Kurzbeschrieb Projekte Bahninfrastrukturforschung

P-1115 INITIATE INtellIgenT maIntenance rAilway power sysTEms

Schwerpunkte Wirkungsziele	Improved preservation of rail infrastructure assets Cost optimisation (operations, maintenance or expansion of the rail infrastructure)	**Geplante Projektdauer**	04/2021-03/2025
Projektträger/ Projektleitung	ETH Zürich, Chair of Intelligent Maintenance Systems Prof. Fink, Olga, ofink@ethz.ch	**Budget total / Anteil BAV**	560'000 CHF 310'000 CHF

Zusammenfassung

The project aims at improving the detection and prediction of critical conditions in railway power network systems and components by developing intelligent algorithms for Control System Data. In particular, the project aims at developing methodology for integrating the spatial-temporal information and underlying physical laws for detecting and predicting critical conditions that may cause significant disruptions. The developed methodology will also enable to prolong the maintenance intervals and extend the lifecycles of power system components, such as hydropower plants and reduce the maintenance costs. This pro-ject will, therefore, safe costs, improve security of supply and increase stability of grid operation.

Problemstellung

Monitoring the condition of railway power network systems can reveal signs of incipient faults which can develop into costly and unexpected failures. Early detection of critical events in railway power systems is a challenging task due to the complexity of the power network systems and the complex transient be-havior. The critical events are characterized by both their spatial neighborhood and the temporal evolu-tion. Condition monitoring data has been collected in the central dispatch system of SBB since 2014. The objective of this project is to develop artificial intelligence algorithms for this data to detect incipient faults, hot spots and systematic faults.. The railway power network of SBB comprises assets of 6.6 BCHF investment value, with an investment backlog of currently ca. 1.3 BCHF. The current project will contribute to prolong the lifetimes of the components and reduce thus investment and maintenance costs.
Even if the availability of the power network has been considerably high, the costs of maintaining this high availability can be substantial, i.e. single events can have substantial intervention costs in the order of several hundred thousands per event. SBB spends on average 37MCHF (compensation eligible and commercial costs) per year for power network maintenance. Studies predict the effect of predictive maintenance of 5-10% cost reduction. This project will lay the foundation for realizing this cost reduction. The reduced operational costs will benefit all the railway operators, i.e. in terms of traction energy price reduction.

Ziele

The main goal of the project is to improve the detection and prediction of critical conditions in railway power network systems. To enable this, we will develop methodology for the detection and prediction of critical events in railway power networks and components (based on central dispatch big data archive):
1) Integrate spatial and temporal monitoring data from the railway power networks
2) Extend the developed methodology by integrating power system dynamics in deep learning algorithms

As an additional goal, erroneous measurements and sensor drifts will be automatically detected, improving thereby the data quality significantly and making the decisions based on those measurements more reliable. Here, the manual efforts of data administration and quality assurance (ca. 15 FTE, which an in-ternal study showed) can be significantly reduced.

Vorgehen / Module

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The methodology developed in the proposed research project will focus mainly on graph deep neural networks and physics-guided neural networks (partly combined with graph neural networks). Both methods are novel in many application fields and have recently been developed further in several domains. Furthermore, the integration of underlying physical laws in graph neural networks is a very recent and promising research direction in the context of the proposed research.
In the first step, we will develop physics-guided neural networks for selected grid components for early fault detection. In a second step, we will develop graph neural networks for integrating the spatial and temporal information of condition monitoring signals (from central dispatch big data archive) for early detecting and predicting critical conditions that may cause significant disruptions. Furthermore, high-resolution data for max. one day can be retrieved from the dispatch center. We will validate the developed methodology first on simulated data from sub-networks of the SBB railway power networks. Based on the obtained results, we will evaluate the requirements and the needs for monitoring the components and the sub-networks in real time.
In the next step, we will extend the developed methodology by integrating power system dynamics in deep learning algorithms. We expect an improved performance of the algorithms, and decrease the requirement for the availability of training data and an improved interpretability of the obtained results.
The developed algorithms will enable to detect hotspots and bottlenecks based on utilization and sensitive components and derivation of suitable intervention measures in grid design or operative dispatch.

In summary, we expect improved performance of continuous business measures and decreasing system vulnerability.

COO.2125.100.2.10602084 4 / 7 Moreover, we will apply the developed methodology to power system components, such as hydropower plants. Early fault detection for hydropower are especially cost effective as single events can lead to consecutive costs in operations (of several hundred thousands of additional costs), and delicate service situation.
Furthermore, we will develop methodology for automatic detection of erroneous measurements and sensor drift.
The following work packages are foreseen:
WP1/Year1. Develop physics-guided neural networks for selected grid components (early fault detection, detection of systematic faults) -> demonstrated on at least one hydropower plant.
WP2/Year1+2: Develop methodology for automatic detection of erroneous measurements and sensor drift -> demonstrated on at least one hydropower plant
WP3/Year2. Develop graph neural networks for power quality monitoring (detecting incipient faults) -> demonstrated on at least one sub-network (i.e. Tessin, which is crucial for Operation GBT and necessity for delicate stand-alone operation could appear)
WP4/Year3. Develop physics-guided graph neural networks to improve the interpretability of the algorithms and derive intervention recommendations -> validated on a sub-network and a hydropower plant

WP5/Year4. Develop an offline prototype and define requirements and recommendations to transfer the developed methodology to real-time operation.

Erwartete Resultate

1. Early fault detection with the proposed methodology demonstrated on at least one hydropower plant
2. Methodology for automatic detection of erroneous measurements and sensor drift demonstrated on at least one hydropower plant3. Detection of evolving faults, hotspots and bottlenecks in power networks, particularly for critical sub-networks with the bottleneck character3. Developed methodology validated for improving the fault location estimation in power networks4. Prototype for offline application of the developed methodology and requirements for online applications defined.