Use of remote or aut omatic grid reconfiguration to a void critical grid load, reduce outage times, and reduce grid losses

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USE OF REMOTE OR AUTOMATIC GRID RECONFIGURATION TO AVOID CRITICAL GRID LOAD, REDUCE OUTAGE TIMES, AND REDUCE GRID LOSSES

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1 CONTENTS

2 PREFACE

This report assumes that the reader has some basic background knowledge about the iPower project, such as work package structures, general vision and aim of the project, etc. Furthermore, the reader is assumed to be familiar with advanced engineering terminology and concepts (M.Sc.-level in many cases) on a broad scale, although the authors will do their best to provide a comprehensive description. In cases where further explanation is required, please contact the authors.

3 INTRODUCTION

Introduction to Task 3.3:

- Analyse to what extend use of remote or autonomous grid reconfiguration (under different control architecture e.g. centralized vs. decentralized) will be beneficial in order to avoid critical grid loads, reduce outage times and grid losses. Benefits are compared to the costs of necessary equipment in especially in 10 kV grids.

Explain the methodology applied in this study:

- Chapter 4: Identifying the circumstances for grid reconfiguration
  Addressing the question “Where and when grid reconfiguration is requested or can be potentially applied to”
- Chapter 5: Characterizing the state-of-the-art grid reconfiguration technologies
  Addressing the question “How can different grid reconfiguration technologies (e.g., decentralized vs. centralized, system solutions vs. components) be applied to distribution system operation from different angles”
- Chapter 6: Simulation-based value identification for grid reconfiguration
  Addressing the question “To what extent can grid reconfiguration technologies improve the distribution system operation and planning”

Purpose of this document:

- Summarize the study performed in T3.3
- Serve as a guideline on use of grid reconfiguration in 10 kV grids.

4 CIRCUMSTANCES FOR GRID RECONFIGURATION

When discussing the circumstances for network reconfiguration, one must consider two very different operating conditions under which reconfiguration can occur – normal operation and fault situations. In the following the two will mostly be treated separately. Even though many of the use cases are similar between normal and fault operation, the considerations in each can be very different.

Before discussing the use cases for network reconfiguration, it is important to note what assumptions have been made. The following assumptions are based on a Danish context. The first assumption is that the grid consists entirely of cables. As a result of technical, economic and political considerations in the late 80's and early 90's, today nearly all distribution grids in Denmark use cables only. As such, the assumption that the grid consists only of cables and no overhead lines is true for the Danish case. This assumption is important, because for overhead lines, re-closers are common, as faults can be transient (e.g. a branch hitting the overhead lines and causing a temporary short circuit between phases). With cables it is assumed that no faults are transient and thus re-closers are not used and faults must be cleared by disconnection of the faulted equipment. The use of cables also means that short circuit indicators are common and to an increasing degree capable of being remotely read and reset (i.e. from the DSOs control central).

Secondly, it is assumed that network reconfiguration only occurs in MV grids. In Denmark distribution grids mainly consist of MV and LV grids, as a large portion of HV grids belong to the TSO. Reconfiguration in HV grids is not considered in the following for several reasons. One reason is that the cable assumption is not true for HV grids – a vast part of HV grids in Denmark consist of overhead lines. Another reason is that the structure of HV and MV grids are usually different. In Denmark HV grids generally use a meshed structure, while MV grids generally use a radial structure with backup connections between radials. LV grids are left out for a different reason. In Denmark the ability to reconfigure LV grids is usually very limited, because LV grids, as opposed to MV and HV grids, are generally not designed based on N-1 criteria. However, for LV grids that can be reconfigured, the same considerations as in MV grids would apply.

A more detailed description of the network structures used in Denmark can be found in [1]. The network structure described in chapter 4.1 of [1] is what is described in the previous paragraph. This is the most common distribution network structure in Denmark and is the one that will be considered in the following.

