Control Algorithms and HiL-Integration Testing for Virtual Power Plant Realizations

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Abstract - The increasing role of small-scale power plants will add another layer of complexity to today's existing system of liberalized energy markets and power systems. Here, intelligent monitoring, information and communication technologies are key features for the application of interoperable management and control solutions. Accordingly, a communication and monitoring system for Virtual Power Plant (VPP) realization is introduced. The embedded system provides the opportunity for the development and validation of optimization models and control algorithms and aims to process real-time operations within 1-minute timeframe.

Interoperable Management and Control Solution

The system architecture enables **remote-control** of power system components and energy sources, interconnected in geographically dispersed Microgrids environments **(Fig. 1)**, each operated by different **control systems**. Necessary data are exchanged bidirectionally, processed to calculate optimized set-points [1]. This enables the Virtual Power Plant operator to meet optimized schedules, e.g. contracted in energy market tradings or respond to redispatch measures requested by system operators.

A) System Architecture - modular structured and scalable, advanced information and communication technologies, utilizing:

- distributed energy resources
- network infrastructure
- databases / terminal servers
- optimization programs
- telecontrol systems and equipment

Virtual Power Plant provides control, up- and downstream processing and graphical visualization of system states and measurements.

B) Control Environment - secured and interoperable, application of control algorithms, considering:

- integrity, availability, confidentiality
- authentication control
- enhanced communication efficiency
- self-healing and resilience

Bidirectional information exchange is realized applying VPN, redundant versions of hard- and software components and time synchronization.
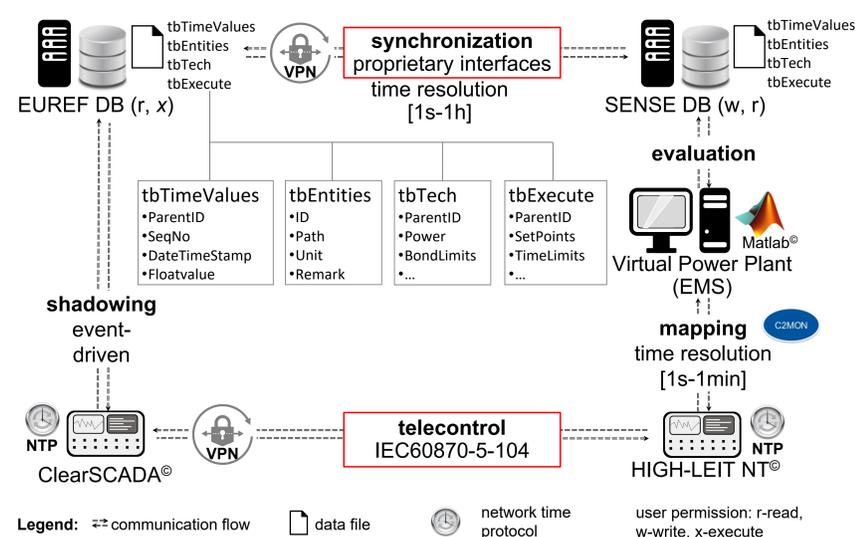

Fig. 1: Communication and monitoring system.

