EVALUATION AND TESTS OF ISOLATED EXISTING CABLING OF ITAIPU HYDROELECTRIC POWER PLANT AFTER YEARS OF OPERATION : ASPECTS TO BE CONSIDERED ON THE UPDATING TECHNOLOGICAL

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Introduction

Itaipu is currently the world´s largest generator of renewable clean energy. With installed capacity of 20 generating units of 700 MW each (14,000 MW), the operation of the Plant began in 1984 and since then has been presenting exceptional rates of power generation and very low failure rates in its equipment.

Itaipu seeks excellence in its processes and currently plans the replacement and modernization of its equipment, because many of them are obsolete and at the end of its useful life. Advanced new equipment with new functionalities must be installed in Itaipu in the stage called "Technological Update", including the existing system of isolated copper cabling.

Itaipu brings together an expressive amount of insulated electrical cables of different types, complex applications and functionalities. Itaipu carried out the evaluation of the current condition of the cables installed in the Plant about 30/35 years ago. This evaluation will be useful in the Technological Update Stage.

In order to evaluate the existing cabling, a number of factors that influence cable service life have been considered, among which are: electrical and mechanical stress, chemical attack, thermal fatigue and environmental contamination.

- Itaipu is a joint venture belonging to Brazil and Paraguay.
- Itaipu produces 15% of energy of Brazil and 86 % of Paraguay . In 2016, Itaipu established the historic annual production mark of 103 million MWh.

Wiring Systems

- Control and power cables are run in cable trays , steel conduits and cable trenches.

The cable trays are of ladder type and are manufactured from hot dipped galvanized steel

Twenty-four samples of instrumentation, control and power cables up to 1 kV were selected, which were taken from different Itaipu installation sites :powerhouse, main dam, spillway and 550 kV Right Margin substation. Such samples were chosen considering the most critical conditions imposed on the cables, such as: high mechanical stresses, humid environments, high operating temperatures, exposure to sunlight, etc. In addition, 11 samples were collected, which were stored in the Itaipu´s warehouse for about 30/35 years, and were never installed in the field, that is, 35 samples were evaluated in total. The 35 samples were evaluated in the physical, electrical, mechanical, chemical and thermal aspects, according to Brazilian technical standards currently in force and applicable for each test.

All the tests were performed at the ITEN laboratory - Instituto Tecnológico de Ensaios / Testing Technological Institute, in São Paulo, accredited by INMETRO - National Institute of Metrology, Quality and Technology

ITEN fulfill all the requirements of the ISO / IEC 17025 standard. (www.itensp.com.br)

Tests carried out on the cables (instrumentation, power and control) *

(*) Includes 1 cable of 15 kV

Test	Standard	Test	Standard
Electrical voltage in the insulation 2.500 Vac/ 5 min.; 3.500 Vac/1 min 1.000 Vac/1 min	NBRNM - 247-2 NBR - 10.300 NBR - 6881	**Oxigen index**	NBR 6245
Insulating resistance at ambient and operating temperature 500 Vcc / 1 min 1.000 Vcc/ 1min	NBRNM-247-3 NBR 10.300 NBR 6813	**Thermal chock**	NBRNM IEC60811-3-1
Construction and dimensional	NBR NM 280 NBR NM IEC 60811-1-1 NBR 6251	**Cold bend**	NBRNM IEC 60811-1-4
Mutual capacitance of pairs	NBR 9128	**Hot deformation**	NBRNM IEC 60811-3-1
Vertical flame propagation	NM-IEC 60332-1	**Ozone resistance**	NBRNM IEC 60811-2-1
Traction and elongation (sheating and insulation) before and after ageing	NBRNM-IEC 60811-1-1	**Electrical voltage long life**	NBR 7286 NBR 7289
Traction and elongation after ageing in air pump	NBRNM-IEC 60811-1-2	**Electrical voltage of screening (cable 15 kV)**	NBR 7286 NBR 6881
Traction and elongation after immersion in oil		**Partial discharge (cable 15 kV)**	NBR 7294
Electrical resistivity	NBR NM 280		
Water absorption by the gravimetric method	NBRNM- IEC 60811-1-3		

35 samples of cables were used for the evaluation

Electrical voltage long life ; 4hs inside water / 2.400 Vac

Elongation test of sample of cable

Samples subjected to flame test

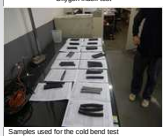
Flame test of the sample cable

Flame test of the sample cable after 1 min

Oxygen index test

Ageing of the sample(insulation and sheating(100 °C/168hs)

Thermal shock – 1 hour inside oven / 150 °C



Samples used for the cold bend test

Samples inside of the cold chamber ;temperature -15°C ± 2°C during 16 hs.

