Development of optical fiber cable's inspection technology and maintenance criteria

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1. Introduction

Improve the reliability and establish the systematic maintenance methods for the digital control facilities' optical fiber cable, reviewed the technical requirements and the current maintenance procedures, analyzed the optical fiber cable's characteristics through actual test like bending, tension, attenuation. Based on the results of review, test and analysis, prepared the maintenance criteria and standard maintenance guideline. Also we verified those can be applied directly to the operating nuclear power plant through the actual test at Ulchin Unit 6. The details of test and analysis are presented in this paper. Also introduce the contents of maintenance criteria and guidelines.

2. Test and Analysis

2.1 Actual Test and Results

To verify the mechanical and the environmental characteristics of optical fiber cables, follows tests were performed according to the IEEE 383[2004].

1) Tensile strength Test of optical fiber cable
2) Bending Test
3) Compression Test
4) Torsion Test
5) Shock Test
6) Waterproof Test
7) Packing jelly dropping test

Tensile strength Test is performed as follows, and table 1 shows a result.

- Tensile strength: 1.5 times of cable weight(1Km)
- Velocity: 50 mm/min
- Lasting time: 1 Hour
- Acceptable criteria: less than 0.2 dB in proceeding, less than 0.1 dB after 1 hour

Table 1. The result of Tensile Strength

Test Item	Dreum No.	Core No.	Results					
			Mesaured Value					Crack
			Initial	Under Test	Changes	After Test	Changes	
Tensile strength	3474646	1	-47.35	-47.35	0.00	-47.35	0.00	No Crack
	3474645	1	-20.91	-20.91	0.00	-20.91	0.00	No Crack

Bending test is performed as follows and table 2 shows a result.

- Wind 5 times around a cylinder (OD is 20 times of cable OD)
- Acceptable criteria: No crack of outer coating, attenuation is less than 0.1 dB

Table 2. The result of Tensile Strength

Test Item	Drum No.	Core No.	Results			
			Mesaured Value			Crack
			Initial	After Test	Changes	
Bending	3474646	1	-47.24	-47.24	0.00	No Crack
	3474645	1	-22.31	-22.31	0.00	No Crack

2.2 Aging Analysis

Table 3 shows a result of aging analysis based on the materials of optical fiber cable.

Table 3. The result of Aging Analysis

No.	Item	Ln(life)	Expected Life (Yrs)	Qualified Life (Yrs)	Note
				E.L.*1/3	Material of Application
1	Quartz	18.689702	1.49E+04	4.98E+03	GaAsP
2	Plastic	23.81412	2.51E+06	8.37E+05	Plastic
3	Loose Tube	18.969367	1.98E+04	6.59E+03	PBT
4	Moistureproofing Layer	15.149401	4.33E+02	1.44E+02	Aluminium
5	Ext. Sheath	22.334786	5.72E+05	1.91E+05	Polyethylene
6	Int. Sheath	22.334786	5.72E+05	1.91E+05	Polyethylene

2.3 Thermal Imaging Test and Simulation

To analyze the heat generation status of power supply, measured the temperatures of LM 323 and resistor R1 using thermal imaging test method.

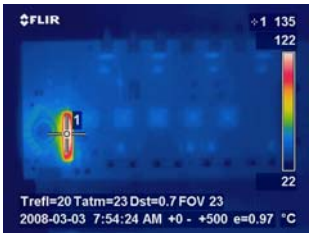

Fig. 1. Thermal image at the time of power supply input begins

The average temperature of R1 at the time of power supply input begins is 122℃. After 1 hour later, the average temperature of R1 is 140℃. (18℃ is increased)

At the time of saturation, the temperature of LM323 is about 43.9℃. This result shows R1 and LM323 is operating properly.