HiL-Integration Testing of Communication Technologies

To handle both, emerging technical and economic boundary conditions, optimization models and control algorithms [2] are developed under Matlab environment that applies simplex algorithm, offered by ILOG CPLEX Optimization solver. The obtained operation schedules are forwarded as set-point settings utilizing telecontrol protocols for real-time data exchange to manage the power plant portfolio **(Fig. 2)**. In order to identify the shortest possible time frames for real-time operations in the proposed architecture, the communication, latency and synchronization times are measured **(Fig. 3)**.
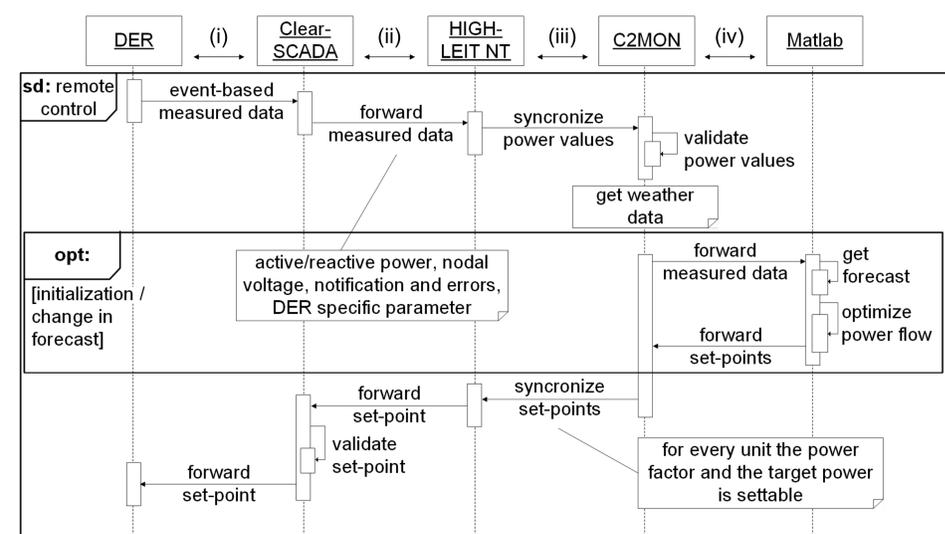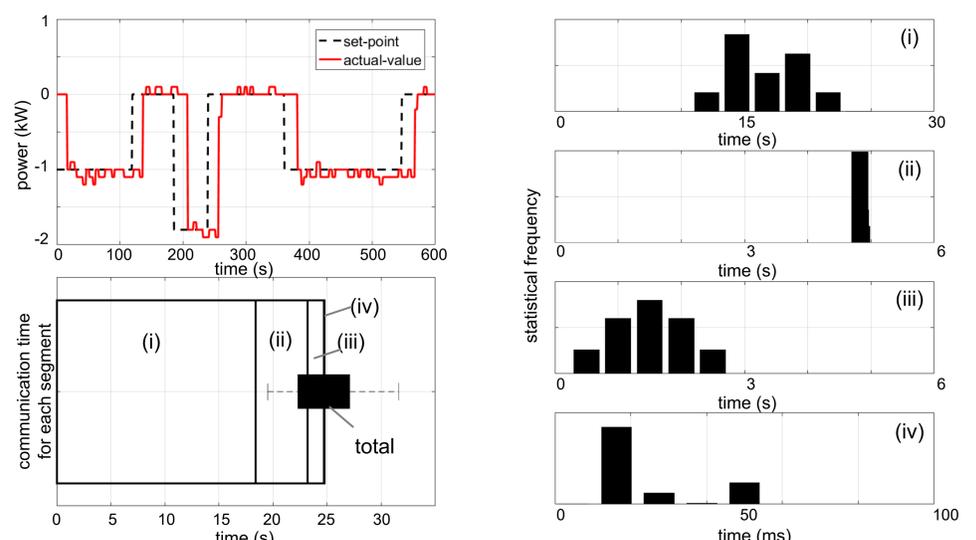

Fig. 2: Sequence diagram for remote-control.

Fig. 3: Measured communication times in the proposed architecture.

Conclusion and Outlook

The proposed communication and monitoring system provides a unique opportunity for the development of Virtual Power Plants and validation of control algorithms. Specifically, the secured testing environment allows real-time remote control by a central energy management system.

Selected References

[1] N. Etherden, V. Vyatkin and M. H. J. Bollen, "Virtual Power Plant for Grid Services Using IEC 61850," in IEEE Transactions on Industrial Informatics, vol. 12, no. 1, pp. 437-447, Feb. 2016.

[2] Andreas F. Raab, "Operational Planning, Modeling and Control of Virtual Power Plants with Electric Vehicles," Doctoral Thesis, Technische Universität Berlin, 2018. [Online]. Available: http://dx.doi.org/10.14279/depositonce-6650

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