SIREN

Smart Integration of RENewables

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General Info

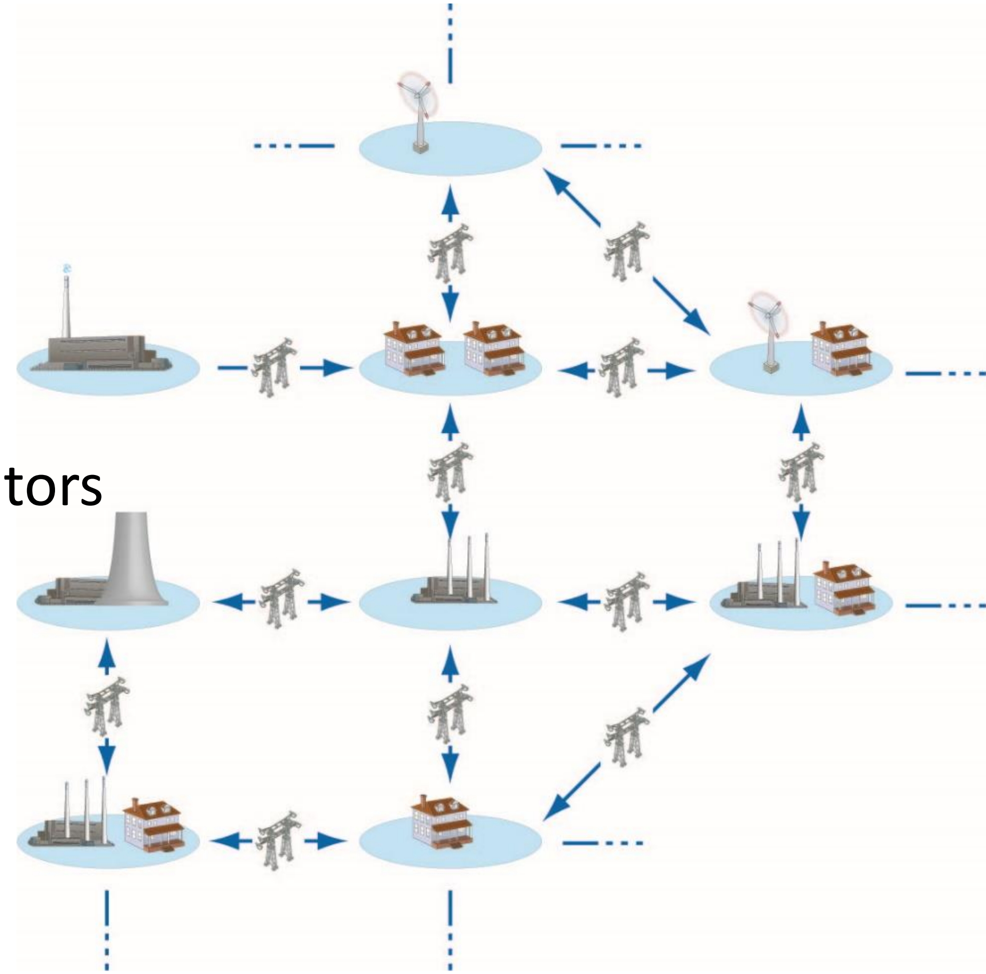
- Partnership with industry call (50% HOPS and 50% HRZZ funding)
- 280.000 Eur
- Three-year project: Dec. 2015- Nov. 2018
- 7 people from FER, 15 from HOPS, 2 PhD students funded

Research Objectives

- Investigate operating procedures of running the Croatian power system with high level of uncertain wind generation.
- Derive investment strategies that will enable high penetration of wind energy into Croatian power system.
- Determine requirements for connection of new wind power plants to the Croatian transmission network.
- Analyze the needs for storage in Croatian transmission network. This analysis includes the services that storage needs to provide to the system, as well as suitable storage technologies.
- Define regulations for utilization of such storages depending on the ownership (HOPS vs. third parties).

