Automatic Load Transfer in Nuclear Power Stations: A Case Study of India
S. P. Panda, N. Sankaranarayanan, K. Jagannath

Abstract—Nuclear power plant has a provision of two independent sources of power for its in-plant auxiliary loads required for the operation of plant. These loads include high inertia, large capacity motors such as primary coolant pump-motor, condenser cooling water pumps; boiler feed pumps, condensate extraction pumps etc. Two sources of power are meant for increased reliability of power supply to the plant. One of these feed two buses through Unit Transformer (UT) taking its incoming supply from either the generator or Grid while the rest two buses are supplied directly from the grid through Start-Up Transformer (SUT). In case, one of these two supplies fails, the buses are restored through the other healthy source by closing the tie circuit breakers. This is termed as Automatic Load Transfer (ALT). In this paper the existing set up for load transfer is analyzed and the optimal settings are prescribed for the safe and successful load transfer based on experience. Actual load transfer data and trends obtained from Kaiga Atomic Power station-1&2 are presented for study.

Index Terms—Automatic Load Transfer (ALT), Nuclear Power Plant (NPP), shaft torsional torques

I. INTRODUCTION

Transfer of induction motors connected to the buses from one power supply to the other can cause abnormally high inrush currents and shaft torques depending on the motor residual voltage magnitude, phase angle between the motor residual voltage and incoming power supply voltage, and phase relationship between oscillating shaft torque and transient electrical air gap torque at the time of energisation. Motors are subjected to large oscillations following rapid reconnection of another supply of unknown characteristics. Motor inrush currents and shaft torque are the two important considerations for specifying the allowable residual voltage and angle at the time of re-energisation during transfer. Predicting these parameters becomes difficult while dealing with multiple motor loads with different electrical and mechanical characteristics. If the reconnection is done in an unfavorable instant the shaft torsional torque may exceed the allowable value for the shaft, which may lead to break down of the shaft. Failure of ALT following any disturbance with either of the two independent sources, affects the reactor operation and other cascading effects.

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II. SYSTEM DESCRIPTION

The auxiliary power supply scheme in nuclear power plants is divided into two groups’ viz. group-A and group-B. The two groups are physically separated and electrically isolated [5] to meet the basic requirement of class 1E system. As shown in fig. 1 the 6.6 kV buses AB and GH are supplied from two secondary windings of SUT and buses C and F are supplied from two secondary windings of UT. In case either SUT or UT is out of service then appropriate breakers close to change over the supply. The motors connected to the disconnected bus are reconnected to the other source.

Fig. 1. Kaiga NPP 6.6 kV Single Line Diagram

III. GENERAL

Bus transfer schemes are generally divided into three types [2] based on timing: parallel (hot) transfer, fast transfer, and delayed transfer. Based on the operating criteria, the delayed transfer is further divided as residual transfer and in-phase transfer. The bus transfer scheme adapted in most of the Indian PHWR can be classified as fast, sequential and supervised. It is called sequential and supervised because it selectively allows or blocks the fast transfer under actual measured conditions. Based on operational practices, for smooth auto transfer the phase angle difference between the running (de-energized) and incoming buses adapted is maximum 60 degrees and minimum voltage of the running bus is taken as 70%. The time window for fast transfer specified is 200ms from the instant of UT/SUT out going breaker opening. All these transfers and other supervisory activities are performed by a dedicated microprocessor based system for up coming NPPs. It can be programmed based on system needs.
IV. LOAD TRANSFER CASE STUDIES

a) Case-1: Successful ALT

![Image](6.6 KV bus Voltage details during tripping of SUT)

![Image](6.6 kV bus Voltage and phase angle difference between bus D2 and E2 during ALT)

**Fig. 2** 6.6 kV bus Voltage details during tripping of SUT

**Fig. 3** 6.6 kV bus Voltage and phase angle difference between bus D2 and E2 during ALT

**Case-2: Unsuccessful ALT**

![Image](6.6 kV bus Voltage details during tripping of SUT)

**Fig. 4** 6.6 kV bus Voltage details during tripping of SUT

![Image](Fig. 5 Phase angle difference between bus E2 and Bus F during ALT)

**Fig. 5** Phase angle difference between bus E2 and Bus F during ALT

### TABLE I

<table>
<thead>
<tr>
<th>Serial No.</th>
<th>Load name</th>
<th>Rated Power (kW)</th>
<th>Full load PF</th>
<th>$\frac{T_{\text{max}}}{T_{\text{norm}}}$</th>
<th>Slip %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Primary Coolant Pump</td>
<td>2800</td>
<td>0.88</td>
<td>2.3</td>
<td>1.26</td>
</tr>
<tr>
<td>2</td>
<td>Condensate extraction pump</td>
<td>720</td>
<td>0.89</td>
<td>2.5</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>Boiler feed pump</td>
<td>1450</td>
<td>0.9</td>
<td>2.1</td>
<td>1.03</td>
</tr>
<tr>
<td>4</td>
<td>Condenser cooling water pump</td>
<td>465</td>
<td>0.74</td>
<td>2.1</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>HPAC auxiliary pump</td>
<td>375</td>
<td>0.85</td>
<td>2.66</td>
<td>0.86</td>
</tr>
<tr>
<td>6</td>
<td>Primary feed pump</td>
<td>350</td>
<td>0.88</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>Centrifugal chiller</td>
<td>435</td>
<td>0.9</td>
<td>3.5</td>
<td>0.53</td>
</tr>
<tr>
<td>8</td>
<td>Active LPPW pump</td>
<td>390</td>
<td>0.85</td>
<td>2.4</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**V. DISCUSSION**

As observed from Fig. 2 and Fig. 3 and the plant records the rms voltage at bus- AB dips to 73% and phase angle difference is 30.51° and ALT is successful in group-A

Similarly as observed from Fig. 4 and 5 and the plant records, the voltage at bus E2 has dipped to 64% and the maximum phase angle difference is 54.53° and subsequently the ALT is unsuccessful in group-B. Bus-E2 voltage dies down rapidly after failure of ALT.

**VI. CONCLUSION**

Even though Bus-AB and bus-GH are disconnected from the same source and connected to the UT, ALT is successful for Bus-AB where as it fails in case of Bus-GH. The voltage dip after disconnection from source depends entirely on the characteristics of motor and loads connected to the respective buses. After examining the details of motors (TABLE I) operating at that instant it is observed that few motors connected to bus-GH have small open circuit time constant, which is one of the reasons for rapid fall of voltage in that bus. Allowing voltage dip to some lower value and the angular difference accordingly to a higher value, provided the torsional shaft torque is within acceptable limit may solve the problem of ALT failure.
REFERENCES

[1] DTR report on Kaiga Nuclear Power Plant Unit-1 trip during the grid disturbances on 7-11-2005


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