PREDICTING THE IMPACTS OF THE MAJOR DISTURBANCES FOR BETTER RESOURCE MANAGEMENT AND SITUATIONAL AWARENESS

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ABSTRACT

This paper will present a method and a tool to help with the resource allocation in major disturbance situations based on system made prediction. Prediction algorithm uses network information from network information system and combines it with the latest weather forecast data available. This tool predicts the amount of medium- and low-voltage faults in defined geographical service areas based on weather forecast, technical information from the network, fault statistics, fault repairing time and environmental conditions. Fault forecast is introduced for the next 3, 6, 12 and 24 hours.

Predicted number of faults to the given hour determines the needed resources in given areas before weather impact. up to date prediction helps to plan the moving of resources in timely fashion to right areas but also improves DSO's own resource planning and customer information. With the tool it is easy to plan the responsible areas, the number of operators and customer service professionals for the next following hours. Serving customers with the correct estimated fault fixing time is easier because of the future rush hours on the field are visible.

INTRODUCTION

Dealing with the major power disruptions is a part of distribution system owners (DSO) responsibilities. During the decade of 2010, Finnish DSOs have faced several major disturbances which have caused long outages to the customers and high costs to DSOs and society. Therefore, Finnish government introduced the new Electricity Market Act (EMA) in 2013. EMA set new targets for the quality of delivery. After year 2028 storms or snow loads can´t result in over 6-hour outages in urban areas and over 36-hour outages in non-urban areas.

Because of the new EMA, distribution system owners started investing to underground cabling and to the other quality of delivery improvements.

In the same time companies must handle outages and especially major outages better than before. These major disruption situations can cause hundreds of simultaneous outages and it means that the usual methods for the power restoration don't work. Elenia Oy, which is the second biggest electricity distribution company in Finland with 425,000 customers and over 70,000 km of network, has developed its major power disruption management process in recent years in several ways.

One very crucial part of major disturbance management is electrician manpower allocation to the areas with highest impact of storm or snow loads. During years 2015-2016 Elenia had developed situational awareness system with Futurice to manage bottle necks and resources of major disturbance situation [1]. This situational awareness system is an efficient part of resource management and with it a fault repairing is possible to start earlier than without the situational awareness tool. As Kupila et.al. introduced, dividing medium voltage fault management, low voltage fault management and resource coordination to separate areas has improved the management of the whole operation. [1].

An issue with the situational awareness system mentioned above is the lack of forecasting. All information presented in situational awareness tool are based on the events and allocations that have already happened. Therefore, all the actions based on situational awareness tool are done without the clear picture of the situation to come. Hence, Elenia decided to develop a situational awareness tool to predict future faults to help decision-making for the following hours of the day.

PREDICTING THE EFFECTS OF THE STORM

First version of situational awareness tool [1] provided up-to-date information gathered from DMS in order to improve overall situational awareness in the grid during a major disruption situation. The first version also provided information from upcoming weather via another API (Application programming interface) to Finnish Meteorological Institute's open data. This data was used to predict changes in big picture or in portfolio level and based strongly on historical experience from previous major disruption situations. Different geographical areas – which in this case equals contracting areas – have very different resilience to weather related incidents such as storms.

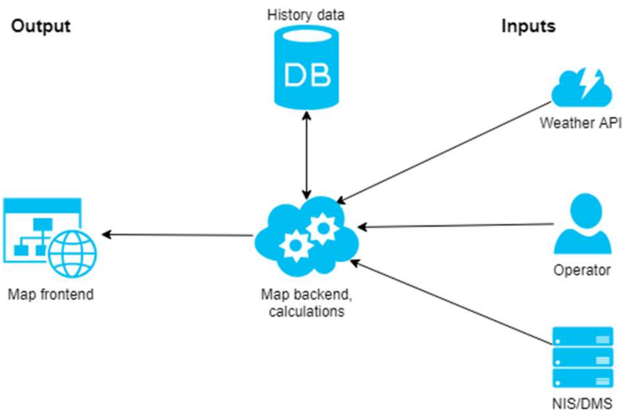
Resilience towards storms differs due to variables such as area's cable rate or amount of overhead lines, tree coverage and the time of the year. Some areas also seem to be more resilient towards storms even if there is somewhat significant tree coverage.

