A Practical Measure to Deal With Linear Power Signal Saturation of a WRFC

Sanghoon Bae*, I.K. Hwang, W.M.Park, G.Y.Park, and C.H.Kim
Korea Atomic Energy Research Institute, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea
*shbae@kaeri.re.kr

1. Introduction

The sensitivity of a fission chamber in the neutron measurement system (NMS) is considered a key factor during a commissioning. Because the wide range fission chamber (WRFC) sensitivity influences the linearity and power coverage during a power ascension test and it indicates how much the design requirement is met. However, if this sensitivity of WRFC is severely deviated from what it should be due to a certain reason, the aftermath of this impact must be exactly analyzed and an appropriate countermeasure should be prepared. In particular, taking account for the importance of nuclear test the reactor power measuring capacity should be fully negotiated with a core team. The delicate issue about its sensitivity compensation, herein is intensively introduced.

2. Nuclear Test and Signal Saturation of WRFC

2.1 Nuclear pretest scheme for Safety NMS

Nuclear test are involved in the type test sequence for safety NMS which generally proceeds according to the specified manual. Before the nuclear test, every process is almost identical to other safety systems. The Nuclear pretest was performed with a WRFC which is used as a detector of NMS. The test specimen is usually prepared for conventional test with being connected via the field cables to the signal processing unit.

The WRFC is mounted and electrically isolated in a dedicated movable standpipe in the test reactor pool as shown in Fig. 1 with the detector axis parallel to the standpipe axis. The same vertical position to the reactor core for all measurements is maintained during the test. The WRFC is placed in the reactor pool at two different locations, referred to position 1 (low neutron flux, far from the reactor core, SE-Pool1) and position 2 (high neutron flux, close to the reactor core, NE-Pool2), to achieve the required neutron fluxes. This scheme is employed to always operate the reactor at power levels above 2.5E-3 %FP to be able to stabilize desired reactor operation at the chosen power level and to improve the accuracy of power measurement by the reference instrumentation.

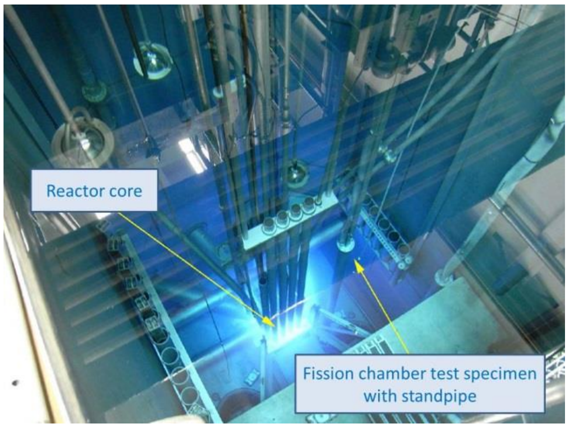

Fig. 1. Nuclear Pretest Setup of NMS channel.

2.2 WRFC linear power signal saturation

The discrepancy was found on the DC sensitivity of WRFC which occurs between the produced ones and its associated datasheet. As a result, the practical range of current NMS is limited to a maximum of 5E+9 nv (instead of the design value of 1.5E+10 nv) at the detector position. In general, the DC sensitivity of a WRFC is determined by amount of uranium coating, geometry of the electrode system, gas filling including gas mixture and density, and applied high voltage. During the design phase, the DC sensitivity of a new WRFC can only be estimated which is based on precedent data with same detector specification.

However, if a detector manufacturer does not receive correct information on the actual sensitivity of the WRFC as it was qualified by a different company, in this case, the detector's sensitivity had to be assumed the predefined specification. This non-conformance resulted from wrong gas mixture (95% N and 5% He) being filled into the test specimen, which was alleged due to temporary malfunction at the filling station. For this reason the increased DC sensitivity was not detected in time to apply corrective actions (regarding to the detector housing dimension). But the detectors shipped are filled with the correct gas and at the correct pressure as specified in the final design documents. The impact due to this sensitivity deviation can be categorized as elicited in the Table 1. The pulse range has no impact, on the contrary, the Campbell and DC current signal range has partiall been influced because of saturation effect which results from the WRFC malfunction not fulfilling the full power measurement.

