Feasibility study of a cryogenic power supply for superconducting DC devices

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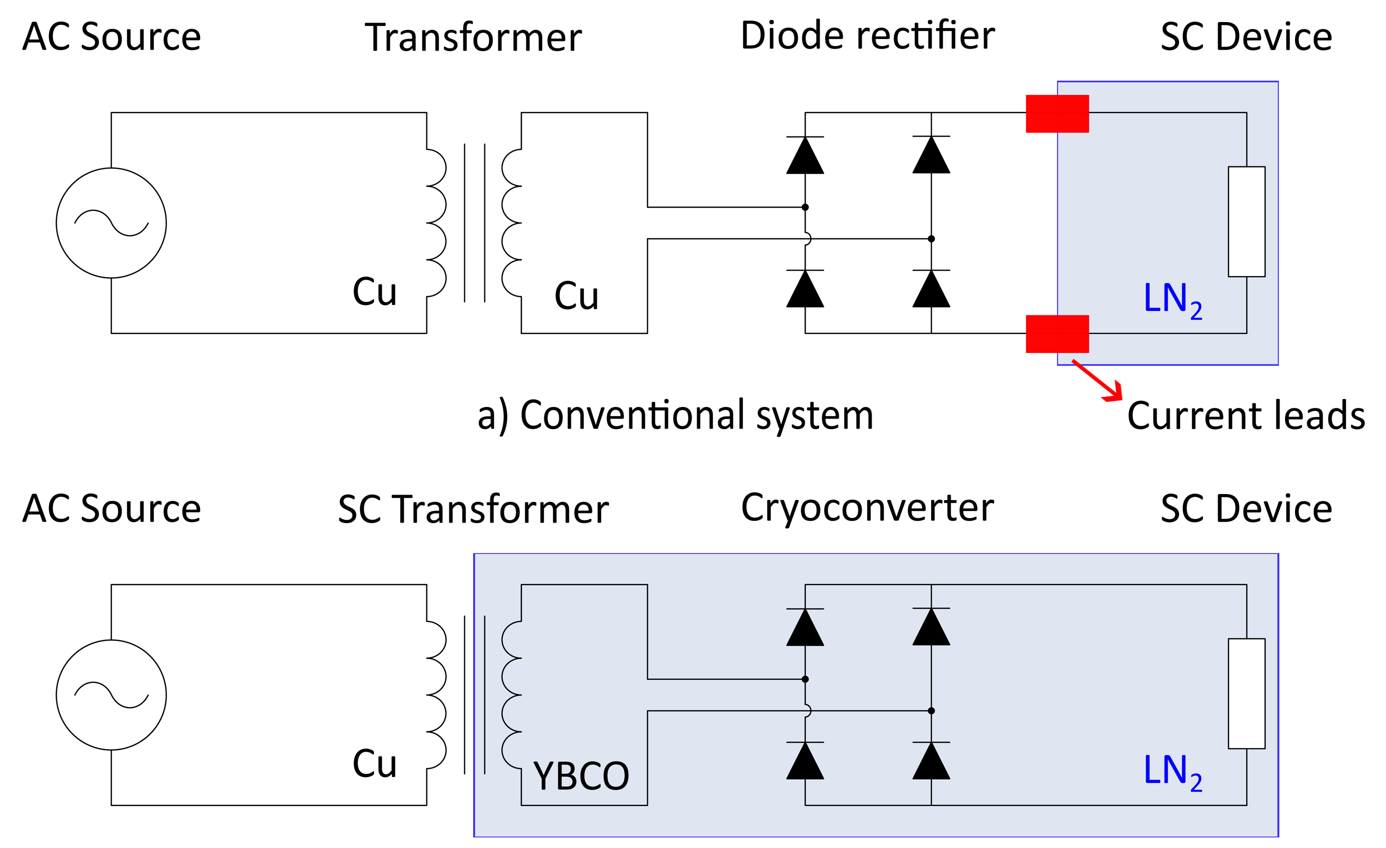
Purposes

- Alternative option to dispense the current leads, responsible of high losses in superconducting systems [1].
- Design of a superconducting transformer with its diode rectifier operational at cryogenic temperature.