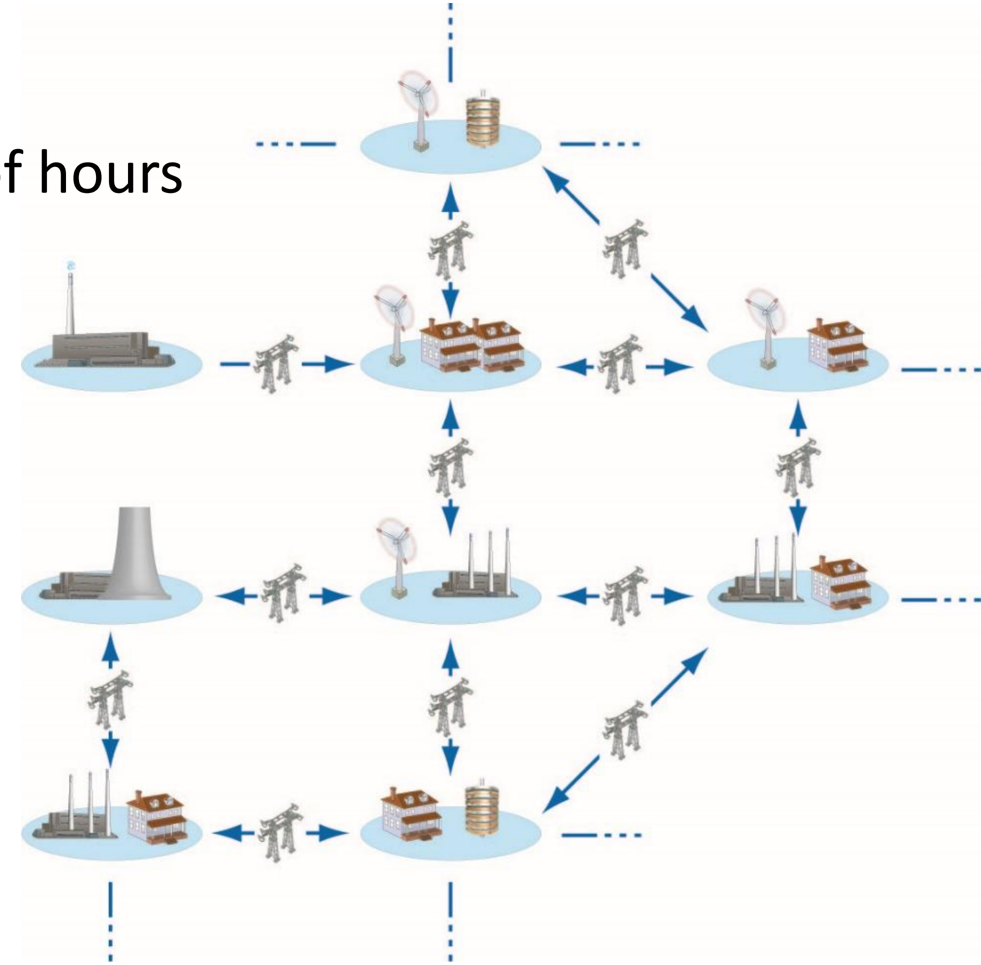
Power System

- Generation follows demand
- Allows moderate integration of non-dispachable generation
- Requires significant regulation capacity of controllable generators
- Costly flexibility
- Expensive preventive security needed to handle the contingencies



Energy System

- Energy balance over a period of hours
- Allows high integration of non-dispachable generation
- Requires less regulation capacity of controllable generators
- Flexibility mostly provided by storage
- Storage used for post-contingency control

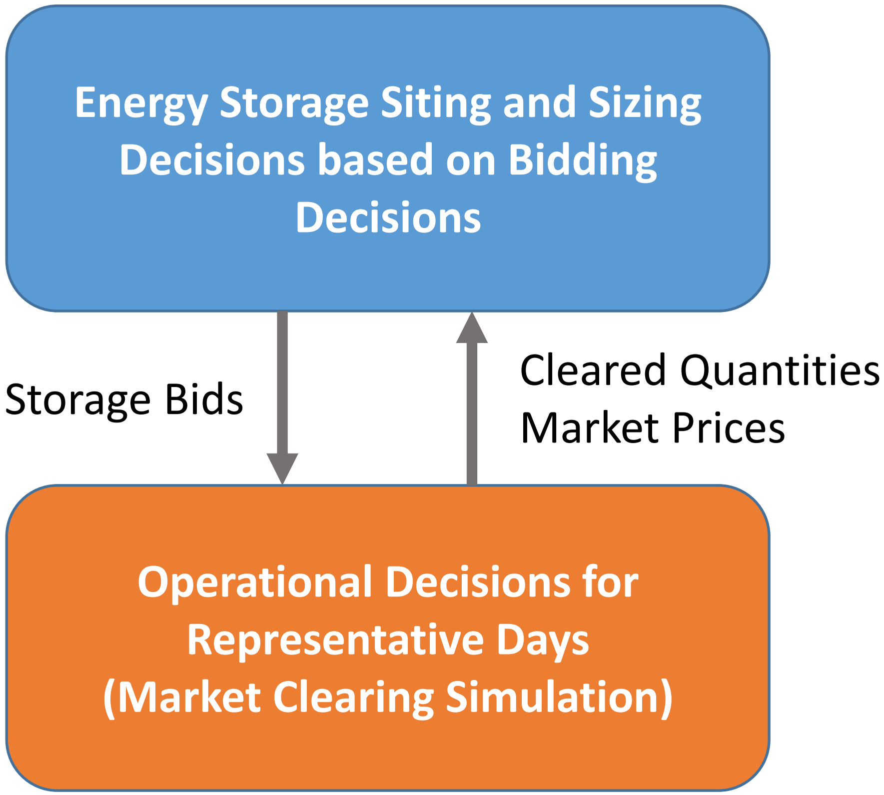


Storage Sources of Value

- Arbitrage
- Regulation services
- N-1 security
- Deffered investment in peaking generating units and transmission lines
- Less generator cycling –> lower maintenance cost

