Engineering change management during replacement and up-gradation of reactor systems of Dhruva

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ABSTRACT

Dhruva, 100 MW_{th}, tank type research reactor has been operating since 1985 at Mumbai, India with maximum thermal neutron flux of 1.8 X 10^{14} $n/cm^2/sec$. Natural metallic uranium is used as fuel and heavy water as coolant, moderator and reflector. The reactor has been well utilized for over 27 years with high availability and excellent safety record.

Initial design of SSCs of Dhruva was carried out with stringent specifications and strict quality control to assure safe and reliable operation for the entire service life. During operational phase, a well formulated in service inspection and surveillance programme has been put in place to provide timely feedback on the healthiness of systems, structures and components (SSC) important to safety. Based on systematic in-service inspection (ISI) programme, insights from regular surveillance programme and structured system performance monitoring & review, certain incipient degradations in the reactor systems could be noted in time and replacement of certain systems/components, like secondary coolant heat exchangers, certain portion of emergency cooling water pipelines have been undertaken.

Technological obsolescence has necessitated some of the replacement/upgradation actions for power supply and controls & instrumentation systems of the reactor. Replacement of 150 kVA class II MA set with 250 kVA MA set, upgradation of 20 kVA class II inverters, complete up-gradation of control room and fuelling machine instrumentation was taken up, without significantly affecting the reactor availability.

While implementing these changes in the reactor systems, although the initial and the final system configuration were well analyzed and well established, during the transition phase adequate care had to be exercised in order to ensure that the system configuration does not lead to an unsafe state, taking into account various possible failures in the system under commissioning. Further, in order to ensure this requirement, the system change protocol followed a multitier review and approval procedure with adequate quality control during execution of these changes.

This paper provides an overview of engineering change management during replacement and up gradation of the reactor components/systems of Dhruva.

1. Introduction

Dhruva, 100 MW_{th} research reactor was commissioned in 1985. Having completed a trouble free service life of over two and half decades at an average availability factor of 75%, certain changes were undertaken on many systems, structures and components (SSC) important to safety to ensure continued high availability, safety and reliable operation of the reactor.

Necessity for changes were brought about by a number of drivers such as: ageing, technological obsolescence, performance degradation etc.

In reactor systems, the rewards for changes are great, but the cost of failure is also great [1]. When changes are well managed, they resulted in significant improvements in operating life, efficiencies, and in overall safety, in many nuclear installations [2]. Failure to manage change well can adversely affect the reactor systems. Reactor systems are complex, and it is inherently demanding to foresee all the implications that a change may have. There is an array of important factors to be considered when undertaking changes in reactor systems such as: adequate justification for changes, change management policy that gives priority to safety and independent reviews by regulatory bodies.

While implementing changes in the reactor systems, a detailed change management protocol was followed in Dhruva to ensure that the changes achieve their desired objectives and have no detrimental effect on safety.

2. Change management protocol in research reactor Dhruva

Basic principles for managing change is based on to implement effective change whilst remaining focused on safe and reliable operation of reactor. Change management protocol followed in Dhruva consists of six main activities. These are: identify potential change, analyze change, review and approve change, plan change, implement change and performance analysis and change notification.

2.1 Identify potential change

Necessity for changes are brought by number of drivers such as: ageing, technological obsolescence, performance degradation, etc. All the SSCs are subject to some forms of physical ageing, which could eventually affect the margins and/ or impair their safety functions and service lifetime. A well formulated surveillance programme, systematic in-service inspection and structured system performance monitoring & review has been put in place to provide timely feedback on the healthiness of SSC important to safety. Based on the above certain incipient degradations in the system/equipments could be identified in time. Consequently replacement of certain reactor systems/components, like secondary coolant heat exchangers and certain portion of emergency cooling water pipelines which indicated degradation have been undertaken. Technological obsolescence has necessitated some of the replacement/upgradation actions for power supply and controls & instrumentation systems of the reactor. Based on this, replacement of 150 kVA class II MA set with 250 kVA MA set, upgradation of 20 kVA class II inverters, complete up-gradation of control room and fuelling machine instrumentation was taken up.

2.2 Analyze change

Whenever a need for change is identified or a change is implemented all technical and safety aspects are comprehensively analyzed. Technical feasibility of the change is explored. Various alternative options and inclusion of new features for improved functionality is considered. Cost of the change is also determined at this stage. After elaborate analysis a change proposal is prepared. Subsequently proposal is put up for independent review and regulatory clearance.

