do degrade the power quality. Recent developments in islanding detection are reviewed in details in [6]. To overcome the problem with existing islanding detection techniques, hybrid islanding detection was developed in [7]. It uses both passive and active technique. However, the active technique is

---

The work is funded by PSO program, project 2006-1-6316, “Operation and Control of Modern Distribution Systems”.

Pukar Mahat is a PhD student at the Department of Energy Technology, Aalborg University, 9220 Aalborg, Denmark (e-mail: pma@iet,.aau.dk , phone no. +4599409289).

Zhe Chen is with Department of Energy Technology, Aalborg University, 9220 Aalborg, Denmark (e-mail: zch@iet,.aau.dk).

Birgitte Bak-Jensen is with Department of Energy Technology, Aalborg University, 9220 Aalborg, Denmark (e-mail: bbj@iet,.aau.dk).

Paper submitted to the PhD Seminar on Detailed Modelling and Validation of Electrical Components and Systems 2010 in Fredericia, Denmark, February 8th, 2010

used only when the passive technique cannot clearly discriminate between islanding and grid connected conditions.

III. Control and Operation

Small generators have to be operated at constant power factor or VAr when connected to the grid because if they are connected to the grid in voltage control mode, it may cause either over or under excitation of the small generators and may result in overload or loss of generator synchronism [8]. Also they can generate more revenue by producing real power only. However, they have to control the voltage when the distribution system is islanded.

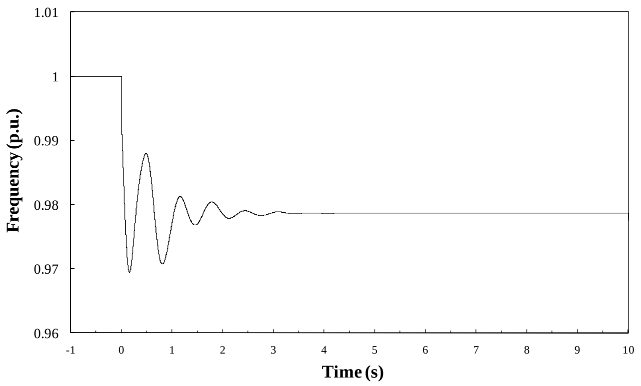

Fig. 1. Distribution system frequency with droop controller.

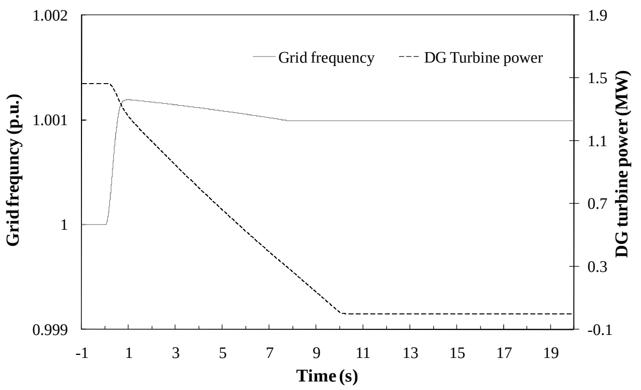

Fig. 2. Grid frequency and DG turbine power with isochronous controller.

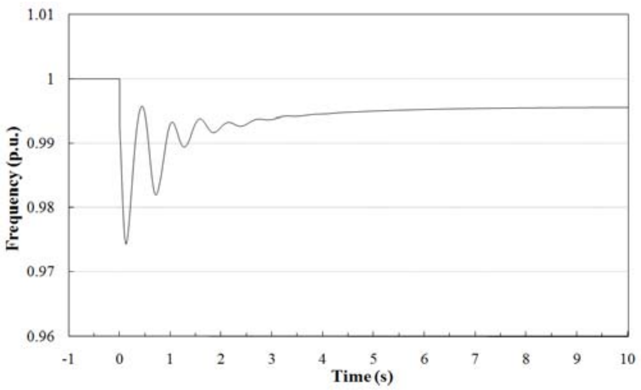

Fig. 3. Distribution system frequency with isochronous controller with feedback.

Droop control is used for primary control. When the droop controller is employed, the frequency might go beyond the power quality limit when the system is islanded as shown in Fig. 1. An isochronous controller, which is basically a PI controller, can regulate the frequency to nominal value. However, its output power is driven to extreme limits with the slightest change in grid frequency when it is still connected to grid as shown in Fig. 2. Isochronous controllers with feedback as presented in [9] performs relatively well in both situation as shown in Fig. 3 and 4. However, it should be noted that the droop controller has better performance during the grid connected condition and the isochronous controller is better during islanding. Unfortunately, isochronous controllers cannot be used with more than one generator connected to the same system since all the generators else would need to have the same speed set point; otherwise each generator will try to bring the frequency to its reference setting [10]. Hence the optimal way to control a DG for island operation is switching between droop control and isochronous control as the DG switch form grid connected to island condition and vice versa. However, if there is more than one DG in the distribution system, only one DG employs isochronous control and rest employs isochronous control with feedback during islanding.

