IMPACT OF LOAD CHARACTERISTICS AND LOW-VOLTAGE LOAD SHEDDING SCHEDULE ON DYNAMIC VOLTAGE STABILITY

Huawei Li
School of Electrical Engineering, Beijing Jiaotong University, Beijing 100044, China
email: mslihuawei@sohu.com

Yu Fan
School of Electrical Engineering, Beijing Jiaotong University, Beijing 100044, China
email: fany@dq.njtu.edu.cn

Tao Wu
North China Electric Power Research Institute, Beijing 100045, China
email: wutao@ncepri.cn

Abstract

The impact of load characteristics and the low-voltage load shedding schedule on dynamic voltage stability is studied for part of the power grid in Beijing. The research is conducted on a Real-Time Digital Simulation (RTDS) system and based on the projected data for the power grid in the Northern China Region. We show that under severe shortage of active power, the larger proportion of asynchronous motors in the total load is, the more likely voltage collapses; while the larger proportion of fixed impedance in the total load is, the more likely frequency collapses. Therefore, load characteristics has significant impact on the voltage stability. Proper application of the low-voltage load shedding schedule will improve the power grid stability.

Keywords: *Power grid; Dynamic voltage stability; Dynamic characteristics of load; Low-voltage load shedding schedule; Low-frequency load shedding schedule; RTDS*

1. Introduction

Blackouts in major power grids in Russia, North America and Europe were happened in recent years. They have been regarded as the result of voltage collapse. Therefore, voltage stability in load center power grids and technologies to improve power system security are studied widely [1~10].

The proportion of asynchronous motors in the total loads, over-excitation limits of generators and auto-regulator of transformers will affect on the voltage stability significantly. The low voltage load shedding schedule is one of procedures to prevent voltage collapse.

The Beijing power grid has to depend on outside power supply greatly because of resources and environments. As a result, the proportion of power supply from outside is main, which is likely to bring about voltage stability. Under severe conditions, if blackouts are happened in the power grid, the part or total of outside power supply will be shed, the severe shortage of active power will be brought about, which will make the pilot bus voltage and frequency decrease. Therefore, voltage or frequency collapses probably without any security schedules [1].

Applied on a Real-Time Digital Simulation (RTDS) system [7], the dynamic processes of voltage and frequency are simulated under the severe shortage of active power.

The main objective of this paper is to show the two different modes of collapse under severe shortage of active power depending on two load models, voltage collapse for load model 1 or frequency collapse for load model 2.We conclude that load characteristics has significant impact on the voltage stability.

The second main part in this paper is to compare and construct the low-voltage load shedding schedule and the low-frequency load shedding schedule. We conclude that proper application of the low-voltage load shedding schedule will improve the power grid stability.

2. Introduction to part of the power grid in Beijing

The normal power flow of the part of the power grid in Beijing is illustrated in Fig.1, based on the projected data for the power grid in the Northern China Region.

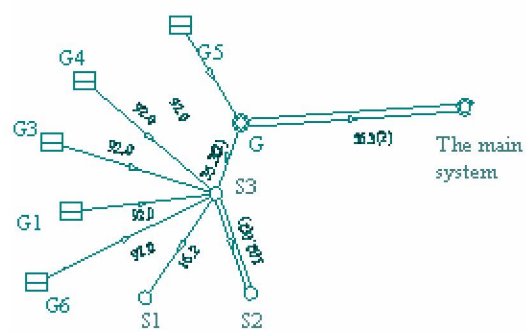

Figure 1. Power flow in part of power grid in Beijing.

Through two 220 kV lines, the part of power grid is connected to main power system and power flow is 56MW in the connection lines.

For the convenience of study, we assumed that the load rise to 720MW in the part grid while the power supply of local generators is only 420MW, so outside active power has to be 300MW.

3. The model of simulation for the part of the power grid

During the simulation, we apply exact models and parameters for excitation systems and governor systems and consider two kinds of dynamic load models, that is for model one, asynchronous motor is the main portion in the total load, and for another, the portion of fixed impedance is the larger, as shown in Table 1.