Third-party Storage Investment

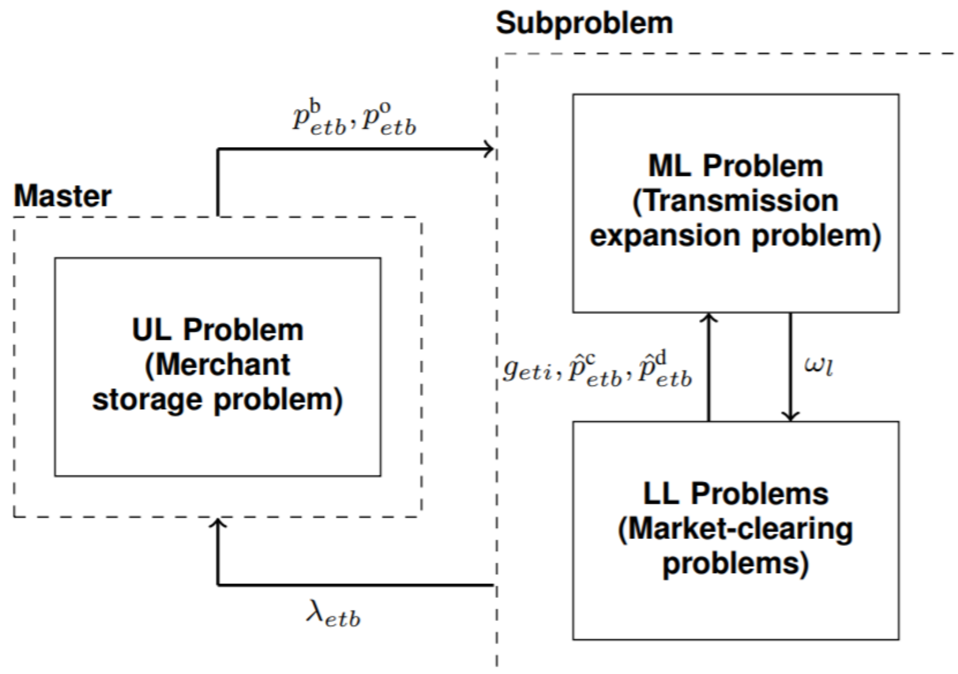
- Energy storage does not want to influence market prices
- Limited profitability when acting only in enery market



Yury Dvorkin, Ricardo Fernandez-Blanco, Daniel S. Kirschen, Hrvoje Pandzic, Jean-Paul Watson, and Cesar A. Silva-Monroy. Ensuring Profitability of Energy Storage, *IEEE Transactions on Power Systems*, vol. 32, no. 1, Jan. 2017, pp. 611-623.

Storage Investment Considering SO Expansion Decisions

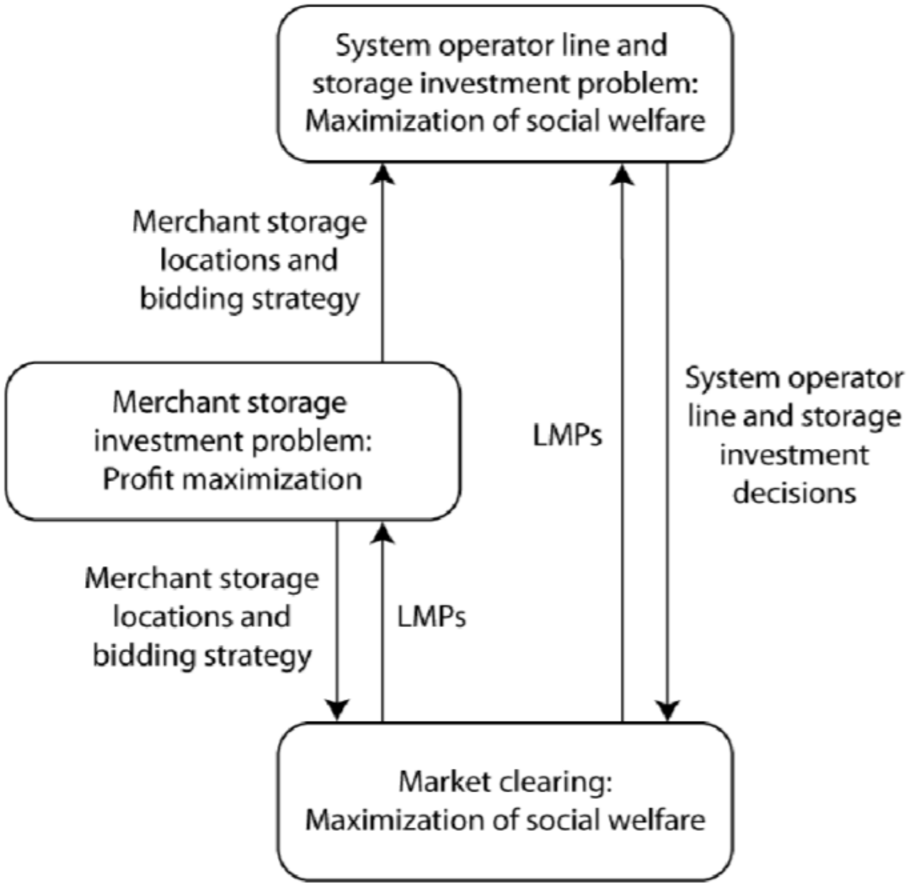
- Investment decisions by merchant storage operators accounting for the consequences of potential investment in transmission capacity by the SO
- Tri-level model to co-optimize merchant storage siting and sizing with centralized transmission expansion planning