2.3 Review and approve change

Multi-tier review of a proposed change is performed at plant level. The recommendations (if any) after review is incorporated. Final proposal is then put up for regulatory clearance. After getting approval of regulatory body, detailed planning is done for implementation of the proposed change.

2.4 Plan change

Once the changes are identified, analyzed, reviewed and approved, a comprehensive plan is developed to implement. A detailed procedure is prepared at this stage which includes scheduling of the job, required resources, safety precautions, system preparations, execution sequence, contingency plan and verification/checks after the implementation. The procedure is reviewed by experts and approved by appropriate authority for implementation.

2.5 Implement change

The approved procedure is taken for execution at this stage. This is the most important step. It is absolutely essential that throughout the period of time that changes are implemented and after the changes have occurred, very high standards of safety are maintained. Reductions in the level of safety are not acceptable, even for short periods of time during transition phase. Additional surveillance is done. Effective and immediate action is taken if any off normal situation is noticed. All the required testing, checks and verification is done by independent authority after completion to ensure that the changes achieve its desired objectives and have no detrimental effect on safety.

2.6 Performance analysis and change notification

At the end, performance analysis of the applied change is carried out at various stages of reactor operation. All the documentation is updated appropriately. A new system release, which reflects the applied change, is prepared. Dissemination of information to O & M personnel for familiarization is done before inducing the change for regular operation.

3. Application of change management during replacement and up-gradation of reactor systems

3.1 Secondary coolant heat exchangers

Dhruva reactor uses heavy water as primary coolant which removes heat from core. Heavy water is cooled by demineralised water (secondary coolant). Hot demineralised water is in turn cooled by sea water (tertiary coolant) in a set of 5 shell and tube heat exchangers (secondary coolant heat exchangers). Introduction of this intermediate coolant system of de-mineralized water has avoided direct contact of the primary coolant system heat exchanger tubes with the corrosive seawater, thus enhancing the reliability of primary coolant system integrity and reducing its maintenance requirements [3].

Periodic inspection of secondary coolant heat exchangers reveal that the projected end of cupro-nickel tubes at the tube sheet have been considerably eroded especially for the tubes in inlet pass. Inspections, dimensional measurement and ECT results of tubes at regular intervals indicated significant reduction of wall thickness for quite a large number of tubes. Hence, it was decided to replace the heat exchangers. Replacement of only one heat exchanger was taken up at a time. Replacement was planned in such a way that normal reactor operation should not get affected. After ensuring satisfactory performance of newly commissioned heat exchanger, replacement of other heat exchanger was taken up. So far replacement of 4 heat exchangers has been completed.

3.2 Emergency cooling water pipelines

Emergency Cooling Water System (ECS) is a safety support system provided for removing the decay heat of the reactor from the primary coolant. Visual inspection of the emergency cooling water lines are done regularly and thickness measurement is done if any sign of external corrosion is observed. Reduction in thickness of certain portion of the pipe line was observed. Though the observed thickness was much more than the required thickness to hold the line pressure, it was decided to replace that segment of pipeline as long term preventive measure. Detailed planning and preparation was done before taking the outage of the line segment for replacement. An alternative line was installed and commissioned. Apart from regular pumps, provision of emergency make up was provided on this alternative line from engine driven pumps. After replacement of the lines, QA checks were done to ensure the required standards.

3.3 Power supply equipments

Overall performance of power supply system of Dhruva have been quite satisfactory. However, based on O&M feedback as also up-gradation requirements of some systems for improved safety and reliability several changes were identified. While taking replacement and upgradation of any electrical equipment/component it was always ensured to feed the affected loads by alternative source.

3.3.1 Replacement of 150 kVA class II MA set with 250 kVA MA set

150 kVA MA sets started showing signs of ageing by frequent failure of control cards. In addition, since additional loads were incorporated owing to modifications in emergency core cooling system, it was considered necessary to augment the rating of the unit to 250 kVA. Further, an additional MA set was also installed as a spare to enhance reliability of class II supply.

