IMPACT STUDY OF INTENTIONAL ISLANDING OPERATION OF SYNCHRONOUS AND INDUCTION GENERATOR

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ABSTRACT

Since intentional islanding operation of Distributed Generation (DG) can increase system reliability, and reduce the customer outage cost due to loss of power supply from main grid, some utilities may permit islanding operation of DG. As a result, the impact study and operation criteria of DG for islanding operation should be performed. Typically, only synchronous generator with exciter and governor control can operate appropriately during islanding operation. In contrast, induction generator, which is stand-alone, cannot operate properly during islanding operation since it cannot control both frequency and voltage. This paper investigates how to operate and control of a synchronous generator and an induction generator while islanding operation if there are both types of DGs connected to the islanding system. The operational conditions, such as size of synchronous generator and induction generator, control of generators, load conditions, and system configuration, also take into account in this paper. Both steady- state and dynamic studies are performed for DG impact study.

INTRODUCTION

Several DGs are connected to electric power systems for different purposes, varying from avoiding cascading outages to reducing power losses. Many more units will be installed because of some advantages over large remote generation units [1]. The significant advantages have been developed by many researchers [1-3]. Operating the DGs in an islanding mode is one of main research topics. In the islanding mode, the DGs can increase system reliability and reduce the customer outage cost from loss of supply [4-8]. Outage cost can be reduced by reducing repair time and improving load characteristics. Islanding operation of DGs provides an opportunity to reduce a repair time.

Normally, during islanding operation, it is necessary to have a synchronous generator (SG) with exciter and governor control [7-8]. In a case that there is an induction generator (IG) in a system, if the IG is smaller than the SG, it is possible that the IG and the SG are operated together. This paper will investigate the size, type, and installed location of IG and SG in different load conditions.

This paper starts with the test system, the forming of intentional islanding operation, an impact study from disturbances during islanding operation, and effects of operating control modes of SG and IG during islanding operation. Finally, conclusion is drawn from results of the study.

TEST SYSTEM

As shown in Fig.1, 7 buses, 5 loads (Full load at 130 MW and 63 MVAR), and 2 DGs connected to subtransmission system (115 kV) is used as the test system.

In this study, it is assumed that protective devices can separate the faulted part from the islanding area before performing intentional islanding operation of DGs. Loads are represented by only a static load model. The size, type of DG, installed location, and type of control modes including disturbances that affect to islanding operation of DGs are studied. Size of IG is 25% and 50% of SG. The SG has to be bigger than the IG because during islanding operation, the SG has to provide reactive power to both loads and IG. In addition, locations of IG and SG are exchanged.

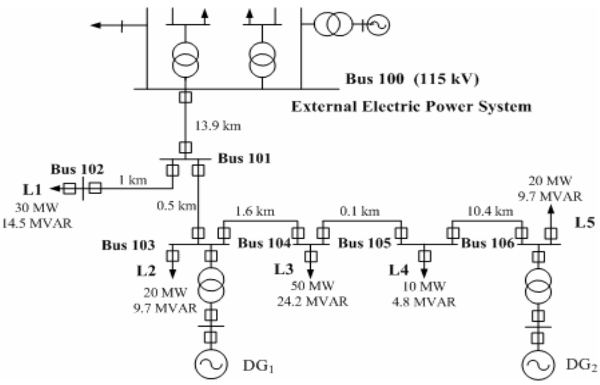


Fig. 1 Test system

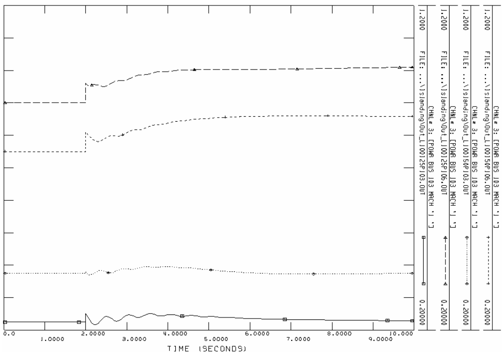
FORMING OF INTENTIONAL ISLANDING OPERATION

Islanding may result from system fault or scheduled maintenance. They create different operating conditions that require different handling procedures and considerations for islanding operation. The forming of international islanding operation caused by fault is difficult because it is hard to know the difference between total capacity of DGs and total load. If the difference is large, frequency deviation is high and then generation protection performs its functions. In practice, intentional islanding operation caused by maintenance is proposed. This paper presents only intentional islanding operation caused by maintenance.

