

COAXIAL GAS INSULATED LINE WITH LOW STRAY FIELD FOR POWER TRANSMISSION

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Abstract

Electrical power transmission systems produce stray magnetic fields around the lines. In a three phase AC system the sum of line currents is always zero, but the spatial arrangement of the wires create a displacement of the magnetic field. This causes interferences to adjacent systems, especially to accelerator beams with weak focusing, which require a magnetic and electrical environment with low parasitic fields.

A multi coaxial line system has not this disadvantage. Therefore a coaxial gas insulated line (KOGIL) for medium and high voltage has been developed in a cooperation between DESY Hamburg and Darmstadt, University of Technology, High Voltage Laboratory. A prototype was built up for 20 kV and 25 MVA. The measurements and simulations as well as the possible applications of this new power transmission system will be presented.

1 INTRODUCTION

The Deutsches Elektronen-Synchrotron DESY in Hamburg, Germany, is investigating the research facility "TESLA": a linear collider of 33 km length with electron and positron collision and a new kind of free electron laser X-FEL in the midway of the facility. The tunnel of the particle accelerator is a straight concrete tube, in which the facility is set up. The tunnel is 10 to 30 m below ground. The diameter is about 5.20 m.

The total electrical power of the TESLA linac is about 160 MW. High power cables require high voltage plus high currents. The electrical fields in cables are shielded but the high currents in the power cables generate magnetic stray fields which might disturb the beams. To allow an undisturbed operation of this collider, a magnetic disturbance field in the tunnel with less than $2 \mu\text{T}$ of the energy supply is necessary. For this application a low interference, space saving and low losses system for the electrical supply is needed.

A distribution device system for $U_N = 20 \text{ kV}$, $I_N = 750 \text{ A}$ with a very low magnetic disturbance field was designed and built using a coaxial gas insulated line KOGIL (100 % N_2 at $p = 1,1 \text{ bar}$). The special arrangement of the three conductors nearly neutralizes the surrounding magnetic field. Different thermal, magnetic and dielectric measurements have been made at the test set-up. The resulting magnetic field has been studied with simulations and verified with measurements.

2 POWER DISTRIBUTION

This power is distributed to 7 service halls with cryogenic system, klystron modulators, power supplies, auxiliary systems and the experimental area with the final focus, beam dumps and the detector hall in the center. The distance between two halls is between 2,5 km to 5 km. The electrical mains power is up to 20 MW per service hall. The service halls are surface buildings. The access points to the mains of the power company can be on the surface or through the tunnel from one service hall to the next.

3 DESIGN OF THE TUNNEL

The tunnel design according to the Technical Design Report of TESLA is shown in figure 1. The modulator pulse cables and the power cables are under the walk way. The damping ring under the sealing is sensitive for magnetic fields. The AC stray fields shall not exceed $2 \mu\text{T}$. The magnetic earth field of $47 \mu\text{T}$ is a DC field and doesn't disturb.

