Networked Energy Services

eSmart SYSTEMS

MAKING THE SMART GRID INTELLIGENT: USING SOFTWARE TO IMPROVE POWER RELIABILITY

Timely actionable insight is the key to making the correct business and operational decisions.

Over the last few decades, significant investment has been made in the monitoring and management of the medium- and high- voltage grids. In the low-voltage grid, this has not been possible because the value of the assets under management do not make it cost effective, when one looks purely at traditional infrastructure monitoring and management needs.

The latest generation of smart meters provides new levels of visibility of power and voltage quality at the substation transformer and the consumer. Some smart grid solutions even provide visibility of the low-voltage grid topology and connectivity, and can create measurements from within the low-voltage grid.

With the availability of information from the low-voltage grid, software solutions that process and analyse this information can make a positive contribution by providing timely actionable insight. This insight can be used to improve operational processes and can also have a positive impact on the quality of service that the end consumer receives.

In this paper, we look at how the latest smart metering solutions can be combined with new analytics tools to improve power reliability, by looking at three key scenarios:

- Improving Power Quality
- Assessing Impacts of Power Quality Problems
- Restoring Service.

In doing so, we show how timely actionable insight in the low voltage grid leads to practical benefits including better power quality and service availability for consumers. It also provides the DSO with additional information concerning grid capacity flexibility, load forecasting and predictive maintenance.

We start with the perspective of the challenge from the DSO:

THE DSO'S PERSPECTIVE

The low voltage grid is not generally monitored by the Scada system.

Information from some smart meters can be used to provide voltage and power information from the substation and the consumer, and indicate when power quality is poor or there is an outage. Whilst this is useful information, it is provided too late because, by this time, the customer is impacted. Furthermore, it only provides notification of those consumers whose smart meters are communicating back to the head-end, and does not allow the topology of the grid to be assessed to identify wider outages or degradations of service which affect multiple consumers.

In short, while the information is useful, it does not support proactive work methods.

Any future smart grid system needs to:

- Provide extended information concerning the topology of the low-voltage grid, so that more operational insight can be drawn from the information being presented by the smart meter
- Allow the complete range of an impacted community of consumers to be identified
- Provide visualization tools allowing immediate problems and longer-term trends to be spotted faster and reacted to before they become critical
- Apply analytics to draw out inferences from patterns buried deep within the information-set
- Use complementary information to identify other forms of strain on the grid which may lead to problems and identify the impacts on energy flows of micro-generation and electric vehicles.

The goal is to obtain lower costs and improved customer satisfaction through early identification of weaknesses in the grid, implementation of reinforcement to avoid outages and degradation through better prioritization of grid investments and to assess social and business impacts of any outages when prioritizing problem resolution.

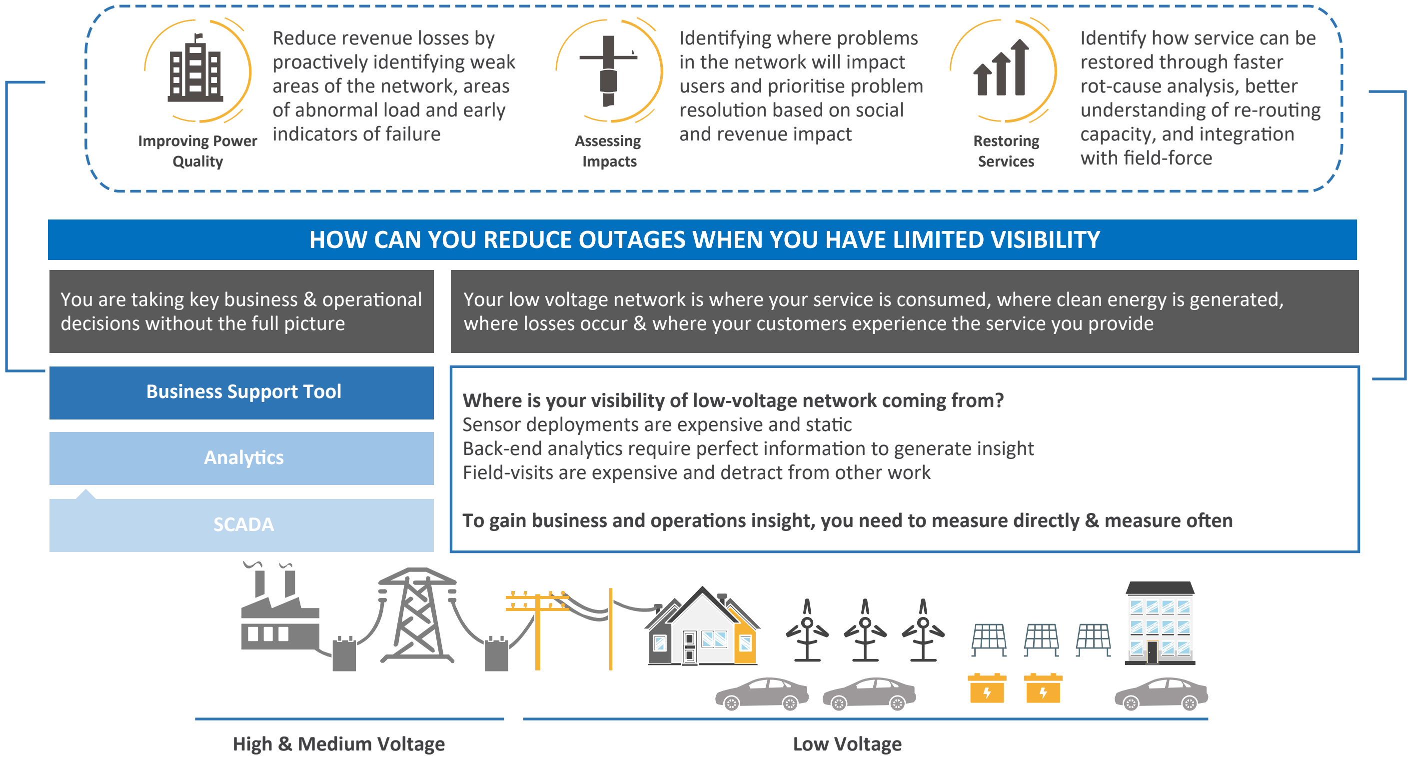
THE CHALLENGE IN THE LOW-VOLTAGE GRID

The challenge of achieving visibility in the low-voltage grid is only partially because SCADA solutions are not cost-effective for deployment. The lack of SCADA is somewhat mitigated through using smart meters at the substation transformer and at the consumer premises to record voltage and power quality. This, itself, is a challenge, and relies on a highly robust and proven communications solution.