Coastline in Baltic Sea is an example of such an area. Because of these facts it was seen important to create a regional impact factor (RIF) for the prediction tool. The idea of the RIF in prediction is to fine-tune the model after the actual outcome of the prediction. The RIF for an area is determined using long time historical data from previous major disruption situations. The RIF is visible to a person responsible for the prediction and it can also be changed if needed.

VISUALITY PROMOTING USER FRIENDLY USER EXPERIENCE

The service gathers data from multiple systems and/or entered by operators during major disturbances. Combining the inputs from the data sources and making calculations based on the data in one place enables efficient visualization of the situation and results in quicker and better decisions.

Data is gathered with the various methods based on the source format. At the time of writing, the service interprets data provided by RESTful APIs and reads also XML content. The combined data is served from the backend to frontend using RESTful APIs and JSON.



Picture 1: Inputs from various sources are used to calculate predictions for the end users.

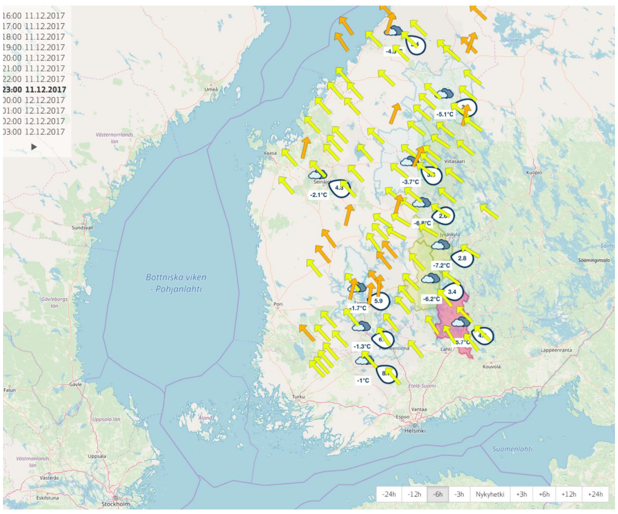
Core views of the service are the map view (Picture 2) and table view for detailed look into all relevant KPIs (key performance indicators). The UI (user interface) is role dependent and focuses on different KPIs based on the role selected by the user. Based on interviews with the operators, the selected views are the ones that are most relevant during the major disturbances.

Key feature of the map is in its ability to visualize the effects of different weather conditions and how the situation is developing in short and long term. By combining the data entered manually by the user, supported with more static variables in the system and enriched with real time weather data, it is relatively easy for the operators to get good overview of how things are developing, and which areas need more focus.

Severity of the situation in one area is always calculated in relation to the overall situation and most critical areas are highlighted on the map. The algorithm dynamically calculating the severity enables the map to be used in all situations, no matter how good or bad things are. The most troubled areas always stand out from the noise.

Making use of openly available weather data from Finnish Meteorological Institute [3], it is possible to visualize the wind front and how it is advancing over the operational area of Elenia. The shape and size of the geographical area usually catches some of the bad weather when such event strikes Finland. Weather data gathered from the open API includes variables such as wind speed (max), direction and temperature.

User can evaluate reliability of different weather models and in some cases, there can be need to use some other than openly available weather data as a base for prediction. In these cases, the user can manually input weather data to operational areas where the extreme weather conditions will have impact.



Picture 2: One visualization of the wind situation, looking back 6 hours (replaying past storm/major disturbance from 2017).

The whole UI has been iterated multiple times during the past years to ease the cognitive load of the end user and focusing the efforts of people on the things that matter the most.