Yury Dvorkin, Ricardo Fernandez-Blanco, Yishen Wang, Bolun Xu, Daniel S. Kirschen, Hrvoje Pandzic, Jean-Paul Watson, and Cesar A. Silva-Monroy. Co-planning of Investments in Transmission and Merchant Energy Storage, IEEE Transactions on Power Systems, early access.

Merchant vs. SO Storage Investment

- Storage investment can be made by both the SO and a merchant, but with significantly different roles
- In case of the SO ownership, energy storage can be operated as any other transmission asset, i.e. transmission line, with the only difference that transmission lines transfer electricity in space, while energy storage transfers electricity in time
- Merchant–owned energy storage is an active player in the market seeking to maximize its profit



Kristina Pandzic, Hrvoje Pandzic and Igor Kuzle. Coordination of Regulated and Merchant Storage Investments, submitted to IEEE Transactions on Sustainable Energy.

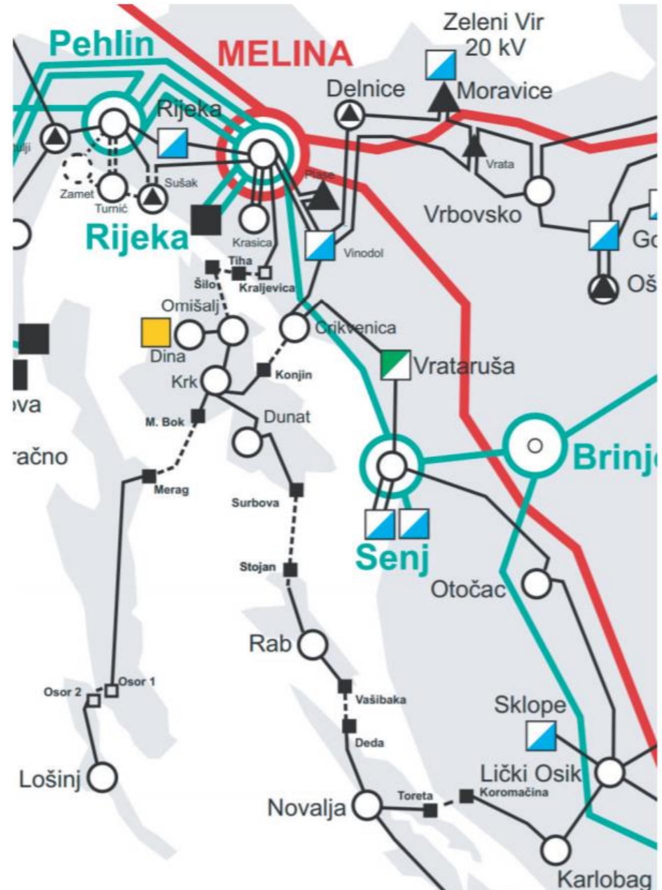
Storage Providing Primary Response

- Coordinated generation and storage expansion formulation considering primary frequency response constraints
- Considering PFR reduces the frequency and expected value of the unserved demand
- The value of energy storage can be increased if scheduled to provide PFR services in addition to performing spatio-temporal energy arbitrage

Miguel Carrion, Yury Dvorkin, and Hrvoje Pandzic. Primary Frequency Response in Capacity Expansion, IEEE Transactions on Power Systems, early access.