Cold bend test – impact against the sample

Results of tests and verifications

Dieletric fail with punching of the sample 17,under 1,2 kVac when should witstand until 3.5 kVac/5 min
Cable 5,2 mm2 ; EPR ; Use: slip ring of generator

Dieletric fail with punching of the sample 56,under 1,2 kVac when should witstand until 3.5 kVac/5 min
Cable 5,2 mm2 ; EPR ; Use: slip ring of generator

Summary of rejections

Type	Total of samples	Samples rejected	Percentage (%)
Power low voltage	13	11	85
Power medium voltage	01	01	100
Control	19	07	37
Instrumentation	02	01	50
Total	35	20	57

Sample	Origin of sample /Type of circuit	Rejection	Sample	Origin of sample /Type of circuit	Rejection
5	Powerhouse Elev. 98,50 m Power, 600 V	• Elongation after ageing of the sheating • Loss of mass	37	Powerhouse Elev. 132 m Power, 600V	• Elongation after ageing of the sheating
17	Powerhouse Elev. 98,50 m Power, 600 V	• Electrical voltage in the insulation • Insulation resistance at ambient and operating temperature	38	Powerhouse Elev. 128 m Control, 600 V	• Elongation after ageing of the sheating
26	Powerhouse Elev. 128 m Control, 600V	• Insulation resistance at ambient temperature.	39	Powerhouse Elev. 128 m Power, 600 V	• Elongation after ageing of the sheating
29	Powerhouse Elev. 128 m Power, 600 V	• Loss of mass	40	Powerhouse Elev. 128 m Control, 600V	• Elongation after ageing of the sheating
30	Powerhouse Elev. 132 m Power, 600V	• Insulation thickness • Thickness of the sheating • Elongation after ageing of the sheating	43	Warehouse Power, 15 kV	• Elongation of copper wire • Elongation after ageing of the sheating and the insulation • Loss of mass
31	Powerhouse Elev. 128 m Control, 600V	• Elongation after ageing of the sheating	46	Warehouse Control, 300 V	• Elongation after ageing of the sheating
33	Powerhouse Elev. 132 m Power, 1 kV	• Insulation resistance at ambient and operating temperature; • Traction of conductor after ageing on air greenhouse • Hot elongation • Water absorption by the gravimetric method	47	Warehouse Control, 300 V	• Elongation after ageing of the sheating
34	Powerhouse Elev. 128 m Power	• Insulation of the sheating • Elongation after ageing of the sheating	50	Warehouse Power, 1 kV	• Insulation resistance at ambient and operating temperature • Ageing of complete cable • Elongation of the insulation before and after ageing • Water absorption by the gravimetric method
35	Powerhouse Elev. 128 m Power, 600 V	• Thickness of the sheating • Traction and elongation of the insulation after ageing • Elongation after ageing of the sheating	53	SEMD Substation Right side Control, 600V	• Elongation after ageing of the sheating
36	Powerhouse Elev. 132 m Power, 1 kV	• Traction of conductor after ageing on air greenhouse	57	Powerhouse Stator of generator RTD	• Traction after ageing of insulation • Traction before and after ageing of the sheating • Hot elongation

Conclusions

The EPRI - Electric Power Research Institute, in its Guide to Modernization of Hydropower, estimates that cables working in perfect operating and environmental conditions can have a life of 40 years or more; and recommends that tests be performed to assess the cable's life condition.

The tests carried out in this evaluation do not allow to estimate the useful life of the cables installed in Itaipu; On the other hand, the main Brazilian manufacturers were consulted by Itaipu on this aspect, and it can be estimated around 25/30 years, provided that, for example, the design conditions, installation procedures, maintenance practices and conditions. Degradation of insulation and sheathing of the cable can compromise the efficiency and safety of the installations

Considering that the failure rate in the 35 samples tested was significant, that is, 20 samples presented nonconformities (57% of total samples) in relation to the requirements of the applicable technical standards, which compromises the use of the cable for failing to meet the mechanical, thermal, and chemical characteristics required for a new cable, it is recommended that in the Itaipu Technological Update, all existing cabling be replaced by a new one, in order to not compromise the quality and reliability of Itaipu's electrical installations .

On the other hand, It should be noted that despite of the results obtained in this evaluation , Itaipu has never had any problem or fail due to functioning and operation of its cabling system .

For the new generation of equipment to be replaced in Itaipu in the Technological Update stage, new technologies will be adopted, including not only cables, but also equipment, components and accessories. It is expected that this new generation of equipment can ensure performance at least equivalent or better to those that Itaipu currently has.

[1] 6047-50-T0077-P – Avaliação de Cabeamento Existente – Relatório Final de Avaliação de Cabos Elétricos – Relatório Técnico Itaipu

[2] EPRI – Hydro Life Extension Modernization Guide – Volume 4-5 Auxiliary Mechanical and Electrical Systems.