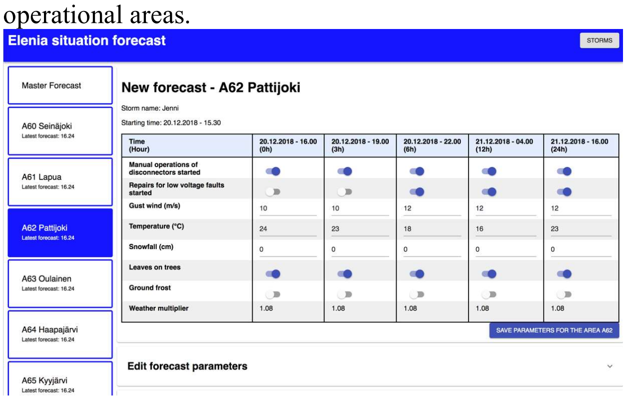
Since there is a lot of information that can be accessed through the service, it is currently optimized for desktop use. A mobile friendly version could be developed to serve partial data for field use, but users have not seen this yet as a critical need. Mobile connectivity during worst major disturbances is not guaranteed, so the coordination is still done from control rooms and contractor offices and information is relayed to the field through other means.

TOOL FOR PREDICTING THE IMPACT OF THE MAJOR DISTURBANCES

The use of the tool starts with naming the storm and giving the storm a starting time. This creates time stamp which is used in database to mark the starting time of the storm. In addition to parameters that user gets from the open data sources like gust wind(m/s), the user can also manually change basic parameters that affect the severity of the storm to the network.

These basic parameters are ground frost(Y/N) and leaves in the trees(Y/N). Ground frost reduces the probability of trees falling due to gust wind and leaves in the trees has opposite effect to the probability. Elenia has network both in southern parts and northern parts of Finland which means that even if northern parts of the network have ground frost, that might not be the case in southern parts of Elenia’s network.

With these manually adjustable parameters the user can change the extreme weathers impact to the network in the prediction. In picture 3 one can see how the adjustment of the parameters can be done to each of the separate operational areas.



Picture 3: Data input view, parameters can be input separately to specific operational areas

The prediction algorithm

The fault predicting algorithm is based on historical data of past storms and actual fault occurrences during storms on a general level. The algorithm calculates estimates of faults that are likely to occur under the given circumstances and their respective repair durations. These estimated faults are used to calculate the relevant data shown to the end users on the map: the amounts of estimated medium- and low-voltage faults per each operational area, as well as the estimated need for work groups for both fault types.

The fault forecast simulation can be run multiple times. The forecast operator can preview the resulting fault predictions before publishing the forecast to the end users of the situational awareness map. Finally, the forecast operator reviews and accepts the most probable forecast simulation and saves it for the map users to view.

The human supervision is needed mainly for two reasons. Firstly, the operators have vast experience on storms and what to expect at certain kinds of weather conditions. With this expertise they can evaluate whether a simulated forecast seems plausible, or if it needs to be tweaked still. Secondly, the operators can utilize data that the algorithm cannot (at the current iteration). One example is the publicly available nationwide electricity blackout data. If the operator notices that an approaching storm has caused unexpectedly numerous faults on grids operated by other companies, they know it is likely to do so also in Elenia's grid.

This need for human supervision is why the algorithm's input parameters can be modified manually, and why the regional impact factor (RIF) is used. As the general input parameters and factors are adjusted and saved to the database, the algorithm gets more accurate over time, providing better results that need less manual adjustment.

The essential idea of both prediction and up-to-date data in a major disruption situation is to provide it to all significant stakeholders. These stakeholders include both internal and external parties. This is very important to create a mutual understanding of current situation and for all parties to see what they should be prepared for in the short-term future.

Allocating the right amount of resources in the right time and in the right place is crucial in any major disruption situation. The data provided by the prediction presents clearly the needs for resourcing in order to overcome a situation which is going to be realized in 3, 6, 12 or in 24 hours.

