Study Committee D2

Information Systems and Telecommunication

Paper 10833_2022

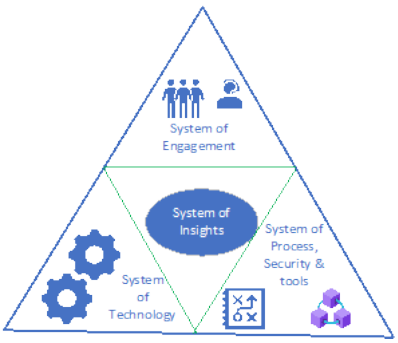
COMPUTING INTELLIGENT INSIGHTS ABOUT HEALTH OF STATION SUBSYSTEMS WITH DATA ANALYSIS AND LEAN IIOT

Sarala. M. NAIDU[1]

[1]Hitachi Energy

Motivation

- complexity of power converters and its degradation mechanisms
- Not enough data to assess the overall conditions.
- Dependency on traditional preprogrammed rules that trigger the alarm or events to perform a run-to-failure diagnosis.
- Easy and flexibility of increase in adaption of the Industrial Internet of Things (IIoT).
- The potential of Artificial Intelligence (AI), specifically ML, with benefit of the results obtained in various other domains/industries



- Thus, the aim of this paper is 2-fold:
  - 1st present the experience of implementing an end-to-end integrated IIoT in an HVDC transmission system
  - 2nd present examples of the analysis of data collected from the above enhancements

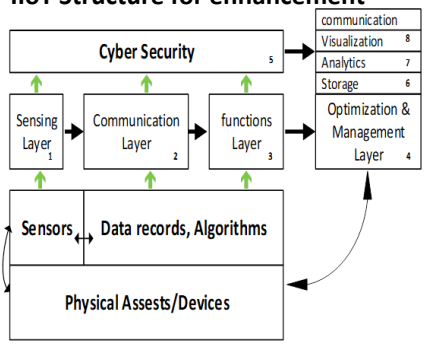
Method/Approach

1. ***IIoT Architecture enhancments:*** *To enable IIoT to trigger additional data collections, a detailed feasibility study of existing HVDC station(s) for:*
   - *risk & cost-benefit analysis for pilotting.*
   - ***Followed by a Decision 'to go' or 'not-to-go'***
   - *Planning implementations- hardware and softwares*
   - Connectivity on the digital twin platform, with key features to:
     - (i) present live monitoring and anomalies detected (if any)
     - (ii) Present correlations and recommendations from experts.
2. *Setup d*ata analysis pipelines: for each specific subsystem in the station
3. document challenges & lessons learnt

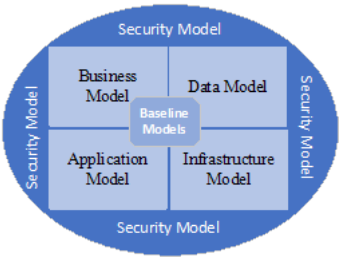
Objects of investigation

- A Classic monopole HVDC topology was used in the study in collaboration with the customer . Thus, it was brown field station that was partially upgraded.
- data sets are from a real subsystem of an HVDC station like Transformer, Valve cooling, CPU Board life assessment, tap changers, etc. Simulated datasets have been used only for model validations. The data was stored locally in the station and after a period (frequency decided by customer), a channel was opened for sending data to the Data Lake platform for further processing
- Python, Keras, scikit lib, tensors flow has been used in processing and analysis of the data.

IIoT Structure for enhancement



- an ecosystem in which the objects and associated industrial equipment, can communicate and exchange information with each other, in a networked system in a secure way.



Typical challenges overcome:

- Communication technology interoperability
- Additional supplementary security measures like unique IDs on IIoT devices, trust levels within network components, isolation or zoning to prevent cascade of undesirable effects of failure in other areas, implementation of cryptography techniques to prevent data tampering.
- processing data closer to the originating source, optimizes for efficient data transfers

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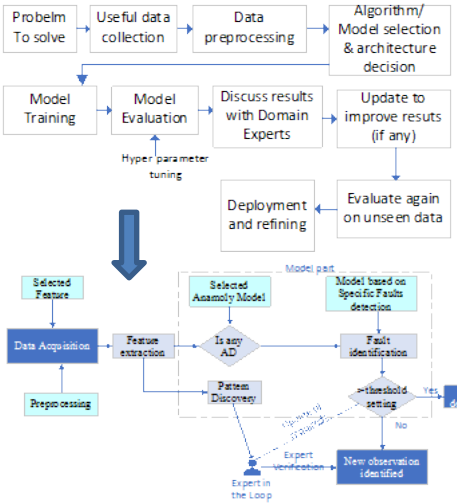
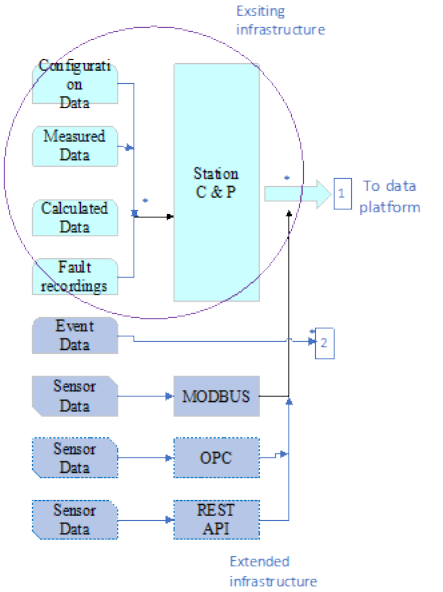
Machine Learning workflow

- choice of the right workflow, depending on origin of the data and objectives of the analysis.





