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Technical note

# Fuzzy logic control for improved pressurizer systems in nuclear power plants

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ABSTRACT

The pressurizer system in a CANDU nuclear power plant is responsible for maintaining the pressure of the primary heat transport system to ensure the plant is operated within its safe operating envelope. The inventory control for the pressurizer system use a combination of level sensors, feed valves and bleed valves to ensure that there is adequate room in the pressurizer to accommodate any swell or shrinkage in the PHT system. The Darlington Nuclear Generating Station (DNGS) in Ontario, Canada currently uses a proportional controller for the bleed and feed valves to regulate the pressurizer inventory control which can result in large coolant level overshoot along with excessive settling times. The purpose of this paper is to develop a fuzzy controller to regulate the pressurizer inventory control and compare its performance to the current proportional controller used at DNGS. The simulation of the pressurizer inventory control system shows the fuzzy controller performs better than the proportional controller in terms of settling time and overshoot.



## 1. Introduction

The primary heat transport (PHT) system for the CANDU nuclear power plant (NPP) is responsible for removing heat produced by fission and fission products and transferring that heat to the boilers to produce steam for the turbines (Heat Transport System, 2014). The heat produced by the fuel must be removed to prevent damage to the fuel bundles and pellets to ensure containment is maintained. The pressurizer system is part of the PHT system and has two main functions; to maintain the coolant level in the core at a safe level and to maintain the pressure of the PHT system. Fig. 1 shows how the pressurizer fits into the primary heat transport system for a CANDU nuclear power plant.

The pressurizer system uses a collection of valves and heaters to increase and decrease the coolant level and pressure in the pressure vessel. Normal operating conditions at DNGS has the PHT system held at a pressure of 9.89 MPa(g) and approximately 300 °C to keep the coolant in a saturated state and prevent the coolant from boiling.

The pressurizer plays a critical role in safe plant operation, the accident at the Three Mile Island (TMI) nuclear power plant on March 28th, 1979 can attest to that (Three Mile Island, 2014). A transient occurred on the Unit 2 reactor which resulted in the automatic actuation of the shutdown system and the control rods were dropped into the core and stopped the fission process. As a result of the transient, the temperature and pressure of the PHT coolant began to rise. To accommodate the increase in pressure, the pressurizer pressure relief valve operated to reduce the pressure in the system. At this point, the system had operated properly. However, when the pressure in the PHT had been reduced, the pressure relief valve failed to close, and among other problems, this eventually resulted in a severe loss of coolant to the fuel in the reactor and a partial meltdown.

The importance of the pressurizer for the PHT system cannot be overlooked. It is for this reason that the shortcomings in the pressurizer control system should be remedied by replacing the basic proportional controller with a fuzzy logic controller to maintain a safe and reliable system (Bhatt et al., 2009).

## 2. Pressurizer system

The pressurizer system for the PHT system is vital to ensure sufficient coolant for the fuel and accommodate the volume change of the PHT coolant from zero to full power (ZHANG et al., 2012; Liu et al., 2014; YE et al., 2010). The coolant ($D_2O$) is kept in a saturated state with part of the pressurizer filled with liquid coolant and the remainder filled with coolant vapour. The vapour space of the pressurizer allows for PHT pressure transients. The pressurizer itself is a cylindrical pressure vessel with pressure and level sensors to monitor the pressurizer state.

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**Nomenclature**

Acronyms

| | |
|---|---|
| DNGS | Darlington Nuclear Generating Station |
| NPP | Nuclear Power Plant |
| PHT | Primary Heat Transport |
| TMI | Three Mile Island |

*2.1. Design specifications*

The pressurizer has two primary functions; to maintain the PHT coolant at the appropriate pressure and to manage coolant inventory changes in the PHT due to coolant swell and shrinkage. There are two distinct control systems for the pressurizer; the first to manage the coolant inventory and the second to maintain the pressure of the PHT coolant.

