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Study Committee SC-A1 | PS 3 – DEVELOPMENTS OF ROTATING ELECTRICAL MACHINES AND OPERATIONAL EXPERIENCE

FAILURE OF LARGE TURBO-GENERATOR DURING FIRST RUN- CASE STUDY OF INDIAN POWER UTILITY

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SUMMARY

This paper shares a case study of recent major failure of large generator initiated from cooling blockage of stator winding connections to bushing. The experience shared in this paper is from NTPC Ltd, a leading power sector utility having a large fleet of more than 200 Generators of different sizes and manufacturers in range of 100MW to 800MW (Fig.1). It is pertinent that the Generators should give long uninterrupted service during and beyond the expected design life. The business model of the Utility is entirely dependent on the availability and reliable operation of generating units. Small outages are acceptable but a failure causing a long outage puts severe financial burden on utility. It has been estimated that the cost of outage in some cases far exceeds even the cost of a brand-new Generator itself. Repair options have also found to be exorbitantly expensive.

As discussed, it is utmost important for commissioning team to ensure that every step is taken with due care as per Operation and maintenance manual, even a minor ignorance can lead to catastrophic failure. Paper suggests monitoring of connecting bus bars to avoid such occurrence in future.

KEYWORDS

Phase Connectors (PC), Phase Rings (PR), Connection Rings (CR), Connection Bus-Bars (CBB), Phase Connection Bus-bars (PCB).

CASE STUDY

This 800MW unit generator have star connected windings (with two parallel star circuits) and star point is formed outside the generator. Corresponding to each phase winding two terminals are taken out of the generator frame. Six (6) terminal bushings are available outside the generator frame. Out of six (6), three form the star point at neutral end and the other three terminal bushings are connected to line side, from where the power output is taken.

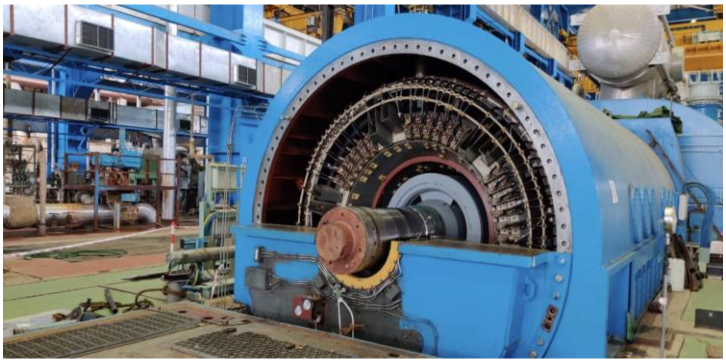

Fig.1 A large generator from the Utility's fleet

Fig.2 Detailed view of flexible droppers from CBBs to Bushings.

If an observer travels along the generator phase bushing towards inner side of the turbogenerator, then observer first reaches the flexibles (Fig.2) connecting the terminal bushing to phase rings and next stop before reaching the actual winding conductor is large circuitous phase connection ring. Six such circuitous paths i.e. six phase rings connecting the winding to six number generator bushings can be seen inside the machine.

Different manufacturers use different terminology to describe these high current carrying connection rings. The term CBB is used here to describe phase rings and its arrangement in this paper. These CBBs in this 800MW generator are Hydrogen cooled (Fig.3a and 3b).

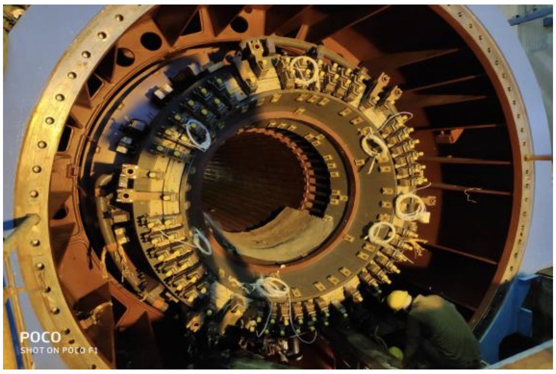

Fig.3a End winding portion of Generator. CBBs can be seen
Fig.3b Another view of CBBs

Generator bushing connection being located at the bottom, the flexible connections besides thermal stress experience high environmental stress due to presence of dust, grease and contamination. Specific issues with CBBs have been insulation abrasion due to rubbing and grease formation. This phenomenon is common among other similar machines.