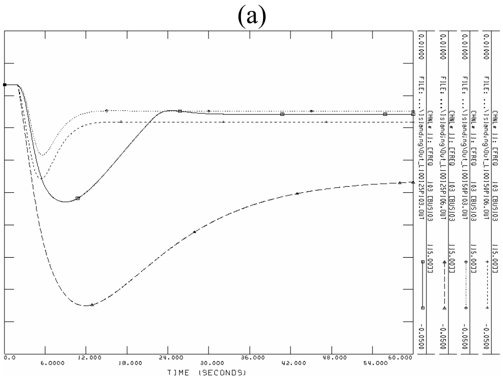
Forming Islanding Caused by Maintenance

If a utility wants to carry out the maintenance of subsystem, the subsystem is disconnected from a main grid. In Fig.1, intentional islanding for maintenance is formed by disconnecting bus #100 from the main grid. Simulation results of islanding part in Fig.2 show power outputs of DGs, system frequency, and bus voltage.

Fig.2 shows that the system remains stable. Power output of SG is increasingly high enough to supply loads whereas power out of IG firstly higher and then lower to its rated value. In the case that sizes of SG and IG are unchanged but locations of SG and IG are interchanged, there is a great impact on frequency deviation (Δf). Specifically, when SG is moved to bus #103, Δf is high as shown in both Fig.2 and Table 1. In the case that locations and loads of SG and IG are unchanged but size of IG is changed to 25% and 50% of SG, a large SG results in high Δf. On the other land, bus voltages deviation differs from Δf. When the SG is high, bus voltage is also high. In Table 1, when 40% of peak load are supplied, system voltage profile is higher than other load conditions – 100%, 80%, and 60% of peak load. This is because frequency varies directly with power output. The larger change in power output, the larger change in frequency. Change in bus voltage varies directly with an adequacy of reactive power. As limited reactive power of SG, if loads require low reactive power, system voltage is high. In Table 1, the SG can not supply enough reactive power in many cases. These cases lead to voltage collapse if loads require constant power such as large induction motors.



(a)



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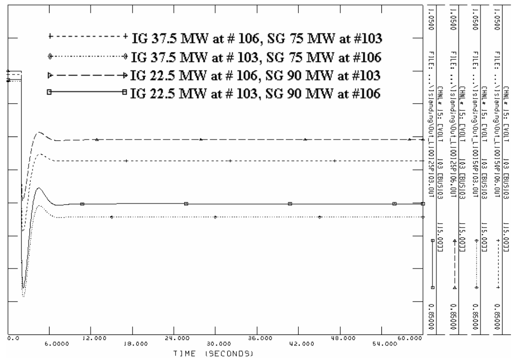


(c)

Fig.2 Forming of intentional islanding for maintenance the upstream system by opening CB at Bus #100 (100% loading condition). (a) power output of DG1, (b) frequency deviation, and (c) bus voltage at bus #103.

Table 1 Steady-state condition after forming islanding

Case	DG Information			Load	Output of SG		Bus Volt (pu)		Δf (pu)
	Type	MW	Bus	(%)	(MW)	(MVAR)	#103	#106	
1	DG1 (SG) DG2 (IG)	90 22.5	#103 #106	100	102	71	0.968	0.962	-0.0190
2	DG1 (SG) DG2 (IG)	75 37.5	#103 #106	100	86	80	0.956	0.947	-0.0070
3	DG1 (SG) DG2 (IG)	90 22.5	#106 #103	100	98	69	0.947	0.930	-0.0050
4	DG1 (SG) DG2 (IG)	75 37.5	#106 #103	100	83	78	0.941	0.922	-0.0040
5	DG1 (SG) DG2 (IG)	90 22.5	#103 #106	80	78	59	0.968	0.962	0.0080
6	DG1 (SG) DG2 (IG)	75 37.5	#103 #106	80	62	68	0.966	0.958	0.0085
7	DG1 (SG) DG2 (IG)	90 22.5	#106 #103	80	76	58	0.954	0.939	0.0100
8	DG1 (SG) DG2 (IG)	75 37.5	#106 #103	80	60	67	0.947	0.931	0.0120
9	DG1 (SG) DG2 (IG)	90 22.5	#103 #106	60	53	47	0.967	0.962	0.0250
10	DG1 (SG) DG2 (IG)	75 37.5	#103 #106	60	38	56	0.964	0.958	0.0255
11	DG1 (SG) DG2 (IG)	90 22.5	#106 #103	60	52	46	0.960	0.949	0.0265
12	DG1 (SG) DG2 (IG)	75 37.5	#106 #103	60	37	55	0.953	0.940	0.0270
13	DG1 (SG) DG2 (IG)	90 22.5	#103 #106	40	29	35	0.968	0.963	0.1250
14	DG1 (SG) DG2 (IG)	75 37.5	#103 #106	40	23	40	0.965	0.961	0.0150
15	DG1 (SG) DG2 (IG)	90 22.5	#106 #103	40	29	35	0.966	0.957	0.0350
16	DG1 (SG) DG2 (IG)	75 37.5	#106 #103	40	23	39	0.964	0.955	0.0380

