Development of the Power Restoration Training Simulator for Jeju Network

Heung-Jae Lee* · Seong-Min Park · Kyeong-Seob Lee · In-Jun Song · Nam-Ho Lee

Abstract

This paper presents an operator training simulator for power system restoration against massive blackout. The system is designed especially focused on the generality and convenient setting up for initial condition of simulation. The former is accomplished by using power flow calculation methodology, and PSS/E data is used to set up the initial state for easy setting. The proposed simulator consists of three major components - a power flow(PF), a data conversion(CONV), and, a GUI module. The PF module calculates power flow, and then checks over-voltages of buses and overloads of lines. The CONV module composes a Y-Bus array and a database at each restoration action. The initial Y-Bus array is composed from PSS/E data. A user friendly GUI module is developed including a graphic editor and a built-in operation manual. The maximum processing time for one step operation is 15 seconds, which is adequate for training purpose.

Key Words : Operator training, Simulator, Black-out, Restoration, Primary restorative system(PRS)

1. Introduction

Due to a continued improvement of reliability, total blackouts occur less frequently in a modern power system. But the breakdowns tend to be very large once they occur, although the reliability might be good[1-2]. After the massive blackout, power system restoration has been achieved by the operator's expert knowledge and experience. Huge disturbances as well as damages to equipments under the restoration process can be caused if the blackout situation is not properly diagnosed by the operator or if there are some mistakes in the restoration process. Therefore, a quick and reliable diagnosis and restoration measures for the blackout are required.

Power systems of radial structure have higher possibility of the massive blackout than meshed structure. Operators in these systems have enough experience to restore blackout power systems. But as the massive blackout has not been occurred yet in Korea because Korean power systems are strongly coupled, so far Korean operators have not faced the total or massive blackout, and opportunities to improve ability handling emergency are decreasing gradually.

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Therefore, it is necessary to develop a restoration training simulator which can provide operators effective restoration training opportunity for the total or massive blackout, and aid them to restore the blackout power system quickly, confidently, and accurately[3-7]. This simulator can improve their ability to cope with the emergency. In general, widely used commercial power system analysis packages are used based on some scenario, so it is hard for the trainees to control the simulator arbitrarily under the simulation process.

In this paper, a restoration training simulator is presented for Jeju network. This system does not operate on the scenario base, but offer the operators discretionary control action starting from the arbitrary initial condition. Each restoration step and its results can be shown in reasonable time.

2. Functions of the restoration system

Lots of data are generally required to set up the initial state of power restoration systems. PSS/E raw data are used as the initial input of this simulator to raise reliability of the training system using accurate input data and to set up the initial state conveniently.

This system consists of the PF module which calculates power flow, and checks overloads and over-voltages, the CONV module which makes Y bus and compiles a DB using PSS/E raw data, and the GUI module which offers graphic environment to users for convenience. Configura- tion of the modules are shown in fig. 1. The DB and the GUI display can be modified based on PSS/E data when the power system configuration is changed. As illustrated in fig. 1, the system database consists of the DSK DB which is managed in file form and the DYN DB which is managed in memory for fast accessing and writing.

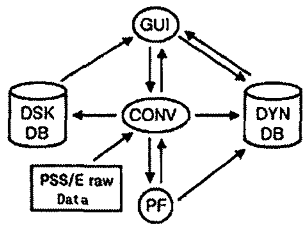

Fig. 1. Configuration of the simulator

Three major functions of the training system are as follows. First, Jeju network is shown at a window named KMView as a main display when the simulator starts up at first. This display can be changed to another one using display changing function. These displays are linked with each other as kmd files presenting power systems' graphic information share the DB, but there is an only main display in this simulator as Jeju island has small power system. Second, visual alarm can be displayed after simulating the results of various CB switching and control action. Over-voltages and overloads can be caused, and line charging capacity can exceed generators' reactive power capability when lines are energized to restore the power system. At this situation, the system can warn the operator using a visual alarm function and a pop-up window. Finally, reconnecting the restored subsystems with each other can be simulated. Restoration methods are largely of two types which are centralized downward and decentralized upward. The former requires lots of time for service restoration, and it is not suitable in case of wide area outage because economic loss and social confusion are increasing over-proportionally with the time of outage, so the latter is commonly adopted[8-11]. This method is reconnecting the subsystems after restoring each of them. The proposed training system can also simulate decentralized method, and reconnecting function can be used as loading *.cas files after saving restored subsystems' information to them.

2.1 Power flow algorithm to simulate reconnecting separate subsystems

The PF module solves power flow based on Y bus which the CONV module makes, and saves the results to the shared DB, so active/reactive power of each bus and overvoltage buses(yellow)/ overload lines(purple) can be displayed on the screen. A simulation result is shown in fig. 2. This system is a PRS of Jeju power system. The blackstart generator is started up setting the terminal voltage about 1[PU]. Both, an over-voltage and an overload occur, and the overvoltage is caused by Ferranti effect. This situation is not real, and the lower terminal voltage is used to consider Ferranti effect under the actual restoration procedure.