System design



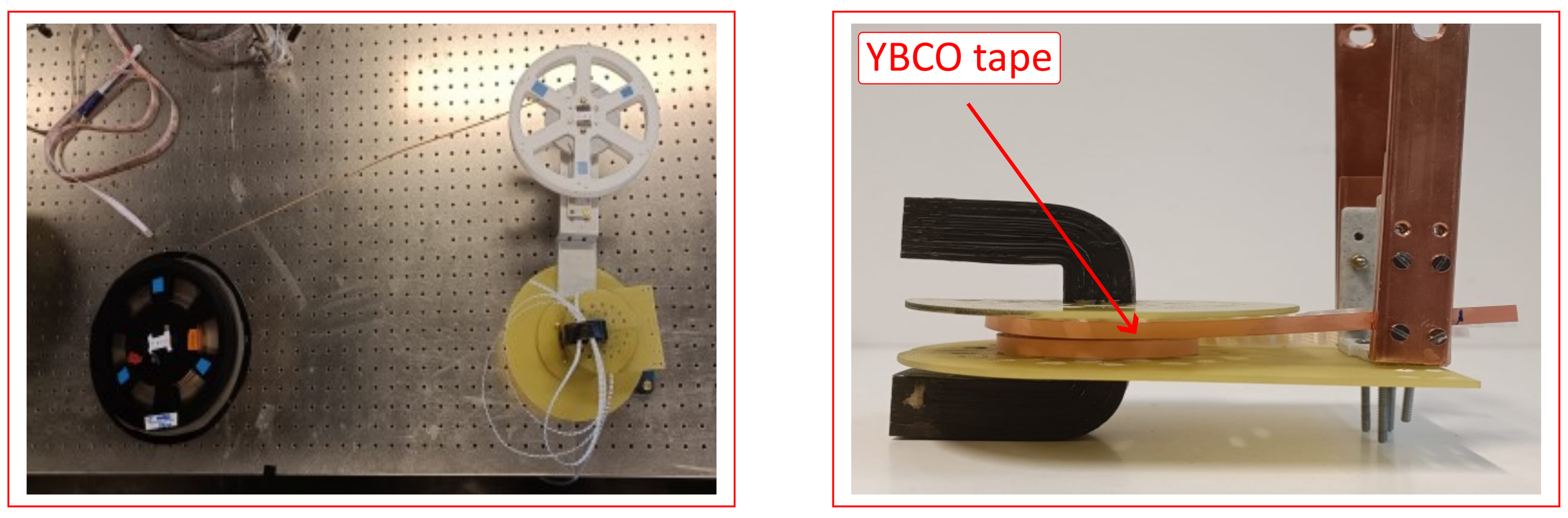
b) Studied system

Fig. 1 - DC superconducting device power supply system.

Superconducting transformer

Double pancake coil

- A coil winding configuration where two pancake coils are stacked on top of each other.
- After the coil characterization in LN_2, we measured a critical current of ~ 40 A.

