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Smart Sensing of Feedwater Flow Rate Using a CFNN Model

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***Abstract*:** *In pressurized water reactors (PWRs), the feedwater flow rate is commonly measured using Venturi flow meters. However, the feedwater flow rate is overmeasured by the fouling phenomena. That is, it is limited to accurately measure the feedwater flow rate due to the accumulation of the corrosion products near the flow meters. Therefore, in an effort to develop an advanced measurement technique, the cascaded fuzzy neural network (CFNN) model, as a smart software sensing technique using artificial intelligence (AI), is applied to estimation of the feedwater flow rate in this study. The data applied to the proposed model are acquired real data from Hanbit NPP unit 3 of Republic of Korea. The application results are expressed as root mean square error (RMSE) and maximum error. The proposed model is successfully validated since estimation errors are quite low.*

Keywords: *Cascaded fuzzy neural network (CFNN), Feedwater flow rate, Fouling phenomena, smart sensing.*

1. Introduction

is certain to precisely measure the feedwater flow rate since thermal reactor power is typically evaluated with secondary system calorimetric calculations that highly depend on accurate feedwater flow rate measurements [1]. In pressurized water reactors (PWRs), Venturi meter, as a nozzle-based meter, is commonly used for measuring the feedwater flow rate. The Venturi meter measures the feedwater flow rate by developing a differential pressure across a physical flow restriction. However, this type of meters can induce measurement drift on account of corrosion product accumulation near the Venturi meters by long-term operation (LTO).

These fouling phenomena increase measured pressure drop across the flow meters, and accordingly overmeasurement of the feedwater flow rate is induced. Whenever the calorimetric calculation is carried out during an operating cycle, thermal reactor power must be reduced to match the feedwater flow rate overmeasured by the Venturi meter [1]. In other words, nuclear power plants (NPPs) have to operate at lower power level than planned power level due to the fact that thermal reactor power is restricted by the operating license. It is commonly known that the fouling is the considerably influential factor to derate power level in PWRs [1].

Although the common resolution for this phenomena is to inspect and clean the Venturi meters during a refueling cycle, the corrosion products near the flow meters are reproduced in as quickly as one month [1]. Therefore, to efficiently and accurately measure the feedwater flow rate, an artificial intelligence (AI) technique is proposed in this study. This study can be considered as the same efforts for applying the on-line monitoring (OLM) using AI techniques to the NPPs, which were reviewed in several studies [2], [3].

Cascaded fuzzy neural networks (CFNN) [4] was used to increase the thermal efficiency by precisely estimating the feedwater flow rate. A subtractive clustering (SC) scheme and a genetic algorithm (GA) were