OrxaGrid Pilot Case studies

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IoT based distribution analytics system

Challenge

The electricity distribution utility faced high technical & commercial losses and frequent power outages. As part of its operating license, the utility was obligated to provide electricity to several low-income consumers that were spread out across a wide geographical area. The utility required a solution that would enable it to provide reliable and affordable electricity to its rural and low-income customers.

OrxaGrid was tasked with designing a low-cost technology for automation and business process improvement, focusing on monitoring power supply, proper planning, decision support, taking corrective actions as well as increasing transparency of power flow. The key solutions that the OrxaGrid system offered were:

- Locating outages in networks quickly, proactively and efficiently restoring power, thereby improving its reliability indices
- Monitoring the condition of transformers to reduce maintenance downtimes
- Identifying and predicting network violations such as over voltage, phase imbalance and excessive peak demands

Solution

OrxaGrid deployed its unique, entirely Internet of Things (IOT) based system. The system constituted sensors for data collection and a Grid Analytics Platform (GAP) for data management, analysis and visualisation.

SEED sensors were deployed to measure feeder energy parameters and fault status. STEM sensors were installed on transformers to measure primary and secondary transformer readings as well as transformer condition.

The sensors communicated through HTTPS REST services using secure Machine to Machine cellular cards to the GAP software deployed at the utility's control centre. Doing so, the overall monitoring data was centrally managed where advanced machine learning algorithms were applied to compute and predict the future usage and faults. Additionally, the sensors stored backup data onboard for extra reliability. OrxaGrid enforced security using device specific logins to prevent unauthorised access and SSL Encryption for secure data transfer. The web and mobile enabled dashboards were designed to be intuitive and simplicity driven for use by both domain experts and non-technical users of the utility.

Result

The project return on investment was apparent within days of implementation. Key results were:

- Real time visibility into the network identified daily peak loading on transformers and energy on feeders
- Automated SAIDI SAIFI reliability calculations benchmarked for fulfilling regulatory requirement and ensuring improvement in reliability
- Energy accounting identified lines and assets with the highest losses
- Outage classifications identified that agricultural consumers had the most faults
- Asset Health monitoring of transformers and DC batteries detected unreliable battery chargers

OrxaGrid's IoT based solution proved to be a viable alternative to the distribution utility for not only monitoring their entire substations but also finding key efficiency improvement insights. The system was scalable through retroactive addition of sensors from other substations in other divisions of the utility. The system was also interoperable where existing data sources from metering or SCADA could be fed into the system for deriving insights.

Transformer temperature and load analysis

Challenge

Utility companies transitioning to Smart Grid operation of their networks can realise significant benefit from real-time knowledge of the internal operating state of their assets. For power transformers, the key parameters required for optimal utilisation and economic operation are oil and winding temperature indications (OTI/WTI), these being both an indicator of losses and a constraint on the quantity of power that can be allowed to flow without causing damage.

A transformer operated without knowledge of OTI and WTI values must be utilised conservatively to avoid internal temperature constraint violation. Traditional methods permanently install OTI and WTI sensors inside the transformer case which necessitates a plant outage, oil draining operation and sensor commissioning and maintenance. Although legacy transformers often contain WTI and OTI sensors which were fitted during manufacture, these are typically connected to analogue indicator dials and thus not suitable for digitisation of their readings. A smart solution was required for the utility with legacy transformers to indicate internal temperatures and permissible loading without the need to fit or replace physical OTI and WTI sensors.

Solution developed

A six-month project was undertaken on the utility's grid-supply-point transformers with physical OTI and WTI sensors installed. Load current and ambient temperature sensors were fitted, with values streamed to a database every 15 minutes. The temperature estimation application retrieved the live readings from the database, estimated the WTI and OTI values then inserted these into the database.

For determining additional spare capacity in real-time under continuously varying load and ambient temperature condition, the algorithms were designed to be iterative and online which required no initial oil temperature information. The results converged in a reasonable number of timesteps, to give an accurate estimation of values which would be reported by an OTI and WTI if they were fitted to the transformer under consideration. OrxaGrid built its Transformer Temperature Estimation application which was designed to optimise temperature estimation accuracy when the I^2R losses dominate, This occurs when the load current is above the transformer's maximum efficiency point, because it is in this region that the transformer's thermal limits are approached. This temperature estimation was then used to determine:

- Maximum Permissible Operating Power: a real time function of allowed load on the transformer as a function of its core design material and operating conditions
- Future Load: a predictive algorithm to forecast and alert the operator of violations of maximum operating power

Result

The project proved successful with low estimation errors (Mean error 0.59°C and standard deviation 1.49°C). A method for estimating power transformer oil and winding temperatures from load current and ambient temperature, in lieu of OTI and WTI sensors, was built and validated. The utility was able to determine the real-time thermal rating of power transformers, to release spare capacity or to defer network reinforcement.

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Predicting voltage alerts

Challenge

Recent years have seen a large uptake in Low Carbon Technologies (LCTs) which have significantly changed traditional energy flow profiles. This shifting energy flow due to LCTs coupled with ageing assets and growing electricity demand puts extra stress on the local distribution networks. Research indicates that LCT integration would lead to an increased risk of power cuts and an inevitable rise in system energy losses. This risk will negatively impact end customers, who may see their electricity bills rise to meet network reinforcement costs; this would not be an acceptable scenario for energy regulators.

It is known that high penetration of Low Voltage connected solar can lead to voltage swells at substations, leading to tripping of the inverter relays. Meanwhile, if the same installation were dominated by electric vehicles then voltage sags are likely to occur. Traditional methods of tapping the substation transformers ceases to be a viable solution for substations with higher penetration of LCTs. OrxaGrid was tasked with developing a smart solution to these issues for a utility with growing LCT connections.

Solution

OrxaGrid developed and piloted a machine learning based voltage violation prediction algorithm for the utility. The voltage violation prediction algorithm informs the distribution utility of future voltage violations of the limits set out by the regulator. Real time busbar voltage data, feeder current, real and reactive power, energy, transformer top oil temperature, outdoor ambient temperature along with historical data and external influence data where available, were fed into machine learning algorithms to predict voltage violation events and estimate at what point in the future they may occur.

A gradient boosting regression tree model with a squared error objective function was selected to form the core of the voltage forecasting algorithm. This class of model was highly configurable based on a set of model-tuning hyperparameters, which meant that the trained model size could be traded off against learning rate. The regression model was trained with cyclical input features, engineered from sensor timestamps which minimised the requirement for external data feeds such as weather feeds.

Results

A voltage forecasting algorithm with incremental machine learning was designed, built and deployed on an edge-computing platform with limited computational resources. Validation on historic data showed that temporal voltage profiles could be predicted for the day ahead with an average root mean square error of only 0.776 V.

This algorithm provided the utility with a deeper visibility into its LV networks, enabling it to categorise risk on a substation by substation basis, and to plan for reinforcement works based on medium to long term predictions. Alerts generated by this algorithm could identify locked out transformer tap changers or undeclared overgeneration on domestic solar installations.