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Application of Canned Motor Reactor Coolant Pump for Advanced Reactors

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1. Introduction

Reactor coolant pumps (RCPs) provide forced circulation from the reactor to the stream generators for adequate cooling of the reactor core in a pressurized water reactor (PWR). Reactor coolant pump is one of the major components in the reactor coolant system of PWRs. Most reactor coolant pumps are of type that has a mechanical shaft seal system [1]. On the other hand, canned motor pumps without seal injection have been highlighted for advanced reactors and small and modular reactors (SMRs) [2, 3]. Those relatively new reactors are likely to be featured with passive systems. It is noticeable that canned motor pumps are considered harmonious with the passive reactors.

Both sealed and seal-less canned motor reactor coolant pumps need to be cooled by an external auxiliary system and shall have adequate rotational inertia for coast down characteristics which assure adequate RCS flow during pump coast down after loss of power to the pump motor [4].

The purpose of this paper is to provide the basis of application for canned motor reactor coolant pump in advanced passive reactors and characteristic differences from conventional sealed RCP.

2. Discussion

The canned motor pump is one hermetically sealed unit and has a common shaft to link a centrifugal pump and induction motor without external seal injection. The bearings are lubricated and cooled by process liquid. In general, the canned motor pumps provide advantages of no leakage during normal operation and no periodic shaft seal replacement. However, canned motor pumps have several limitations such as problems of temperature of motor windings, control of bearing environment, corrosion potential consideration, and potential for higher repair cost [5].

2.1 Shaft Seal Requirements

Canned motor pumps are considered to have a base of satisfactory operating experience and meet the EPRI (Electric Power Research Institute) Utility Requirements Document (URD) requirement [4] that rotating shaft seals shall not be used if a passive plant design employs reactor coolant pumps to eliminate or reduce potential reactor coolant leakage under plant blackout, necessity for extensive external systems, and the substantial down time due to the periodic shaft seal replacement. The smaller power output of the passive reactors is considered to make canned motor pumps practical. However, attempts to make larger canned motor pump are relatively rare and considered only available by few advanced suppliers. Large canned motor reactor coolant pumps still need more investigations and innovations to make them generally practical.

Canned motor reactor coolant pumps avoid loss of coolant accidents through pump seals, which reduces the probability of core damage.

2.2 RCP Flywheel Missile Protection

EPRI URD [4] suggests that the canned motor reactor coolant pump flywheel in passive plants should be inside the reactor coolant pressure boundary (RCPB) and the RCPB parts of the pump-motor assembly can confine the missiles generated from the flywheel failure. The intent of regulatory criteria for RCP flywheel integrity is still applicable to the canned motor reactor coolant pump but the details are not applicable tactlessly just as they are.

The flywheel design for AP1000 design demonstrates that the missiles will not penetrate the pump pressure boundary structures in case of the flywheel failure. Therefore, the NRC concluded in the safety evaluation report (SER) that the design is acceptable to meet the requirements of GDC 1, GDC 4, and ASME Code, Section III [6, 7].

If flywheel is necessary for the adequate rotational inertia but not available to be installed inside of the boundary of pump-motor assembly due to any spatial limitation including characteristics of the canned motor pumps, a separate external inertial system may be considerable as can be seen in the design of some sodium fast reactors [8]. It will be similar to design of the motor-generator sets for power supply for CEDM.

2.3 Cooling Water Systems

The inherent eddy current losses and heat generations from the bearings make the canned motor reactor coolant pump need some cooling and lubrication [5]. The reactor coolant as process liquid has high normal operating temperature and essentially need a heat exchanger to be cooled. Therefore, component cooling water (CCW) is still necessary to be supplied for cooling of the canned motor reactor coolant pump.

The EPRI URD [4] requires that reactor coolant pump-motor assembly shall be capable of operation without cooling water for a minimum of 10 minutes without any damage and a minimum of 30 minutes without damage which could affect pump coast down. These requirements are incorporated for APR1400 RCP design and proper demonstrations by analyses and tests have been provided [1]. SRP 9.2.2 [9] requires to withstand complete loss of cooling water and to demonstrate it by testing the pump operation for a period of 20 minutes as necessary for the operator action. Otherwise, a protection system is required to initiate automatic protection of the plant upon loss of cooling water to a pump, or the component cooling water system for the reactor coolant pump shall be designed as American Society of Mechanical Engineers (ASME) Section III Class 3 and seismic Category I.

3. Conclusions

Canned motor reactor coolant pumps have benefits of capability to eliminate necessities of supporting systems and maintenance aspects. Canned motor reactor coolant pumps are characteristically essential for the design of advanced passive plants in accordance with utility design requirements. The general considerations for the reactor coolant pumps in PWRs such as the flywheel integrity and component cooling water still account even for the canned motor reactor coolant pumps. Table I summarizes the above conclusions as a comparison between the sealed reactor coolant pumps and the canned motor reactor coolant pumps.

Table I: Comparison between two types of RCPs

	Sealed RCPs	Canned motor RCPs
Seal injection	O	X
Seal replacement	O	X
Seal leakage	O	X
Component cooling water	O	O
Flywheel integrity	O	O (Detail requirements may not be applicable directly.)

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