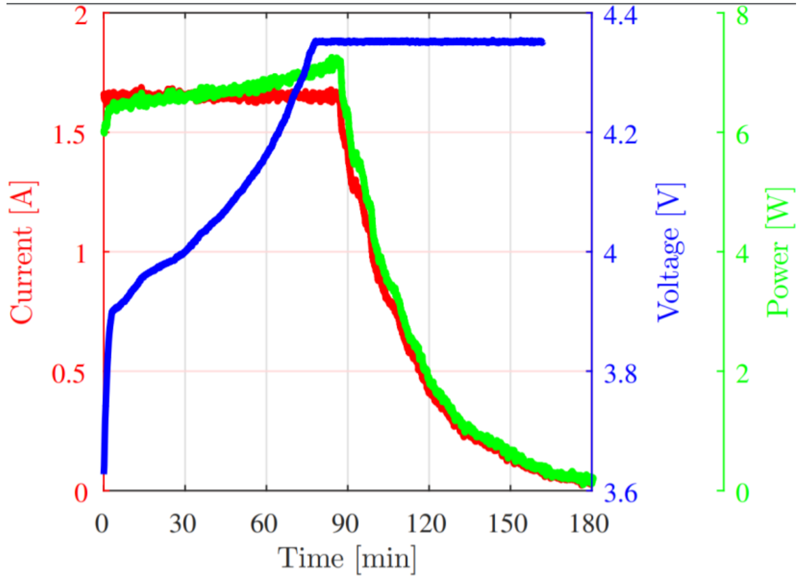
N-1 using Energy Storage

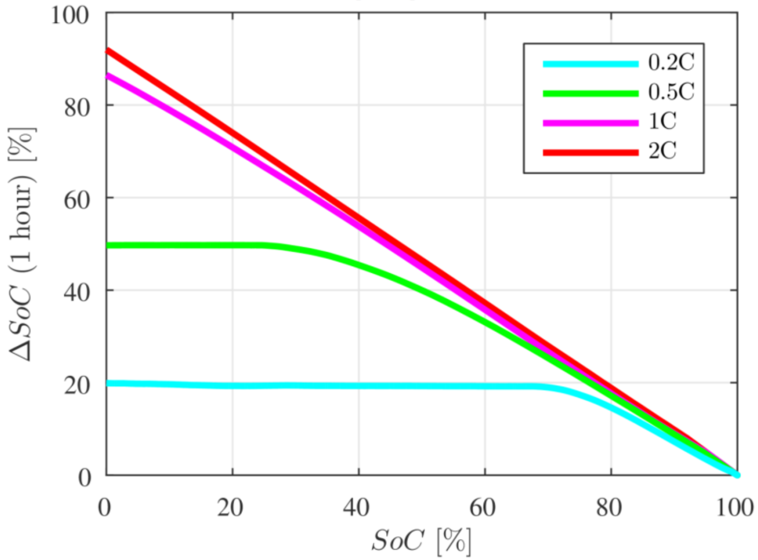
- Can energy storage improve power system security at Croatian islands
- Problems: frequent thunderstorms, severe storm wind, wind coats salt on insulation of transmission lines, substations and power transformers, which leads to leakage currents and system failures (often blackouts), high variations in voltages levels

