Fakultät für Elektrotechnik
und Informationstechnik

Institute of energy systems, energy
efficiency and energy economics

Masterthesis

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Investigation of the computational feasibility of the deployment of a service based Digital Twin to industrial hardware edge devices under real world operating scenarios

In the course of the energy transition, large power plants such as nuclear and coal-fired power plants are being shut down in Germany and replaced by decentralized generation plants such as photovoltaic and wind power plants. This leads to a shift of feed-in from the transmission to the distribution grids and thus to bidirectional power flows as well as a new understanding of the provision of ancillary services. Moreover, new loads, such as electric vehicles and heat pumps, are being deployed to the distribution grids. These decentralized generation units and decentralized loads cause an increase in voltage congestion and thermal congestion, especially at the low voltage level. It has been shown that physical grid expansion is not the most efficient solution to solve the newly arising grid congestions. it also does not enable the assets in the distribution grids to provide ancillary services to the power system. Therefore, in recent years, plenty of research in distribution grid automation has been conducted to enable a smart grid executing ancillary services such as monitoring, congestion management, or grid state forecasting. However, for the deployment of distribution grid automation and additional smart grid services, such as time series-based grid planning or predictive maintenance, a digital twin providing an interface between existing system models and asset data at distribution system operators (DSO) and various interconnected services is required.

In the given master thesis, the computational requirements of executing a decentralized Digital Twin for low-voltage distribution grids on hardware edge devices in local substations are to be investigated. Furthermore, an overview of the computational capabilities of different industrial edge devices and an analysis of their feasibility will be given. Moreover, the operation of the Digital Twin and its interaction with a central human-machine interface (HMI) is to be validated in the Protection and Automation laboratory under close to real-world conditions. At last, the question of resiliency concerning the secure and reliable operation of the low-voltage grid considering communication outages between the sensors and the Digital Twin and the server-based HMI is to be addressed by implementing countermeasures and validating them in test scenarios.
The following structuring of the work is proposed:

1) Literature research on the digitalisation of low-voltage grids and Digital Twins in industry and power systems
2) Selection and alteration of low-voltage benchmark grids of multiple sizes and their deployment on real-time simulators or IED simulations
3) Deployment of a Digital Twin architecture developed at the institute ie^3 on a virtual machine considering varying degrees of grid digitalisation. Monitoring of key performance indicators (KPIs) for the computational requirements
4) Optimisation of the Digital Twin architecture for computational efficiency
5) Analysis of industrial hardware edge devices' capability to host the Digital Twin, formulation of computational requirements and selection of suitable devices
6) Deployment of the Digital Twin to a selected edge device and validation of its operation in defined scenarios
7) Investigation of abnormal operational conditions for the data-driven opration of a low-voltage grid
8) Research on countermeasures to ensure the reliable operation of the low-voltage grid by the Digital Twin

9) Validation of the countermeasures in the Protection and Automation laboratory at the ie^3 institute.

Following this work, the results are to be reported in a presentation.
This master thesis is available for master students of Industrial Engineering, Electrical Engineering, Automation and Robotics and Sustainable Energy Systems.
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