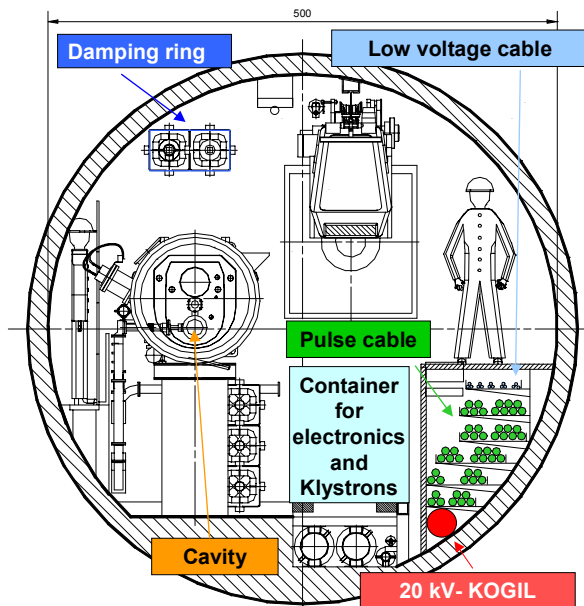


Fig. 1: Design of the TESLA tunnel

4 DESIGN OF THE NEW COAXIAL GIL

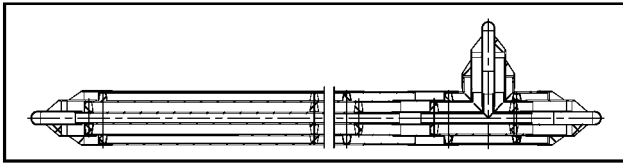


Fig. 2: 25 MVA Prototype coaxial gas insulated line KOGIL

To obtain a low stray field power line a gas insulated line with three coaxial conductors was designed and built at Darmstadt, University of Technology, High Voltage Laboratory (Fig. 2). By superposition the currents of the three phases compensate each other to zero at any time.

The prototype consists of three coaxial aluminum pipes, which are fixed by disc insulators. The insulation gas is nitrogen with a pressure of 1.1 bar absolute. The modular construction consists of the modules straight line, end caps and T-junction. The joints between the pipes are pushed muffs. This allows an easy assembly and fast repair.

The design parameters are:

Voltage:	20 kV _{AC}
Current:	750 A _{AC}
Power:	25 MVA
Pipe L1:	80 mm
Pipe L2:	230 mm
Pipe L3:	350 mm
Wall strength:	10 mm
Length prototype:	5 m

5 ADVANTAGES OF KOGIL

The main advantages are

- Minor magnetic fields in the surrounding
- No fire load
- Minimized transmission losses because of the missing return lines
- Minimized heat losses and thermal stress
- Non-aging because of the gas insulation
- Self-restoring insulation
- Fabrication in workshop

6 APPLICATIONS

The applications are in the range of medium high voltage and high voltage for power transmission. The low magnetic fields at the outside of the KOGIL and the lack of the fire load are most interesting features. This allows the application in high voltage application. In Switzerland a discussion is going on to restrict the magnetic field down to 1 μT. Other possible applications are in medicine technology and EMC sensible equipment. The lack of fire load is a very interesting feature in tunneling, mining industry and ship industry.

7 FIELD CALCULATION AND MEASUREMENTS

The radial field distribution was calculated with MAFIA. The field vectors are concentrated between the gaps of the pipes.

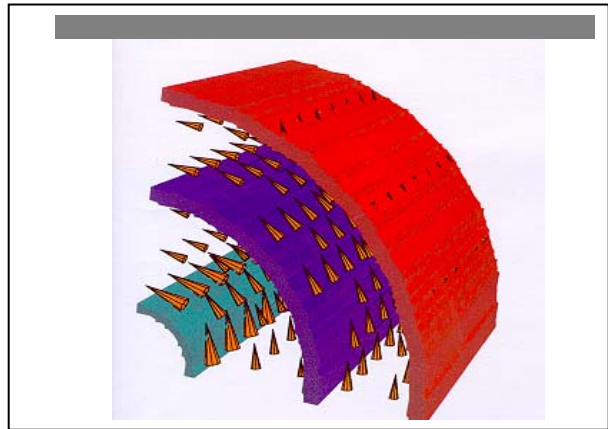


Fig. 3: Radial field calculation of the KOGIL

The fields in the surrounding is nearly zero if the length is infinite. In reality tolerances are in the assembly of the pipes. The skin effect causes an uneven distribution of the current inside the conductors. The largest impact to the surrounding fields derives from the terminals and connecting cables the bus bars. The field measurements of the 5 m prototype show a minimum in the middle. The fields are at the end caps and at the T-junction stem from the connecting cables.