4.1 NORMAL OPERATION

4.1.1 RECONFIGURATION DUE TO LOSSES

Dimensioning of distribution grids is generally dominated by loading limits and voltage limits. As such, losses on their own are usually not a problem for the DSO, as overload and voltage are more critical parameters to address. However, losses are closely related to both load and voltage. A minimization of losses will therefore generally result in a better load and voltage distribution in the grid.

Network reconfiguration due to losses is a possibility, but it is unlikely that DSOs will use network reconfiguration for this purpose. The gains are very limited [2] and other parameters are more important.

4.1.2 RECONFIGURATION DUE TO VOLTAGE

Voltage is a critical parameter in distribution networks. While voltage is often the dominant dimensioning parameter, voltage is also the parameter that is most easily improved due to the availability of voltage regulation (e.g. tap changers and reactive power compensation). During normal operation it is unlikely that voltage will be at critical levels, as MV distribution grids are designed based on the N-1 principle.

Network reconfiguration for improving voltage during normal operation is unlikely. In MV distribution grids the voltage will usually be well within limits and local issues can be corrected through other methods. Furthermore, voltage regulation generally has to be fast and other methods for voltage regulation are usually significantly faster than network reconfiguration.

4.1.3 RECONFIGURATION DUE TO OVERLOAD

Overload is a critical state in the network. Loading limits are the primary dimensioning criteria for many components in distribution grids (e.g. transformers). Loading limits are mainly based on thermal concerns and as such short term overload may not always be critical, as long as temperatures are within acceptable limits. During normal operation, it is unlikely that loading will be critical, due to the use of N-1 criteria in MV networks.

Network reconfiguration to avoid overload during normal operation is unlikely. The loading of MV distribution grids is generally well within limits. However, unlike voltage issues which can be solved by different methods, loading issues can only be solved by reducing the load on components. Therefore network reconfiguration for this purpose is more likely than network reconfiguration due to voltage.

4.1.4 RECONFIGURATION FOR CONTROL OF COMPONENT LOADING

It is possible to reconfigure the network in order to control the relative loading level of network assets (e.g. transformers and cables). For instance it could be desirable to have as even a loading of network assets as possible, in the sense that the relative loading of all network assets is the same (e.g. 70%). Another example could be that one wishes to reduce the relative loading of a given component (e.g. a transformer).

Generally this is an unlikely use of network reconfiguration for the DSO. With MV grids being dimensioned for N-1 conditions, there’s little reason to worry about their relative loading level. The normal network configuration will likely already take into account any such loading level optimization.

4.1.5 PARTIAL CONCLUSION

Overall, it is unlikely that DSOs will use network reconfiguration in normal operation to correct or optimize any of the parameters in the previous sections. That is to say that active network reconfiguration that happens on a daily basis or multiple times per day is unlikely.

Network reconfiguration as a static optimization for longer time periods is an option that DSOs would likely use to ensure the optimal utilization of their grid and to avoid more expensive corrective measures which are designed for dynamic correction of voltages and loading.

Such static optimization could be used periodically to deal with singular events, e.g. large social events that change the load distribution for several days or weeks. It could also be used during maintenance, to optimize the network state with some components out of service. In both of these cases network reconfigurations are rare and happen few times per year.

4.2 RELIABILITY AND FAULT CONDITIONS

MV networks are designed based on N-1 criteria. Therefore, it is generally possible to resupply customers from a backup connection in case of faults. In this context network reconfiguration is used to enhance reliability by reducing the outage duration and the number of affected customers.

4.2.1 OUTAGE REDUCTION

Network reconfiguration can be used for outage reduction. Outages are usually caused by component failure. By reconfiguring the network the affected customers can be resupplied from a different point in the grid until the failed component can be replaced or repaired.

This is a use of network reconfiguration that DSOs use today and have used for a long time. In recent years automation has been used to improve the speed at which the network is reconfigured and customers resupplied from a backup connection.