Gauss Seidel and Newton Raphson are numerical analysis methods to solve power flow. Gauss method has better robustness to the initial condition but slower convergence speed compared with Newton Raphson. On the other hand, Newton Raphson method has faster convergence speed, but it easily diverges depending on the initial condition or power system states. Gauss Seidel and Newton Raphson are used together in this system considering that simulation can be diverged easily because states of power system are bad under restoration procedure. Gauss Seidel is used to select the approximate initial value at first before Newton Raphson's iterations. The system converges well, and its results are good even though power system's states have big R-X ratio which is hard to be converged by Newton Raphson alone.

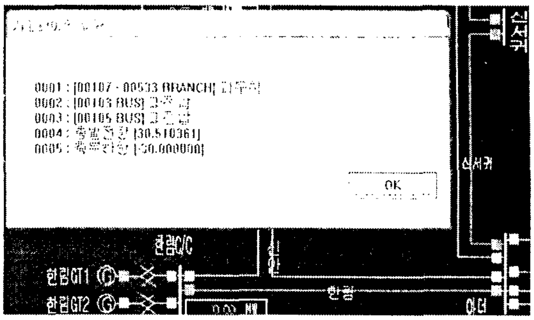

Fig. 2. Simulation results(overvoltage/overflow)

2.2 PSS/E data conversion module

The CONV module reads PSS/E raw data, and makes them DB form which is used in this training system. It exchanges data with the GUI and the PF modules, extracts necessary data from PSS/E raw data, and saves them to the DB splitting them into two kinds.

Data for solving power flow and results from it are accessed and modified frequently. Active/ reactive power, voltage, angle, on/off state, bus types(load, generator, slack), and components of Y bus belong to these data, and they are saved in the memory(DYN DB) for rapid access. Lasts of PSS/E raw data except them are related to power system configuration, and saved in the disk(DSK DB). The CONV module refers to the current shared memory (DYN DB related to buses and lines), and transfers simulation starting command to the PF process after making Y bus data which are saved in the shared memory.

2.3 GUI Module

The GUI module includes an editor which can modify the graphic information easily to provide users with convenience. Trainees can switch on/off lines, and regulate loads and generate power, then overvoltages and overloads can be displayed using power flow results of the PF

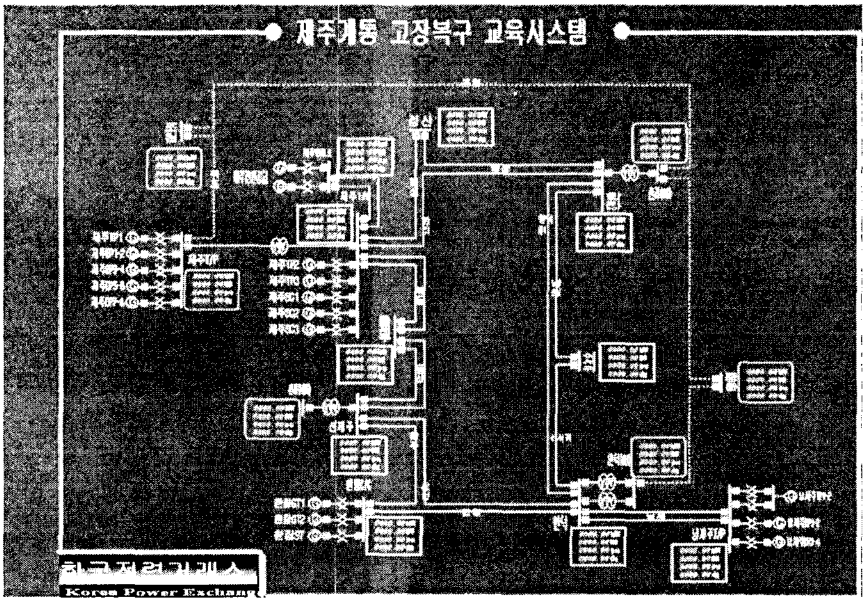

Fig. 3. Initial display of the simulator

module to make the system suitable for training environment. Some functions are provided for user convenience, and they work with icon clicking. For example, 'Undo' is for going to the previous step for searching new solution when overloads or overvoltages occur, and 'Run Mode' is for calculating power flow manually or automatically when a state of CB is changed.

Fig. 3 shows the initial state of the simulator based on PSS/E raw data, and this display of Jeju network can be constructed using the built-in graphic editor. Initializing of this system can be conducted as loading PSS/E raw data of Jeju network. The DB consists of analog and digital data. The analog DB is used for tap values of transformers, bus types(slack, generator, and load), and power flow results(active/reactive power, voltage, phase angle, overvoltage, and over reactive power capability of generators) and, the digital DB is for on/off state of each device. The color, size, mouse operation, etc. for graphic effect of each component can be set as shown in fig. 4.

3. Restoration case study

Accuracy of training system's algorithm is verified as comparing with the PSS/E simulation result for the 39 bus IEEE system[12].

