OPTIMIZATION OF SECONDARY TESTING WITH CLOUD BASED FLEET ANALYTICS

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ABSTRACT

In this paper novel cloud based fleet analytics was utilized for advanced asset management. The target was to optimize the maintenance and testing procedures of the secondary system in primary distribution substations. In the case study a series of 3007 different fault cases were automatically analysed in the cloud environment, gathered from 51 substation from the period of 18 months, containing both SCADA events and disturbance records. The result of the analysis was that 68% of the required secondary testing was actually tested already during the normal operation of the network, leaving only 32% that still need dedicated manual testing.

INTRODUCTION

Modern electricity distribution systems gather lot of data from automation system devices, but this data is often not sufficiently utilized when making business or operation decisions. For example protection and control devices create data from fault situations, which could be utilized also for other purposes besides fault clearance. In this paper new methods are explored for using this data to planning of maintenance activities. Methods include optimizing the amount of additional secondary testing, i.e. testing only the functionality which has not been verified during normal network operations.

When data processing is taken to higher than traditional process level, to the fleet level, new challenges arise, as indicated in Figure 1. There is need to integrate results from multiple different devices and multiple different IT systems (e.g. weather data) to one common data analytics infrastructure. This new kind of heterogeneous data is often labelled as ‘Big Data’. The processing of this data calls for new infrastructures which are explored and presented in this paper.

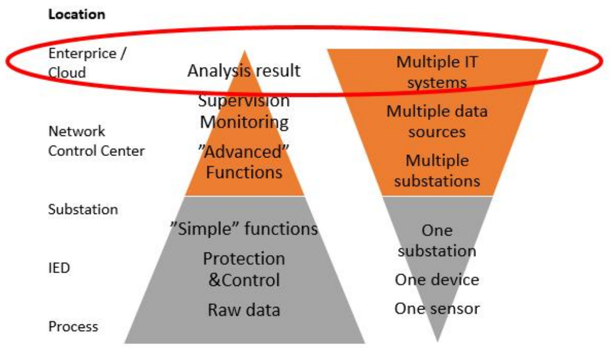

Figure 1 Data processing in cloud level

In this project, as part of Flexible Energy System (FLEXe) research program, these data analytics features were realized as cloud services in ABB Ability™ platform. New needs for data utilization and increasing amount of open data sources require technology providers to develop more agile platforms based on cloud technology, which are also presented in this paper.

Currently utilities are obliged to perform additional scheduled testing for the secondary system of substations. The testing needs to be done, even if the protection system has been successfully operating in real live network fault situations. This paper presents a concept, where fault clearance analysis from network faults is used for identifying which protection functions have been already properly operating to real live faults, and which functions still need to be tested. Also the maintenance needs of protection components can be determined during this process, and individual fault incidents can be linked to open weather data for more detailed analysis.

SECONDARY TESTING IN PRIMARY SUBSTATIONS

In Finland Distribution System Operators (DSO) are also bounded by a law regarding electrical safety, the Electrical Safety Act [1]. It states that DSOs shall have a maintenance program for electrical equipment to ensure the electrical safety of the system. Maintenance program is a plan that determines how different actions and regulations (laws, decrees, standards and recommendations) and other requirements (customer needs, company goals, maintenance strategy etc.) will be fulfilled. According to the Electrical Safety Act, the maintenance program must be followed accordingly and the DSOs must be able to demonstrate that the program has been followed, if required during an inspection.

Objective of maintenance activities is to ensure the safety, to maintain the reliability, to prevent disturbances and to repair of the noticed failures by optimal costs. Substation maintenance in Elenia Oy includes among other maintenance actions protection system testing and breaker maintenance. Both of these actions are executed time based. Intelligent Electronic Device (IED) testing is done to ensure the correct operation of the IED, whereas the breaker is maintained according to manufacturer’s guidelines. Together these maintenance operations ensure the protection system operation in a network fault situation.

At present protection system testing is done on site and the goal is to ensure the functionality of the whole system influencing the operation of the substation and the network safety, i.e. only testing the IED itself is not enough. Also the operation of the breaker needs to be ensured and that the trip-signal from the relay to the breaker is received correctly and the breaker operates. Also interlocking between two different protection levels (outgoing feeder / incoming feeder) are checked. In order to do these maintenance actions, the electricity supply from the station needs to be interrupted and therefore sometimes very heavy switching operations are made in order to backup feed the entire substation area.

When a fault occurs in the networks, the IED trips and the breaker is opened. The requirement for tripping comes also from the Finnish legislation which states that the system must be protected with devices that switch off two and three phase short-circuit faults automatically. Earth-faults must either be indicated, or in case of challenging grounding conditions, switched off automatically. Standard SFS-6001 [2] (high voltage electrical installations) presents maximum allowed grounding voltage in respect of relay tripping time. In spite of extensive cabling of the rural area medium voltage networks, there is still a large amount of overhead lines, where faults still occur quite regularly. By utilizing the data gained from the IED and from the tripping operation, the functionality of the IED and the protection system could be analysed. It could also be concluded if the operation has been correct and the tripping time is within certain time limits, including maximum allowed deviation. The risk for large interruptions could also be avoided, when the need for back-up feed of the whole substation area due to maintenance operations is decreased.