Elenia purchases all its electricity network construction, maintenance and fault repairing services from partners. Furthermore, Elenia has created a cooperation model with its regional contracting partners (RCP) to streamline fault repair in a major disruption situation [1]. The cooperation model in short means that RCP is responsible for its own area or areas fault repair coordination and resourcing. In order to be successful at these tasks RCPs require information to which direction a situation at hand is developing. Other contracting partners require the same information as well in order to plan optimal use of their resources.

Besides the map itself (which is the user interface for most of the users), predictions of future scenarios and needs in the field are calculated based on inputs from various sources. Prediction logic considers the weather, amount of power lines above the ground, known outages in different areas and special multipliers which are based on years of experience of Elenia. Combining all this information, it is possible to proactively move resources in the field towards the areas which are estimated to need more help in the coming hours.

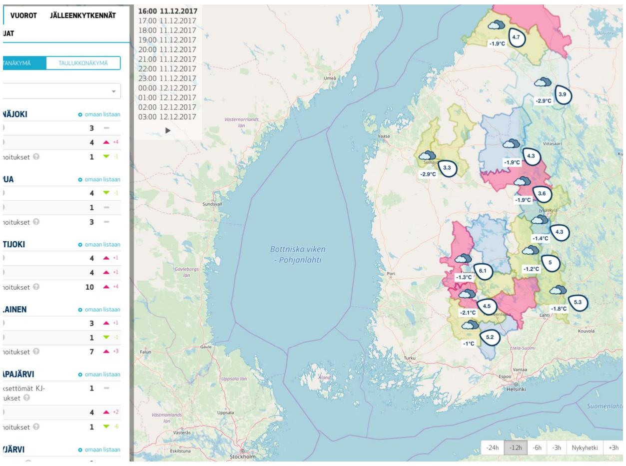
As stated previously the predictions are done by fetching as much data as possible from other systems and giving the prefilled prediction form for the operators to produce the actual prediction data into the map view. Weather data is being fetched from Finnish Meteorological Institute's open data APIs and key figures related to the power grid come from Elenia's NIS & DMS systems.

All the users access the cached or otherwise stored data at the map service backend to ease the load of the critical control systems producing the data. The backend of the prediction service combines and stores all the values, so using the service does not put additional stress to the NIS/DMS systems which are in critical role during major disturbances.

The pre-filled values are available for the operator to tune, in case they see something that needs tweaking. Automatically filled data is enriched with operator-controlled variables related to the special conditions observed in the field. These variables are things which usually need visual confirmation such as if trees still have leaves or is there frost in the ground.

Providing full transparency to the variables used for calculations is essential for the operators to make correct assessment of the situation. Using a black box type of prediction engine is not a viable option – the logic behind the results need to be shown for the users.

Predictions are done for each operational area, but once done to one area, it can be used as a template for the other areas. It is not mandatory to prepare prediction to all areas, in case the situation is geographically focused on smaller areas.



Picture 4: History view, looking back an outage situation highlighting most problematic operational areas

In the long run, the automated calculations are tweaked with the feedback from operators and historical realizations from the previous storms. Accuracy of predictions gets better when amount of data increases and more data sources are added.

It is possible to replay past disturbances for training purposes and to gain insights on the events that happened in other places during some specific event. Based on the historical data, the prediction algorithms can also be tweaked to provide better estimates in the coming major disturbances.

SUMMARY

Situational awareness tool is a powerful tool in steering the situation in major disturbances. The power of the tool lies in depicting the critical areas in a such way that the fast reaction is possible. This has been hard tested in real life major disturbances situations.

Only reacting to the existing issues with the help of the situational awareness tool can lead into a situation where made decision are less than optional. With the new situational predicting tool can the decisions be done taking into a consideration coming weather conditions. Predicting tool lies heavily on given parameters, which while adjustable, are still rough values that need expertise of the user to adjust.

Transparency of the predicting tool to all relevant parties is essential in effective steering of an operation in major disturbance situations. Next step with the predicting tool is to continue testing with the data from the old storms and thus adjusting and bettering the used parameters.

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