IMPROVING THE SITUATION AWARENESS OF DSOS IN MAJOR DISTURBANCES BY VISUALIZING THE STATE OF MOBILE NETWORKS

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ABSTRACT

The interdependency of distribution and mobile networks causes issues in the recovery process of major disturbances as the mobile network is necessary for some distribution automation devices and for repair group communication. Mobile networks go down quickly after a power outage complicating the recovery process. In this paper a situation awareness (SA) system demonstration with a visualized state of both distribution and mobile networks is presented. The aim of the system is to improve the recovery times and reduce the outage costs by improving the mobile networks SA of DSOs and other actors during outages.

SITUATION AWARENESS IN MAJOR DISTURBANCES OF ELECTRICITY SUPPLY

The storms of summer of 2010 and the storm Tapani in 2011 caused major disturbances of electricity supply in Finland. The power outages caused by the storms lasted in some cases for several weeks. The outages also affected mobile networks causing issues with the communication. For example the communication between control center and both distribution automation and repair groups was difficult. A common thing in these major disturbances was that they affected a large part of DSO's customers and multiple actors such as rescue services and municipalities participated in the recovery process in addition to DSOs. One observation from the major disturbances has been that the information exchange during the disturbances is difficult. In 2013 the Finnish Electricity Market Act was changed and now requires e.g. the DSOs to provide information about the situation in order to increase the SA of actors such as the telecommunication operators and rescue services during disturbances. Several projects were started in Finland to improve the information exchange and SA during the major disturbances of electricity supply. [1]–[3]

A concept of SA system for managing disturbances of electricity supply, described in [3], has been extended in this paper. The objective of the system is to improve the information exchange between actors during disturbances of electricity supply in order to improve the recover times and reduce the costs caused by the disturbance. The extended system improves the SA of actors by providing a visualized state of the mobile networks.

SITUATION AWARENESS IN MAJOR DISTURBANCES OF ELECTRICITY

During major disturbances of electricity supply there are many different actors working together in order to achieve a common goal; recovering from the disturbance. Currently the majority of SA forms based on the information provided by the DSOs' Supervisory Control and Data Acquisition (SCADA) system and Distribution Management System (DMS). The DSOs' own SA is mostly based on these systems as they are used in daily operation. Other actors' outage SA is based on systems built on top of DSOs' systems. In Finland most DSOs provide a disturbance web page service to provide information about the affected areas during outages and maintenances. Some DSOs provide a direct access to the DMS view to some actors. The problem with these systems is that they are either inaccurate or difficult to use. [3]

The mobile network is important during the recovery process. Currently the mobile network SA of DSOs in power outages is low. Finnish communication regulatory authority (FICORA) requires that the telecommunication operators must provide customers information about the disturbances in the network. FICORA has set minimum information accuracy requirements for the telecommunication operators but the set limit is low. The accuracy of provided information between operators varies a lot. Some operators provide information about the affected base station and the approximate coverage areas of the affected base station. Others still only provide information about the disturbances in municipality level accuracy or lower. Such information cannot be used to make decisions during outages. [5]

INTERDEPENDENCIES BETWEEN ELECTRICITY AND MOBILE NETWORK

Electricity distribution and mobile networks are interdependent. Nowadays the mobile network is utilized in multiple ways in distribution networks such as distribution automation (DA) and communication with repair groups. DA devices improve the outage recover times. The amount of DA devices in the distribution network has increased in recent years. After the introduction of remote connection to the substations the utilization of remote controlled disconnectors started. Nowadays in addition to these devices a connection is also needed for automatic meter reading (AMR). The connection between control center and DA devices is often based on mobile network technologies. Powerline communication (PLC) is also used together with mobile network (e.g. for AMR meters). These connections also depend on mobile network as part of the communication link to control center is implemented using mobile network. [6]-[8]

Nowadays, DSOs are utilizing smart meters for low voltage (LV) network management. AMR meters are capable of detecting issues like fuse blowouts located in LV distribution cabinets unlike the secondary substation monitoring devices. AMR meters are also capable of detecting phase faults and voltage issues such as a broken neutral line. Alerts to the DMS can be sent from the AMR. Using AMR meters generally increases the SA of distribution network operators. [9], [10]

In addition, repair group communication is important during major disturbances. Repair groups are dependent on mobile networks as the communication between the groups and control rooms is often done using mobile networks. To perform any actions the groups must first ask for permission, which is difficult once the mobile networks go down. [11]

Mobile network base stations require electricity to operate and are usually backed up by a battery but go down quickly after a disturbance in the electricity network causes an outage. In Finland, FICORA requires the 2G base stations to have a battery capacity of minimum of 3 hours by the year 2017. This makes the recovery process more difficult as DA and communication with repair groups often requires mobile networks. [5], [12]

As an example a field communication system used by a DSO in Finland is shown in figure 1. Main communication between substations and control center is done using 3G network.