Table1 Two dynamic load models

Load models	asynchronous motor	fixed impedance
1	60%	40%
2	40%	60%

We used typical parameters for the asynchronous motor and assumed that:

1. Low voltage shedding of the motors is not considered;
2. The torque of asynchronous motors is constant and has no relationship with frequency.

During simulation, the low voltage load-shedding schedule is 12% of the total loads will be shed under the case when voltage is lower than 0.8p.u and lasts 0.5 seconds for 220kV pilot bus.

The low frequency load-shedding schedule is shown as Table 2:

Table2 Low frequency Load Shedding Schedule

The order of operation	Frequency value	Shed load
first	Lower than 49Hz	Postpone 0.2 seconds and shed 12% of total load
second	Lower than 48.75Hz	Postpone 0.2 seconds and shed 12% of total load
third	Lower than 48. 5Hz	Postpone 0.2 seconds and shed 12% of total load
fourth	Lower than 48.25Hz	Postpone 0.2 seconds and shed 12% of total load

4. The simulation of stability for the part of power grid

We assumed that the connection lines are opened suddenly, which makes the part of power grid be isolated to the main power system and therefore the shortage of active power is up to 300MW.

4.1. The impact of load characteristics on stability

We analyzed impact of the two load models on the stability of power system, including dynamic processes of voltage and frequency.

4.1.1 The dynamic process of voltage. The characteristics of loads will affect the dynamic process of voltage when the severe shortage of active power happens, as shown in upper Figure2.

For load model 1, when a fault happens, the pilot bus voltage decreases and slip of motors increases, therefore, the load absorbs reactive power greatly from power systems, which accelerates the process of voltage decreasing, as shown in “A” label curve upper Figure2.

For load model 2, when it is 2.6 seconds after a fault, the bus voltage maintains to 0.73p.u and does not decrease while restores a bit, as shown in “B” label curve upper Figure2.That is probably because active power of the fixed impedance load decreases quickly with respect to square to the bus voltage decreasing after a fault, which limits the speed of voltage decreasing.

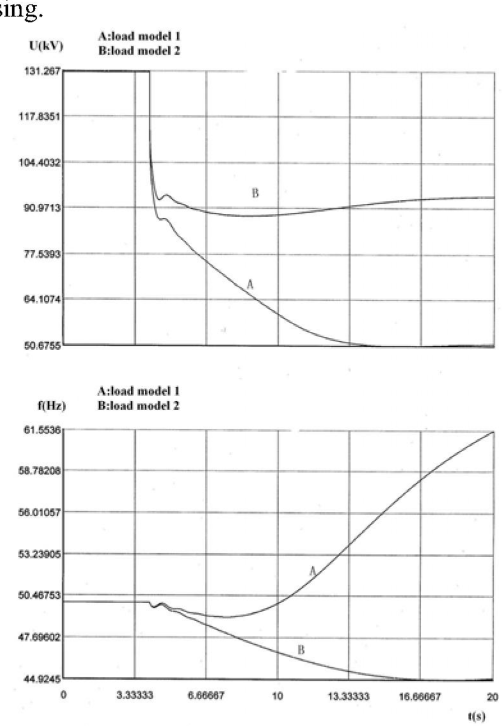

Figure 2. Voltage and frequency curves for two load models.

4.1.2 The dynamic process of frequency. For load model 1, frequency is down to 49.06 Hz when it is 6 seconds after a fault and then increases to 61.6 Hz rather than continues to decrease when it is 20 seconds after a fault, as shown in “A” label curve lower Figure2.Probably it is because total shortage of active power in the part grid decreases, even increases a bit under some critical conditions, which is caused by active power in fixed impedance decreases quickly with the bus voltage decreasing after a fault while active power in motors changes a bit.