CLOUD INFRASTRUCTURES

Cloud computing is an innovative IS architecture which is seen as the future of computing. In cloud computing, hardware and software services are delivered on-demand dynamically to customers. This means that the resource allocation can be adjusted and manipulated on the fly, allowing for optimal resource utilization. Resource consumption is kept minimal without sacrificing agreed service levels while additional resource allocation is kept on-par with service delivery. From the financial perspective, resource utilization leads to reduction of capital costs and subsequently, optimal use of investments.

More than just a new design pattern, cloud computing enables new forms of analysis that were previously impossible, and opens up new business opportunities to outreach to clients with large amounts of data. In this particular case, cloud computing is provided by ABB Ability™ platform with new capabilities for handling data surge and performing analysis across all data in the substations.

ABB Ability™

ABB Ability™ is a complete distributed application platform from device integration and data collection to cloud level fleet and big data analytics. Device integration and data collection can be established with various proprietary and standard protocols. Raw data is refined and aggregated in the gateways or data concentrators that are the edges of the ABB Ability™ platform. Relevant key performance indicators and e.g. fault information is transferred to the ABB Ability™ cloud for further analytics, fleet level statistics, and for visualization for the users.

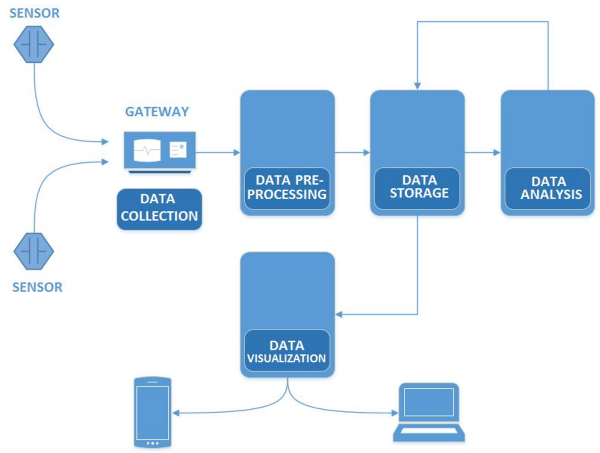

Figure 2 Information flow in the ABB Ability™

Implementation of ABB Ability™ in the pilot case

In the case application, input data is collected from three main sources: the disturbance recordings from the customer grid, weather data service and location service. The collected data is transferred to cloud based system for the analytics. The setup in described in Figure 3 [3].

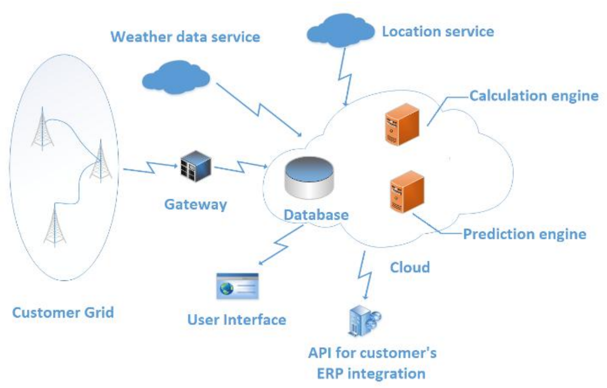

Figure 3 Pilot case setup

Cloud powers the database, the calculation and prediction engine and serves analysis results to customer user interface or customer's system through the provided API. System resource is kept to the desired customer's SLA while Calculation and Prediction Engine are requested on-the-fly when there are incoming data. Data flow pattern in this scenario is transparent: data from the data source is filtered, processed and analysed before being visualized in the visualization stage.

The largest data set collected during the testing phase was approximately 20 GB. This volume do not reflect the actual capability of ABB Ability™ but is sufficient for Big Data volume requirement when the application scales up to all substations. In terms of velocity, the ultimate goal is to achieve near real-time processing speed, which is well supported by the real-time database of the Case Company and Azure Cloud.

PILOT CASE DESCRIPTION

In the case study a series of 3007 different fault cases were automatically analysed in the cloud environment, gathered from 51 substation from the period of 18 months, containing both SCADA events and disturbance records. In addition, weather data related to the time and location of each fault case was gathered from open data sources. The weather data was not utilized in automatic analysis algorithms, but it was visualized in the user interface next to the analysis results. The automatic analysis mechanisms are further explained in [4]. Two different analytics were performed, fault clearance time analysis and fault distance calculation. Results of the analysis were published via web interface; example is presented in Figure 4.

