Development of 17 high-current power supplies for the TCABR tokamak

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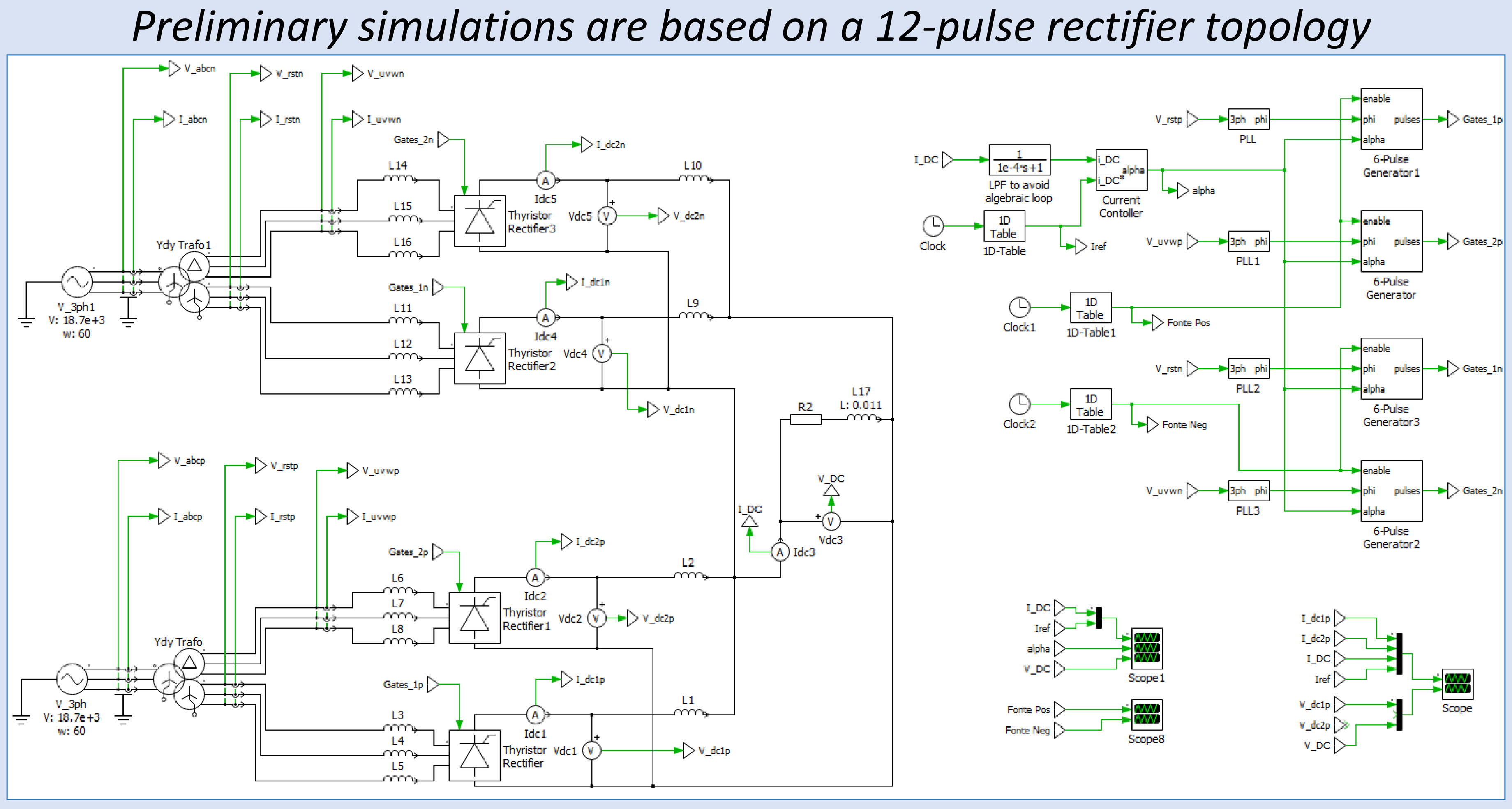
ABSTRACT

- An upgrade is being conducted on the TCABR tokamak, which is a small-size tokamak (R0 = 0.62 m and a = 0.2 m) operated at the University of São Paulo, Brazil.
- This upgrade consists is the installation of additional shaping coils to allow for the generation of various divertor configurations such as single-null, double-null, snowflake and x-point target divertors.
- The control of these various magnetic configurations requires the development of 17 robust and high-performance power supplies.
- To identify the most appropriate solution, different power electronic topologies are being considered such as thyristor-based, IGBT full-bridge, and resonant converter power supplies. In this work, a comparison between these topologies in terms of controllability, complexity and cost will be presented.

