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Importance of Power Transfer Design with Bus Protection Logic in Nuclear Power Plants

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1. Introduction

In nuclear power plants, the safety buses have a role of supplying stable and vital power to essential loads and safety features. These essential loads and safety features perform their safety functions during design basis accidents in nuclear power plants. If the essential loads and safety features become inoperable due to loss of power, the risk of nuclear power plants is increased. One of the design methods to provide reliable and stable power is the power transfer which is to make a switchover from normal power source to alternate power source[1]. It is necessary to furnish the optimal power transfer design to prevent loss of power at onsite power bus and to minimize propagation of electrical faults. In this study, therefore, the importance of power transfer design with bus protection logic is analyzed by means of operating experience from recent event case in nuclear power plants.

2. Power Transfer

2.1 Power Transfer in Nuclear Power Plants

The power supply systems in nuclear power plants should be designed as a defence in depth to prevent loss of power supply to the safety bus. The defence in depth of power supply systems should consider all possible loss of power sources due to various electrical events and should consist of several levels of power sources to avoid loss of total power sources. If the normal offsite power supply circuit is not available due to electrical faults, the safety bus can be also supplied from physically and electrically independent alternate offsite power supply circuit. Power supplying from alternate offsite power source can be accomplished by the function of power transfer that is to make a switchover from CB #1(normal power circuit side) to CB #2(alternate power circuit side). The power transfer in nuclear power plants has a role of the first level design for the defence in depth of power supply systems

The overall sequential process of power transfer from fault initiation to circuit breaker actuation are shown in figure 1. The power transfer time is defined as the interval between opening time of CB #1 and closing time of CB #2. The time of power transfer should be conducted as short as possible to minimize electrical transients of power bus and impact on related loads. The transfer time is normally required within 10 cycles in accordance with ANSI Std. C50.41[2].

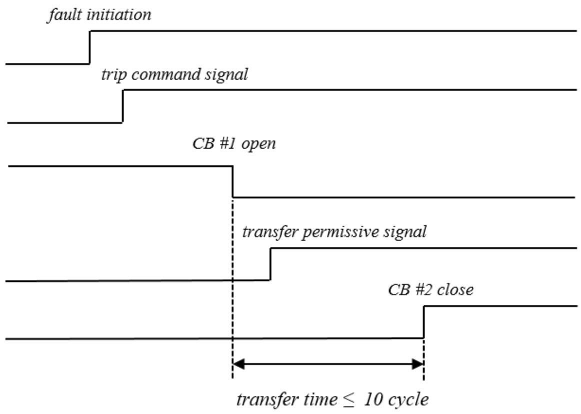

Fig. 1. The sequential process of power transfer

2.2 Bus Protection Logic in Power Transfer

To make a successful power transfer, various factors in power transfer design should be considered. As seen from figure 2 that represents the logic diagram for power transfer design, the successful power transfer which is the all logic completion for CB #2 close should be satisfied with various factors as well as CB #1 open conditions. The various factors to accomplish power transfer can be determined by design conditions of power systems and by changed system conditions due to electrical faults.

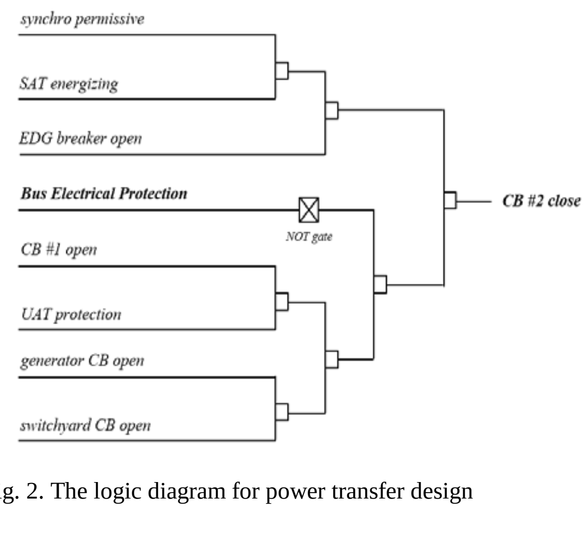

Fig. 2. The logic diagram for power transfer design

With regard to Bus Electrical Protection logic in figure 2, the design of power transfer in several old nuclear power plants has not reflected the bus electrical protection logic because the power system designer decided that the design of power transfer fulfilled the purpose to make fast bus re-energizing and to minimize impact on related loads. In case of typical electrical faults on feeder or equipment in power systems, the power transfer can accomplish a stable power supply to the bus without influence of faults. However, as for the electrical faults on bus, healthy power systems can be electrically connected with the faulted conditions even though power transfer is conducted. The power transfer design without bus electrical protection logic can result in the propagation of electrical faults to the healthy power systems including alternate power supply circuit.

