Development of an Accelerated Ageing Test Bench for HV Fast Pulsed SF6-Free Coaxial Cables for Kicker Systems at CERN

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ABSTRACT

To validate the performance and lifetime of new SF_6-free prototype cables and connectors, an accelerated ageing testing facility has been developed. Electric circuit analysis have been conducted to optimize the circuit design taking different fault conditions into account. The circuit models have been validated and adjusted by low voltage measurements on physical components. The general control, hardware protection and data collection system were implemented in LabView. This paper presents the important development stages of the accelerated ageing testing facility and outlines the performance of the final system that will enable the improvement of kicker systems throughout the existing accelerator chain.

KEYWORDS

Kicker Magnets, SF_6-Free, Pulse Forming Lines, Ageing Test, Injection, Extraction, 120 kV, Fast Transient, Spice, Test Bench, Pulsed Power Engineering.

INTRODUCTION

SF_6 gas filled coaxial cables are used at CERN in fast pulsed magnets systems for energy storage (pulse forming lines (PFL)) and as transmission lines. The PFLs are resonantly charged to high voltage and then quickly discharged, transferring the pulse via transmission lines to the kicker magnets: these magnets are responsible for injection, extraction, and disposal of particle beam. Newly developed, for maintenance and environmental reasons, SF_6-free coaxial cables need to be validated to assure high reliability during operation.

CERN has committed to decreasing the environmental impact of its activities [1]. The strategy to deal with this challenge involves reducing the emissions of greenhouse gasses that are being used throughout the accelerators complex. This paper puts the spotlight on SF_6, as it is the most relevant gas being used for electrical insulation in the fast pulse generators for kicker systems.

Eliminating SF_6 from the Organization's activities represents an important contribution in view of the evolving European environmental regulations, future limited availability of SF_6 gas and the related tedious training needed to maintain it.

SF_6 and kicker systems

Following the simplified electrical diagram of a kicker system [2], SF_6 can be found inside pulse forming lines, transmission cables and connectors located between pulse generators and kicker magnets. The gas is pressure-injected in the insulation, typically polyethylene (PE), foil between inner and outer conductors of the cable.

Performance with SF_6

Coaxial cables with PE insulation, pressure filled with SF_6 are used at CERN for their overall good performance [3], [4]. The dielectric strength of SF_6 allows higher voltage levels to be reached, by increasing the partial discharge inception voltage of the cable and reducing the risk of breakdown, which translates into longer cable lifetime.

With reference to fast transient events in pulsed high voltage, the coaxial cables for kicker systems at CERN need to fulfil a combination of unique requirements [5], such as: an homogeneous impedance to avoid loss of kick strength and reflections along the line; low attenuation to avoid droop and pulse distortion; high dielectric strength to support voltages high enough to drive the required current; radiation hard and fire protection in compliance with CERN standards, and long life expectancy to avoid maintenance works in radioactive environment or premature stops of the accelerators. From this combination of requirements to be met by any new prototype, the spotlight in this paper falls on the evaluation of lifetime via accelerated ageing.

Accelerated ageing tests

Pulsed coaxial cables being currently used at CERN have been in operation for up to 40 years [5]. Therefore, before installing a new replacement cable, it is necessary to answer questions regarding operational behaviour such as: What is the prototype's performance-to-time ratio? Which requirement is the most critical for the cable? e.g., voltage, frequency, radiation, heat, bending radius… How many years will the cable maintain an acceptable level of performance? In other words, what is the lifetime of the cable.

This is where the accelerated ageing concept comes into consideration. It exposes the device under test to extremes of its electrical operation conditions in order to predict its ageing behaviour, without having to wait for it to age naturally.

In the specific case of fast pulsed high voltage cables, extremes of the electrical operating conditions mean higher operating voltage and higher repetition rate. To qualify and validate the cables using a testing standard, two main activities are required:

- Definition of an ageing equation which correlates natural ageing with accelerated ageing in a HV fast pulsing environment. Existing research focuses mainly on DC and AC constant voltage and frequency operation.
- Establishing a testing facility capable of performing accelerated ageing tests.

The following sections address the different project stages: design, analysis, assembly, automation, and operation of that Accelerated Ageing Test Bench.