BACKGROUND

- The proposed modernization of the TCABR tokamak, located in the Laboratory of Plasma Physics (LFP) of the Institute of Physics of the University of São Paulo (IFUSP), provides for the study of plasmas with more varied forms that are relevant to controlled thermonuclear fusion.
- For such plasma formats to be obtained, it will be necessary to control a set of 17 magnetic coils responsible for plasma control.
- Among these coils, one of them is responsible for the induction of high currents in the plasma (around 100 kA), called the Ohmic coil, while the other 16 coils, called shaping coils, are responsible for position control, shape and stability.
- As each coil must be independently controlled, each coil must be individually powered.
- The sources should provide direct current and follow pre-programmed waveforms. In addition, due to the high inductance and low resistance of the coils, the sources must operate in the four quadrants of a voltage-current diagram.
- Associated with the subsystems of Modular Energy Storage, Reactive Power Compensation, Safety, Control and Operation, these sources represent a complex system of pulsed power supply.
- The topologies currently used in the design of such systems are basically related to the use of inertia flywheels in the energy storage and, thyristor converters, operating at high frequencies, in the design of the power converters [1] e [2].

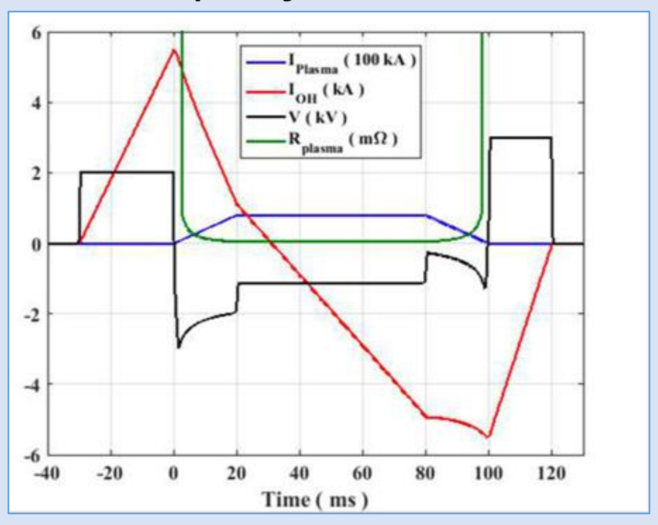
Preliminary simulations are based on a 12-pulse rectifier topology



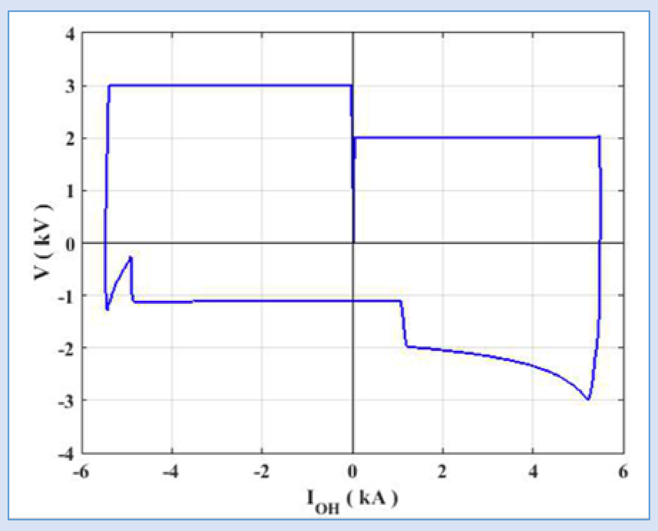
CHALLENGES

- The LFP three-phase power supply is limited to approximately 80MVA (13.2 kV/ 3.5 kA). According to initial specifications, the source responsible for the Ohmic coil supply should be composed of a static converter with a capacity of 24 MW of instantaneous power (4 kV/ ±6 kA), while the other sources responsible for feeding the shaping coils to be composed of static converters with individual capacity of 5.2 MW of instantaneous power (650 V/ ±8 kA).
- Due to the obligatory optimization of resources, space constraints and the high powers involved in the operation of the system to be controlled, this project requires a very detailed planning of the entire laboratory network.
- Given the challenges mentioned above, a study of the technical feasibility of different possible solutions will be carried out to define the most appropriate control strategy, taking into account the different possibilities of technology, topologies and semiconductor switches.