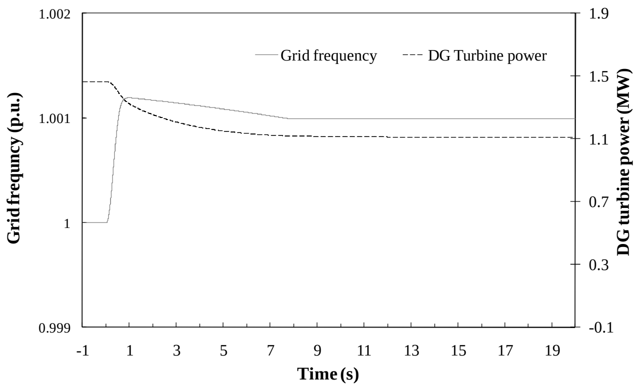

Fig. 4. Grid frequency and DG turbine power with isochronous controller with feedback.

IV. Load Control

When the distribution system is islanded, the frequency will either go up or down depending on the power imbalance in the islanded distribution system. If the frequency goes up, due to excess generation, it can be brought into reasonable limits by reducing the output of the generators. On the other hand, if the frequency goes down, due to excess load, the output of the generators has to be increased. Photovoltaic generators uses maximum power point tracking and variable speed wind turbines optimize the power co-efficient (Cp) to produce maximum power, central heat and power plants are operated at maximum power. Thus, if all the generators are operating at maximum power and the frequency goes down, some loads have to be shed to bring the frequency back to normal. The problem of optimal load shedding has been extensively investigated. Small generators have small inertia and thus the frequency tends to decay more rapidly as shown in the Fig. 5. An under-frequency load shedding procedure for islanded distribution systems with DGs based on frequency information, rate of change of frequency (RoCoF), customers' willingness to pay WTP and loads histories is presented in [11]. It sheds the optimal number of loads if the islanded distribution system does not have enough generation to supply all the loads. Figure 6 shows how the frequency is brought near nominal frequency by shedding loads. It also shows the frequency of the system when one load, which was supposed to be shed, is not shed. This employs that the methodology presented in [11] sheds the optimal number of loads.

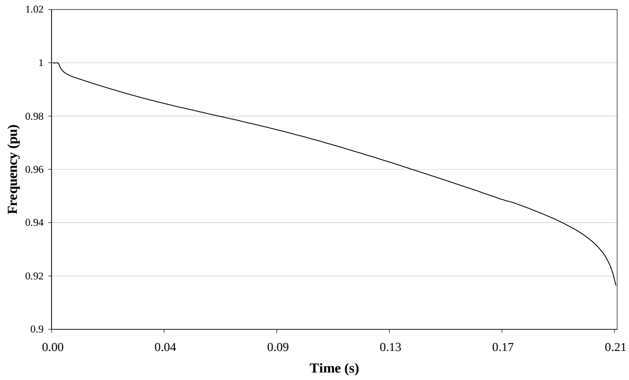

Fig. 5. System frequency after islanding.

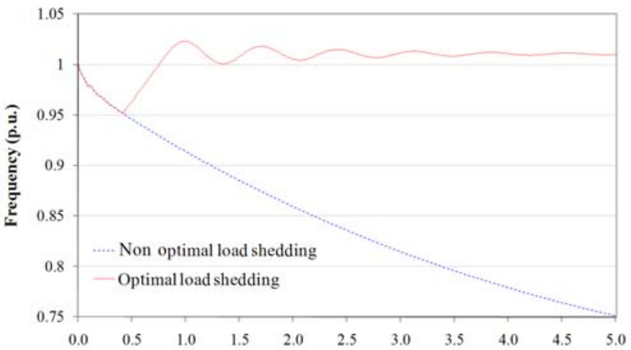

Fig. 6. System frequency for optimal and non optimal load shedding after islanding.

V. PROTECTION

The magnitude of current during the fault depends on available sources. Transmission grids generally have higher fault current contribution compared to small generators. Hence when the transmission grid is lost or when a distribution system goes to an island mode, the fault current is less. Fault studies show that there is signification difference, up to more than 5 folds for a 3 phase short circuit, in fault currents when the system is connected to grid and when it is islanded as shown in Figs. 7 and 8. The figures show current through 4 lines of a radial distribution feeder. Thus, as seen from those figures, a protection system designed to operate in grid connected mode will take longer time to clear the faults when the system is islanded. Equipments are designed to disconnect when the voltage goes low for a certain time period. This also applies to sources like wind turbines which are becoming common in many distribution system. Thus, by not clearing the fault sooner, not only the loads but also some generation might be lost, which is undesirable. Designing the protection for island operation will again run into problems when the grid is connected. It may trip the breakers even when it is unnecessary. Hence the distribution system should be protected with an adaptive protection that will change its settings when the system switches from grid connected to island mode and vice versa. However, a state detection technique is required to detect whether the system is connected to grid or islanded and change the protection system setting accordingly.