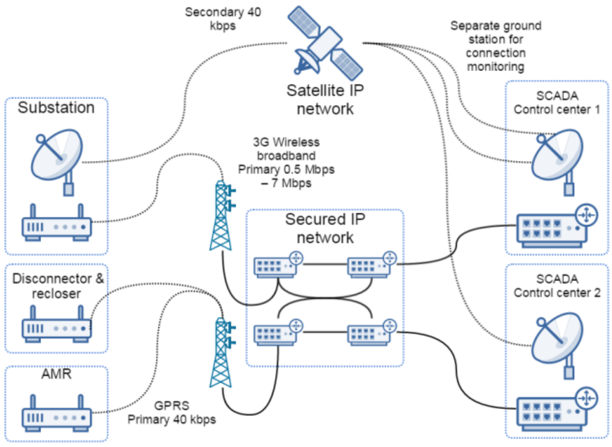

Figure 1. A field communication system used by a DSO in Finland

Communication between substations and control center is backed up by another operators 3G connection. In addition to this, a satellite link is also used. Communication between control center and remote controlled switch disconnectors is done using 2G network. The link is not backed up and in case of a prolonged outage it is likely that the link goes down. In such cases the switch disconnectors have to be operated manually. The connection to AMR meters is implemented using 2G network. In case the 3G network connection is lost, the connection between control center and substations will be switched to the satellite link which is slow compared to 3G connection.

DEMONSTRATION OF SITUATION AWARENESS SYSTEM

A demonstration of SA system has been developed in the research to provide actors a channel for information exchange during outages. The basic idea of the SA system can be seen in figure 2.

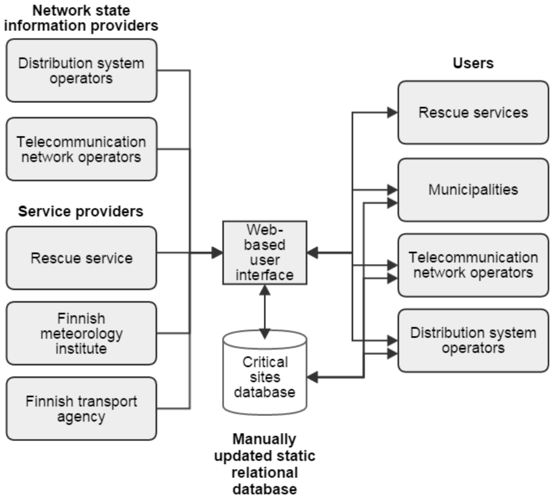

Figure 2. The situation awareness system users and data providers

There are data providers and system users. Data providers are either providing network state information (electricity or mobile network) or additional information such as rescue services activities, weather data and traffic data. System users provide information about sites that are critically dependent on either telecommunications or electricity. The provided information is combined to into one view. Some actors like DSOs and telecommunication operators are both data providers and system users.

Integrating real time information

The information providers usually offer an interface that can be used in order to fetch the data from the provider. It is also possible for the system to provide an interface where the data can be pushed.

In the live demonstration the mobile and electricity network data is gathered in real time, the data is combined and the current situation is shown on the web based user interface. Demonstration is based on data provided by one telecommunications operator and four DSOs. The area has been selected based on information about previous storms.

Areas that are known to get hit by storms often were selected to be able to test the system during a storm.

The concept of live demonstration is presented in figure 3. The interfaces provided by DMSes to enable the disturbance information web pages are utilized to add the DMS information to the system. The data provided by the DMSes contains information about the outage such as start time, end time, affected transformers and customer numbers.

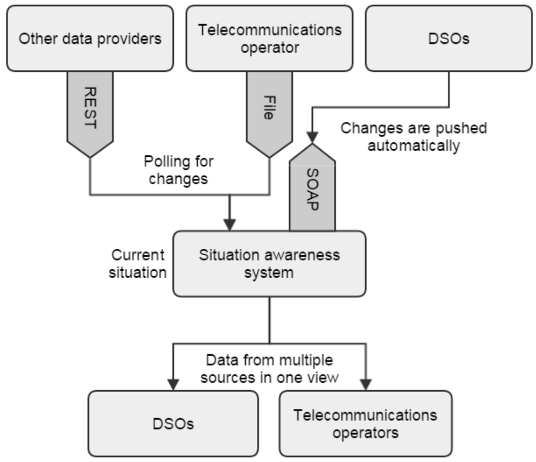

Figure 3. The concept of the live demonstration.