4.2.2 RECONFIGURATION DUE TO LOSSES

Network reconfiguration due to losses in post-fault conditions is highly unlikely. As explained in section 4.1.1, the gains are very limited and loading limits and voltage limits are far more important, especially in post-fault conditions.

4.2.3 RECONFIGURATION DUE TO VOLTAGE

Network reconfiguration due to voltage in post-fault conditions is likely. Even though the grid is design to cope with N-1 conditions, it is still highly strained during these situations. Network reconfiguration offers a way to improve the stationary voltage in the network without the need for additional voltage control measures, which are targeted more at dealing with dynamic voltage variation.

4.2.4 RECONFIGURATION DUE TO OVERLOAD

In post-fault conditions, network reconfiguration due to overload is likely. While the grid is designed based on N-1 criteria, backup situations can still be critical and cause overload of components. If such overloads can be avoided by use of network reconfiguration, then it is likely an option that DSOs would use. Reconfiguration due to overload in post-fault conditions could postpone or remove the need for network reinforcement.

4.2.5 RECONFIGURATION FOR CONTROL OF COMPONENT LOADING

As with network reconfiguration due to overload, in post-fault conditions it can be beneficial to improve the loading levels of network components. The use of network reconfiguration for this purpose in post-fault conditions is likely, though less so than reconfiguration due to overload. Reconfiguration due to component loading in post-fault conditions would mainly serve the purpose of putting the grid in a state where an additional fault in the grid can best be handled, given that the network is already in a highly strained N-1 condition.

4.2.6 PARTIAL CONCLUSION

Overall, network reconfiguration in fault and post-fault conditions is very likely. While the current practice mainly aims at reducing outage time and number of affected customers, network reconfiguration can also be used to avoid violation of loading limits and voltage limits during post-fault conditions, where these parameters are challenged more than in normal operating conditions.

As network reconfiguration is already performed to resupply customers in N-1 situations, extending this reconfiguration to optimize the load and voltage conditions in the post-fault network would be attractive. However, remote control of switches and automation of switching actions is a necessity if network reconfiguration is to be used for dealing with voltage and overload. To deal with overload and voltage issues, it is necessary to do more extensive network reconfiguration than simply switching a faulted feeder to its nearest backup connection. A single switching action of this sort in fault or post-fault conditions only serves the purpose of outage reduction.

4.3 TYPES OF NETWORK RECONFIGURATION

Network reconfiguration can occur in several ways. These can be divided into automated and non-automated solutions. Non-automated solutions are more widespread and include manual reconfiguration – either by a technician physically going to a substation to perform the switching or by remote control of switches from the DSO control center. Automated solutions can be local, decentralized or centralized. A short explanation of each of these types is given in the following. For thorough explanations of the automated types, including costs and communication requirements the reader can look to [2] or other publications.

4.3.1 MANUAL

Manual network reconfiguration refers to manually changing the state of switches by sending a technician to the substation where the state of a switch needs to change. This is the most basic form of switching. It is slow and only useful for making static changes.

4.3.2 REMOTE CONTROL

In this case, the state of switches can be controlled remotely from the DSOs control center. It is still a process that needs to be activated by a person, but the task is simplified by placing it in the control center. With remote control of switches, the operator in the DSO control center can quickly change the state of switches. This significantly reduces the time necessary to perform network reconfiguration, as it is done at the press of a button, rather than having to physically send a technician to a substation.

4.3.3 LOCAL AUTOMATION

Network reconfiguration done with local automation is the simplest automation of the reconfiguration process. It allows a secondary substation to change the state of switches based on local information – i.e. measurements that are present in the secondary substation itself. It allows the secondary substation to reconfigure the network without human interaction. The absence of human interaction allows it to act very fast. However, the use of local information limits the usefulness of this form of automation to that of outage reduction only.

4.3.4 DISTRIBUTED AUTOMATION

With distributed automation, neighboring secondary substations can communicate with each other. The ability to share information with neighboring secondary substations allows each secondary substation to have a more complete picture of the grid around it. With a more complete picture, the secondary substation has better knowledge of its role in the grid and can make more intelligent decisions on how to reconfigure the network. Secondary substations can coordinate their actions with each other to allow for more elaborate network reconfiguration.