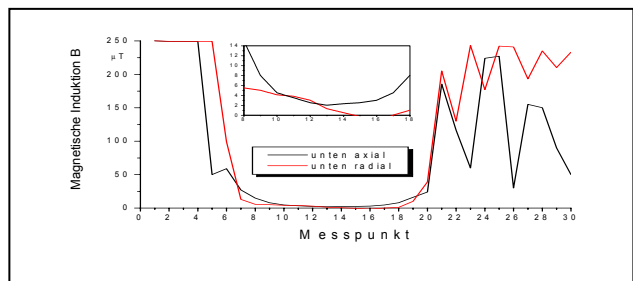


Fig. 4: Longitudinal field measurement

8 THERMAL MEASUREMENTS

The current in a metal pipe creates electrical losses due to the resistance of the material. Each pipe transmits the heat to the surrounding by thermal convection and thermal ray. The temperature of the inner conductor determines the maximum current of the KOGIL. The heat losses from the inner conductor have to overcome two gas gaps and two surrounding conductors. Another important item are the junctions between the modules. More special precautions have to be taken.

The prototype was equipped with 110 measuring thermocouples. The measurements were taken with the nominal current of 750 A. After 2 hours the temperature reached a steady state at 75 °C for the inner conductor.

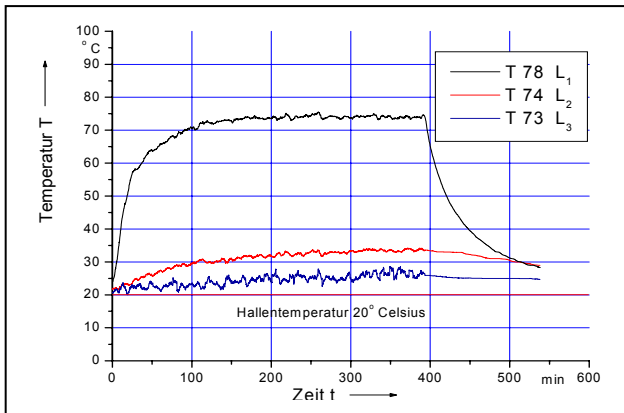


Fig. 4 Temperatures at 25 MVA, 750 A, design value

The time constant is about 1 hour. The temperature rise of the outside pipe is only 7 °C. The difference in the temperature rise results from different current densities and cooling aspects. Since standard pipes from industry are taken the cross section of the inner conductor could not be increased.

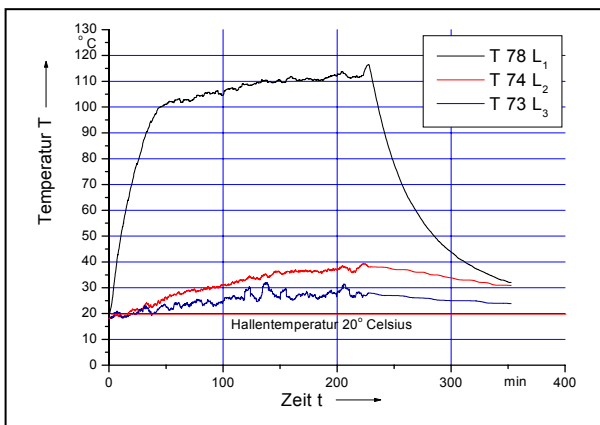


Fig. 6 Temperatures at 50 MVA, 1350 A, 200% design current

A proof test was made shown in Fig. 6. When doubling the current the temperature rises up to 110 °C. This means 50 MVA power transmission.

9 SUMMARY

A multi coaxial gas insulated line KOGIL allows the electrical power transmission with low magnetic fields. The fire load of a KOGIL is zero. This makes it attractive for high energy physics and tunnel applications. The no fire load advantage allows long tunnel sections and a high transmission capability. Laboratories and areas with sensitive equipment are also the domain of this novelty.

The system is much more compact than three conventional gas insulated lines (GIL). The presented KOGIL allows a prefabrication of the modules in the workshop and on site an easy assembly. It could be used in TESLA. The designed prototype would be able to supply one complete service hall of 20 MW. In case of a failure one KOGIL can supply two complete service halls with electrical power.

10 REFERENCES

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- [2] Koaxialer gasisolierter Leiter (KOGIL) zur extrem störfeldarmen elektrischen Leistungsübertragung, D. König, F. Hoertz, Hannover Messe 2002