The mobile network operator provides the necessary data for the base stations in the area in order to model the base station coverages. The operator provides access to a file that contains the current state of the mobile network. This file is polled and whenever a change occurs the new state is displayed on the user interface. The coverage area for each base station is calculated separately using the Okumura-Hata path loss model. Every time a major change affects a single base station coverage area significantly the coverage area will be recalculated. Each time a change of state happens in the network, the coverage area of changed base stations are intersected or merged into the coverage polygon based on the new state of the base station. This way it is possible to display where the coverage is lacking at any point of time.

Integrating static critical site information

The actors that are responsible for critical sites can add the critical site information to the system in two ways. The information can be added manually using the web based user interface. Manual adding of the sites is feasible in cases where the actor is responsible for only a limited amount of sites. The system also provides actors a way to integrate own systems to the system in order to add sites from actor's own databases such as the customer database. Automatic adding of sites is done in cases where the actor has possibly thousands of sites to add e.g. a telecommunication operator with thousands of base stations. Some information will have to be added manually as databases do not necessarily contain required information like transformer or customer number to bind the site to an outage.

Combining the information

In addition to the web based user interface the system provides an interface for different actors to fetch the data from the critical sites database. This enables actors to maintain a local critical site database and integrate it to own systems.

The system combines the static critical site information and the real time network state information automatically. As the electricity network state is reliable the sites affected by the outage can be shown instantly and the information is accurate. Whenever a critical site is added, either a transformer or the customer number of that particular critical site is included. The data can be used to bind the outage to a single critical site. Affected sites can be shown in the user interface. The system also refines the received information by projecting the future. Users are informed of possible future events such as that the critical time (the time a site can be without electricity supply) of a site exceeded in an hour.

IMPROVING THE SITUATION AWARENESS OF DSOS WITH THE SYSTEM

A real case in which a storm caused a disturbance of electricity supply in Finland was studied with the demonstration. The disturbance was relatively short; most outages caused by the disturbance were fixed within 24 hours. A post-mortem analysis of the outage and its effects on electricity and mobile network was conducted. The demonstration was carried out in order to verify the visualizations developed in the research. The results were presented to different actors such as the DSOs and telecommunication operators in order to get feedback about the system and to improve the system.

In the research the demonstration has been further developed to improve the SA of actors during disturbances of electricity supply by providing more accurate information about the state of mobile networks. By improving the SA of the mobile networks it is possible to improve the outage recovering process and reduce the costs caused by the outage. During the outages it is common that the state of the mobile networks is unknown. The DSOs could target repair actions based on the state of the mobile networks in a way that maximizes the coverage areas at all times. Base station battery state information and coverage information can be used when planning the repair order in the distribution system. The information can also be used to guide repair groups to locations where they can use the mobile network for communication. This reduces the time spent on finding areas where the coverage exists. Network repair crews can use the coverage and base station information when trying to communicate with the control room. Knowing which base stations are currently active and where the coverage is the crews can navigate to correct location. Currently crews have to guess the mobile network state based on the distribution network state.

Other actors benefit from the telecommunication networks SA. For example, in Finland municipalities are responsible for elderly people living at home with safety phones and buttons that can be used to alert the rescue services in case of an emergency. In a case where mobile network coverage is lacking in the area a safety phone user lives in, it is possible for the municipalities to inform concerned safety phone users instead of having to visit each of them.

While the system improves the SA during major disturbances some challenges still exist as the coverage areas change depending on multiple variables. These include variables like transmission power and the weather. The simulated areas will not match the real ones entirely and some caution has to be taken when making decisions based on the coverage areas. Especially the edges of the coverage areas are most likely inaccurate.

CONCLUSION

The interdependency between electricity and mobile networks means that to recover fast from the outages, SA about mobile networks is needed in addition to awareness of distribution network. Current information sources are inaccurate and cannot be easily integrated into existing systems e.g. the telecommunication operators provide a very generic picture about the current situation.

By improving the SA of DSOs during major disturbances it is possible to improve the repair and recover times and reduce the recover costs of the disturbances. The developed demonstration of SA system addresses the issue by providing different actors including DSOs a system that combines information from different sources and provides a single view. The system also provides a more accurate mobile network coverage view that will further improve the SA of DSOs.

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