Overall Data flow

1. Types of data for the analysis:
   - Operational Data
   - Maintenance Data
   - Product Data-Design /thresholds
   - Text events message
   - Context data
2. Important data aspects considered:
   - Quality of data-includes accuracy, timeliness, relevancy, reliability, and completeness
   - Data management policy – to control access, store, and archive data
   - Maintain integrity of data in terms of referential, domain and entity integrity
3. A simplified and secure overview to support the flow approach is shown in Fig below that is adopted in an existing (brown field) station, with optimized number of hardware and communication layers in the hierarchy
4. Optimization techniques are adopted for minimizing the volume of data flow due to limited bandwidth design in old stations. Example, within the station, computation on the collected raw data is done closer to the proximity of the devices based on the need. Here, technologies like fog computing, edge computing are adopted.

Machine learning models applicable

- Different classes of algorithms are designed for handling different data and solving different problems with different approaches as the inputs provided, the task performed, and the outputs for each class are quite different.
- For an in-depth look at learning characteristics, ML models are categorized into five for specific use-cases

a. Classification Models

b. Regression Models further split into - Decision Trees, Random Forests and Linear Regression

c. Clustering-involves gathering similar objects into groups automatically without human intervention.

d. Dimensionality Reduction -preserving variance

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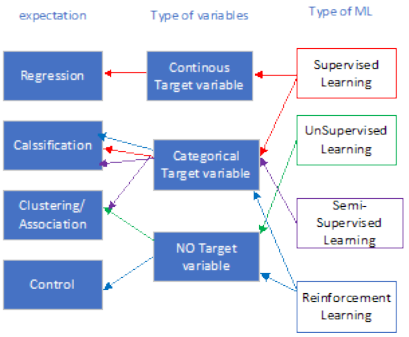
e. Deep Learning -involves neural networks. Most significant are- Autoencoders, Boltzmann Machine, Convolution Neural networks(CNN), Multi-layer perceptron, and Recurrent Neural Networks

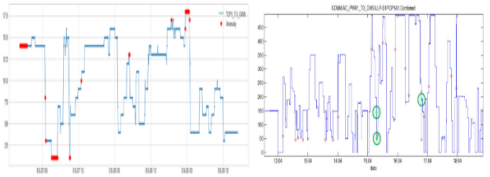


Examples HVDC Case Study results

1. Malfunction detection on vibration signal data:

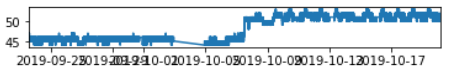
Method: Deep Autoencoder

2. Early abnormal patterns detection in Tap changers



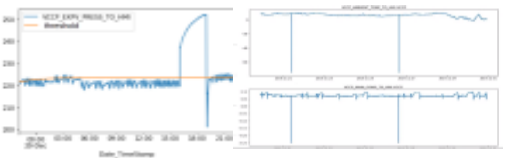
Method: IsolationForest, OneClassSVM to identify Anomalies and hunting before the control system acts.

3. Key device CPU Board health determination

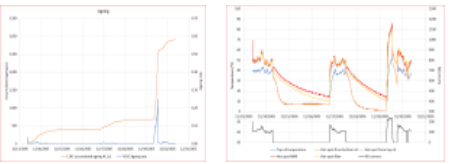


Early detection of cpu board temp. rise triggered cooling in cubicles, even before an alarm is raised.

4. Valve Cooling-exp.Pr and ion-exchange analysis



5. Transformer-aging rate & hot-spot pattern



Conclusions and recommendations

- A brown field station is enhanced with IIoT architecture for subsystem health monitoring (infrastructure extension to data collection & analysis)
- To get right outcome more responsibly, it is necessary to extract data from the interconnected systems, considering the cyber-physical aspects, communication interoperability, strategize the data preprocessing techniques as per the context,
- Even thought ML algorithms presents good performances and a relatively high degree of interpretability, they rely on good quality features and labels that are vetted by the domain experts.
- it is not possible to identify a specific algorithm that clearly outperforms others in all possible settings. Selecting a specific technique depends on the requirements and problem characteristics. Performance metric adaption is specific to the problem and data. Due to continuous advancements in the learning methods and algorithms, there is always scope for more improvements that impact technical & economical improvements from the analysis, making the models predict in an unbiased manner .
- Based on the nature of the data, unsupervised approach also has competitive performance in detection efficiency, while in some case the semi-supervised approached perform better.
- Examples of anomaly detection case-study shows good results on the data collected for early detections and triggering actions in a well-planned manner
- Also, the Case studies with synthetic data corroborate the effectiveness and advantages of the approaches used, which indicates that it can serve as a primitive for further improvements on real-time data analysis.

Recommendations:

- Prepare to overcome the challenges mentioned above
- Ignored non-functional aspects of the ICT system could deteriorate the quality of service
- Many hidden layers is usually associated with a higher risk of overfitting, thus using deep models with more advanced tools contrasts over-training
- Choosing right algorithm is the key factor to train the ML models. The data feed into this helps the model to learn from and predict with accurate results.