However, there remains the challenge of:

- Enriching this information with an understanding of topology to expose more of what is happening throughout the low-voltage grid

• Sifting through the massive volumes of information to find the key indicators of actual problems in supply or patterns which indicate a probable problem in supply developing.



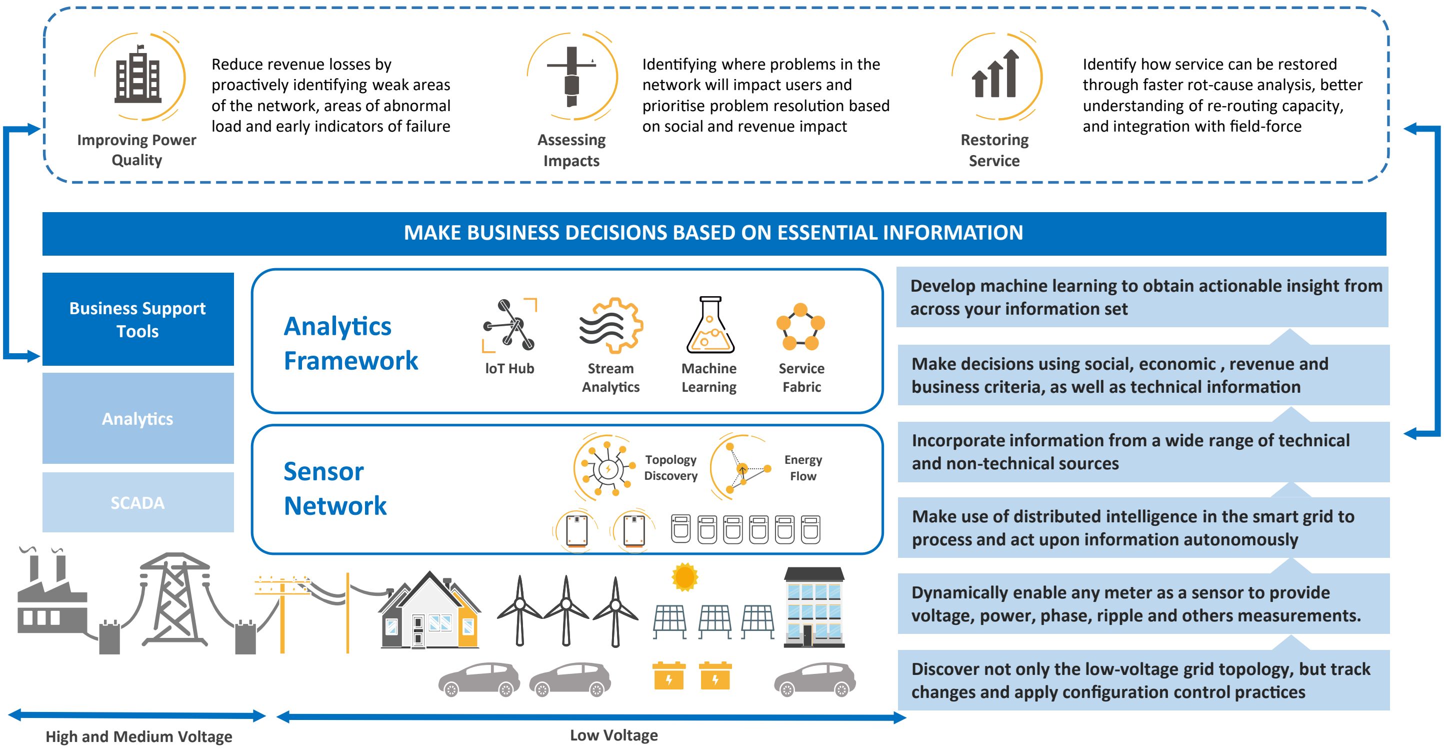
COMBINING A SENSOR NETWORK AND ANALYTICS FRAMEWORK

The solution is two-fold:

• Deploy sophisticated smart grid solutions which not only provide a rich steam of voltage and power quality information, but also discover the topology of the low-voltage grid, and make use of that information to draw conclusions about power flows

• Couple this with an analytics solution with the visualisation, pattern recognizing, machine learning and stream analytics packages for extra indicators of consumer supply quality degradations, outages and long-term trends.

Such a solution combines the capabilities of a sensor network embedded into the smart meters solution and relying on the robust and reliable communications solution with the analytics framework at the back-end to draw out the timely actionable insight.



Smart Meter Infrastructure as a Sensor Network

The use of smart meters to record basic electrical supply parameters is not new. However, the most sophisticated smart meter solutions bring in new capabilities which increase the value of using smart meters in this way:

- **Voltage and Power Quality Indicators** Many quality indicators can be recorded in high resolution
- **On-board Compute Resource** The first level of managing data can be performed by the meters themselves
- **Reliable Communications** Transmission of the information back to central analytics tools is dependent on high levels of communications SLAs
- **Mid-tier Compute Resource** The first layer of analytics can be applied in the field, close to the meter, to filter out unwanted information and provide an initial aggregation
- **Topology Discovery** The interconnections of the low-voltage grid can be discovered from communications quality statistics.