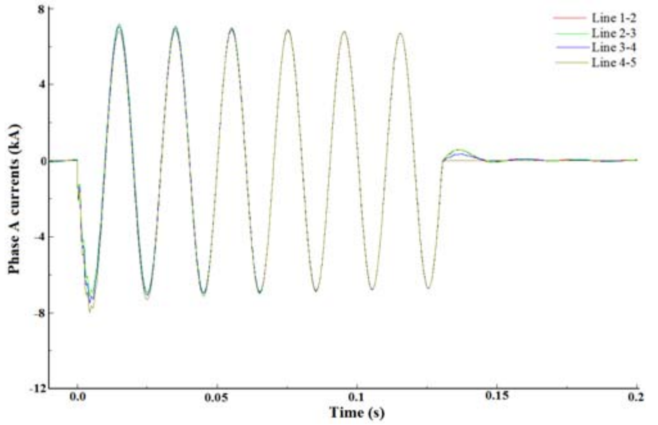

Fig. 7. Current in phase A of lines for three phase fault while connected to grid.

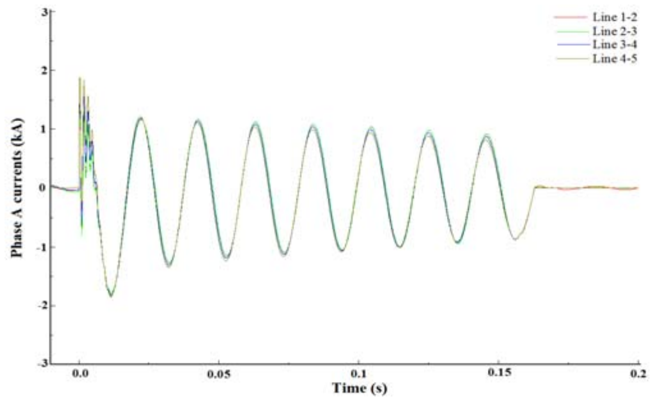

Fig. 8. Current in phase A of lines for three phase fault when islanded.

VI. CONCLUSION

Islanding operation of distribution system can increase the reliability of power supply by supplying customers during transmission network outages. There are various issues with islanding. Islanding detection, control and operation of DG, load control and protection are few examples of the issues with island operation. There are various techniques available for islanding detection and hybrid techniques, which combine both passive and active techniques and use active techniques when passive techniques cannot clearly identify islanding, stands out as the most promising one. Furthermore, DGs can be optimally operated by switching from one control strategy to another when the distribution system is grid connected or islanded. Isochronous controller with feedback can perform satisfactorily in both grid connected and island condition and can hence be used if some error in frequency is tolerable. Some loads have to be shed if the demand in the islanded system is higher than the total generating capacity of the island. Furthermore, due to the difference in fault current in grid connected condition and islanding condition, set points of the protection device has to be changed with the change in operating stage. This clears the fault in distribution systems quickly. Hence, islanding is a realistic solution to improve the readability of power supply if the above issues are properly addressed.

VII. Acknowledgement

Authors would like to thank Himmerlands Elforsyning A.m.b.a, SEAV-NVE and DEFU, Denmark for their support for the work.

VIII. References

[1] K. Nigm and Y. Hegazy, "Intentional islanding of distributed generation for reliability enhancement," *in Proc. of the IEEE Power Engineering Society General Meeting*, pp. 208 – 213, October 2003.

[2] F. Pilo, G. Celli, and S. Mocci, "Improvement of reliability in active networks with intentional islanding," *in Proc. of the 2004 IEEE International Conference on Electric Utility Deregulation, Restructuring and Power Technologies*, vol. 1 and 2, pp. 474–479, 2004.

[3] F. Castro-Sayas and G. Clarke, "The cost and benefits of embedded generation islanding operation," DTI Sustainable Energy Programmes, Tech. Rep. k/EL/00284/REP, 2002.

[4] *Recommended Practice for Utility Interconnected Photovoltaic (PV) Systems*, IEEE Standard 929-2000, 2000.

[5] *IEEE Standard for Interconnecting Distributed Resources into Electric Power Systems*, IEEE Standard 1547TM, June 2003.

[6] P. Mahat, Z. Chen, and B. Bak-Jensen, "Review of islanding detection methods for distributed generation," *in Proc. 2008 Third International Conference On Electric Utility Deregulation And Restructuring And Power Technologies*, vol. 1-6, pp. 2743–2748, 2008.

[7] P. Mahat, Z. Chen, and B. Bak-Jensen, "A hybrid islanding detection technique using average rate of voltage change and real power shift," *IEEE Transactions on Power Delivery*, vol. 24, no. 2, pp. 764 – 771, April 2009.

[8] T. W. Eberly and R. C. Schaefer, "Voltage versus var/power-factor regulation on synchronous generators," *IEEE Transactions on Industry Applications*, vol. 38, no. 6, pp. 1682–1686, 2002.

[9] P. Mahat, Z. Chen, and B. Bak-Jensen, "Gas turbine control for islanding operation of distribution systems," *in Proc. 2009 IEEE PES General Meeting*, July 2009

[10] P. Kundur, *Power System Stability and Control*. New York: McGraw-Hill, 1994.

[11] P. Mahat, Z. Chen, and B. Bak-Jensen, "Underfrequency load shedding for an islanded distribution system with distributed generators," *IEEE Transactions on Power Delivery*, to be published.