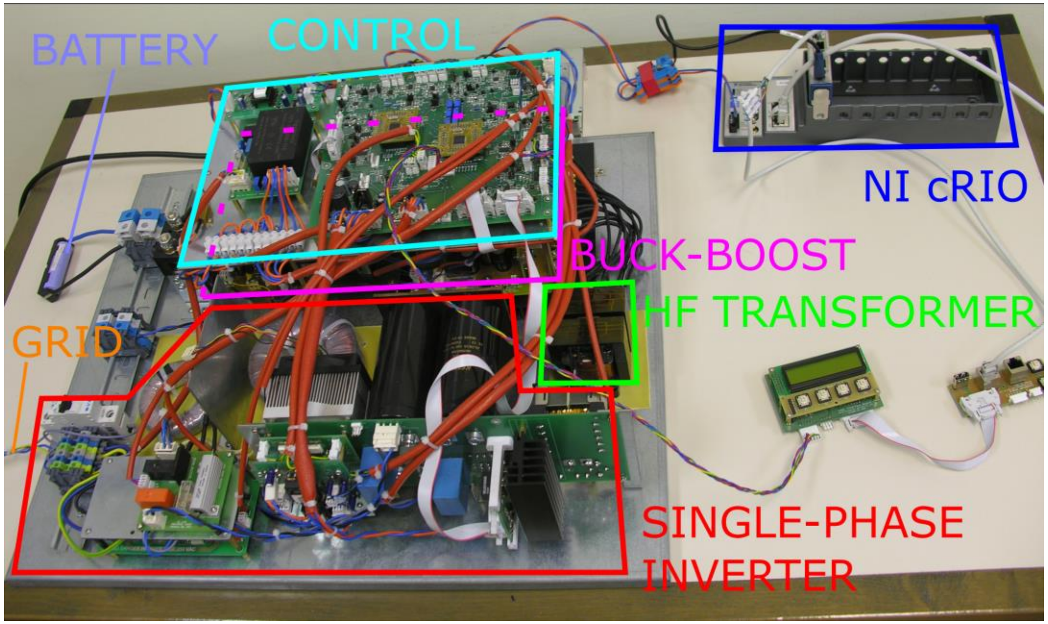


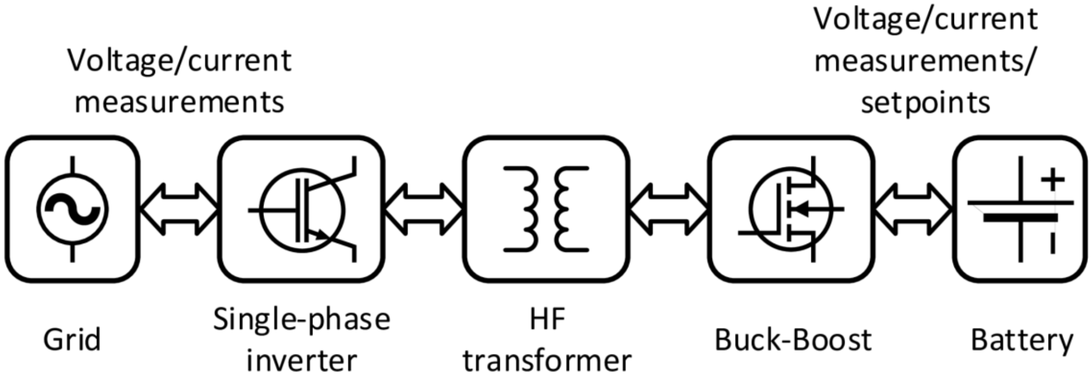
Zora Luburic, Hrvoje Pandzic, Tomislav Plavsic, Ljupko Teklic, and Vladimir Valentic. Assessment of N-1 Criterion Using Energy Storage, in Proceedings of 17th International Conference on Environment and Electrical Engineering (EEEIC), Milano, Italy, June 6-9, 2017, pp. 1-6.

Accurate Modeling of Batteries









Laboratory Testing

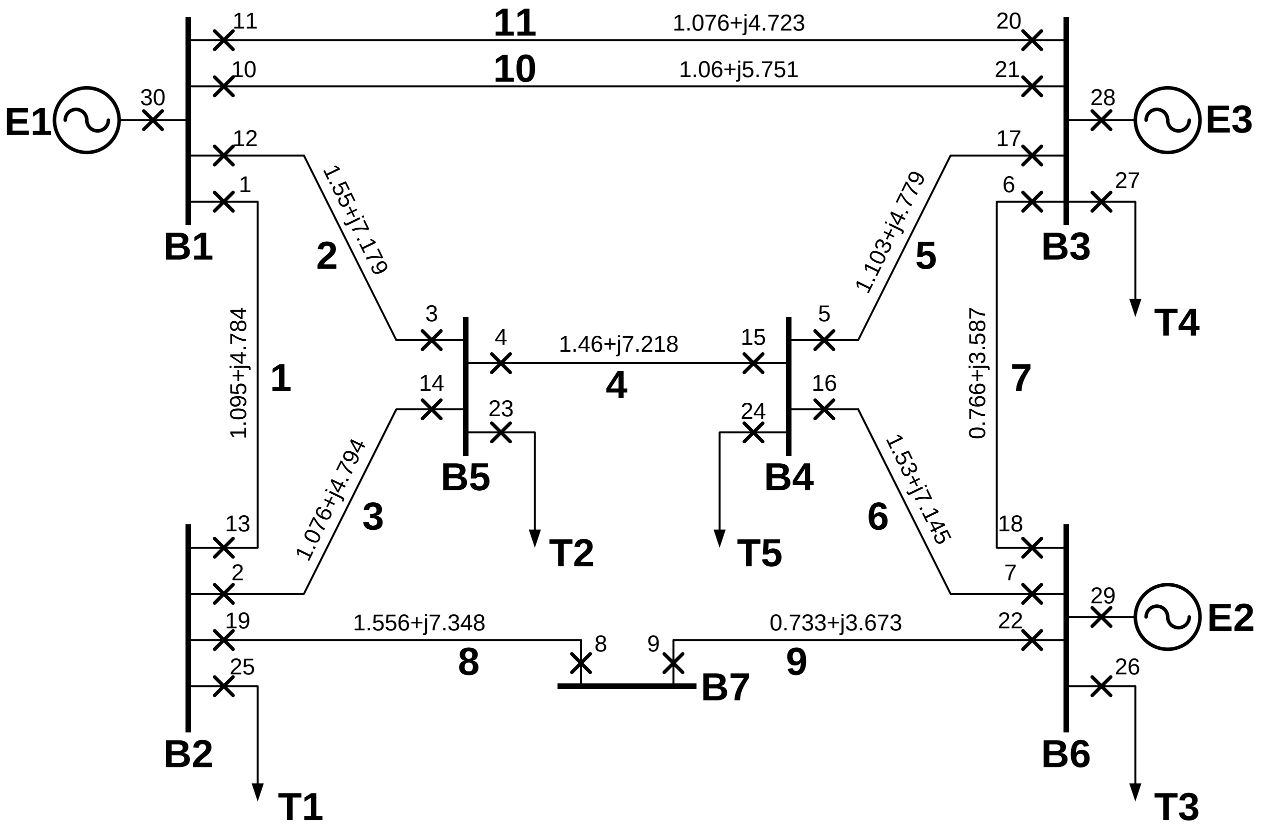
- Model of a thermal power plant (1) with primary equipment:
  - motor simulating a thermal turbine,
  - generator with busbars,
  - circuit breaker,
  - feeder disconnector,
  - secondary equipment: current and voltage transformers, protective relays, and power plant control system, including network synchroscope.
- Model of a run-of-river hydro power plant with a Pelton turbine (2) with nominal flow of 27 l/s. Underneath the turbine is a water reservoir with 7000 liter capacity. Water from the reservoir is pumped to the turbine, thus simulating the penstock.