With this type of smart meter deployed in every consumer premise and communicating reliably, the DSO is provided with an immediate sensor network for no additional investment in HW or communications.

A Micro-computer in the Home

- 32-bit Micro Processor, Dual-Core Cortex-M4, hardware
- AES-128256-/bit encryption support
- High density memory (32Mb) with head-room for future data use growth and application expansion
- 2 MEP expansion ports, H1, Wireless and Wired M-Bus, Zigbee, 2G/3G/4G
- 2 S0 outputs, Control relay, Plug-on IO

Leading edge grid sensing capabilities

- 18-bit resolution measurement with better analog front end engine

A Computer in the Field

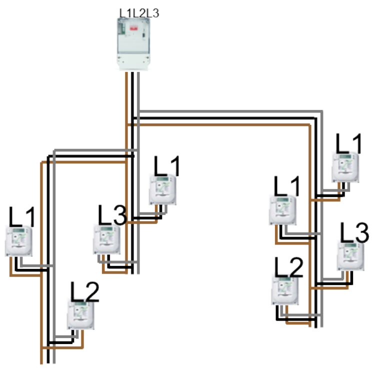
- Full Linux Kernel 3.2 OS
- 600MHz processor, 512MB DRAM, 1.8GB MMC
- Pluggable ethernet, serial, external USB, last gasp, external backup power
- Third-party modules for additional grid monitoring and control

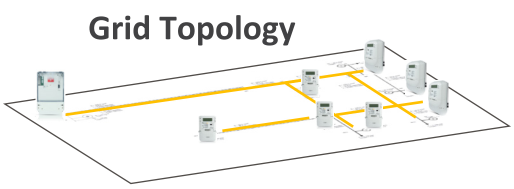
The Platform for Grid Applications

- Energy Application Platform™ framework
- Common smart grid analytics and value-based operational apps
- Utility-specific custom functionality downloadable over the life of the DCN
- Remotely and securely adding distributed applications and device/ sensor support drivers in the field
- Platform for your own monitoring, analytics and automation tools

Grid Topology and Energy Flow Insight

Typically, low-voltage grid topology information, if held at all by the DSO, would be in the form of paper schematics, digitized but still image/raster based schematics, or possibly GIS-based data. All would typically be out of date because the cost to audit and update these records is very high. And the nature of the records means that they slow down operational processes because it is difficult to search for relevant information and expose it into the appropriate operational activity.

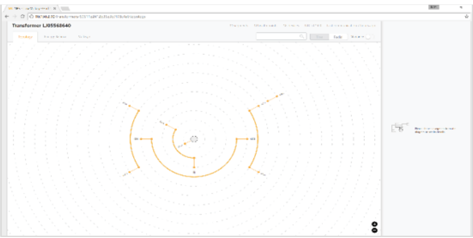


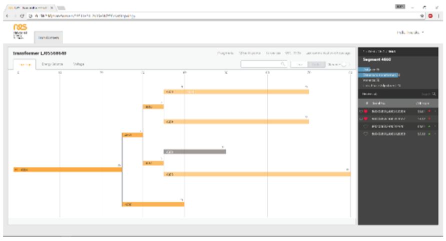


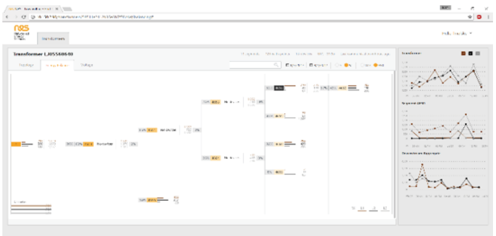
In PLC based smart metering solutions, grid topology can be assessed through analysis of the communications parameters - cross-talk, attenuation, signal-to-noise ratios can all be used to build an understanding of how the low-voltage grid is topologically connected. This provides a unique insight and the potential to expose this information through APIs directly into operational processes.

With an understanding of grid topology, it becomes possible to:

- Understand more about voltage and power levels within the low-voltage grid
- Identify root-cause by analyzing symptomatic events against the network topology
- Assess the range of impacts of an outage or degradation
- Identify change in the configuration of the network.



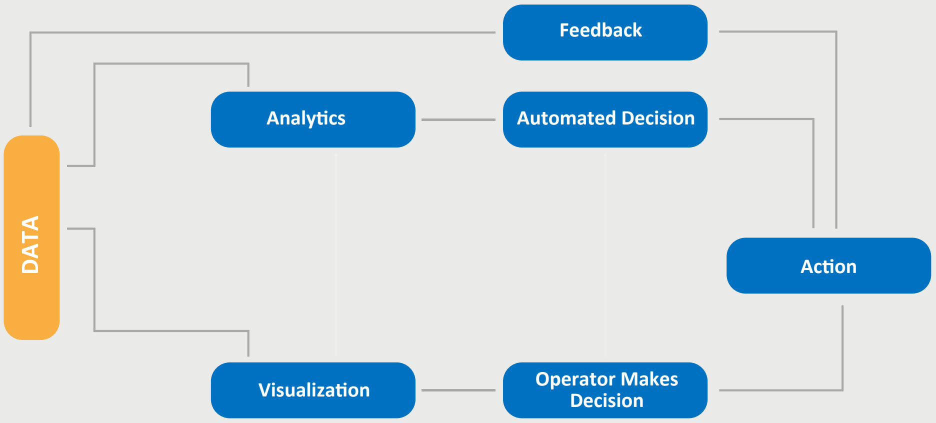




It also becomes possible to better assess the flow of energy within the grid, as micro-generation, local storage and electric vehicle uptake distributes and de-centralises energy sources and changes energy usage profiles.

It also becomes possible to better assess how changing usage profiles will affect loading in the low-voltage grid, which can initiate a capacity planning and reinforcement activity, in advance of demand.

Deriving Actionable Insight



Data becomes more valuable when correlated with even more data and DSOs have a lot of data from:

- Smart meters
- GIS
- Scada
- CRM
- Sensor data
- Weather
- Market data.