Compared with load model 1, the voltage decreases not too much, as shown in upper Figure2.Therefore, the shortage of total active power exists still, which results in the frequency decreasing after a fault, as shown in "B" label curve lower Figure2.

Above all, we can conclude that under the severe shortage of active power, for load model 1(in which asynchronous motors are the main part), the voltage decreases more quickly while frequency increases rather than decreases in some critical conditions, and therefore, it is voltage collapse. At this case, the low frequency load shedding schedule will not be available because the first operation setting value is lower than the lowest value of frequency, 49.06Hz;for load model 2(fixed impedance is main part) frequency collapse, therefore, the low frequency load shedding schedule is available.

4.2. The low frequency load shedding schedule and the low voltage load shedding schedule

We compared and constructed impact of the two security schedules on stability, including the low frequency load shedding schedule and the low voltage load shedding schedule.

4.2.1 Applying on load model 1. Under the severe shortage of active power, if the low voltage load shedding schedule is applied only, the system is still unstable.

If both the low voltage and the low frequency load shedding schedules are applied together, the power grid has been stable, as shown in Figure3.

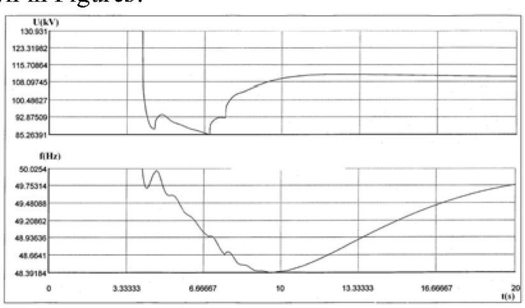

Figure3. Schedules of both low-frequency and low-voltage load shedding for load model 1.

The simulation shows that for load model 1 in which asynchronous motors are the main part, applying the low voltage load shedding schedule on the base of the low frequency load shedding schedule will improve the system stability.

4.2.2 Applying on Load model 2. Under the severe shortage of active power, for load model 2, frequency collapses, in this case, the low frequency load shedding schedule makes the power grid be stable, as shown in "A" curve of Figure4.

Applying both the low voltage load shedding schedule and the low frequency load shedding schedule, it is stable, as shown in "B" curve of Figure4.

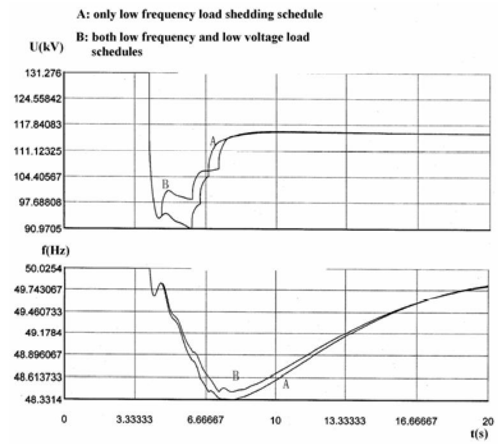

Figure4. Low-frequency load shedding schedule and Low-voltage load shedding for Load Model 2.

5. Conclusions

The load characteristics affects dynamic processes of voltage and frequency significantly. When the severe shortage of active power happened, the larger proportion of asynchronous motors in total load is, voltage decreases more quickly while frequency decreases slowly even increases in some critical conditions, therefore we say that the more likely voltage collapse. And the larger proportion of fixed impedance in total load is, frequency decreases more quickly while voltage decreases slowly, therefore we say that the more likely frequency collapses.

Under the severe shortage of active power, applying both two load shedding schedules makes the system stable for load model 1, in which the proportion of asynchronous motors in total load is main; applying only low frequency load shedding schedule makes the system stable for load model 2, in which the proportion of fixed impedance in total load is main.

In order to guaranty the effect of low voltage load shedding schedule, it is possible to test and statistics to obtain the load characteristics exactly for the part grid. And it must be identified by simulation that whether the low voltage load shedding schedule is applied or not and the whole quantity and setting values of the low voltage load shedding schedule.

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