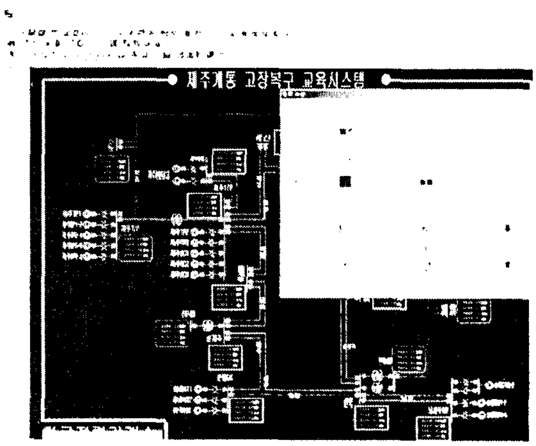

Fig. 4. Graphic editor

In this case study, total blackout of Jeju power system is assumed. The brief restoration process is as follows :

(1) Start up the black-start generator
(2) Energize the primary restorative line
(3) Energize the primary restorative generator which has big capacity
(4) Restore the system which is connected to the primary restorative system
(5) Finish the whole area restoration

Shown in fig. 5, JJ DP is a blackstart generator of the PRS in Jeju network, and its terminal voltage is set to 0.97[PU] to prevent overvoltages by Ferranti effect from occurring. HL GT is a primary restorative generator which needs cranking power and has big capacity. There is no problem energizing transmission lines of the PRS.

Finally restored Jeju power system and the pop-up result window are shown in fig. 6. total of 12 generators and 16 load buses are restarted and re-energized.

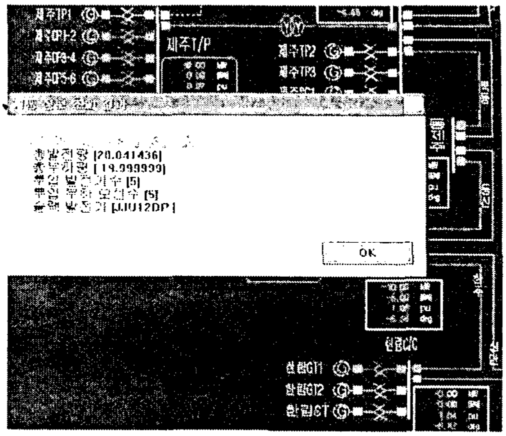

Fig. 5. PRS restoration of Jeju network

4. Conclusion

In this paper, an operator training simulator for Jeju power system restoration is presented. As commercial programs are hard to support black-out scenarios arbitrarily, some contingency analysis based preset scenarios are used to train operators to enhance their capability for

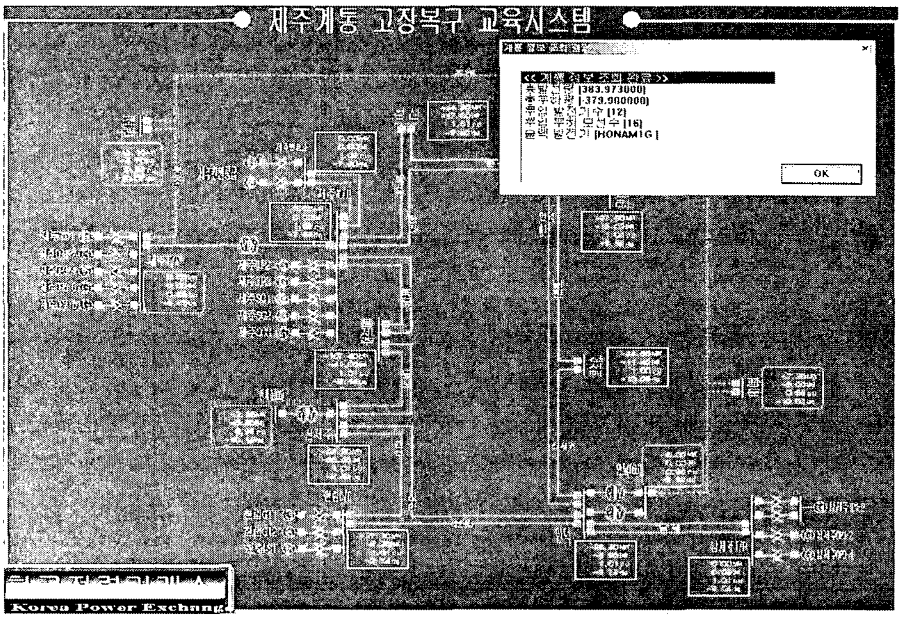

Fig. 6. Restoration of Jeju network

restoration process. Using the proposed system, arbitrary situation can be tested and simulation of an arbitrary control is possible in real time. Therefore, the proposed system can be used for operator support system as well as training system. Easy and user friendly GUI system is also developed, and the DB can be easily modified using built-in graphic editor. As a result the proposed system has shown promising performance.

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Biography

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