Laboratory Testing

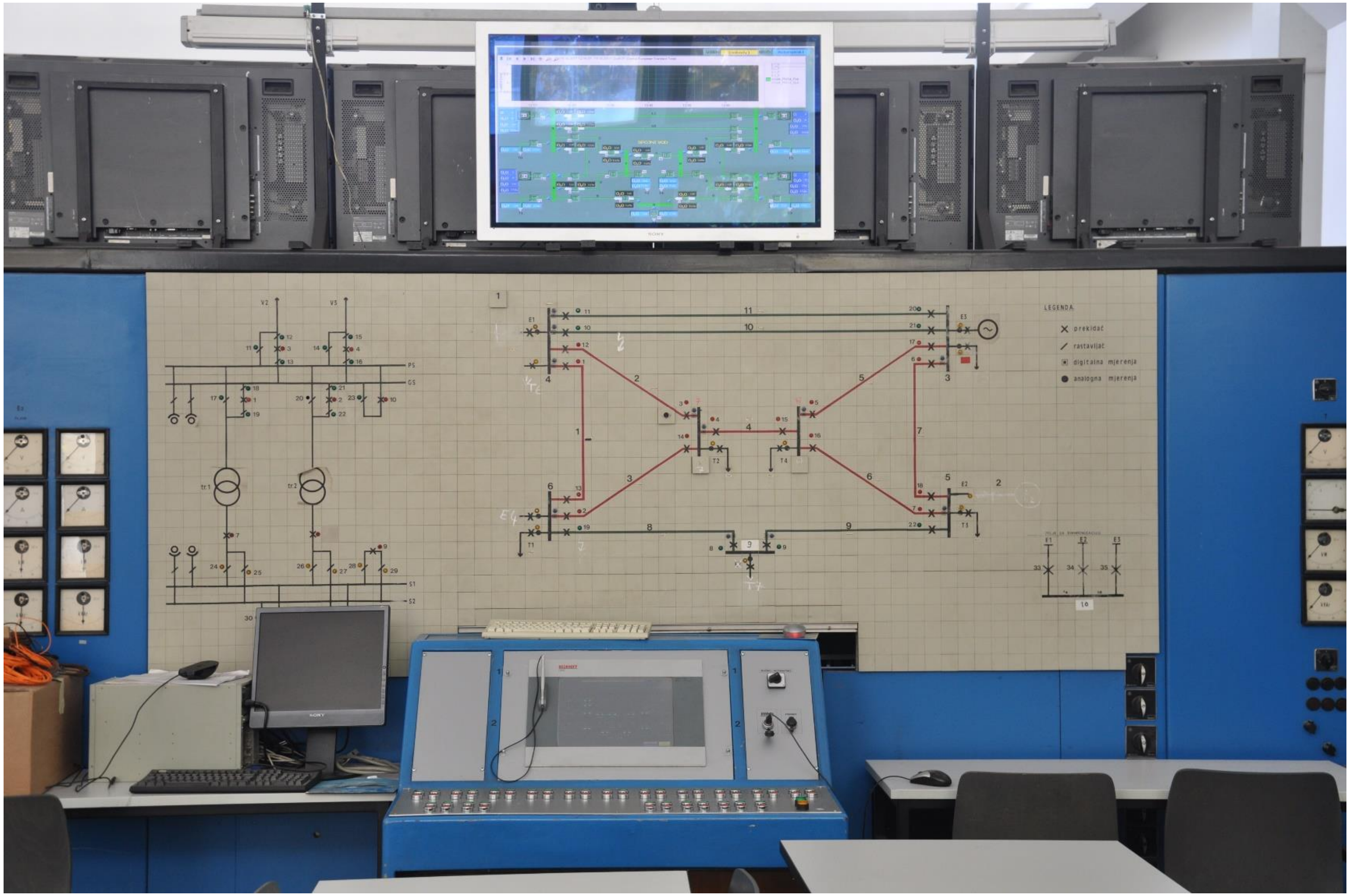
- The rigid network (3) is the utility grid, to which the two power plants can be synchronized.
- Transformer substation, fully equipped with circuit breakers, feeder disconnectors, current and voltage transformers, protection devices and control circuits.
- Different loads connected to the power system model.