So, you have all this data, but it has no value unless you start to utilize it. To really harvest the value of your data you can do analytics; that is working with the data and identifying correlations to support your day-to-day decisions. Using AI (Artificial Intelligence) and machine learning to do your data analytics will dramatically improve the possibilities and the value of your data.

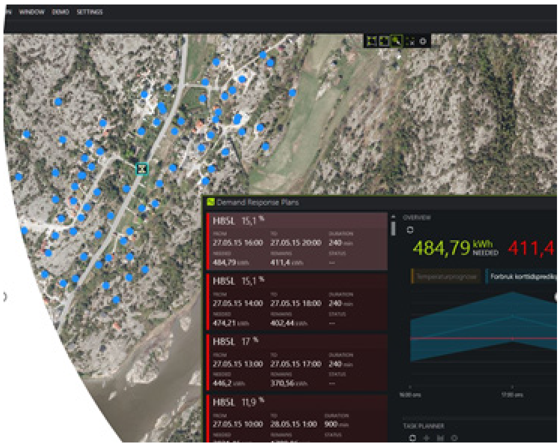
Use of advanced visualizations will also support decision making and really help you improve understanding of the data.

Automated decisions based on the results from analytics will become more common, but the quality of the decisions depends on your data quality. For the immediate future, it still will be the operator who makes the decisions based on good visualization and good understanding. An operator is also still needed to verify the system's suggested automated decision.

The result of a decision leads to an action. This can be an automated process like sending control signals or a field task handled by a field engineer. Or it could be a drone mission.

Either way, it is of utmost importance to track the result of the action and give feedback back to the dataset to improve the process.

Analytics Examples



Data Analytics come in many shapes and forms. One example of analytics can be the use of load forecasting on substation level. The purpose is to optimize the utilization factor of infrastructure, in this case the substation.

Data could come from smart meter data and home automation units. Smart meters are a perfect starting point for analytics like this. Home automation units could give an extra dimension with the support for performing demand response.

Smart meter data can be utilized to become a virtual sensor on the substation. In a scenario where all meters below the substation are smart, then you can aggregate all the values and get a virtual load sensor.

In this scenario, the automated decision is a control plan to switch off residential loads i.e. perform demand/response.

The action is to execute the same control plan. For this to be performed you are dependent on two-way communication with an IoT device on the site.

The feedback to the systems is whether the control plan was a success or not, whether it was performed and if it did have the desired effect.

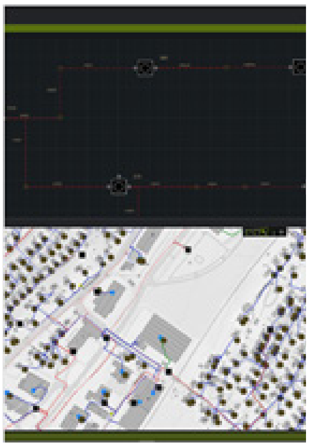
Visualisation Examples

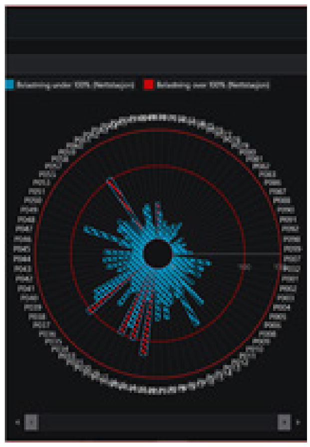
The whole purpose of the visualization is to support the operator in the decision making. DSOs have loads of data available and with smart meters and other sensors it is easy to get lost in the data; it is difficult to identify what really matters. Visualization is a good tool for decision support.

Typically, dashboards are used to give a quick overview; simple dashboards that provide an easy to understand presentation of the KPIs you need to monitor.

Adding maps and diagrams in different forms provides an additional overview of infrastructure and in combination with smart meter data becomes a powerful visual aid.

With the new types of data now available totally new types of visualization arise, like using rose diagrams to indicate overload on certain transformers.





THREE USE CASE EXAMPLES

We look at 3 ways a sensor network and analytics can help to improve power reliability, covering how the sensor network and the analytics framework play a role in supporting these important operational processes:

- Improving Power Quality
- Assessing Impacts
- Restoring Service.

Improving Power Quality	Assessing Impacts	Restoring Service	
Reduce revenue losses by proactively identifying weak areas of the network, areas of abnormal load and early indicators of failure	*Identifying where problems in the network will impact users and prioritise problem resolution based on social and revenue impact*	*Identify how service can be restored through faster root-cause analysis, better understanding of re-routing capacity, and integration with field-force*	
• Identify areas of high load and stress deep in the LV Grid • Identify degradations and trends, don't wait for failure • Monitor across the LV grid up to and including the substation	• Assess outages based on LV grid topology • Don't wait for the call; be aware of impacted consumers • Improve operational data sets with detailed LV grid information	• Identify the root-cause quicker • Spot available capacity for re-routing • Semi- and fully automatic control of loads	Sensor Network
• Identify indicators of future failure to predict outages • Understand growth of demand through demographics • Visualise dynamic flows across the Low-voltage network	• Leverage data from a wider set of sources • Change the priority criteria for fixing problems • Look at social, economic, business impacts as well as technical severity	• Dispatch faster and more accurately • Integration with work-order management platforms, bringing in wider information based on the fault data • Better priority setting based on more contextual information	Analytics framework

IMPROVING POWER QUALITY

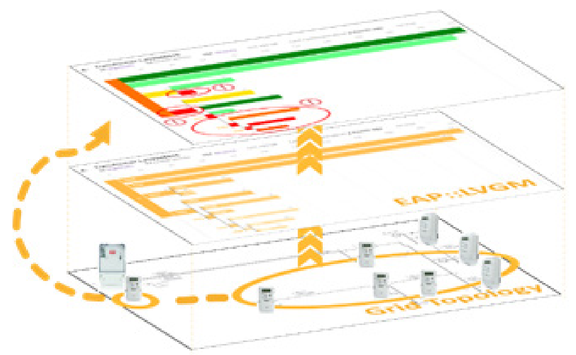
Improving power quality is the fundamental step to take. This involves gathering as much information as possible about the current and historical performance of the low-voltage grid, from the substation to the consumer, and exposing this into analytics tools to help highlight the indicators of network quality problems.

