

A Study on Harmonic Distortion Measurement in NPP

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1. Introduction

The issue of harmonic distortion has increased as more electronic devices are used compared to the past. In nuclear power plants (NPPs), many of the vital bus power supply system (VBPSS) loads are I&C devices that use electronic devices. Due to its importance, the VBPSS is equipped with redundant uninterruptible power supply (UPS) systems to ensure the availability of vital loads. Class 1E power systems must not degrade the performance of any safety system loads below an acceptable level [1]. Therefore, harmonic distortion should be controlled.

This paper investigates the harmonic distortion measurement in Korean nuclear power plants, analyzing the criteria and seeking improvement in testing practices.

2. Harmonic Distortion Measurement in NPP

2.1 Harmonic distortion limits

Specific regulatory guidelines for the measurement of harmonic distortion are not established, except that power quality, including harmonic distortion, should be continuously monitored or periodically measured [1]. Despite this, there are several technical standards and guides available for harmonic distortion, including IEEE Std. 944 [2]. This standard covers service conditions, design requirements, including limitations on the source and output, and testing requirements for UPS in power generating stations. It was first published in 1986, reaffirmed in 1996, and withdrawn in 2006. IEEE Std. 944 is included as a reference standard in overhaul(OH) inspection guides and UPS test procedures, and some NPPs include it as an applied standard in their Final Safety Analysis Reports (FSARs). The harmonic distortion requirements specified in the standard are 10% for AC input voltage and 3% and 5% for single and total output voltage, respectively.

IEEE Std. 519 [3] covers harmonic measurements and limits, but it is not an applied standard for NPPs. The most recent revision in 2014 recommends harmonic distortion requirements for low voltage systems of 5% for individual distortion and 8% for total distortion, which is more relaxed compared to the previous revision, which was the same as IEEE Std. 944. These limits are consistent with IEC Std. 61000-2-2. The Nuclear Regulatory Commission's Guide RG 1.180 [4] evaluates electromagnetic and radio-frequency interference in safety systems and permits exemption

from low frequency conducted emission tests if the equipment will not cause additional harmonic distortions on the existing power distribution system that exceed 5% total harmonic distortion.

2.2 NPP practice

Dedicated equipment for continuous monitoring of power quality is not installed in NPPs. While power quality parameters can be obtained from other equipment, such as fault recorders or digital protection relays, for a short period of time, continuous monitoring is not practical. In most NPPs, harmonic distortions are only measured during OH for the inverter output. Maintenance and testing procedures refer to IEEE Std. 944 and the manufacturer's manuals.

2.3 Status of Harmonic distortion measurement

All NPPs measure harmonic distortion of the inverter output voltages with limits specified in IEEE Std. 944 as shown in Table 1. Only some NPPs measure harmonic distortion of battery charger input voltages or constant voltage transformer input and output voltages. Some NPPs have more severe or more lenient limits than those specified in IEEE Std. 944.

Table 1. Harmonic Distortion Test Practice

NPP #	Charger Input		TR Input		Inverter Output		SI Inverter Output		TR Output	
	Total	Single	Total	Single	Total	Single	Total	Single	Total	Single
A1	O	O	X	X	O	O	N/A	N/A	O	X
A2	10%	X	X	X	O	O	N/A	N/A	X	X
B1	X	X	X	X	O	O	O	X	O	O
B2	X	X	X	X	O	O	O	O	O	O
C1	12%	X	X	X	3%	O	N/A	N/A	3%	O
C2	12%	X	X	X	3%	O	N/A	N/A	3%	O
C3	X	X	X	X	O	O	O	O	X	X
D1	10%	X	10%	X	O	O	O	O	O	O
D2	X	X	X	X	O	O	O	O	X	X
D3	X	X	X	X	O	O	O	O	O	O
E1	X	X	X	X	O	O	O	O	X	X
E2	X	X	X	X	O	O	O	O	X	X
E3	X	X	X	X	O	O	O	O	X	X
E4	X	X	X	X	O	O	X	X	X	X

O means "measure with limit of 5% for total and 3% for single harmonics"

X means "not in the procedure"

3. Evaluation and Improvement

The current practice of measuring harmonic distortion follows IEEE Std. 944. According to the standard, harmonic distortion should be measured for the input voltage of the UPS, which is the same as the battery charger input voltage in the charger-UPS configuration for many NPPs. It would be appropriate to revise the procedure in line with the limitations of the standard. IEEE Std. 944 does not specify requirements for the constant voltage transformer. However, since the transformer output is the input of the VBSS loads during inverter failure, the harmonic distortion should be kept within a limit. The standard and procedures do not specify the load conditions during testing, which can affect the results. Adequate load conditions should be set to reflect the actual operation of the UPS.

3. Conclusion

This study summarizes the technical standards related to harmonic distortion in NPPs, investigates the current practice and status of how NPPs measure it based on test procedures. With above, we evaluated and suggested improvement on harmonic distortion measurement. 1) Harmonic distortion should be measured for input voltage of UPS. 2) The harmonic distortion of the constant transformer should be kept within a limit. 3) Load conditions should be specified during the test.

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