IMPACT STUDY FROM DISTURBANCES DURING ISLANDING OPERATION

An impact of disturbances during islanding operation is studied [7-8]. In that study, both DGs of the test system, shown in Fig.1, are SGs. In this study, one of DGs is the IG. Impacts of only load following, load rejection, and fault disturbances on islanding operation will be studied.

Load Following and Load Rejection

Fig.3 shows load following and large load rejection pattern. Load following is represented by 5% and 10% of load changing in every 5 seconds. Load rejection is represented by a loss of 20% of load.

As shown in Fig.4, Δf of 40% of peak load is lower than Δf of 60% of peak load because change in loads is large by comparison with size of SG. Large change in loads, compared with size of SG, help frequency back to the normal state. In the case of 60% of peak load and the SG installed at bus #106, Δf varies with the size of SG. However, in the case of 40% of peak load, Δf is nearly the same during a load following period but it has an explicit distinction during a load rejection period. A profile of bus voltage is similar to a profile of Δf. Especially, in the same load condition, bus voltage when IG is large is lower than bus voltage when IG is small.

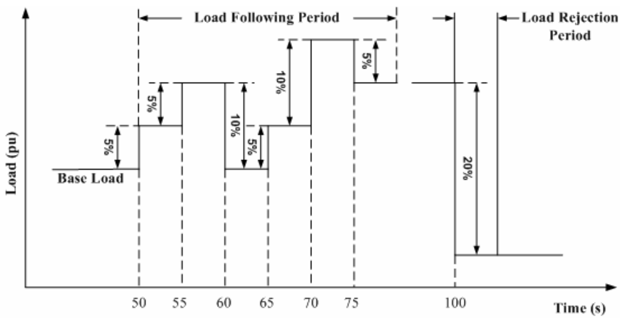


Fig.3 Load following and large load rejection pattern

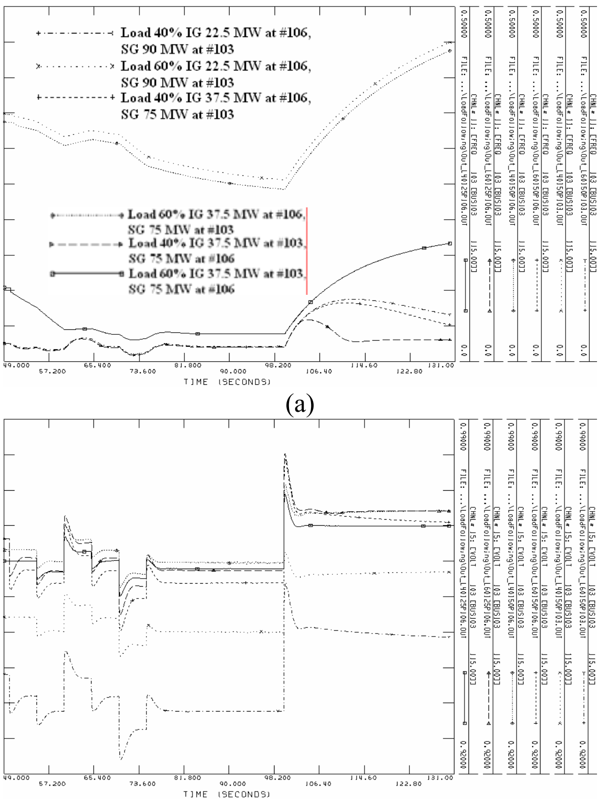


Fig.4 Load following and rejection performance of SG and IG operated in islanding mode of different load conditions (a) frequency deviation, and (b) voltage at bus #103.

Fault on Islanding Part

Impacts of faults on stability of DGs can be examined by investigating (i) whether the system is stable or not and (ii) the extent to which oscillation occurs. Fig.5 shows that the system is stable in all studied cases. Power outputs have small oscillation. In cases of low load, the oscillation is nearly the same but they approach to stead-state of system slower than higher load conditions.