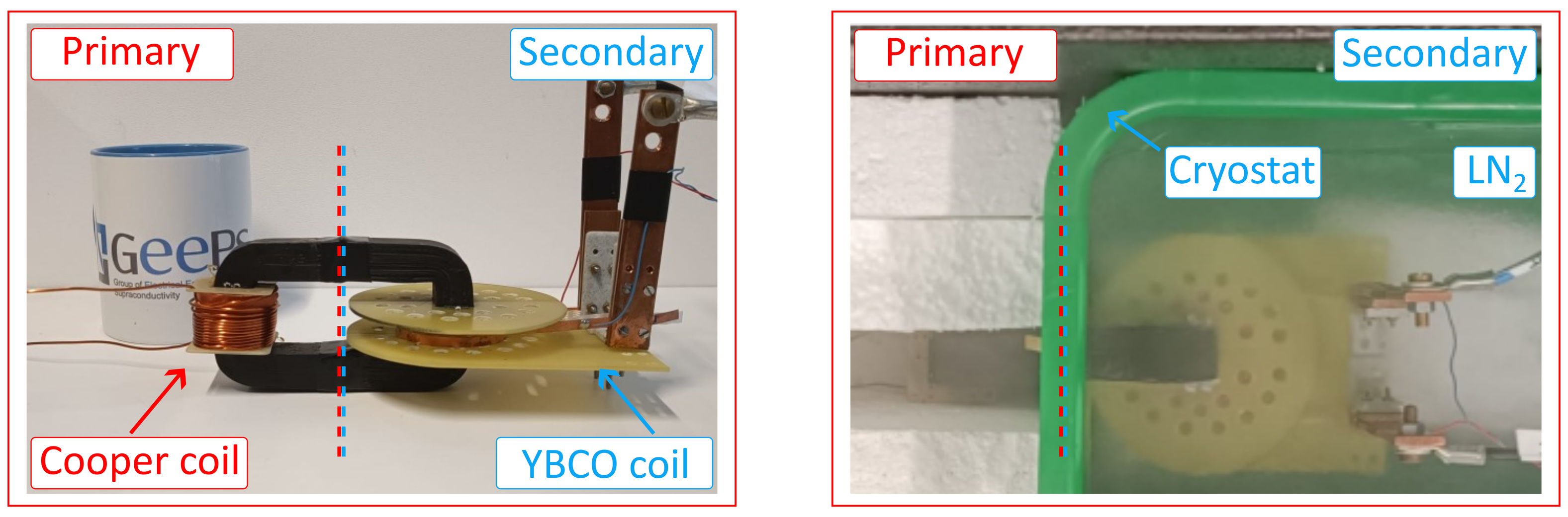


a) DPC Winding system. b) Double pancake coil.

Fig.2 - Realization of the SC double pancake coil.

Transformer test

- The SC transformer consists of the DPC as secondary winding, separated from the primary copper winding by an airgap of 4mm thick plastic serving as cryostat to retain the LN_2.



a) Superconducting transformer. b) Test setup.

Fig.3 - Transformer prototype.

- Following an equivalent circuit of a single-phase transformer (Fig.4), open-circuit and short-circuit tests were performed to obtain the transformer parameters (Tab.1).

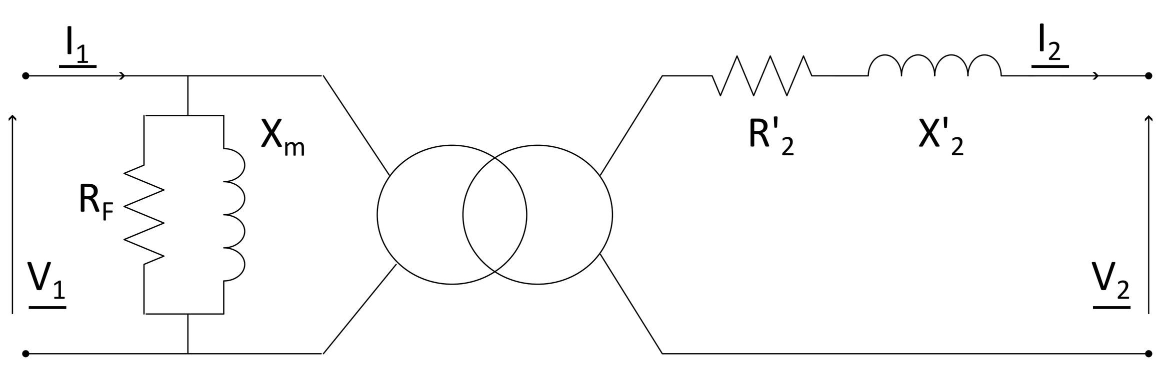


Fig.4 - Single-phase transformer equivalent model.