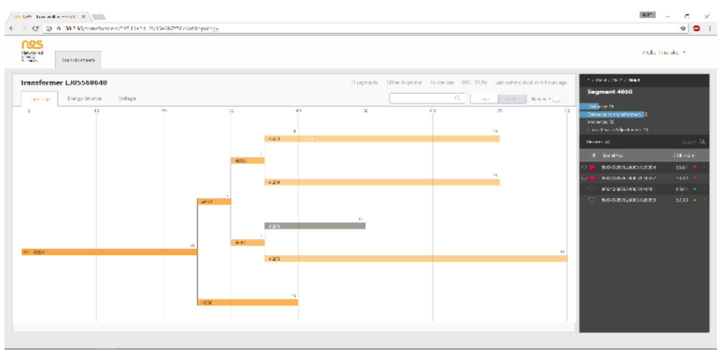
Avoid Consumer Outages and Improve Power Quality Through Proactive Maintenance

The sensor network exposes a wide range of voltage and power quality parameters, at the substation and consumer premise, but also at points deep in the low-voltage grid.

Power Characteristics Measurement:

- Active power (kW): forward, reverse
- Maximum forward active power over a specified interval
- Average forward active power over a specified interval
- Maximum reverse active power over a specified interval
- Average reverse active power over a specified interval
- Active energy (kWh): forward, reverse, forward + reverse, forward – reverse
- Reactive power (kVAr): import, export
- Maximum forward active power over a specified interval
- Average forward active power over a specified interval
- Reactive energy (kVArh): import, export
- Apparent Power (VA)
- RMS voltage
- Minimum voltage over a specified interval
- Maximum voltage over a specified interval
- Average voltage over a specified interval
- RMS current
- Power factor
- Phase Angle.



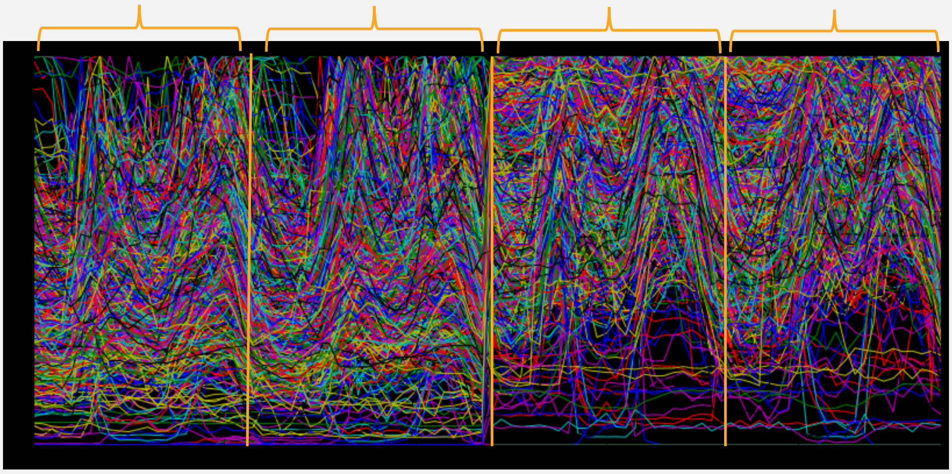


This information can be used to identify capacity problems and non-optimal configurations in the low-voltage grid, which can, through analytics, be used to trigger proactive maintenance activities as well as respond to more immediate problems which are directly affecting consumers, such as voltage and power quality degradations.

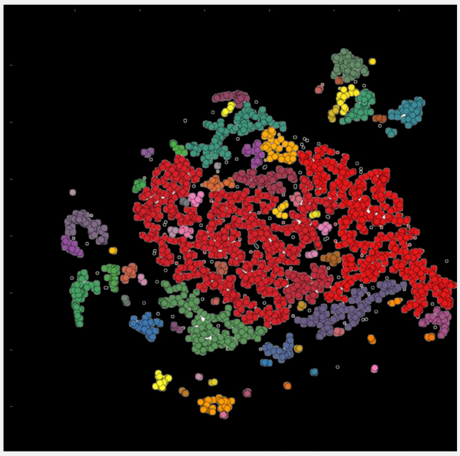
Customer Segmentation Based On Consumption Patterns

COMPOUND PROFILES

Summer Weekday, Summer Weekend, Winter Weekday, Winter Weekend



Very high variability in the load profiles



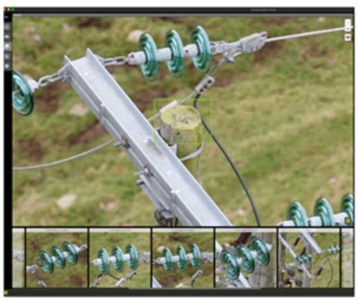
Clustering

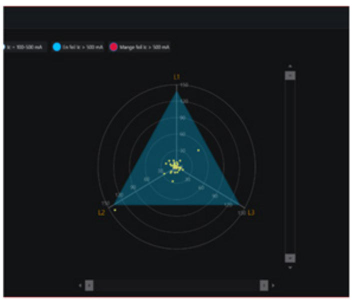
Modern smart meters provide high resolution data about e.g. consumption. By using advanced analytics on consumption patterns it is possible to:

- Group customers that have obvious similarities in consumption. This is not as easy as one would think as research has shown that households with the same age of house, same number of residents etc. can vary the consumption by over 300%
- Identify new types of consumption, such as EVs in a certain area or even identify those consumers who have just bought an EV
- Identify new types of generation in an area, like those consumers who have highly effective solar panels.