This form of automation has a high reliability and redundancy, because the failure of one secondary substation does not prevent the other secondary substations from coordinating their actions.

4.3.5 CENTRALIZED AUTOMATION

When centralized automation is used, all secondary substations communicate with the control center. The secondary substations don’t act on their own, but instead relay all relevant information to the control center. In the control center lies the automation system. The control center automation system decides on the best course of action and sends the relevant control signals to the secondary substations. The main advantage of this form of automation is that the control center automation system has a complete picture of the entire network and can make a network reconfiguration that optimizes the state of the entire distribution grid. The disadvantage of this approach is that there is no redundancy. If there’s a problem in the control center automation system, the entire automation system and its ability to reconfigure the network are lost. However, even if the automation system fails, remote control by the operator in the control center would still be possible.

4.4 APPLICABLE USE CASES

Table 4.1 gives an overview of which types of network reconfiguration can be used for different use cases. Several things are worth noting. First of all, local automation is only really useful for outage reduction. The reason for this is that all the other use cases require a more complete picture of the distribution grid.

The remaining types of network reconfiguration can be applied to all use cases, however with varying speed, efficiency and reliability. While manual switching can and is used for all use cases, it is a very slow process and only applicable to static reconfiguration that occurs rarely (e.g. few times of year). Remote control improves the situation by improving the speed at which network reconfiguration can occur.

For both the manual and remote control types of network reconfiguration, their effectiveness in dealing with all 5 use cases is determined by the tools available to the DSO. If the DSO does not have the tools to calculate the correct actions to deal with an outage, the ability to reconfigure the network does not matter. If the DSO does not have the tools necessary to calculate the optimal network configuration to minimize losses, avoid overloads and control the voltage, then these use cases are mostly rendered as irrelevant. Furthermore, all of these use cases are limited in efficiency and speed by the operator in the control center. The operator will not make any changes to the network reconfiguration until he or she has an overview of the situation. And even then, the operator still has to decide on the correct actions to take.

With distributed and centralized automation, these burdens are moved from the operator to the automation system. For the automation to work, it is required that the tools necessary to deal with some or all the use cases below are available to the automation system. With the removal of human interaction, these automation systems can act very quickly, as their ability to deal with large amounts of information is better than that of humans. Where an operator will often follow a list of predetermined actions for a given function or fault, automation systems can react dynamically and adapt their actions to the current situation without the need to follow a predetermined list of actions. Automation system can quickly generate the list of actions dynamically based on the state of the grid and execute it very quickly.

When it comes to the use cases that require a more complete picture of the network, centralized automation is better suited than distributed automation. While distributed automation has some information about the grid around it, the centralized automation has a full overview of the entire network. This allows the centralized automation to more efficiently optimize the network configuration in order to reduce losses, control voltage, prevent overload or control component loading.

	Manual	Remote Control*	Local Automation	Distributed Automation	Centralized Automation
Outage reduction	1	2	3	3	3
Reduction of losses	2	2		1	3
Voltage control	1	2		1	3
Prevention of overload	1	2		3	3
control of component loading	1	2		1	3

1: Limited applicability to use case
2: Moderate applicability to use case
3: Good applicability to use case
*) With good support tools, remote control can become very similar to centralized automation and have the same level of applicability to all use cases. However, even with good support tools, remote control would still be slower than centralized automation, as all actions have to be evaluated and approved by the operator before they are executed.

Table 4.1: Type of network reconfiguration and use cases to which it can be applied.

4.4.1 CURRENT USE

Current use of network reconfiguration is mainly limited to non-automated types of network reconfiguration. Table 4.2 shows an overview of currently used types and the use cases to which they are applied.

As is clear from Table 4.2, distributed automation is not actively in use by DSOs today. Both local and centralized automation is relatively new and not widely used yet. Remote control is used for critical points in the network, while the rest of the network is operated with manual switching.