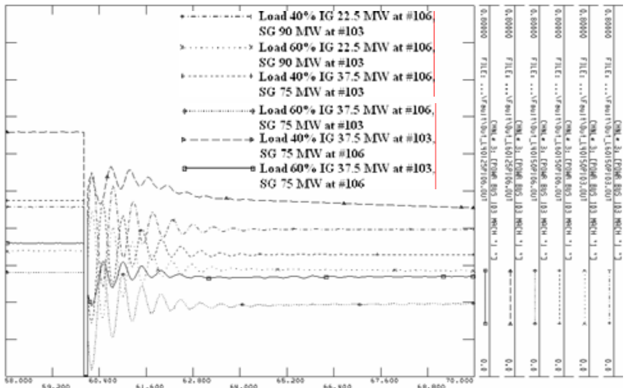


Fig.5 Power output of DG1 at bus #103 when fault at bus #101 for 5 cycles

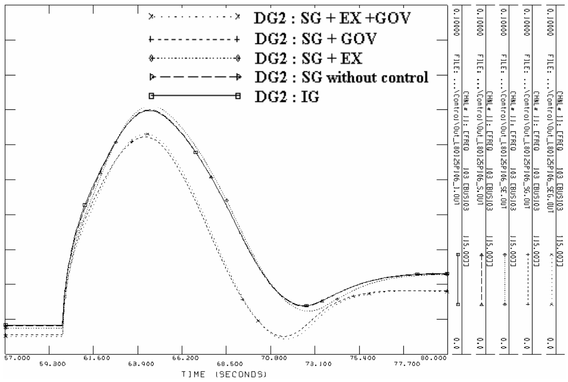
EFFECT OF OPERATING CONTROL MODES OF SG AND IG DURING ISALANDING OPERATION

In studying effect of operating control modes of SG and IG, comparative study is conducted. In this comparative study, SG and IG in the same size are installed at the same location and supply the same loads. The DG1 is the SG with exciter (EX) and governor control (GOV) whereas the DG2 is one of (i) the SG with EX and GOV, (ii) the SG with GOV, (iii) the SG with EX, or (iv) the SG without control and (v) IG. Fig.6 shows that the cases with governor control (i.e. the SG with EX and GOV and the SG with GOV) have lower Δf than cases without governor control because the GOV of DG2 support the frequency control of DG1. Cases with exciter control (i.e. the SG of the SG with EX and GOV and the SG with EX) have better performance of bus voltage than cases without exciter control. The case of the SG without control has lower Δf but higher bus voltage than the case of the IG.

CONCLUSION

Results of this study indicate that both a synchronous generator and an induction generator have significant impacts on intentional islanding operation. Sizes of SG and IG affect to frequency deviation and bus voltage. The SG has to be larger than the IG during islanding operation. A higher percentage capacity of SG has higher Δf and better bus voltage profile than the small one. Dynamic performances of two SGs are superior to the SG and the IG since the IG has no exciter and governor control. If the SG is installed close to loads, Δf is high but bus voltage profile is improved. During forming islanding operation, the higher difference between loads and generator capacity, the higher Δf. On the other hand, during a load following period low load condition has smaller Δf than high load condition.

In practice, islanding operation is depended on load conditions, protection scheme, and type of control of DG. It is necessary to perform a study of typical cases. Frequency variation and bus voltage resulted from the study have to be comply with acceptable ranges and standards.



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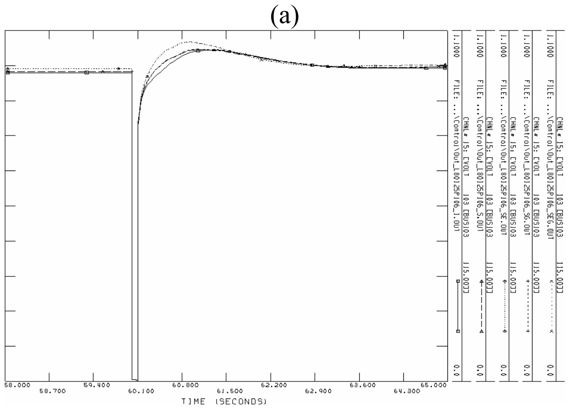

(b)

Fig.6 Dynamic performance of SG and IG when DG2 connected at bus #106 and fault at bus #101 for 5 cycles (a) frequency deviation, and (b) voltage at bus #103.

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