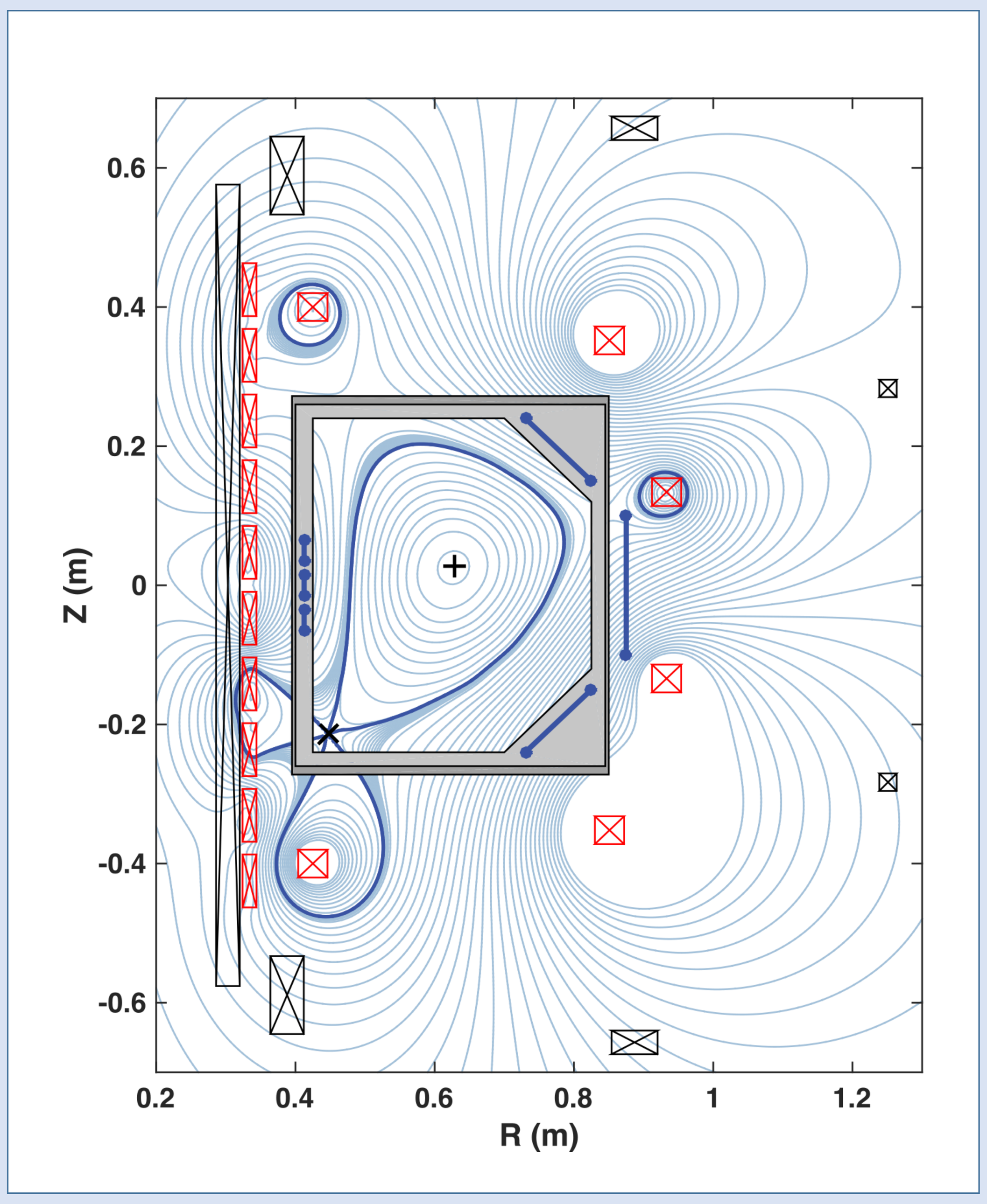
Voltage and current specifications



Operation in four quadrants



TCABR Snowflake configuration



CONCLUSION

- The definition of topologies and the consequent development and manufacturing of the power supplies is an extremely challenging task. The new performance functionalities are complex and require projects with advanced flexibility and reliability.
- Energy and the investments are limited. To reduce all risks inherent in a project of this magnitude, it is always preferable to select commercially available components and materials. However, the majority of the equipment used in this kind of application has very peculiar characteristics of operation, which difficult but also enhances the simulations.

ACKNOWLEDGEMENTS / REFERENCES

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[2] C. P. Kasemann et al. Pulsed Power Supply System of the ASDEX Upgrade Tokamak Research Facility.