# A Study on Improvement of Operator's Measures for Abnormal Occurrence of Main Feed Water pump

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## 1. Introduction

For the past 20 years, there were 14 case of reactor shutdowns have occurred by low levels of the steam generator, and most operation experiences have been applied for improvement of operator's urgent action procedure of the operation procedure.

However, in case of the main feed water pump is shutdown during operation of one main feed water pump at reactor low power (30% or less) and the main feed water pump recirculation valve is abnormally opened during normal power operation., the operator's urgent action procedure is different from plants to plants, not clearly stated. even some plants have not proper procedures for those situations.

These deficient or absence of procedures increase the possibility of reactor shutdown by steam generator low level.

## 2. Methods and Results

The simulation of the shutdown of main feedwater pump during reactor low power operation (30% or less) was performed on CASE A (turbine manual shutdown and control rods manual insertion) and CASE (turbine manual shutdown and Reactor Power Cutback System (RPCS) manual actuation). The simulation of abnormal opening of main feedwater pump recirculation valve during normal power operation was performed on CASE A (sharp decrease in turbine power to 400MW at 64% (WR) of the steam generator level) and CASE B (manual shutdown of the main feedwater pump at 60% (WR) of the steam generator level).

### *2.1 Simulation of Main Feedwater Pump Stop during Reactor Low Power Operation (30% or less)*

The performing results of CASE A (turbine manual shutdown and manual insertion of control rods) and CASE B (turbine manual shutdown and Reactor Power Cutback System (RPCS) manual actuation).

CASE A : 4 minutes and 36 seconds after shutdown of the main feedwater pump, the level of the steam generator decreased to 48% (WR) which is about 5% higher than reactor shutdown setpoint by steam generator low level (42.8% WR) then began to be increased by operator's action. The simulation result is Fig. 1

CASE B : About 3 minutes after the main feedwater pump shutdown, the level of steam generator has decreased to 60% (WR) which is about 18% higher than reactor shutdown setpoint by steam generator low level (42.8% WR) and then began to be increased by operator's action. The simulation result is Fig. 2

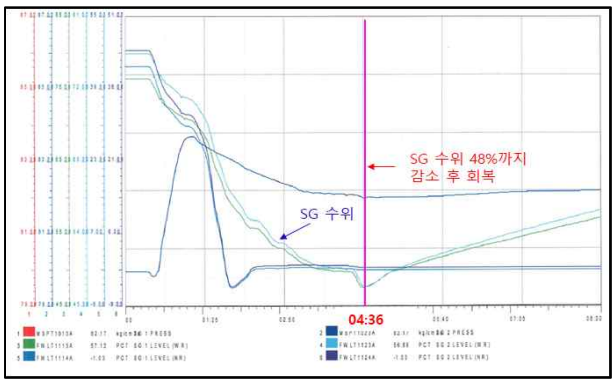


Fig. 1. CASE A : Manual insertion of the control rods

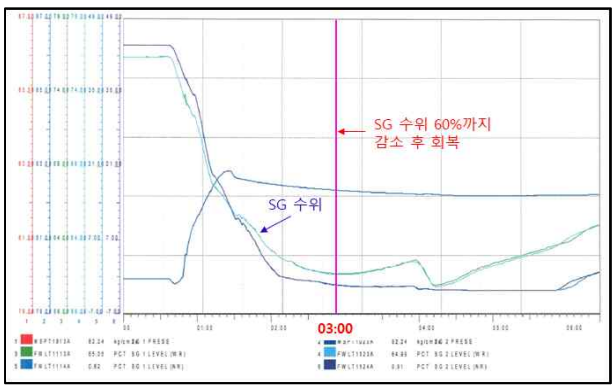


Fig. 2. CASE B : RPCS Manual actuation

Results of the simulations of the main feed water pump shutdown during the reactor low power (30% or less) confirms as follows.

CASE A (turbine manual shutdown and control rods manual insertion) : Because the steam generator level decreased to 48%(WR) which is just 5% higher than the reactor shutdown setpoint by the steam generator low level(42.8%, WR), the operator's action has to be immediate and accurate to prevent the reactor shutdown.

CASE B (turbine manual shutdown and Reactor Power Cutback System (RPCS) manual actuation) : Unlike CASE A, the level of the steam generator decreased to

60%(WR), which is about 18% higher than the reactor shutdown setpoint by steam generator low level (42.8%, WR). Also, it didn't take long time to recover the steam generator level. This means CASE B's action procedures have much lower risk of the reactor shutdown.

In case of the main feed water pump shutdown at the reactor low power, based on the simulation results, it is highly recommended to change the current operator's urgent action procedures to CASE B's action procedures.

