Method for supervising a DC system

Based on discrete event systems theory and classification of operational states

CONTEXT

In HVDC systems, because of the small inertia provided by the power electronic components, any perturbation is rapidly propagated throughout the grid. Moreover, the control of the converters has a great impact on the dynamics, thus if the control and protection actions are not correctly coordinated, they could eventually lead to a blackout of the grid. In consequence, it is necessary to design an automated supervisory control that coordinates rapidly the system operation through a series of control and protection sequences.

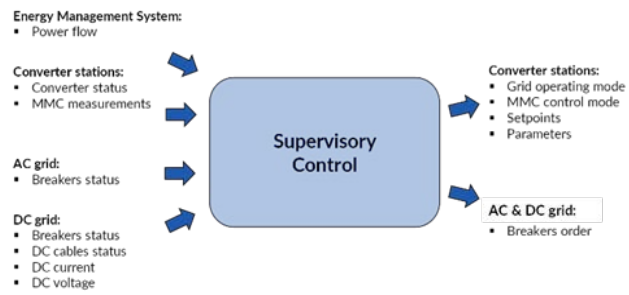
In the new era of increasingly complex and digitalized grids, the scenarios covered by the supervisory control cannot be determined on engineering expertise alone and it is necessary to identify and classify all the possible operational states of the system to maintain the system as close as possible from its normal operation.

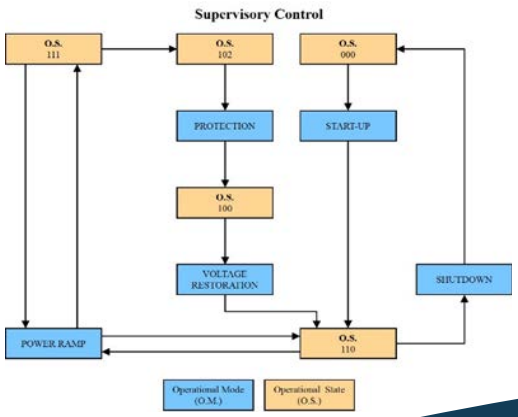
TECHNOLOGY DESCRIPTION

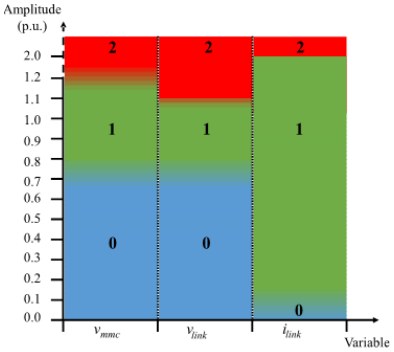
The proposed solution superimposes several layers of monitoring and control while ensuring that system requirements are respected by construction. The proposed approach covers the supervisory control's development process from the design as formal automata models to the implementation as executable code.

In the long term, the proposed solution helps reduce the engineering effort and gives a common framework for all the engineers during the requirements definition stage.

Approach / Characteristic	Hands-on	Formal	Data-based
Prerequisites	Engineer expertise	Engineer expertise	Pre-treated data
Model interpretation	Subjective	Objective	Subjective
Development time	Time-costly	Time-saving	Time-saving
Validation stages	Recurrent	Occasional	Recurrent
Scalability	Non scalable	Scalable	Scalable
Model refinement	A priori	A priori	A posteriori
Diffusion among experts	Wide	Limited	Medium







APPLICATION DOMAIN

Point to point and multiterminal DC systems
MVDC, HVDC, DC microgrids

ADVANTAGES

Formal method allow a supervisory control correct-by-construction, preventing any undesired emergent behaviour

Physical indicators defining the capability to operate of the system based on the components' energy level

Manage complexity with a modular approach

Exhaustive exploration of the operational states of the system prior to its operation, and selection of the transition actions.

TRL SCALE

1 2 3 4 5 6 7 8 9

Virtual mock-ups of supervisors
Demonstrator within WP9 (HIL experiment) of PROMOTiON
Automated software tool to generate a supervisor code

DELIVERABLES

Patent FR20190008975
Technical reports:

- 1169-vAB-A Generic Method for Implementation of Supervisory Control of Discrete Event Systems
- 1407-vAA-Supervisory control synthesis for MMC-based HVDC systems

SCIENTIFIC REFERENCE

M. Romero Rodríguez, Romain Delpoux, Laurent Piétrac, Jing Dai, Abdelkrim Benchaib, Eric Niel. "Supervisory Control for High-Voltage Direct Current Transmission Systems". IFAC World Congress, vol. 50, no. 1, p. 12326-12332, 2017.

M. Romero-Rodríguez, Romain Delpoux, Laurent Piétrac, Jing Dai, Abdelkrim Benchaib, Eric Niel. "An implementation method for the supervisory control of time-driven systems applied to high-voltage direct current transmission grids". Control Engineering Practice, vol. 82, p. 97-107, 2019.