The present case of trouble with CBBs is unique and a learning experience. It has come out as an area of concern which needs to be addressed. It is pertinent to state here that the response of OEM (Original Equipment Manufacturer) to the needs of utilities has tremendous scope for introspection and improvement.

DESCRIPTION OF EVENT

The Generator tripped on earth fault and after several iterations the fault was traced to CBBs. In the CBBs, overheating had occurred, and insulation failed at several locations (Fig.4). The root cause analysis revealed obstruction in the Hydrogen cooling path.

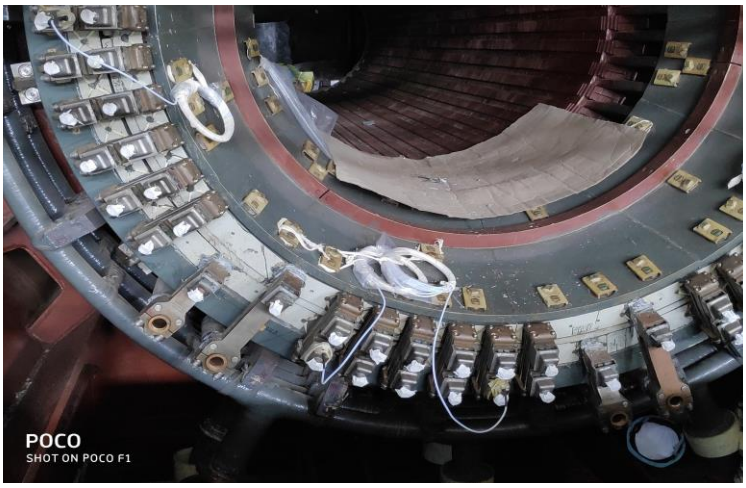

Fig.4 CBBs of the case study. Hydrogen entry path openings in CBBs can be seen

During inspection, it was observed that the packing envisaged by factory included plugs (caps) at the entry points of cooling gas to CBBs to avoid foreign material ingress during transportation and erection at Site (Fig.5). These caps were supposed to be removed before boxing up the Generator. This activity was missed out. Blocked cooling caused severe thermal stress to CBB insulation during the initial operation.
As there is no instrumentation envisaged for monitoring, alarm or tripping, the above problem went undetected. The CBB insulation got charred at several places (Fig.6).

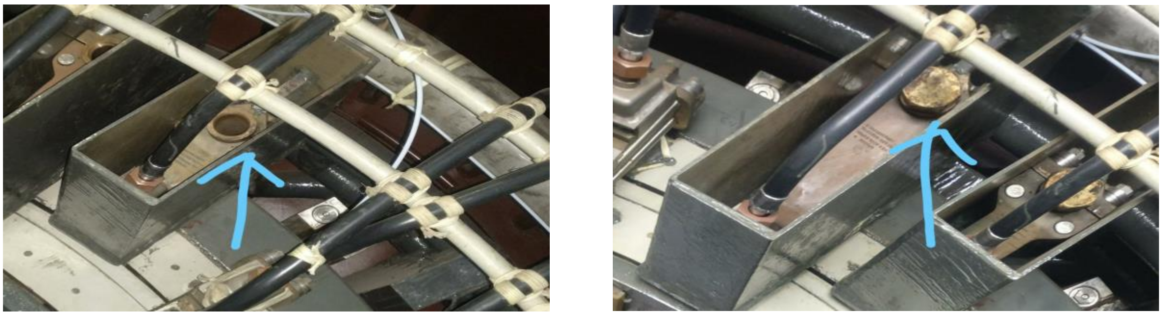

Fig.5 Hydrogen cooling entry point (LHS) and temporary plug (RHS)

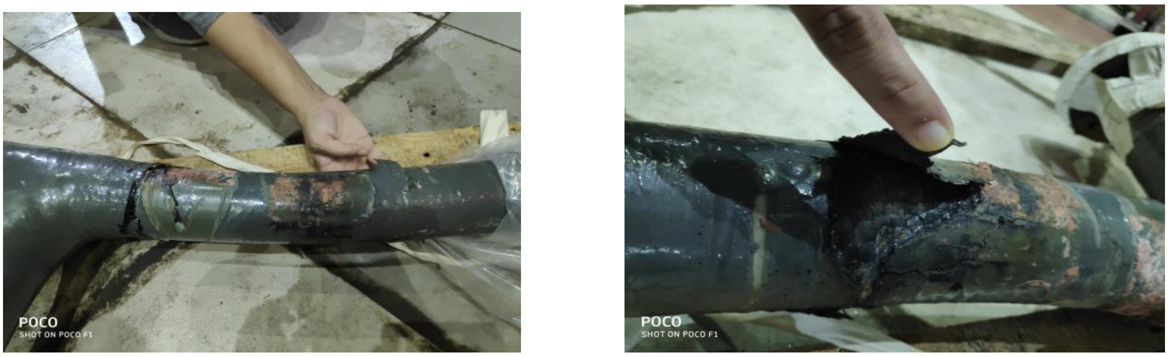

Fig.6 Detailed view of charred CBBs.