The pressurizer inventory is controlled by throttling the dual feed valves to increase coolant levels by taking coolant from the $D_2O$ storage tank and throttling the dual bleed valves to decrease coolant levels by sending coolant to the bleed condenser. The coolant inventory is maintained at a set point dependent on the current reactor power; as power increases, the coolant level is increased. The pressurizer coolant level is required to be kept within certain safety limits. The coolant level must be kept well above the

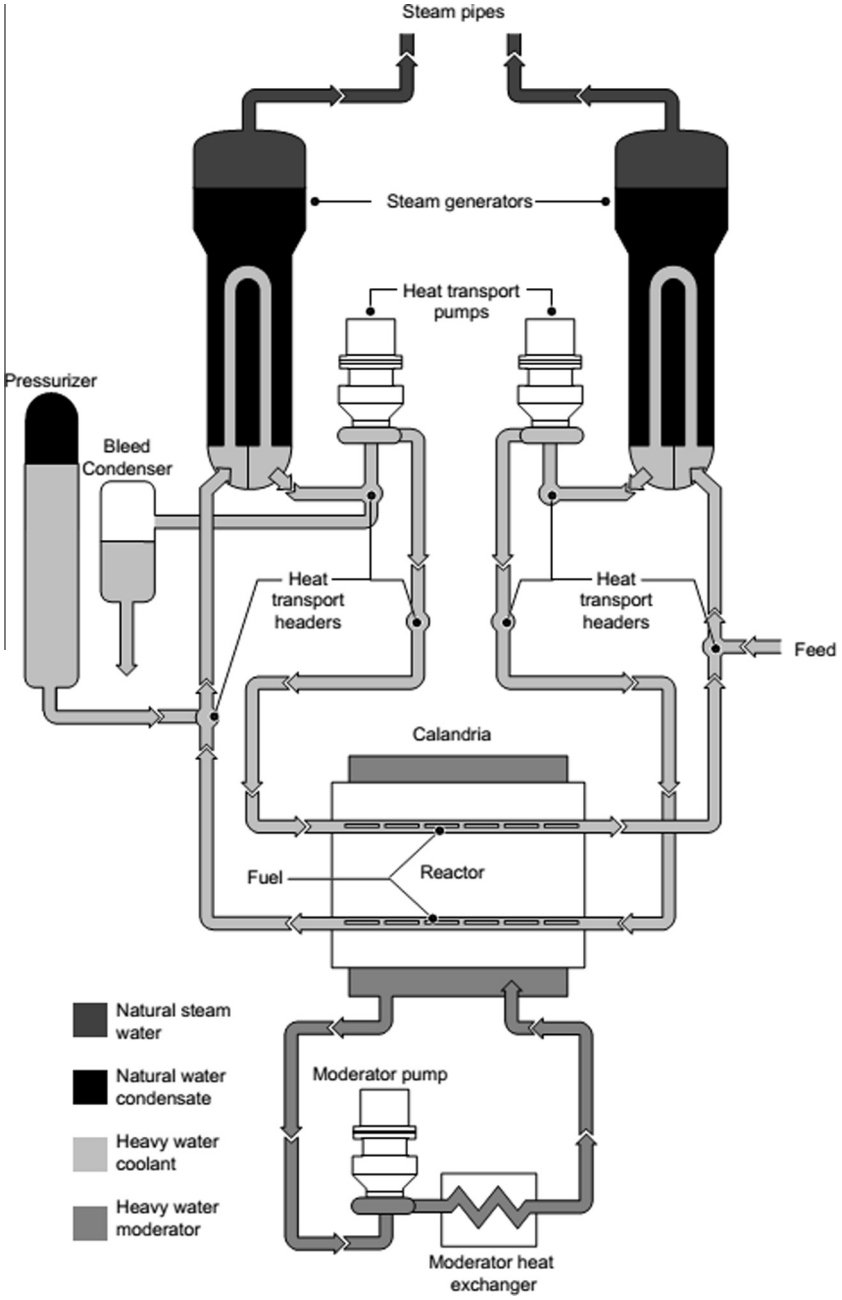


**Fig. 1.** CANDU primary heat transport system (CANDU training centre – heat transport system).