Tab.1 - Transformers parameters

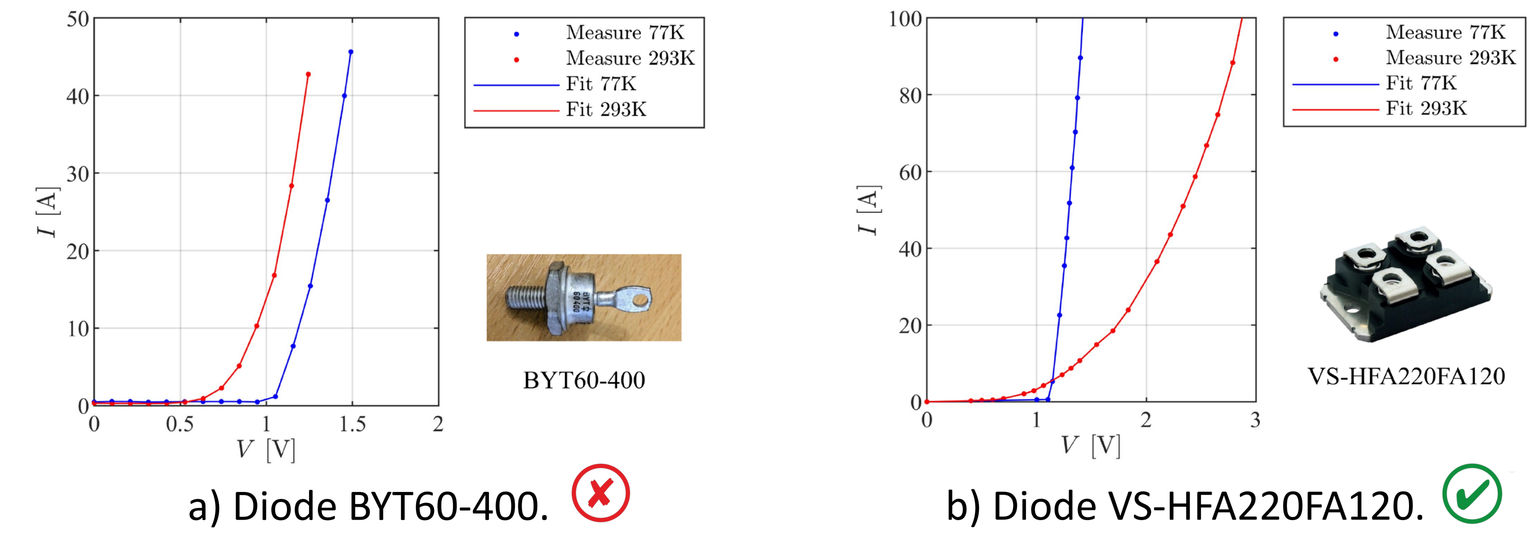
	V_2/V_1	η_t [%]	R_f [Ω]	X_m [Ω]	R'_2 [Ω]	X'_2 [Ω]
Conventional	0.11	**1.5**	1.13	0.42	**3.76**	4.24
Superconducting	0.09	**25.8**	1.74	0.38	**0.05**	0.16

Note: Efficiency does not take into account the cooling system power (i.e $\eta_t = P_2/P_1$).

Cryoconverter

Diode characterization

- Different semiconductor technologies behave differently at cryogenic temperatures [2].
- Some diode technologies are more suitable for operation at cryogenic temperature.