REMEDIAL MEASURES
It is worth to mention that the CBB experiences a very high thermal as well as mechanical stress and is not being generally monitored in large generators. A simple air-flow check by blowing clean air into one end of the CBB and feeling at the other end by hand to ensure clear passage to gas (suspecting a foreign material incursion) might have alerted the staff (Fig.7). Now, OEM has provided temperature monitoring by fixing duplex RTDs on each phase and neutral side CBB and the same shall be followed in future to monitor this critical part of generator winding. Field checks have also been introduced.

The erection, commissioning and design provisions need to be well integrated to avoid catastrophic failure of capital-intensive equipment like turbogenerators. It also emerges that due care should be taken at each pre-defined stages of Generator preparation prior to putting it into operation. Such catastrophic failures can be avoided by arranging training sessions by OEM and ensuring that trained personnel are involved in commissioning of generators.

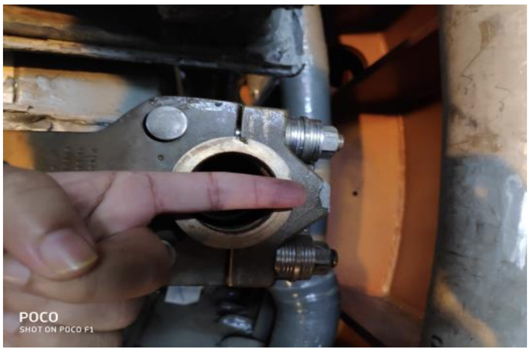

Fig.7 A simple check to ensure free passage of cooling path.

In CBBs, to facilitate optimum performance of high conductivity phase connector carrying 20 kA to 25 kA current, it is necessary to have optimum cooling circuit design for them. CBB are usually hydrogen or water cooled. All current carrying circuits in turbogenerator before CBB carry only part of the total rated current. However, CBB's are the point of exit from turbogenerator providing path for total generator current. A constrained setup of CBB can be better understood by comparing CBB (40 mm inner diameter hollow copper conductor) with Isolated Phase Busducts (768 mm inner diameter hollow aluminum conductor, though air cooled) which connects generator with generator step-up transformer which also carries the rated current but is considerably bigger in size with respect to dissipation of heat.

LEARNINGS

The learning from above failure suggests implementing advanced generator monitoring which can avoid such failures in future machines. Also following preventive measures can be taken:

i) OEM supervision of commissioning is very essential. Commissioning documents should be reviewed and updated to indicate criticality of each activity involved to make the machine ready.
ii) OEM to take Utility feedback regarding machines commissioning issues and accordingly improve upon the design.
iii) Proper training of operation staff is to be given.
iv) Coordination between owner and OEM team is very important.
v) Instrumentation for monitoring to be developed (CBB temperature monitoring in the present case).

Simultaneous occurrence of above issues sometimes may lead to major failures at initial stage of machine operation. It may be noted that several Generators where proper commissioning instructions are defined and implemented, continues to provide reliable service even after being in operation for more than 25-30 years.

CONCLUSION

The paper discusses a major failure of turbo-generator due to blocking of cooling of CBB. Such failures could be avoided by proper instructions in commissioning procedures indicating the criticality of each step involved in making the unit ready. It is important to note that the CBB experience a very high thermal as well as mechanical stress and therefore thermal monitoring of CBB is of utmost importance. Most common practice being followed to monitor the health of generator is to schedule the minor and major inspections. However, the timely detection of fault in CBB is not addressed in presently available schemes. Outage of three months due to the failure of 800 MW machine had resulted in huge revenue loss, to the tune of 100Millions USD. Case study discussed in this paper makes it amply evident the need for online condition monitoring of CBB's in large-turbo generator which is not the standard feature as of today with many leading generator OEM's. The national and international standards also need to address this issue of defining advanced monitoring systems for CBB, to avoid catastrophic failures of turbogenerators, as it greatly affects the utilities.