As depicted in figure 2, the Bus Electrical Protection logic is a significant factor in the power transfer design. If an electrical fault occurs on bus, the logic circuit for CB #2 close cannot be completed by zero logic signal through NOT gate shortly after generating logic signal of Bus Electrical Protection. The Bus Electrical Protection logic in logic diagram of power transfer can obviously prevent the propagation of the fault as a power transfer block. Therefore, it is necessary to reflect bus protection in power transfer design to prevent propagation of electrical faults and to accomplish successful power transfer.

3. Case Study

3.1 Power System Configuration

In case study, a recent nuclear event resulted in loss of all offsite power and reactor trip is verified due to the absence of bus protection at power transfer design in K nuclear power plant. As illustrated in figure 3, the power system for K nuclear power plant is simplified.

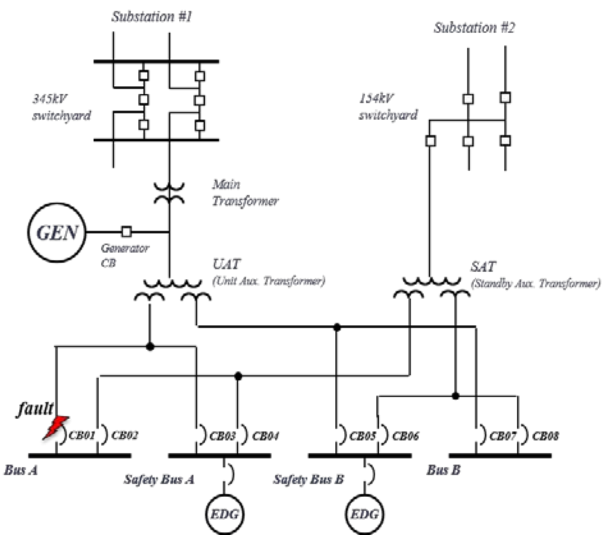

Fig. 3. The power system configuration for case study

3.2 Result of Case Study

To demonstrate the importance of power transfer design with bus protection logic from the event case, the analysis for fault current data of faulted bus and circuit breaker actuation related to power transfer at the sequence of event is performed. Due to arcing fault on the breaker of bus A in figure 3, all corresponding breakers(CB01, CB03, CB05, CB07) were opened. And then, all corresponding breakers(CB02, CB04, CB06, CB08) in response to logic formation of power transfer were closed. This resulted in accomplishment of power transfer from normal power supply circuit to alternate power supply circuit. The vacuum contact of faulted circuit breaker due to arcing fault was in the open condition in response to the protection signal. However, the faulted circuit breaker electrically linked with the bus A because of the conductive environment within enclosed circuit breaker by arcing carbide, which is the electrical fault on bus A was maintained. The power transfer in this situation caused the propagation of fault current to alternate power supply circuit.

If the design of power transfer for bus protection had been reflected, the fault current on bus A could not have been propagated to alternate power supply circuit. As experienced from this event case, the power transfer design without bus protection can lead to the loss of all offsite power including alternate power supply circuit because of the propagation of fault current. Therefore, from the results of event case study, it is important to sufficiently consider bus protection in power transfer to prevent the loss of all offsite power and the propagation of fault current on bus.

4. Conclusions

This paper has conducted the analysis to demonstrate the importance of power transfer design with bus protection logic through the operating experience from recent event case in nuclear power plants. From the event case study, it has been found that the power transfer without bus protection was able to result in the loss of all offsite power, not only normal power supply circuit but also alternate power supply circuit, due to the propagation of fault current. The significance for power transfer design with bus protection logic has been verified to accomplish the successful power transfer.

REFERENCES

[1] IEEE Standard for Preferred Power Supply(PPS) for Nuclear Power Generating Stations(NPGS). IEEE Std. 765-2006, Oct. 2006.
[2] American National Standard for Polyphase Induction Motors for Power Generating Stations. ANSI C50.41-2000.