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Architecture for Automation System Metrics Collection, Visualization and Data Engineering – HAMK Sheet Metal Center Building Automation Case Study

Extended Abstract: Ever growing building energy consumption requires advanced automation and monitoring solutions in order to improve building energy efficiency. Furthermore, aggregation of building automation data, similarly to industrial scenarios allows for condition monitoring and fault diagnostics of the Heating, Ventilations and Air Conditioning (HVAC) system. For existing buildings, the commissioned SCADA solutions provide historical trends, alarms management and setpoint curve adjustments, which are essential features for facility management personnel. The development in Internet of Things (IoT) and Industry 4.0, as well as software microservices enables higher system integration, data analytics and rich visualization to be integrated into the existing infrastructure. This paper presents the implementation of a technology stack, which can be used as a framework for improving existing and new building automation systems by increasing interconnection and integrating data analytics solutions. The implementation is realized and evaluated for a nearly zero energy building, as a case study.

The proposed stack consists of OPC-UA as industrial communication protocol for efficient machine-to-machine data transmission on the field level, combined with Node-RED with OPC-UA package for simple interconnection between different software interfaces. For transmission from multiple fields and reusability of data, Node-RED also performs packaging and sending data through MQTT to a private broker. Following this on the server side, time series storage and analytics software, represented by InfluxData’s time series platform, are used for data ingress, preprocess and warehousing. Grafana is used for generating dashboards to perform preliminary inspection and production of visualization elements e.g. charts, gauges and metrics overview tables. Grafana also supports exporting CSV files from built elements for further analytics with Python such as feature extraction and anomaly detection, which supports the condition monitoring and condition-based maintenance processes. Finally, Docker is used for deployment and management of all components at their respective level.

Reasons for selection of aforementioned technologies include their open-sourced nature, reproducibility and adaptability. OPC-UA is widely adopted by industrial manufacturers nowadays and could be implemented in existing programs with minimal efforts, allowing for operation data extraction from field devices. As all the used software solutions are containerized, the connection from the field can easily be realized by deployment of gateway containers, i.e. Node-RED, on capable PLCs or SCADA computers. Similarly, the server-side stack is easily reproduced by deployment of component containers on any cloud or own IT infrastructure. Aside from the long list of connectable data sources, Grafana supports integration with different identity and access management solutions such as OAuth and LDAP, allowing for information isolation and customized access for different personnel levels in enterprise environment. Analytics microservices built from Python allows for extensive feature extraction, classifications and clustering on collected building automation data to classify operation modes and identify anomalies where the system is not operating in designed regimes. The analytics results can then be illustrated on Grafana to present the information to process operators and maintenance staffs to perform cause analysis in a timely manner. Finally, the framework is implemented in a modular manner, allowing for adoption of better technologies when available.

The case study is conducted using the framework implementation in Häme University of Applied Sciences infrastructure, as an IoT platform for research and education using the building automation data collected from Sheet Metal Center industrial hall building in Visamäki, Hämeenlinna. Using data collected from the building automation system, the framework is utilized for verification of the heating system functionality and fault diagnostics of the geothermal heat pump using two-step PCA and k-Shape clustering algorithm. The analytics results are then applied to verify the control logic of the building automation system, monitor and improve the heat pump operation and the heating process efficiency. The k-Shape algorithm was able to identify the system's modes of operation: winter or summer, which is then used to perform anomaly detection as the current system sometimes operated in summer mode in winter time. The two-step PCA algorithm was able to detect an undocumented setpoint change in the system, as well as an additional flow of energy in the system; currently used for supervision of process operation in general. Finally, further development of the framework includes extending the analytic features for other buildings and benchmarking of analytics techniques for utilization with automation system data in general.

Keywords: Building automation, IoT, anomaly detection, analytics, two-step PCA, k-Shape clustering

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