3.3.2 Replacement of 240 V, 1000 Ah battery bank with 1200 Ah battery bank

In view of upgradation of the capacity of MA set from 150 kVA to 250 kVA, the capacity of battery banks was also enhanced from 240 V, 1000 Ah to 1200 Ah. Since new safety standards require class-I battery banks to be mounted on seismic stands, this requirement was also catered to during this replacement.

3.3.3 Upgradation of 20 kVA class II inverters

240 V AC control power supply (Class-II) of Dhruva are derived using two nos of 20 kVA static inverters. These inverters were upgraded to enhance fire safety and a third inverter was installed as spare to enhance reliability of the control power supply.

3.3.4 3.3 kV motor cable replacement

All 3.3 kV motors at Dhruva were powered through aluminium conductor HRPVC cables. These cables were terminated in copper lugs at motor as well as circuit breaker ends. Due to thermal cycling during start up and shutdown of motors and differential expansion of copper and aluminium metal at the lug-joint coupled with vibration at motor end, cable in the lug used to get slightly loosened over a period of time resulting in premature failures at terminal due to overheating aided by high current during motor starting. All these cables were replaced with copper conductor XLPE insulated cables and frequency of failure reduced to almost nil.

3.3.5 Circuit breaker replacement

The problem associated with switchgear are not so frequent in Dhruva but considering their long service and occasional ageing related problems like wear & tear of mechanical parts and drift in precision to trip/close and latch in mechanism, lack of product support for spare parts, etc. it was considered prudent to replace them before further aggravation of the problem.

3.4 Up gradation of C&I systems of Dhruva

C&I systems of Dhruva have been designed in the late seventies and were facing both obsolescence coupled with limited diagnostic features for speedy identification of the faults. Upkeep of these systems with limited spares inventories together with non availability of components and quality connectors were becoming difficult. Since the expected life of most C&I systems is typically twenty years, it was considered appropriate to upgrade major C&I systems to embedded computer based systems in Dhruva. Adequate verification and validation (V&V) for each of the computer based system were planned as per the recommendations of AERB-SG-D-25 [4]. All the major activities were planned in a manner such that major jobs like system design and development, procurement, cabling, testing at developer's end etc. are done without affecting normal reactor operation schedule. Dissemination of information to O & M personnel for familiarization was done before inducing the changed C&I for regular operation.

3.4.1 Up gradation of Dhruva control room

Considering that many of the major C&I systems were being upgraded to embedded computer based system, it was also essential to house their operator consoles (OCs) in control room. In addition, the indicating and recording instrumentation in the main control room, pertaining to the pneumatic instruments which were being upgraded to electronics, also needed to be changed. Hence all the six panels of control room were replaced. All the panel fascia instrumentation were changed from existing pneumatic indicators and strip chart recorders to chartless recorders and 30" PC screens. Pneumatic to electronic converters (P/I) were installed at the back panels for display of existing pneumatic signals on newly installed chartless recorders. A suitable scheme was evolved to take care of monitoring and safety functions during replacement of panels. Monthly routine shut down was utilized to carry out panel upgrade activities.

3.4.2 Up gradation of fueling machine instrumentation

Owing to obsolescence of various C&I components and increase in maintenance related problems some of the major C&I components of fueling machine A (FM-A) was upgraded. This included replacement of all pneumatic transmitters with electronic transmitters, upgrade of console with a new mimic panel & chartless recorder, upgrade of extractor position indication system and alarm annunciation system. Functional requirement and HMI (human machine interface) was also considered in the design of new console. All the incoming and outgoing cables to and from the control console were identified prior to dismantling. In order to limit the unavailability time of FM-A, the new control console was prewired, populated & tested and then brought to site for carrying out only the field terminations and installation. After commissioning of the console, integrated testing of the upgraded C&I was carried out.

4. Conclusion

Initial design of SSCs of Dhruva was carried out with stringent specifications and strict quality control to assure safe and reliable operation for the entire service life. During operational phase, a well formulated surveillance programme, systematic in-service inspection and structured system performance monitoring & review ensured the healthiness of SSC important to safety. Change management policy adopted at Dhruva provided basis for replacement/upgradation of certain reactor systems/components. The work done in this regard has given enough background to formulate comprehensive ageing management programme to assess the available safety margins for all the SSCs important to safety. This will also provide useful insights to formulate refurbishment requirements to enhance operating life of reactor by another 20-25 years.

5. References

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