High Voltage Instrumentation Cables for the ITER Superconducting Magnet Systems

Summary for Call for Nominations

1. Background and scope

ITER will be the world's largest experimental facility to demonstrate the scientific and technical feasibility of fusion power. The superconducting magnets providing the magnetic fields necessary to the generation and operation of the plasma contain many different sensors. Each sensor measures a specific physical parameter of the magnet system (voltage, helium mass flow, pressure, temperature, strain, displacements, etc.). The instrumentation wires of all those sensors at a temperature level of around 4.2 K will be routed from the inside of the cryostat to the feedthroughs located at the feeders' cryostat wall at room temperature.

A large quantity of these sensors e.g. voltage taps and some temperature measurements are on high voltage (HV) and accordingly also the instrumentation cables for these sensors. This document outlines the technical requirements for the high voltage cables, their testing as well as the qualification to meet ITER requirements.

2. Strategy

ITER IO is conducting a call for nominations with the DAs in the frame of the procurement of high voltage (HV) instrumentation cables. The call for nominations is for companies in the domain of instrumentation cables for high voltage and low temperature (4.5 K) application and for which a high degree of reliability is required.

ITER IO will select companies with whom to launch qualification contracts for the production a short unit length of 200 m. These companies will be selected following the *qualification criteria* as indicated in the section below.

Once these qualification contracts are concluded, and as a part of the same process, a call for tender will be performed with successful companies (the ones having submitted the final products within the specification).

As a result of the tender action, one (or more) companies will be awarded the final production contract (or a large fraction of it). It is expected that if possible at least two companies will be involved in the production. This will help keeping competition and is a fallback solution in case of problems.

3. Schedule and milestones

The following is a forecast of the overall process including series production:

- Call for nominations for qualification prototypes by January 2012
- Contracts for development and qualification prototypes placed by April- May 2012
- Submission of prototypes with certificates by July 2012
- Call for tender for final production by September 2012
- Final contract(s) awarded by December 2012

4. Quantities

As indicated above, the call for nominations for prototypes requires the production and delivery of a continuous unit length of 200 metres.

As additional information for companies, it is announced that the total length for the series production will be approximately 80 km, with the possibility of different numbers of individual wires. The design will be the same independent of the number of wires.

5. Technical requirements

The HV instrumentation cables integrate wires for the connection of the terminal of protection resistors at high voltage to the feedthrough on the surface of the vacuum vessel. The protection resistors are installed next to the voltage taps sitting on high voltage pipes of the superconducting coil. The HV instrumentation cables basically must:

- Give the following galvanic separation at high voltage from the individual wire and the HV shield with respect to the ground shield around it (see Fig. 1):

Rated voltage	30 kV DC	20 kV AC
Test voltage	56 kV DC	40 kV AC

  The DC test voltage of 56 kV and AC voltage of 40 kV is only applied during the tests of the HV cable itself and together with the attached feedthrough. The test voltage must be applied at least for 10 min.

  During routine tests once cables are attached to the superconducting coils, only a test voltage of 30 kA DC will be applied without a limit for time or number of tests.

- Give galvanic separation between the individual wires (in the range from 2 to 6) and also to the HV shield,

Rated voltage	2.5 kV DC	1.8 kV AC
Test voltage	5 kV DC	3.5 kV AC

- Assure the galvanic separation in Paschen condition of helium around the HV instrumentation cable and this requires a continuous manufactured dielectric insulation (for example extruded) and explicitly excludes techniques based only on wrapping of tapes, which may be porous to gaseous helium,
- Include individual wires made of copper filament wires (between AWG19 and AWG28), silver coated and twisted as pairs. The twist pitch can be defined at a later stage,
- Have the HV shield as well as the ground shield fabricated from copper mesh, silver coated and should cover at least 85 % of the surface,
- Use the following insulation materials, or combination of them, in extruded or film conditions can be used for all insulation steps as far as the other requirements like HV Paschen tightness can be met:
    - high density thermoplastic polyethylene (HDPE),
    - cross-linked polyethylene (XLPE)
    - polyimide (PI),
- Have the individual wires coulored/numbered coded every 100 mm,
- Tolerate an operating temperature which is between 4.2 K at the cold end on the superconducting coils side and room temperature at the warm feedthrough of the vacuum port,
- Have an outer diameter (which depends on the number of wires and on the required HV insulation) as small as possible for flexibility and space reasons
- Allow integration as well as Paschen-tight curing into the epoxy resin on the cold side to the protection resistor and the warm side to the feedthrough,
- Have an gassing rate in the range of 1 x 10^{-9} Pa m^3 s^{-1} m^{-1} at 20C after 100 hrs under vacuum,
- Be able to withstand an integrated dose of at least 100 kGy. This will prevent from using insulation materials which are not suited for this level of radiation,
- Allow a bending radius smaller than 300 mm.
- Have a high degree of reliability for an operating life of 30 years.