Table 1. Impact on WRFC sensitivity deviation

NMS channel	Signal	Impact on Signal processing	Impact on analogue output
log power signal processing unit	Pulse count	No impact. It is because the pulse count is used only up to end of the overlapping region of 2E+05cps.	No impact.
	Campbell (MSV)	Partially influenced. For the power above a neutron flux of 5E+9nv where the Campbell (MSV) measurement will show some saturation effects.	Partially influenced.
Linear power signal processing unit	DC current	Partially influenced The DC current measurement is limited by the input range of the NA 31.31 to 2 mA.	Partially influenced.

Fig. 2, for example, shows data obtained during the second reactor test. The WRFC test specimen was operated with the NMS electronics. The system response is linear up to neutron flux of 5E+9nv. But the saturation due to the high DC sensitivity of the detector begins occurring above 5E+9nv. The analysis is still to be considered as preliminary as the neutron flux is estimated using not calibrated power levels. The neutron flux of 5E+9 nv is a conservative value for the definition of the 150% full power, taking into account the slight variations of the DC sensitivity.

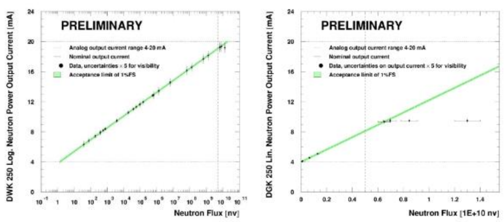

Fig. 2. First Test Result of NMS with curve fitting.

3. Field Test Result for WRFC and Modification for Curve Fitting

The previous nuclear test verified the current performance of WRFC may compromise the required specification with regard to neutron flux and power measurement. The re-evaluation results showcased that the DC sensitivity for the linear power signal for NMS outputs deviated from the specification by a factor 2 to 3, which DC current signal is used for linear power signal. The circuit modification was decided to compensate the some portion of deviation which is aimed at the extension of the DC current output, from 2 mA to 3 mA as feasible as it can.

This modification allows desired full measurement to be unsaturated before the maximum DC current. The signal conditioning modules modification in the NMS constitutes as followings; High voltage module and DC current input module. Then these components were tested in the field with the relevant procedure. The nominal output current of the high voltage module was increased from 2mA to 3mA, which requires the replacement of concerned components on the modules.

At the same time, the WRFCs were recommended to be relocated by traversing their housing toward the reactor core in order to fit DC current. If the detectors were relocated inwards, the neutron flux at the new position could be formulated around 2E+10 nv which can be interpreted to fulfill the requirement. This approach was effective in combination with the circuit modification. Fig. 3 showcases the neutron flux distribution at the initial core of 5 MW after the detector relocation.

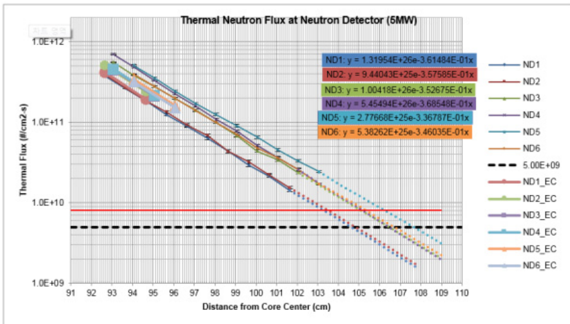

Fig. 3. Thermal neutron flux distribution at WRFC at 5 MW for initial core.

4. Conclusions

Thus far, the issue on the nuclear test result and signal saturation of WRFC has been introduced with several field experiences. This practical approach was suggested based on the test data. The nuclear test finally ended up the circuit modification and retesting, however it implies this case should be dealt with precarious attention factoring in the severity of the linear power signal.

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