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Electricity Supply to Africa and Developing Economies –

Challenges and opportunities

Topic 2: Technology solutions and innovations for developing economies

An integrated, coherent, Big Data network performance management solution

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SUMMARY

A number of market drivers have an impact on network performance management. Some of these drivers do not only pose challenges to the network operator, they also open up opportunities. Most network operators would like to investigate and make use of energy savings opportunities; make their network performance risks and opportunities visible; determine their technical losses and measure the contribution of individual network components. With the introduction of renewable energy sources to the network, it becomes essential to investigate the impact of these renewable energy sources on network stability and capacity. Network operators furthermore would like to monitor and benchmark the character and performance of individual network assets; they would like to ensure that the current network performance is not declining and as such they would prefer to be actively involved in the management of network performance by understanding each incident, building calibrated network models, and capturing relevant historic network performance data.

Monitoring of the operation of the electric network depends on the available information from the network, offered by the information systems. It is possible to derive accurate decisions to control and plan the network and its operation if based on adequate and sufficient information. The current sources of network performance data are not sufficient for the management of network performance in the next decade for a number of reasons: the data is not synchronised; it is mostly RMS with integration periods of up to 30 minutes; the various data sources have different levels of accuracy per parameter; different measuring methods were used to calculate the parameters, to name a few. The data is furthermore not available throughout the company and as a result cannot be manipulated or collectively displayed. Different technical teams are tasked to monitor and maintain the individual systems, resulting in having a billing meter, protection relay, PQ meter and a SCADA transducer being found on the same measuring point. This results in a duplication of data, as well as costs. The context of the data is also lost. Raw data that are in context can lead to new data.

A need exists for an integrated, coherent network performance monitoring and management system. This paper describes the strategy and architecture of an integrated, coherent, Big Data

network performance management system that can address the various market drivers and be used to achieve the above-mentioned aims.

KEYWORDS: Big Data storage; clock synchronised data; Distribution monitoring and management system; Network performance management system

In the last decade, both nationally and globally, more and more emphasis is placed on the electricity supply and infrastructure. Energy efficiency, availability, stability and sustainability have become important topics in society [1]. Integration between many networks is also one of today's global trends [2]. For years the primary driver for network performance management has been the desire to provide reliable and clean power to its customers at the lowest cost. As the market matured, other drivers for network performance management have emerged. These trends and changes result in challenges to maintaining a reliable and stable supply, but they also open opportunities. Effects of these new drivers can be seen in the electricity supply chain where the following trends can be identified:

- *More complex and unpredictable loads* of significant size are connected daily onto the networks. The stochastic nature of demand has significant impact on network stability and the way networks are to be operated [3].
- *An increase in distributed electricity generation:* With the introduction of renewable energy generation, which is generated on a relatively small scale lower in the grid, distributed electricity generation increased, bringing with it fluctuation in strength (in particular sun and wind), causing network instability [3]. Aggregation of distributed generation in so-called virtual power plants is expected to play an important role in addressing the uncertainty of availability. Active distribution networks – networks that have systems in place to control a combination of distributed energy resources (generators, loads and storage) – have the possibility of managing the electricity flows using a flexible network topology [4].
- *Fault levels and network characteristics at different frequencies:* To be able to accommodate new network expansions it would be necessary to determine fault levels, as well as network impedance at various frequencies.
- *IT (information technology) enabled networks:* The introduction of microprocessor based distribution assets, smart user interfaces, resident memory, and remote communication requirements drive the need for IT enabled networks. To IT enable equipment means the provision of monitoring and control intelligence plus real-time communications capabilities to previously isolated and stand-alone remote distribution assets. To IT enable the network allows it to become more efficient and more sustainable [3].
- *Data-driven management decisions:* Management needs to make decisions based on various reports that cover different static, dynamic and stability aspects of the network performance. They need fast responses and combined data from various sources. There is a need for readily available, complex data reports that are accessible in near real-time and '24/7' through dedicated software platforms. This is also known as live management information. Data analytic tools and data analysis operators must therefore be fully equipped and operational.
- *Key customer support:* Apart from the management of individual key customer contracts, modern utilities also have to actively manage the quality of electricity supplied to all customers.

Another market driver impacting utility behaviour is asset health management (AHM). The ability to analyse past network performance data and to correlate this data with remotely monitored distribution assets in real time reduce maintenance costs, prolong equipment life, and prevent premature failure of equipment and distribution lines. This represents a shift from time-based maintenance practices towards those that are condition-based, and from an emphasis on historical performance of assets to an emphasis on future performance and risk. As more intelligence is built into the transmission and distribution system, even down to the device level, utilities are beginning to explore the potential for leveraging the vast amount of data these devices generate. The purpose is to gain a better understanding of the actual condition of grid assets so that operations and maintenance activities can be optimised along with the performance of the network as a whole [5].

