ScuDo

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XXXIII Cycle

Innovative analysis methodologies and tools applied to the transmission electric grid

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Research context and motivation

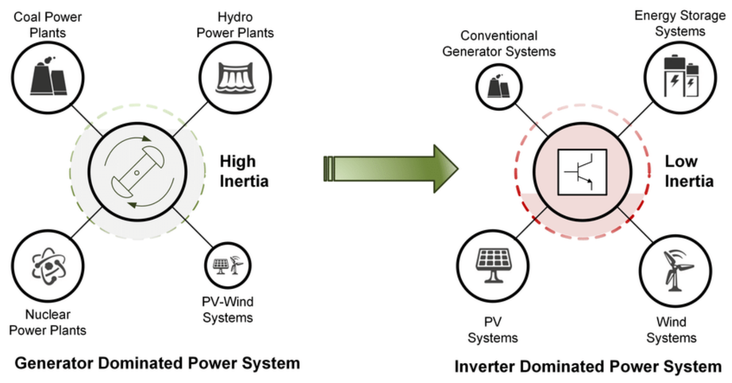
My research activity is based on the collaboration between the Italian TSO, **Terna**, and **Politecnico di Torino**. The aim is the integration of innovative tools into the traditional power system **operation** and **planning** problems, which will account for several new factors like the social-economic impacts and the environmental sustainability of the grid assets. The TSOs are facing quick changes in terms of amount of reserves and regulation performance caused by the high penetration of distributed energy sources. The great flow of renewable energy results in multiple grid events, such as voltage variations and over-frequency phenomena. Furthermore, the increasing share of non-programmable generation entails more complexity in the very short-term forecasting of electric production necessary for ensuring continuously the balancing of generation and consumption.

In this context, some important **issues** and **challenges** are ongoing:

- Reduced inertia in power systems
- Bus-bar configurations
- Real-time tool for sub-transmission systems operation

Addressed research questions & Novel contributions

- In the first topic, the **low inertia** issue in modern power systems is being investigated, which is creating concerns mainly for frequency stability dynamics, during relevant incidents and in the normal operation. Different options to mitigate the impact are being analyzed: **synchronous compensators**, Battery Energy Storage Systems (**BESS**), High Voltage Direct Current (**HVDC**). Objectives:
  - Find a value for the minimum inertia requirements in the grid
  - Analyze the frequency stability of the future Continental Europe power system
  - Develop frequency and voltage stability indicators for operation and planning
  - Address technical and economic analysis of the possible solutions
- Conceptualization of dynamic aspects of power systems related to the frequency-power regulation and realization of an **aggregated model**, calibrated on the real power system of **Sardinia**, with implementation of HVDC, BESS and protection schemes models.



- Traditionally, static security studies use contingency analysis containing only branches and generators, but recent events have shown the relevance and severity of failures on the bus-bar of a substation. The main purpose of this study is to assess the impacts of **bus-bar faults**, including them into the contingency analysis, and to choose the best configuration with the definition of novel **indicators**, based on the violations following a bus-bar fault.

- The third research topic is aimed to the develop and implementation of a new approach for the estimation of "**pseudo-measurements**" in the sub-transmission network in real time, aiming at the optimization of the State Estimation algorithm of the Italian TSO. The question is if it is possible to find a solution for the lack of measurements and redundancy in order to obtain good performance for the State Estimation.

Submitted and published works

- Mosca C., Arrigo F., Mazza A., Bompard E., Carpaneto E, Chicco G., Cuccia P., "*Mitigation of frequency stability issues in low inertia power systems using synchronous compensators and battery energy storage systems*", IET Generation, Transmission and Distribution, 13(17), 2019
- Mosca C., Bompard E., Aluisio B., Migliori M., Vergine C., Cuccia P., "HVDC for frequency stability under RES penetration: the Sardinia island case", AEIT HVDC International Conference 2019, Firenze, Italy, 2019.
- Mosca C., Marin E., Huang T., Bompard E., Cuccia P., Campisano L., Neri S., "A new real-time approach for the load forecasting in the operation of sub-transmission systems", AEIT International Annual Conference 2019, Firenze, Italy, 2019

Adopted methodologies

- The **aggregated model** is used to investigate the impact of variable and decreasing inertia on the frequency signal of the power system. Different solutions to balance the grid are addressing and comparing, considering technical and economical impacts: synchronous compensators, fast primary regulation, synthetic inertia, Battery Energy Storage Systems (BESS). In particular, the importance of the HVDC regulation capability is in deep analyzed.

- Starting from an initial peak load situation, the major substations in the Italian power system are selected to investigate the impact of the bus-bar fault for different configurations. The total number of configurations is computed for each substations, and the current and voltage violations are stored and used to calculate the **ranking indicators**.

- The proposed approach for the load forecasting in the high voltage sub-transmission system starts from the load estimation through **Multiple Linear Regression**, **Artificial Neural Network** (ANN) and a combination of them. The methodology is used to learn the relationship among past variables related to the loads. The results are compared to find the most suitable technique for the TSO, with a compromise between complexity and reliability and demonstrated on a real 132 kV sub-transmission system operated by the Italian TSO.

Other activities

Visiting research period at the European Network of Transmission System Operators (**ENTSO-E**) in Bruxelles.

- Involved in the Ten-Year Network Development (**TYNDP**) plan group within the System Development Committee.
- Support of **Drafting Team Planning Standards.**
  - Investigation on approximation steady-state criteria for assessing the dynamic performance without detailed dynamic studies.
  - Enhancing the dynamic and operational challenges in the TYNDP.
    - Implementation of a European aggregate dynamic model.
    - Investigation of system split impacts.
- Support of **Drafting Team Cost Benefit Analysis.**

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Future work

Several ideas will be subject to further research:

- Extension of the study from the aggregated to a **complete dynamic model**, in order to compare benefits and issues of both.
- Investigation of the minimum inertia level in the European Continental system, with reference to the TYNDP plan of ENTSO-E. Particular attention will be given to the effects of **system splits**.
- **Cost-benefit analysis** of the possible solutions to mitigate the impacts of reduced inertia in power systems.
- Implementation of the tool used for the study of bus bar configurations and for real-time pseudo-measurements in the TSOs systems.

List of attended classes

- 01PQCND – Power generation from renewable sources (19/02/2018)
- 01SHCRV – Unsupervised neural networks (09/04/2018)
- 01QORRV – Writing Scientific Papers in English (21/02/2018)
- 02LWHRV – Communication (15/02/2018)
- 01QAAAA – European PhD School (04/06/2018)
- 01QAAAA – International Project Management (21/06/2018)
- 01QAAAA – CIMdesk Training (10/10/2018)
- 01QAAAA – CIM Training (30/11/2018)
- 01LGSRV – Characterization and planning of small-scale multigeneration systems (13/09/2019)
- 01UEPRP – Graph and Combinatorial Optimization (13/09/2019)

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