Development and qualification of a novel high voltage high frequency pulsed coaxial cable for kicker systems at CERN

Tobias **STADLBAUER**, Federica **BORTOLETTO**, Michal D. **CELUCH**, Laurent **DUCIMETIÈRE**, Jose **GASCON**, Thomas **KRAMER**, Javier J. **RIVEIRO HERRERO**, Berta **RUIZ-PALENZUELA**, Pavlina **TRUBACOVA;** CERN, (Switzerland), tobias.stadlbauer@cern.ch, federica.bortoletto@cern.ch, michal.dalemir.celuch@cern.ch, l.ducimetiere@cern.ch, jose.gascon@cern.ch, thomas.kramer@cern.ch, javier.riveiro@cern.ch, berta.ruiz.palenzuela@cern.ch, pavlina.trubacova@cern.ch

Christian **PFEILER**, Prysmian Group, (Germany), christian.pfeiler@prysmiangroup.com

☐ **Young Researcher** (Proved full-time engineering and science university researchers and Ph.D.students under 35 YO)

ABSTRACT

Particle accelerators use fast pulsed magnet systems (kickers) for injection, extraction and disposal of particle beams. Kicker systems at CERN are pulsed to levels of up to 80 kV and 5 kA with risetimes as fast as 100 ns and pulse length up to microseconds. Coaxial high voltage, low attenuation cables are used for energy storage (pulse forming lines) and as transmission lines (generator to magnet). Important parameters for kicker cables are high breakdown strength with low attenuation with properly matched impedance to transmit the quasi-square pulses without significant distortions. The novel extruded polyethylene cables with low attenuation field screen are intended to replace existing SF6 gas filled cables currently in operation. The paper presents the first qualification tests on the prototype cable including material, low and high voltage tests, breakdown tests, accelerated pulsed aging as well as first in-system tests. The cable performance and possible impacts are compared to the operational SF6 cables. The next steps to series productions are outlined.

KEYWORDS

Particle accelerators; Pulsed magnet systems; Kickers; CERN; High voltage; Low attenuation; Pulse forming lines; Transmission lines; Extruded polyethylene cables; SF6 gas filled cables; Prototype cable; Field screen; Partial discharge; Foil shield conductor; Longitudinal field screen; Material tests; Accelerated aging; In-system tests; Cable performance.

INTRODUCTION

Kicker systems require special cables [1] that can withstand relatively high voltage for a short duration while also facilitating fast wave transmission with low attenuation and distortion. For kicker cables with voltages up to 40 kV, the braid can be applied directly onto the polyethylene (PE) insulator, but the novel cable design will operate at a minimum of 60 kV, and the direct application of the braid onto the insulator can result in high partial discharge values between the braid and the PE insulation. These discharges can generate ozone gas, which reacts with the PE material, causing it to degrade faster over time. The use of semi-conductive layers is not practicable due to the additional attenuation introduced, which cannot be accepted for fast kicker applications. To overcome this issue, we bonded a foil shield conductor as used in RF cables, but without air gaps, directly to the PE insulator. The cable braid is then applied on top of this field screen to provide enough cross-section for current conduction. This construction eliminates partial discharges (PD) between the braid and the insulator by suppressing the air gaps. The cables being replaced have a taped PE foil insulation pressurized with SF6 gas with excellent dielectric properties and performance. The principle of the new construction has been proven to be suitable [2]. In the following, we analyze the first prototype and compare it to the existing SF6 cable.

METHODOLOGY

We studied different cable design options in the past [2] and their impact on the kicker system performance [3]. As a result, this novel kicker cable with longitudinal field screen was developed. The cable requirements and dimensions can be found in Table 1 and Table 2. Several testing methods were used to evaluate the cable performance, including material tests, low and high voltage tests, breakdown tests, accelerated aging, and first in-system tests.

REQUIREMENTS FOR NOVEL CABLE TYPE

Table 1

Nominal Voltage [kV]	60
Impedance [Ω]	25 ± 1%
Pulsed Current [kA]	10 (100µs, 1Hz)
Lifetime [Pulses]	10^8
Attenuation [dB/km]	<5.5 at 10MHz
D.C Resistance [Ω]	<1.2
PDIV [kV]	> 43

CABLE DIMENSIONS

Table 2

Cable	SF6	PE
Dielectric	PE foil + SF6	LDPE
Inner Conductor [mm]	17	17
Dielectric outer diameter [mm]	Corrugated 28.1/33.5	32
Outer conductor [mm]	Corrugated 0.5	Longitudinal foil + braid

RESULTS AND DISCUSSION

The following chapters describe the evaluation of the cable prototype and comparisons to the old SF6 cable.