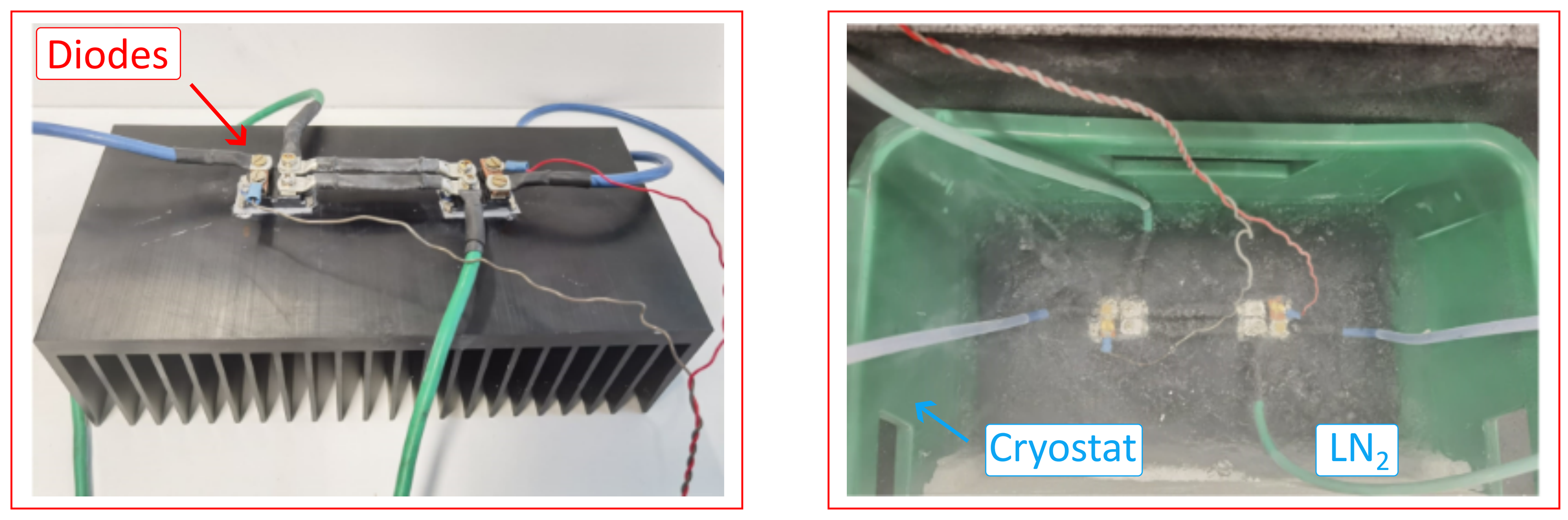


a) Diode BYT60-400. b) Diode VS-HFA220FA120.

Fig.5 - Measured diode current-voltage curve.

Cryoconverter test

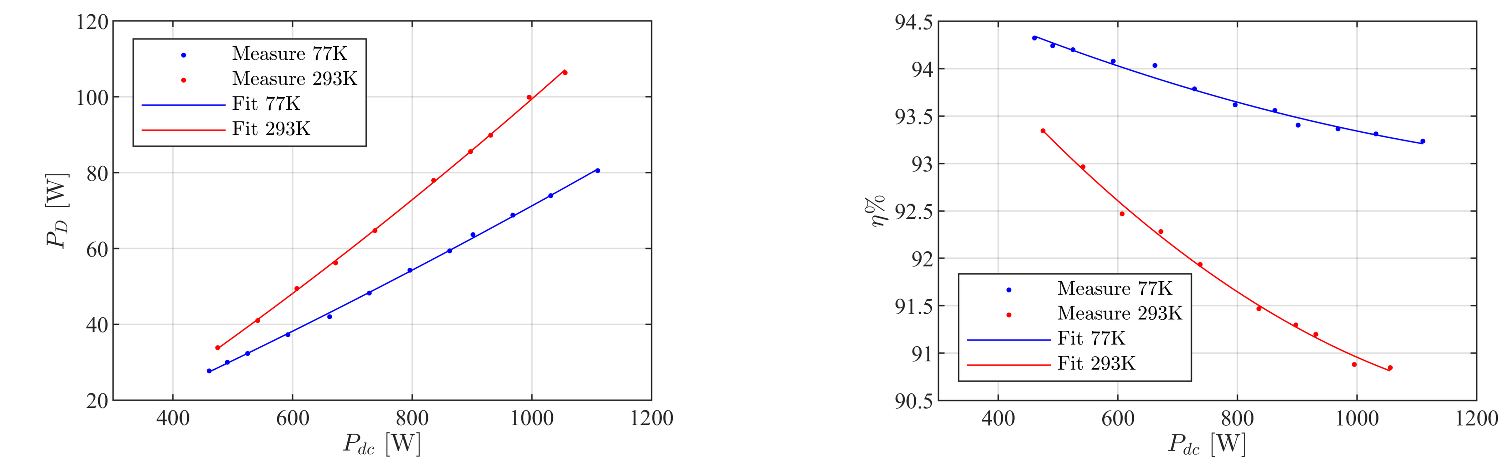
- The diodes with favorable behavior in LN_2 are connected as 4 diodes single-phase rectifier on top of an aluminum heatsink to improve heat dissipation.
- A sinusoidal voltage of 50 V RMS was applied and the efficiency was studied for several load and hence power.



a) Diode rectifier prototype. b) Immersion in LN_2.

Fig.6 - Diode bridge test at cryogenic temperature.

- Diode rectifier losses reduced by an average of 27.6%.
- Diode rectifier efficiency improved by 2% for a DC power of 1kW.



a) Losses per output power. b) Efficiency per output power.

Fig.7 - Cryoconverter performances at room and cryogenic temperatures.

Conclusion

- Development of the superconducting double pancake coil.
- Realization of a first superconducting transformer.
- Power transfer through the cryostat between different temperatures.
- Characterization of diodes at cryogenic temperature.
- Realization and test of the diode rectifier operational at cryogenic temperature.

Next steps

- Further assembly of the system improving the output level of the transformer to 1kW.
- Improvements of the cryostat for the reduction of the airgap.
- Make a techno-economic analysis between systems under study.

References

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