This is information that affects the power distribution so it is important to get an overview of this and it also helps in marketing use to make sure you increase the possibility for up-sales.

Predictive Maintenance





Predictive Maintenance is on everybody's lips these days. And in a critical industry like the energy industry, it is of utmost importance to make sure that your assets and equipment is in good shape at any time.

What is exciting is that you now can utilize new sources of information. You can use inspection data as part of the analytics, for example, from drones. It is also perfectly possible to automate the image inspection, to further automate the process.

By utilizing data from sensors on transformers and other equipment, and home automation and combining this with imagery from e.g. drones you have a good starting point.

It is also important to have control of information from other parts of the operations like identifying challenges with communication. Many IoT devices depend on mobile networks. Getting an overview of data usage compared to plans is important. Obtaining full control of data flows is becoming almost as important as the energy flow.

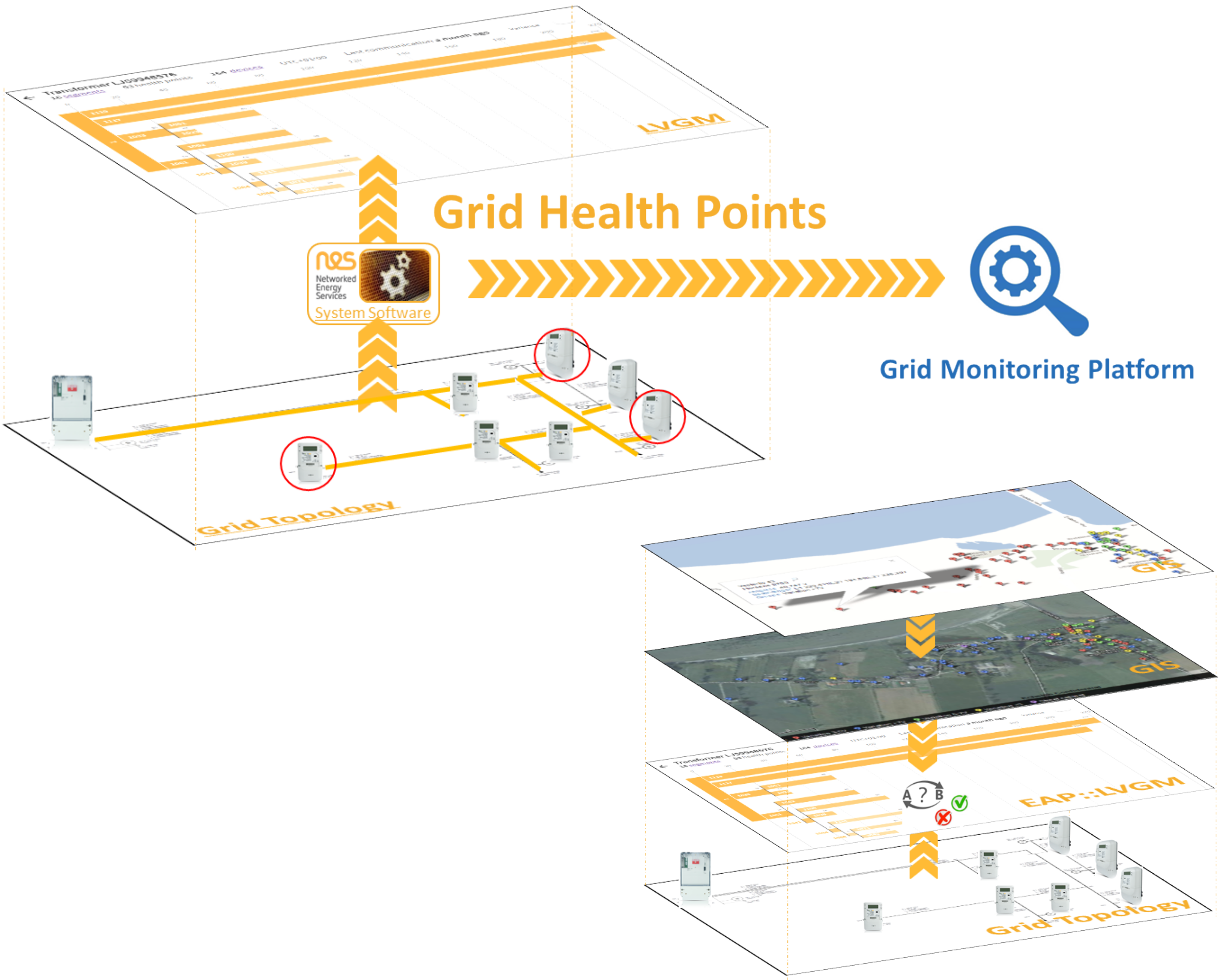
Again – it is all about data quality.

ASSESSING IMPACTS

With problems in the low-voltage grid identified, it then becomes important to identify the scope of the impacts. Through closer integration of the sensor network and the analytics framework, it becomes possible to assess impacts in terms of both affected consumers, but also the business and social impact of the outages.

Automated Low Voltage Grid Mapping

Not only is the topology of the low-voltage grid mapped out by the sensor network; the mapping between the topology and physical infrastructure, and topology and consumers can also be defined through integration with back-end systems. Furthermore, because the sensor network is communicating across the infrastructure, it becomes possible to identify those end-points which normally communicate with a high degree of accuracy, and so failure in communication of these points can be attributed to a probable fault in the low-voltage grid.