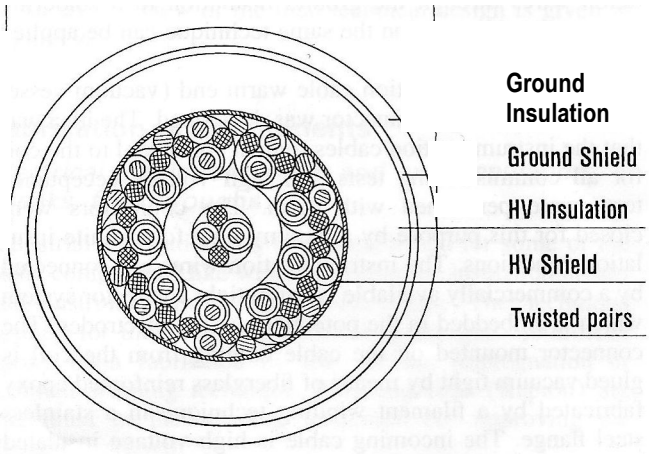

Fig. 1 Cross section of an example of a HV cable [1]

6. Test programme

The HV and partial discharge tests carried out by the Contractor during the prototype production must confirm the quality of the insulation. All the other tests -marked below with an *- will be carried out by Associated Institutes to the ITER Organisation (IO). The Contractor shall propose a detailed test programme for the tests carried out by its means. Test certificates must be provided accordingly with respect to the established standards. The IO Associated Institutes will provide test reports to the suppliers for tests carried out at their premises. This should be considered as an advantage by the Contractors who will receive complete datasheets for their records providing considerable added value.

- AC and DC voltage tests in air using the following voltages: wire to wire and wire to HV shield 5 kV and wire and HV shield to ground shield 56 kV, and corresponding AC values,
- *AC and DC voltage tests with low pressure helium around the cable in Paschen condition and the same voltages as above,
- *Fatigue bending test at room temperature and at 77 K,
- Partial discharge test: the partial discharge inception and extinction voltages shall be determined at a discharge magnitude of 5 pC, the sensitivity of the detector shall be better than 1 pC,
- *Radiation resistance, and in particular fatigue bending tests at 77 K after irradiation,
- *Outgassing test at room temperature
- *Assembly tests with a subsequent HV and Paschen test to
    - a feedthrough,
    - a coil sensor mock-up including the protection resistor

During prototype and series production all manufactured items will pass a strict quality control test procedure which shall be proposed by the Contractor.

The detailed HV and partial discharge test programme for the prototype production shall include at least:

- Equipment
- Testing plans
- Testing electrical diagrams
- Ambient atmosphere temperature and relative humidity
- Method of voltage application
- Acceptance criterion
- Calibration of equipment plans
- Non-conformances report and corrective actions
- Identification and traceability plans
- Reports templates

The detailed HV and partial discharge test programme shall be submitted to IO for approval prior to the start of high voltage testing operations.

7. Pre-qualification criteria

In order to be pre-qualified, Companies must have in hand all the following aspects of proven experience and know-how for at least the last 10 years:

- Experience in the domain of high voltage instrumentation cables (PQC1)
- Experience with insulation materials used in applications at cryogenic temperatures (supercritical, super fluid or liquid Helium) (PQC2)
- Experience with insulation materials used in applications under radiation loads (PQC3)
- Experience with Partial Discharge measurements and related equipment (PQC5)

Companies must be equipped with all machines and equipment which allow the complete in-house manufacturing of the cables (stranders, braders, film-insulating machines, continuous extruders, jacketing lines, etc) (PQC6)

Companies must have in possession an ISO 9001 certificate or equivalent. (PQC7)

8. References

[1] "*The electrical insulation system of a forced flow cooled superconducting magnet*", K. Bauer et al. (ITP-FzK, Leopoldshafen, Germany), Cryogenics 38 (1998) 1123-1134.

9. Candidature

Participation is open to all legal persons participating either individually or in a grouping (consortium) which is established in an ITER Member State. A legal person cannot participate individually or as a consortium partner in more than one application or tender. A consortium may be a permanent, legally-established grouping or a grouping, which has been constituted informally for a specific tender procedure. All members of a consortium (i.e. the leader and all other members) are jointly and severally liable to the ITER Organization. The consortium cannot be modified later without the approval of the ITER Organization.

Legal entities belonging to the same legal grouping are allowed to participate separately if they are able to demonstrate independent technical and financial capacities. Bidders' s (individual or consortium) must comply with the selection criteria. IO reserves the right to disregard duplicated references and may exclude such legal entities form the tender procedure.