§36. Effects of Gamma-ray Irradiation on Electronic Equipment of Large Helical Device

Ogawa, K., Nishitani, T., Isobe, M., Yokota, M., Hayashi, H., Kobuchi, T., Nishimura, T.

Highly integrated electronic components such as a programmable logic controller (PLC) are essential for the control and diagnostics of a plasma in order to achieve high-temperature and high-density plasmas. Deuterium operation will be started from 2017 on the Large Helical Device (LHD). LHD is controlled by means of many semiconductor integrated circuits placed around LHD. These circuits are regularly replaced with the latest highly-integrated circuit. Thus, the circuits become weaker against the radiation because of the higher integration. By neutron and gamma-ray transport calculation, it is expected that the absorbed dose by Si within nine years is around 100 Gy and the gamma-ray is dominant in dose [1]. Therefore, for safety operation of LHD we need to investigate the effect on radiation on electronic and non-electronic equipment to rearrange of equipment around LHD.

Gamma-ray irradiation on equipment is done at the Cobalt 60 irradiation facility of Nagoya University; this is one of the largest gamma radiation facilities in the Tokai area of Japan. The facility has 60Co gamma-ray source whose intensity of 163 TBq was renewed in 2004. The personal computer (PC: HP Mini 5101, Hewlett-Packard), two media converter (DMC-700SC, D-Link), a PLC (FA-M3, YOKOGAWA), two isolation amplifiers (P62-A, NF Corporation), one web camera (TS-WLCAM, I-O DATA), one optical flow meter (R-760-E, TOKYO KEISO Co., LTD) are used in this experiment.

To see the effect of the irradiation on two media converters, we transfer the image taken by a web camera at the diagnostic room to the PC in the diagnostic room through the media converter placed in the irradiation room. We found that there is no transient noise and no decrease of the speed of the network up to the integrated dose of 320 Gy. We input the sinusoidal function created by the function generator at diagnostic room to the isolation amplifier in the irradiation room. The output signal is monitored by the oscilloscope in the diagnostic room. The output signal does not change up to the integrated dose of 112 Gy. The optical flow meter is composed of a light emitting diode and a photodiode. The signal of a photodiode becomes a high level when light emitting diode is off and a low level when the light emitting diode is on. We use a simple logic circuit to get a light emitting diode with 1 Hz flashing. The output signal of the photodiode in the irradiation room is monitored by the oscilloscope to check the light emitting diode and the photodiode. The signal is stable up to the integrated dose of 240 Gy. A PC in the irradiation room is monitored through the network by means of the remote desktop application of Windows OS. Although the connection looks stable just before the integrated dose of 224 Gy, it is suddenly disconnected at 224 Gy. Note that, after irradiation, we could not start even the basic input/outputs system (BIOS) of the PC. The movie taken by a web camera placed in the irradiation room is monitored through the network from a PC. Noise due to the gamma-ray appears and disappears repeatedly from the beginning of the irradiation. The noise completely disappears when we stop the gamma-ray irradiation. It means that the noise is the transient effect due to the gamma-ray. No permanent effect is observed up to 112 Gy. The status of the PLC is monitored. The input/output signal is monitored through the network by the PC. Offset of the signal measured by the analog input module channel two is gradually increasing with an increase of the integrated dose. The analog output module is broken at 88 Gy. The CPU module and the analog input module of the PLC1 are broken at 96 Gy. Time-varying voltage is applied from the analog output module to the Devicenet input module. The input and output voltage is monitored from the PC through the network. Table 1 shows the summary of the gamma-ray irradiation experiment on the electronic equipment used in LHD. Finally, if we consider the dose only, these components may survive more than nine years. However, the safety factor is low. For the safety of the LHD operation, electronic components placed on the torus hall have been rearranged.

1) Nishitani, T. Ogawa, K. and Isobe, M.: Plasma and Fusion Research **11** (2016) 2405057.

Table1 Summary of gamma-ray irradiation on electronic equipment

Component		Manufacture	Model Number	Maximum Dose (Gy)	Transient Effect	Permanent Effect
PC		Hewlett-Packard	HP Mini 5101	320	Not observed	Broken (224 Gy)
Media Converter		D-Link	DMC-700SC	320	Not observed	Not observed
Optical Flow Meter		TOKYO KEISO	R-760-E	240	Not observed	Not observed
Isolation Amplifier		NF Corporation	P62-A	112	Not observed	Not observed
Web camera		I-O DATA	TS-WLCAM	112	Noise	Not observed
PLC	CPU	YOKOGAWA	PU10-0S	112	Not observed	Broken (96 Gy)
	Power		SP71-4S	112	Not observed	Not observed
	Analog Input		AD04-0V	112	Not observed	Offset increase Broken (96 Gy)
	Analog Output		DA04-1N	112	Not observed	Broken (96 Gy)