More recently, the term ‘network optimization’ has been used to define the ability to maximise the utilisation of remote assets, such as capacitor banks, voltage regulators and transformers to improve network reliability and efficiency, avoid the investment of additional generation, and improve overall demand response [4].

TECHNICAL CHALLENGES ASSOCIATED WITH NETWORK PERFORMANCE MANAGEMENT

The availability of quality data is a major challenge faced by network performance managers. The current sources of network performance data are smart billing meters, disturbance recorders, SCADA transducers and power quality recorders. This type of data is not sufficient for the management of modern networks’ performance for a number of reasons. Some of these reasons are that the data is not synchronised; it is mostly RMS data with long integration intervals (only report steady state performance); the various data sources have different levels of accuracy per parameter (certified vs. non-; 8-bit vs. 12-bit vs. 16-bit data, etc.); and different measuring methods were used to calculate the parameters (e.g. different aggregation intervals, as well as aggregation methods such as gapped and un-gapped aggregation).

In order to use real-time measured, sinusoidal wave data from various measuring sources to deduct new parameters, high level, individual time synchronisation is needed. Most network parameters furthermore display different static and dynamic behaviours. The sampling tempo of parameters resultantly becomes an important aspect to consider. Modern synchrophasor devices require phase accuracy of 0.1%. The 20 ms period therefore needs to be measured with an accuracy of ±20 μs. Micro synchrophasor measurement equipment thus requires absolute time synchronization in excess to ±20 μs.

Another well-known challenge faced by network operators is the fact that more than half of the generated energy are processed by switched loads, resulting in rapid load changes, harmonics and even DC transients. Traditional RMS data integrate over half hour intervals are thus not sufficient for the management of the modern grid. Distributed renewable energy sources also result in network stability issues, making it essential to monitor the micro synchrophasors.

The data is furthermore not available at a central place and as a result cannot be manipulated or displayed collectively. Data collected in silos within different departments in an organisation are closed off to the different departments making it inaccessible to the various role-players in the organization. This may lead to duplication and increased costs and it inhibits the ability to derive new data from different data sources. Different technical teams are tasked to monitor and maintain the individual systems, resulting in having a billing meter, protection relay, power quality meter and a SCADA transducer being found on the same measuring point. This results in a mass duplication of data, as well as costs. A further consequence of decentralised data is the loss of data context. To be able to derive new data from raw data, network operators would need access to contextualised, quality data of sufficient depth (both in parameter set and integration intervals) to allow the network operators to add value to the original, real-time data. This generation of new data is only possible if data is available at a central place. The creation of robust network simulation models requires detailed quality field performance data. The more accurate the data is, the more accurate the model and resulting analysis and optimisations will be.

Basing critical maintenance decisions on the actual condition of assets implies a need for storage of historical performance data. With a proliferation of data streams, the utility is faced with two interrelated challenges: How to manage the influx of so much data from various sources, and How to make it available to a variety of applications. The latter is particularly of importance since the value of a given piece of information is often amplified when combined with others [5]. There is however a difference between data and information. In order to best leverage the increasing volumes of data, a network performance management system must include tools for visualising the data so that users can extract meaningful information from them. To complicate matters, relevant data may be stored in a variety of different systems, e.g. SCADA, energy management systems, enterprise asset management, mobile workforce management, etc. - each with their own unique data format.

With the need for more detailed data, another challenge emerged – the need for data storage capacity. A typical phasor measurement unit (PMU) can record 50 synchrophasor sets per cycle. This results in ±150 GB of storage per device per annum. A fleet of 100 devices will require ±15 TB of storage per annum. Five years of history will require 75 TB of storage space. Big Data storage technology is therefore required to allow systems to store and manipulate such vast sets of data.

Distribution monitoring requires significant commitment and a complex set of capabilities. Network performance management capability of utilities generally is not in line with the modern challenges experienced in the power industry. The electricity supply industry is in a dire need for ‘institutional’ knowledge around planning for, implementation of and sustainably operation of modern smart grid solutions at all the levels and roles. This institutional knowledge includes data, information, and practical experience. Training and capacity building is also needed. The electricity supply industry (ESI) in general lack institutional knowledge around the establishment of new abilities, researching new technologies, as well as translating user requirements into sustainable system specifications and operations specifications.