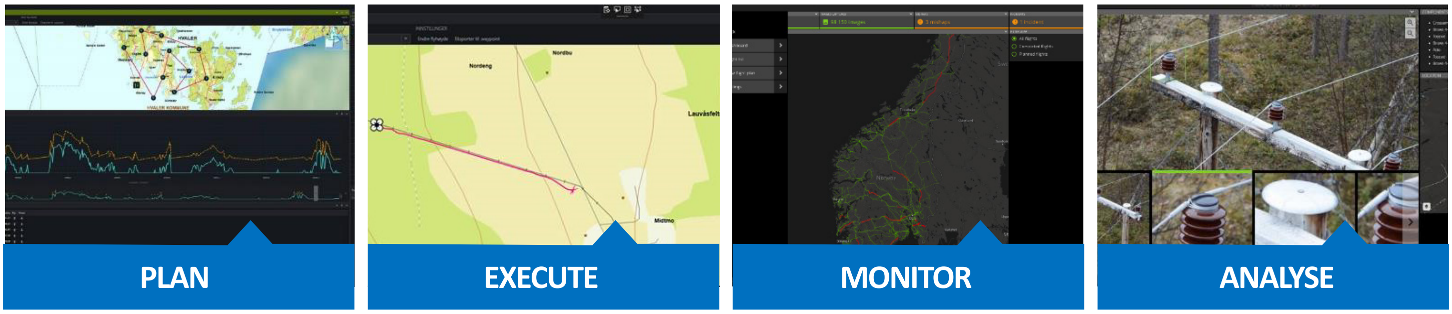


These capabilities mean that both the possible root-cause and impact of fault can be assessed:

- **Root-cause** Indicators of poor voltage or power quality can be mapped on the topology to «triangulate» towards a probable root-cause, such as a physically damaged line serving a wider range of consumers. The DSO can then dispatch field-engineers or technicians with more certainty as to the location of the fault, which, in turn, reduces the time to restore and the field work costs
- **Impact** With the root-cause identified, the same approach of using topology can be applied to identify those consumers depending on supply over the faulty infrastructure, and so the DSO is able to start prioritising work based on consumer impact and track the end-customer's experience with greater accuracy.

This is a key capability required for the DSO to move from a reactive to a proactive mode of operation.

Impact Assessments And Faster Resolution



To improve the process of impact assessment and get faster resolutions it is important to have a wider perspective, a holistic view.

DSOs need to utilize all data available see as many correlations as possible.

DSOs should also automate the process:

• Escalate the notification if there are prioritized customers affected
• Send messages directly to the customers
• Provide extensive information to the field crew, based on your holistic view
• Create waypoints for your automated drone inspection, using the topology information
• Provide information on the load that would be expected when restoring power and possibly provide information on alternatives, such as demand/response.

RESTORING SERVICE

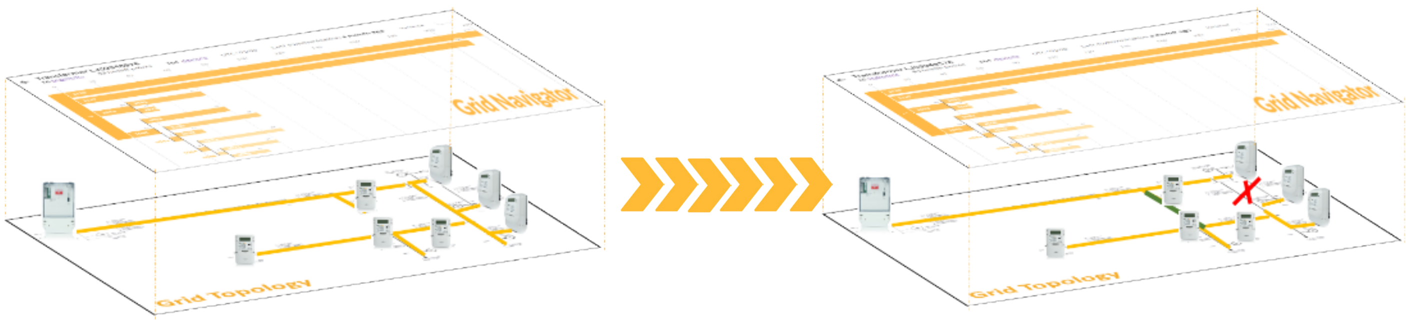
With the root-cause and the consumer impact identified, it now becomes possible to stream-line how problems are resolved through:

• Improved information More of the right information, and more up-to-date information can be shared with the teams responsible for restoring the service. This can include information about the fault and information about possible recovery actions, such as identifying available capacity for re-routes
• Improved priority setting Whilst prioritising based on the number of impacted consumers is a positive first step, the ideal should be to prioritise based on commercial, business and social impacts. This requires close integration, through analytics, of a wide range of information sets which have not historically been part of the service restoration process.

Better Operational Information

The information generated from the sensor network provides a rich source of alarm/event and historical performance information, which can be used by the analytics framework to define actions, embedded into the field-engineer’s pack and accessed on-line by the engineer from the field if required.

Key to problem resolution is topology, and allowing the engineer to see how the low-voltage grid is connected gives them great insight when mapping what they see in the field to the described problem.



Many problems are the result of change – either damage or faults, or undocumented or poorly executed configuration change. The sensor network can identify recent changes in the topology which might actually be the root-cause for a consumer impacting problem.