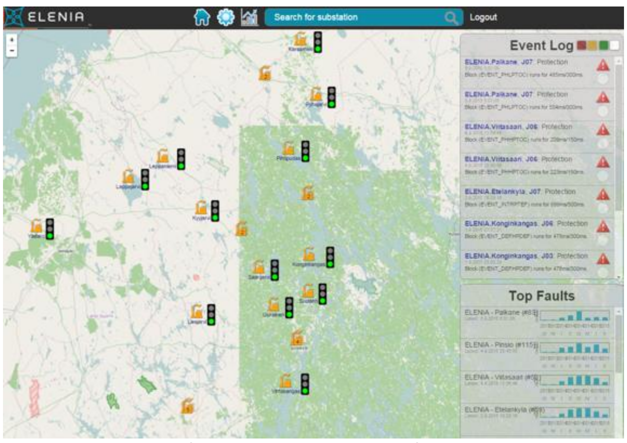

Figure 4 Example figure on end user interface

Fault clearance time analysis

The initial challenge in the data analysis was, that event descriptions were not harmonious, and there was no modelling for the data. The event list consisted mainly of manually written descriptions, with varying notation conventions. Therefore in the beginning of the project a fuzzy rule set had to be built for modelling and classifying events. Also during a fault occurrence in the distribution network an avalanche of events is often created, making it difficult to determine the root cause. Analytics logic was implemented to determine from the event list, which protection functions was the root cause for the Circuit Breaker (CB) opening.

After the root cause was identified, the total fault clearance time, i.e. the time from fault detection to the moment of CB opening, was calculated based on events and the data gathered from disturbance records. The derived fault clearance time was compared against the target clearance time, which was dependent on the operating protection function. Small deviation from the target time was considered as a warning (yellow colour), and larger deviation as an alarm (red colour). In addition to highlighting the alarm cases, all results were also visible in the Web interface as diagrams, structured based on substations, substation feeders and different protection functions, as illustrated in Figure 5.

Figure 5 Statistics on analyzed fault cases

For overall summary, protection functions were divided into four categories: overcurrent, non-directional earth fault, directional earth fault, intermittent earth fault. With 51 substations this resulted to 204 different test scenarios. All 51 substations contained some fault cases, which the system was able to analyse, so some level of automatic testing was achieved for all 51 substations.

The result of the analysis was that 68% (138 out of 204) of the test scenarios were tested during the normal operation of the network, just by analysing history faults, leaving only 32% that still need dedicated manual testing. Since the environment is automatically analysing all protection operations, it can also be used for improving the process of manual testing. Also the data created by manual tests is recorder and analysed, and these results can be used for complementing of verifying manual test reports.

On the other hand, only 10 out of 51 substations (19%) contained events from all four analysed fault types. If the requirement is to test all protection functions, and maintenance team needs to visit the substation for testing even one function, part of the benefit of the system is lost. Also backup protection was not tested in cases where main protection has been operating successfully.

Fault location analysis

In addition to fault clearance time, also the distance to fault was calculate for part of the cases. The algorithm for this calculation required current and voltage waveforms from the moment of the fault [5]. Therefore the information in the SCADA event list was not sufficient, and only the incidents with disturbance recorder files were analysed by this application. In addition, for accurate fault distance calculation, the algorithm also requires more detailed information from the network (distribution line length, line parameters, load distribution etc), than the fault clearance time analysis application.

Since the project was focusing on analysing history data, and not interacting directly with SCADA system, the results were not used for network operation (e.g. automatic Fault Location, Isolation and Power Restoration, FLIR), but the results can be used for identifying the weaker areas in the network. Web Interface was developed for visualizing the results in diagrams and in a timeline.

SUMMARY AND FUTURE WORK

The project was able to prove that some level of maintenance activities could be avoided by analysing process data from real fault incidents, and that cloud environment is suitable for performing required fleet analytics. The result of the analysis was that 68% of the required secondary testing was actually tested already during the normal operation of the network, leaving only 32% that still need dedicated manual testing.

However, for fully avoiding maintenance activities of the secondary system, more work is still needed. Only 19% of the substations contained fault data from all analysed fault cases. Full benefit is achieved only, when all testing can be performed automatically. If the maintenance team needs to visit the substation only for testing one single function, big part of the benefit is lost. Also backup functionality has not been tested in cases where main protection functionality has been successfully operating.

One future challenge from the point of view of automatic testing is the increase of underground cabling. Increased underground cabling improves the security of supply, and reduces the amount of faults, but then also reduces the amount of fault data of the analyser. In order to achieve automatic fleet analytics in a network with very small amount of faults, more fine grained analysis is needed. In addition to total fault clearance time analysis, several aspects of the automation need to be analysed separately and combined to the analysis, for example: measurement circuit accuracy, trip circuit supervision, horizontal communication supervision etc. Many such supervision functions already exist today in modern IEDs, so the question is more on data utilization than new data creation.

ACKNOWLEDGEMENTS

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