STRATEGY – an integrated, coherent, Big Data network performance management system

In order to address some of the above mentioned market drivers and technical challenges, various strategies are needed to establish an integrated, coherent, Big Data network performance management system. These strategies include a system management strategy, technology strategy, measurement device placement strategy, communication strategy, measurement strategy, communication strategy, and an implementation strategy. Each strategy will be presented in the section to follow.

System management strategy: It is not good practice to operate a distribution system according to limit criteria as set out by regulatory or other limit requirements. Networks should be operated to stay within its designed specification. This will ensure longevity of equipment/assets and it will ensure that problems be identified long before it becomes a crisis. If the design criteria is exceeded, the operator should intervene to get the system back to within its design criteria, or changes should be made to the network to free up or expand on capacity. A system management strategy involves the following:

- Determine the design criteria for each parameter to be monitored and set operational limits. If the design criteria are unknown, learn the existing operational criteria and manage the system to at least stay within existing operational limits.
- Generate alarms when any of the network parameters exceeds the operational criteria.
- Aggregate all alarms originating from a single network exceedance into a single event. Add GIS, single line and any other context information relevant to the incident.
- Make the data immediately available for analysis to the system operator - preferably via a mobile friendly web interface to enable the operator and other engineering support personnel to access information after hours, at any location, without having to use a computer.
- Open a ticket for every system alarm. Measure the operator's ability to timeously recover the network exceedance. If the ticket stays open for too long, then escalate it to a higher level to expedite the recovery of the system.
- Create live dashboards or live reports for every operational or functional area to gain visibility of the system's performance for that specific functional area. Different users want to look at the same set of data from different contexts. For example: the power quality dashboard should contain a different data set compared to the billing dashboard or to the network stability dashboard.
- Use statistical network performance dashboards and reports to benchmark the network performance and to identify trends and characteristic values. Make these dashboards and reports accessible throughout the organisation.

Technology strategy: We live in a fast changing world and our industry is undergoing a revolution. A technology strategy is required to enable the system to meet existing requirements, but also to be adapted to future changes.

- Two types of measurement platforms are required:
    - Top-end device – Full featured multifunction measurement platform.
    - Low cost device – Affordable multifunction measurement platform to be deployed in large quantities throughout the network.
- The measurement platforms have to be field programmable to allow them to be functionally modified, should the requirements change. The modern world talks about edge computing or fog computing. Devices must have the ability to record data at high speed and analyse the data in real-time. Slower speed statistics and alarms need to be derived and sent to the central data store to be archived and reported on.
- The main functionality of the measurement platforms should include billing, power quality, digital fault recording and synchrophasor recording.
- All parameters to be measured must conform to the published international standards.
- The clocks of all measurement devices must be permanently clock synchronised to be within ±1 μs. This high level of clock synchronisation is required to automate the derival of new network parameters from waveform, synchrophasor and other data types recorded at different geographical locations.
- Interfaces for external telemetry transducers like temperature probes and flow sensors must be available. This will allow measurement platforms to be used to monitor valuable environmental telemetry data like transformer case temperature and breaker status.
- The data should be stored in a scalable Big Data store. The performance of traditional relational data stores digress significantly as the amount of data increases and they do not scale linearly when the amount of data to be stored encroaches its storage capacity. Big Data stores traditionally scale linearly (if you need more storage or performance you can just add hardware) and the performance does not deteriorate with increased data storage.

- The retrieval of raw data must be fully automated. This maximises the time value of information as it will be accessible in near real-time. Each measurement device must have local on-board cache to buffer raw data in the event of faulty communication. If the communication link is restored, the data must be synchronised with the central data store.
- Archived data must be made available to users via an interactive mobile friendly web interface. Alarms must be propagated onto subscribed users via push notifications, SMS or E-mails. This will ensure that data is accessible throughout the organisation, even after hours.

Communication strategy: The communication strategy should ensure that:

- All communication is encrypted;
- All communication is IP based as it can be transported over a variety of mediums;
- The communication starts with the metering instrument as base and not the server. The meter would recognise the server (this is beneficial as the instrument can communicate behind the firewall), which is not always possible if the communication started with the server as reference point;
- Built-in cellular communication is used for remote communication; and
- Built-in WiFi is used for point-to-point communication where instruments are installed on poles or inside kiosks.

Measurement device placement strategy: Different network locations require the monitoring of different types of network parameters and optional telemetry data.