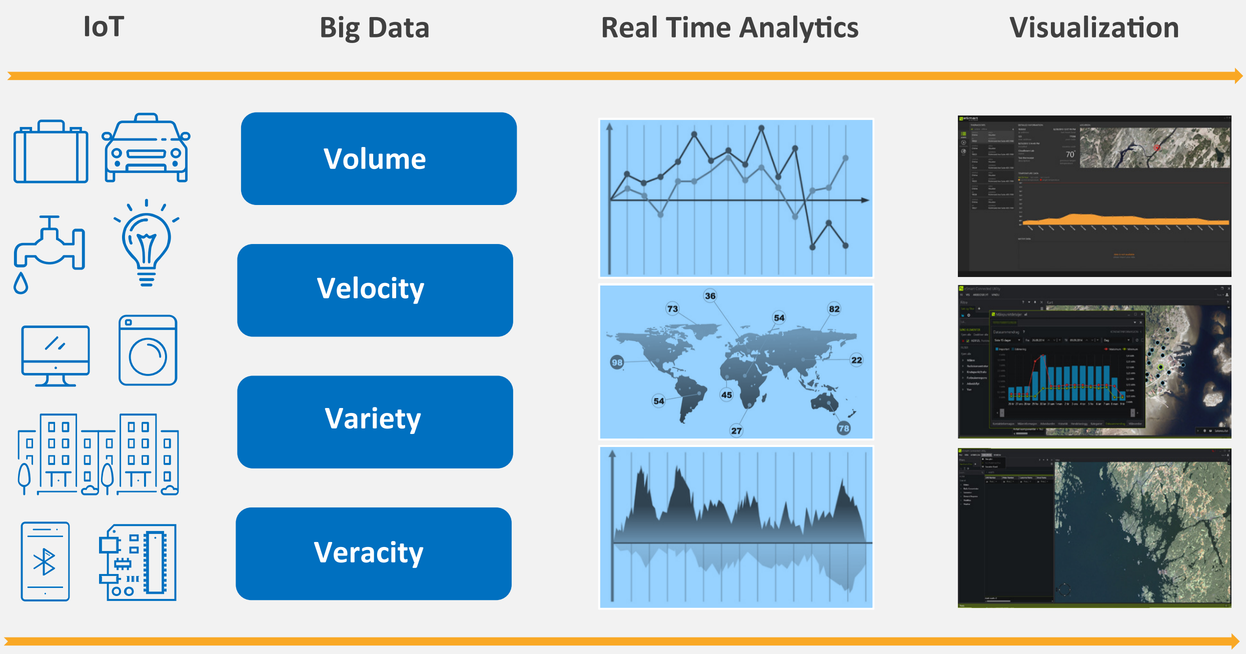
This information can be exposed into the analytics framework for enrichment before being used to initiate resolution actions.

Examples of Actions

With the amounts of data now available, we believe the ones who win are the ones that can utilize this data, do the right analysis and take the right actions.

- We have discussed examples of how DSOs, with a holistic view, can utilize several data sources combined with smart meter data to further improve your decisions
- New technology gives DSOs the possibility to perform actions like load forecast predictions
- We have touched upon the use of automatic Demand Response on substation level based on smart meter data, weather and home automation
- Integration of new technology such as drones and image recognition can really improve your maintenance

It is all about utilizing your available data to do advanced grid planning and predictive maintenance.



THE FUTURE FOR DSOs

The combination of a sensor network in the low-voltage grid, together with an analytics framework to draw insight from the information it exposes, provides a new and exciting set of possibilities for DSOs:

- The first step is to enrich the information available from the low-voltage grid; not just the voltage measurements at the substation and consumer, but also a wider range of quality information, on each phase of supply, with more detail within the low-voltage grid, and with additional topology discovery
- The second step is to provide this information into an analytics framework so that the large volumes of information can be processed to extract timely, actionable business and operational insight.

Such systems are available today, with Network Energy Services Patagonia Energy Applications Platform and smart meters, along with the eSmart Systems analytics frameworks being excellent examples.

The requirement on DSOs is to start to embed the timely actionable business and operations insight these systems can provide into operational processes which need to become proactive, customer-aware, and impact aware.

THE CONTRIBUTORS

Networked Energy Services

Networked Energy Services Corporation is a global smart energy leader in the worldwide transformation of the electricity grid into an energy control network, enabling utilities to provide their customers with a more efficient and reliable service, to protect their systems from current and emerging cybersecurity threats, and to offer innovative new services that enable active, intelligent use of energy. NES was formed as a result of the spinoff of Echelon Corporation's Grid Modernization Division in October 2014. NES is headquartered in the US with R&D centers located in Silicon Valley, North Dakota and Poland, and sales offices throughout the world. NES' smart grid technology is used in nearly 40 million smart meters and other smart end devices around the world. NES is a member of the OSGP Alliance, a global association of utilities and smart grid companies, which promotes the Open Smart Grid Protocol and cooperates to provide utilities greater value by enabling true, independently-certified, multi-vendor interoperability based upon open international specifications and standards. You can find out more information about NES, its Patagonia Energy Applications Platform (EAP™) (including grid management software, distributed control nodes, and smart meters) and services at: **www.networkedenergy.com**

eSmart

eSmart Systems develops digital intelligence for the energy industry. As a software company with expertise in energy software, eSmart systems wants to be part of this Intelligence revolution (Next Generation MDM Solution). eSmart systems is stacked with deep market knowledge experts with a long and strong history of developing and pioneering IT-systems.

eSmart systems has strong belief that with the introduction of smart grid technologies, including distributed storage, the energy industry is about to face a major change, a revolution. We believe that our thinking and system platform represent the ability to process huge data flows, accommodate massive changes due to market dynamics and the need for high quality systems supporting business-critical functions in any markets. For more information, please visit: **www.esmartsystems.com**

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In 2017, Erik was nominated as Microsoft Regional Director – Norway. This is a program that consists of 150 of the world's top technology visionaries chosen specifically for their proven cross-platform expertise, community leadership, and commitment to business results, and therefore nominated as trusted advisors to the developer and IT professional audiences and Microsoft.

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Jon Wells has 25 years of experience in the telecommunications industry, moving into the similar industry of smart grid a few years ago. Through this time, Jon has focused on helping network operators manage their distributed technology infrastructure; providing management solutions and also helping them develop business cases. He is able to bring the experience of the telecommunications industry into the arena of smart grids, quickly drawing upon the parallels to assess opportunities for cost reduction, efficiency improvement and customer experience improvement and use this to develop relevant and practical business cases for DSOs. Jon has held director roles in technical consulting, business consulting, and business development and is currently Director of Product Marketing for Networked Energy Services.

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