### *2.2 Simulation of Recirculation Valve Open During Normal Power Operation*

The performing results of CASE A (sharp decrease in turbine power to 400MW at 64% (WR) of the steam generator level) and CASE B (manual shutdown of the main feedwater pump at 60% (WR) of the steam generator level).

CASE A : After abnormal opening of recirculation valve, even if the operator decreased immediately turbine power to 400MW, the feedwater flow rate was reduced due to opening of recirculation valve. The reactor was shutdown by steam generator low level (WR 42.8%) and it took 2 minutes and 29 seconds from turbine power decrease to the reactor shutdown. It was failed to recover the level because of steam pressure increase and shrinkage of feedwater. The simulation result is Fig. 3

CASE B : Right after the Reactor Power Cutback (RPCS) was actuated by manual shutdown of the main feedwater pump, the selected control rods group by RPCS was inserted into the reactor in one to two seconds to decrease the reactor power at the same time. Turbine setback/runback system is actuated for sharp decrease of turbine power. Despite feedwater flow reduction by opening of the recirculation valve, increase of the steam generator pressure by turbine power decrease and feedwater shrinkage phenomenon, steam generator level started to increase from 50.3% (WR), 29 seconds after manual main feedwater pump shutdown. The simulation result is Fig. 4

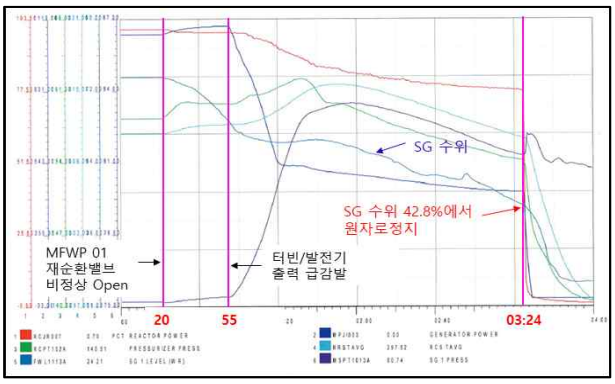


Fig. 3. CASE A : Sharp decrease in turbine power to 400MW at 64% (WR) of the steam generator level

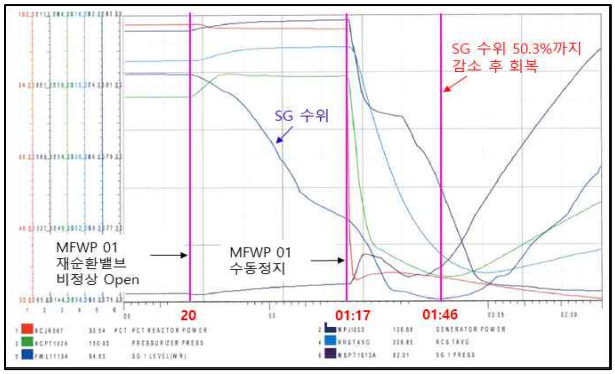


Fig. 4. CASE B : Manual shutdown of the main feedwater pump at 60% (WR) of the steam generator level

The simulation results of abnormal open of the recirculation valve of one of the main feedwater pumps during normal power operation confirms as follows.

CASE A (sharp decrease in turbine power to 400MW at 64% (WR) of the steam generator level) :
The simulation results of CASE A have shown that operator's actions can't prevent the reactor shutdown by steam generator low level.

CASE B (manual shutdown of the main feedwater pump at 60% (WR) of the steam generator level) :
On the other hand, The simulation results of CASE B proved possible to prevent the reactor shutdown with quick restoration of steam generator level through manual main feed water pump shutdown causing the reactor and turbine power decrease by immediate control rods insertion by Reactor Power Cutback System (RPCS) actuation and operation of turbine setback/runback system actuation.

As a result, the reference level of the steam generator (60%, WR) shall be specified in the procedure for manual shutdown of main feedwater pump.

## 3. Conclusions

The operator's urgent action procedure for main feed water pump shutdown at the reactor low power (30% or less) will be improved as starting Startup feedwater pump after manual turbine shutdown and manual actuation of Reactor Power Cutback System (RPCS), rather than decreasing the reactor power by manual insertion of control rods.

The operator's urgent action procedure for abnormal recirculation valve of one of two main feedwater pumps during normal power operation will be improved as follows.

When steam generator level decreases to 60% (WR), immediate manual shutdown of the main feedwater pump is needed to decrease the reactor power and turbine power by actuating Reactor Power Cutback System (RPCS) and the turbine setback/runback system. The reference level of the steam generator (60%, WR) shall be specified in the procedure for manual shutdown of the main feedwater pump.

It is hoped that improved procedures developed through the simulations will be applied to operator's procedures to prevent the reactor shutdown and to contribute to safe operation of the plant to help restore public trust in nuclear power.

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