Laboratory Testing

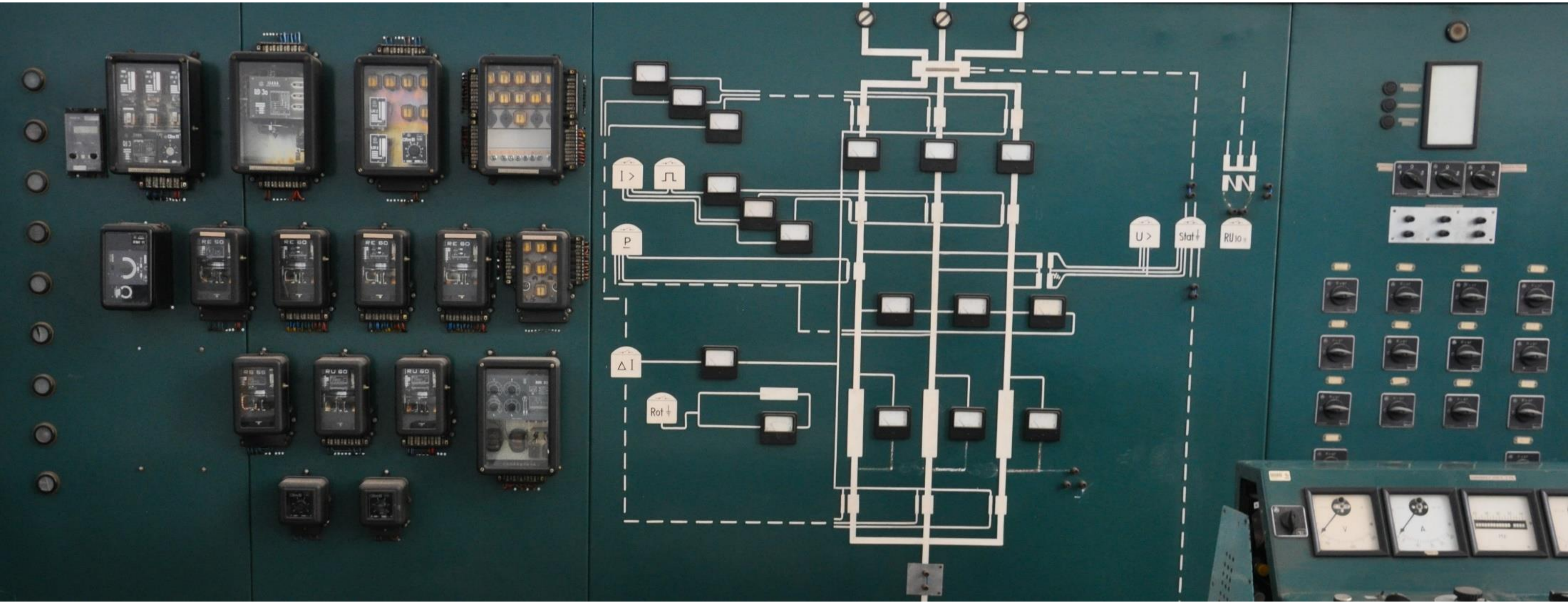
- A series of line models with circuit breakers and feeder disconnectors simulating a high voltage power system network. Line parameters and network topology may be changed.



Laboratory Testing



Laboratory Testing



Laboratory Testing

Laboratory Testing

Final Thoughts

- Storage investment vs. transmission expansion: lines still win
- Opportunity for storage: deferral of investment in transmission lines, N-1 where new lines are hard to construct
- How does energy storage operate when providing reserves?
- How will TSOs handle storage?
  - Investor owned storage
  - TSO owned storage

Thank you for attention

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