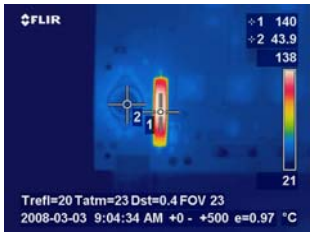

Fig. 2. Thermal image at the time of saturation (about 1 hour later)

To analyze that the circuit of power supply is designed suitably, power supply circuit was modeled using the code PSpice. Fig.3 shows the modeled circuit.

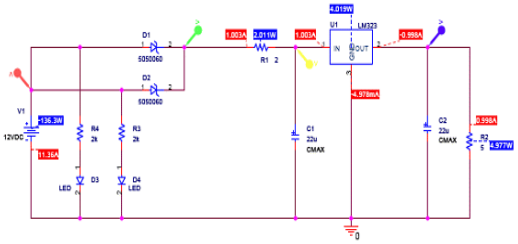

Fig. 3. Power Supply Circuit Model using the code PSpice

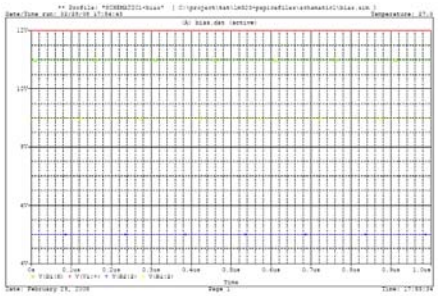

Fig. 4. Voltage Characteristics of Each Measuring Points

- V1: input power, +12 Vdc
- V2: 1st measuring point, +10.9Vdc
- V3: 2nd measuring point, +9Vdc
- V4: 3rd measuring point, +5Vdc

When input is +12Vdc, this modem consumes about 1.138A in normal operation. And this modem will be in constant current mode because of insufficient current of power input. From thermal imaging test and simulation, verified that optical modem is operating properly within a tolerance limit.

3. Maintenance Criteria

Based on the result of test and analysis, follows are selected as maintenance criteria.

1) Allowable radius of curvature
   At least 10 times of cable OD is selected.
2) Cable surface
   A, B and D will be uses as is. C and E will be replaced

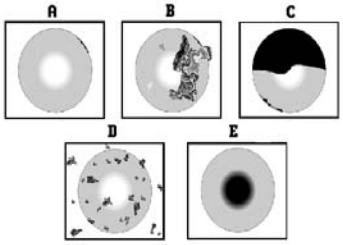

Fig. 5. Surface grade of Optical Fiber Cable

3) Attenuation and insertion loss (connector, adapter)

Table 4. Attenuation Criteria

Cable Type(㎛)	Mode	Wavelength (nm)	Manufacturer's (dB/km)	Attenuation Criteria (dB/km)
9/125	Single	1310	0.45	0.64
		1550	0.3	0.43
50/125	Multi	850	3	4.29
		1300	1	1.43
62.5/125	Multi	850	3.5	5
		1300	1.3	1.86
100/140	Multi	850	3.5	5
		1300	1.3	1.86

Table 5. Criteria of Insertion Loss

Connector	Criteria of IL [dB/EA]
SC, FC, ST, MU, LC, MTRJ	less than 0.5
SMArt Ferrule	less than 0.8
SMA Stainless Steel Ferrule	less than 2.0

4. Standard Maintenance Guideline

Standard maintenance guideline comprises

1) General (except CPCS)
   A. Operation condition
   B. Surface & attenuation
   C. Judgment
2) Core Protection Calculator System (CPCS)
   A. Surface and Attenuation
   B. Operation Margin
   C. Optical switch
3) OTDR usage

5. Conclusions

The results of optical fiber cable test, aging analysis, thermal imaging test, and simulation can be applied directly to establish the maintenance criteria and the maintenance guidelines of optical fiber cables in nuclear power plants. We expect that it makes a great contribution to prevent the unexpected transient or shutdown by optical fiber cable's trouble.

REFERENCES

[1] Reliability Test Procedure for Optical Fiber Cable and Optical Modem [G401], 2007.12, Korea Test Lab.
[2] Test Procedure for Optical Fiber Cable, 2007.03, LS Cable