- Primary Substations
  - Incoming feeders - A top-end device is required to monitor the performance of incoming feeders. Valuable information could be obtained if the device could monitor additional telemetry parameters from the transformer, tap changer, breaker and the protection relay.
  - Outgoing feeders – A low cost device can be used to monitor each of the outgoing feeders. Steady state and dynamic feeder load profile information is important during investigations of network faults, as well as current waveform and ½-cycle RMS diagnostic data.
- Bulk supply points – A top-end device is required to monitor bulk supply points. Bulk supply points traditionally generate substantial revenue to the suppliers. Key customer contracts might be applicable and profiling of bulk supply point consumption will provide valuable business intelligence to the supply authority.
- 400 V Low Voltage (LV) transformer outputs – A low-cost device is required to monitor the output of LV transformers. Very little is known internationally about the dynamic load characteristics of LV transformers. The integration of small-scale renewables will have a significant impact on the LV voltage performance. The high level of visibility offered through monitoring of LV transformer outputs will assist supply authorities to accurately measure and calculate both technical and non-technical losses. In one of the largest metros in South Africa, a 1% decrease in losses translates into a monthly saving in excess of R150 million.

Implementation strategy: The implementation strategy requires attention be given to the following aspects.

- Information needs to be collected on the client's operational needs. The project needs to be broken up into smaller operational applications and the technology, operational, capacity and support needs for each of the operational applications need to be determined.

- Draw up an integrated plan that would enable the client to fulfil all his operational needs. Follow up the integrated plan with a calculation of the implementation costs. All the while, it is advised to iteratively interact with the client to determine the most economical solution, to identify the low hanging fruits, and to determine the scope of the first phase of the project.
- The integrated plan should be followed up by a long-term plan to assist the client to achieve sustainable growth and to adapt to the lessons learned. The plan should be revisited annually to ensure the client receives the maximum value and that the project stays in line with the client's changing needs.

ARCHITECTURE

Network performance management has traditionally included monitoring of the transmission section of the electric network. Historically, a silo-oriented approach was followed in the strategic planning and infrastructure design of power networks [6]. The changing topology of power networks and operating conditions, however, require a different architecture for the management of the performance of modern networks. There is a need for a modernised, highly integrated, coherent and technology-driven power grid based on big data capabilities.

The architecture proposed in this paper involves a:

- Central Big Data store with a mobile friendly web interface to access data and devices.
- Fleet of remotely installed devices permanently connected via an encrypted link to the central Big Data store.
- Few stand-alone or roaming devices for diagnostic purposes where data need to be manually downloaded and then manually imported into the Big Data store.

5. Implications for network operator

Since you can only manage what you can measure, the availability and access to real-time data on both the dynamic and static behaviour of the power network are invaluable for the network operators. This enable network operators to profile and benchmark the performance of various sections (elements) in the entire network, improving visibility and situational awareness. Decentralised access is enabled via the web and mobile technology. An integrated, coherent, Big Data performance network management system would hold implications for the network engineer and manager, but also the power network industry as a whole.

Implications for the network engineer: The network engineer is able to derive new parameters from the coherent data that would become available. They can address challenges such as network models, technical and non-technical losses and network stability. The availability of high quality data enables the engineer to characterise both static and dynamic behaviour of the network. This would empower the network engineer to pro-actively manage the grid, instead of reacting on events in the network.

Implications for network manager: The improvement of operational awareness enables the network manager to proactively manage the performance of the network. Operational awareness is achieved through the use of push notifications. Network managers receive relevant information that allows them to describe KPIs, assign tickets and enable the implementation of a micro management system.

CONCLUSION

There is a pressing need for an integrated, coherent network monitoring system. This paper describes the strategy and architecture of a Big Data monitoring system that can be used to achieve the above-mentioned aims. Integration between many networks is one of today's global trends [2]. The primary objective is to optimize network performance – which means identifying and removing weak points and maximising asset utilisation. In a data-rich power grid, converting the data to models and then to information and controls, becomes a fundamental enabling step.

In summary, all different management solutions can be implemented with different levels of benefits. More advanced solutions require more sensing, measurement, communications, and software but they provide greater benefits. Depending on the level of sophistication of the system operators, a solution can be developed to suit the needs of the consumer and the system owners at the investment level that makes the most sense for a specific system, provided that the system provides integrated, coherent, Big Data regarding the performance of the network. In the context of network performance management, development of an integrated, coherent, Big Data network performance management system will enable a paradigm shift in the engineering of power grid monitoring and control, which will undergo a transition from a human-centric to a data-centric decision-making process.

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