Paris Session 2022

# End-to-end architectures for substation O&M

B5 PS3 Q3.01

What are the benefits of digital solutions like IoT-sensors, machine learning, artificial intelligence, drones, robots etc. for substation life cycle from planning to maintenance?

Which measures are necessary to increase the acceptance of intelligent IoT-based power equipment in substations?

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# End-to-end architectures for substation O&M

*Any specific IoT and AI application is part of an overall architecture*

Decision-making

human-readable reports

**2 AI-based centralized monitoring**

- ✓ Easy to maintain
- ✓ Automatization of tasks
- × Unique point of failure
- × Not scalable
- × Not completely secure

structured datasets

Remote servers

large, heterogeneous and unstructured datasets

Data preparation, data analysis, decision-making

**1 Manual centralized monitoring**

- ✓ Easy to implement
- × Cumbersome and time-consuming
- × Not scalable
- × Not completely secure
- × Error prone

heterogeneous and unstructured datasets

structured datasets

Data filtering, data fusion, data encryption

structured datasets

Edge
(station computer)

raw data

**3 AI-based distributed monitoring**

- ✓ Privacy-preserving
- ✓ Fault tolerant
- ✓ Scalable
- ✓ Federated and collaborative learning can be applied
- × Difficult to maintain
- × Local storage and computing requirements

Edge
(station computer)

HV equipment | IEDs | Physical security | Mobile IoT devices (robots) | Data traffic analysis

**Data sources**
(physical and digital assets monitoring)

HV equipment | IEDs | Physical security | Mobile IoT devices (robots) | Data traffic analysis

# End-to-end architectures for substation O&M

## *Future research directions*

**Benefits of digital solutions for substation O&M**

- IoT (and robotics)**:** data *collection*
- Artificial Intelligence**:** data *management* (filtering, organization, refinement, synchronization), *protection* (e.g., encryption), and *interpretation* (to facilitate decision making)

**Still several measures are necessary to increase the acceptance of intelligent IoT-based power equipment in substations**

| | | | |
|---|---|---|---|
| **Multi-modality** | *The integration and correlation of different information sources opens up new perspectives in substation monitoring.*<br>E.g.,,<br>• thermography and isolator sensors for hot spot detection<br>• RGB images and radar signals for substation physical security | **Persistent monitoring** | *IoT-technologies provide continuous data flows.* |
| Research directions | • Sensor-rich platforms to minimize hardware installation and correlated O&M efforts.<br>• Data-fusion algorithms to cope with source diversity (data synchronization, different dimensionality, different statistical distribution). | Research directions | • Automatic data ingestion modules to cope with unreliable datasets and avoid extensive human data preparation.<br>• Task scheduling programs to release intensive computation from resource constrained devices.<br>• Self-configuration and self-adaptation strategies to cope with dynamic environmental conditions and changing requirements. |
| **«Pervasive O&M»** | *Ubiquitous sensing increases the substation digital assets; hence, it comes at the cost of a higher system complexity.* | **Privacy and security** | *Environmental sensors pose severe questions on possible privacy violations, while complex data flows are exposed to data breach and poisoning attacks.* |
| Research directions | • Criteria and conditions for the pre- and post-installation of substation pervasing sensing infrastructures.<br>• Self-diagnosis, fault tolerance and fault mitigation mechanisms for large sensor networks (e.g., by leveraging on the advantages offered by multi-modality). | Research directions | • Robust privacy-preserving and secure systems, where formal guarantee of privacy and security is needed with tight accuracy loss. |



Thank you for your attention!