Network reconfiguration is used as a static optimization in normal operation, where voltage and overload are the primary parameters considered, with losses being a lesser concern. Remote control and local automation are used for outage reduction. While remote control can be used to control voltage and prevent overload in post-fault situations, it is only applied for that use in a limited manner. Optimization of the network in normal operation and post-fault conditions today largely depends on the operator, because the support tools necessary for finding the optimal network state are unavailable or not sufficiently good. For the larger part, the only tools available for the DSO and control center operator to optimize the network state are basic load flow calculations. Looking in a Danish context, centralized automation is not yet used. The use of local automation is very limited and relatively new.

	Manual	Remote Control	Local Automation	Distributed Automation	Centralized Automation
Outage reduction		Reduction of outage duration and number of affected customers.	Reduction of outage duration and number of affected customers.		Reduction of outage duration and number of affected customers.
Reduction of losses	Static optimization in normal operation	Static optimization in normal operation.			
Voltage control	Static optimization in normal operation	Static optimization in normal operation. Limited use in post-fault conditions.			
Prevention of overload	Static optimization in normal operation	Static optimization in normal operation. Limited use in post-fault conditions.			Basic load flow in post-fault conditions.
control of component loading					

Table 4.2: Current use of network reconfiguration.

4.4.2 FUTURE USE

In the future as availability of support tools and commercially available automation is improved, it is likely that DSOs will use network reconfiguration more actively. However, the DSOs use of network reconfiguration will likely continue to be static optimization in normal operation and outage reduction in fault situations. The main difference from the use today will likely be more extensive network reconfiguration for post-fault situations, so that voltage and current limits are respected and the overall loading and voltage level in the post-fault network is optimized. Table 4.3 shows an overview of network reconfiguration types and their likely application to use cases.

Optimization of post-fault network configuration will likely be done by distributed or centralized automation systems – or by remote control from the DSO control center with the operator relying on improved support and decision tools.

Static optimization in normal operation will likely continue to be done by manual and remote control systems. However, the optimization algorithms of centralized automation systems may also be applicable for static optimization in normal operation.

While it's difficult to foresee how the future will unfold, the increased use of remote control and automation seems highly likely, but will be highly dependent on communication infrastructure.

	Manual	Remote Control	Local Automation	Distributed Automation	Centralized Automation
Outage reduction		Reduction of outage duration and number of affected customers.	Reduction of outage duration and number of affected customers.	Reduction of outage duration and number of affected customers.	Reduction of outage duration and number of affected customers.
Reduction of losses	Static optimization in normal operation	Static optimization in normal operation.		Optimization in post-fault conditions.	(Static optimization in normal operation.) Optimization in post-fault conditions.
Voltage control	Static optimization in normal operation	Static optimization in normal operation. (Optimization in post-fault conditions.)		Optimization in post-fault conditions.	(Static optimization in normal operation.) Optimization in post-fault conditions.
Prevention of overload	Static optimization in normal operation	Static optimization in normal operation. (Optimization in post-fault conditions.)		Optimization in post-fault conditions.	(Static optimization in normal operation.) Optimization in post-fault conditions.
control of component	Static optimization in	Static optimization in		Optimization in post-fault	(Static optimization in

loading	normal operation	normal operation. (Optimization in post-fault conditions.)		conditions.	normal operation.) Optimization in post-fault conditions.

Table 4.3: Future use of network reconfiguration.

4.4.3 THE SMART GRID PERSPECTIVE

Looking to the future, one can't ignore the smart grid perspective. Increased use of network reconfiguration is undoubtedly a part of that perspective. However, the use of network reconfiguration in the future will also be influenced by other aspects of smart grids, such as distributed generation and demand response. Other important aspects will be communication and the development of new more flexible and dynamic products – both on the consumer side and the network side.

On the network side, one of the challenges with network reconfiguration today is the limited number of switching actions that switches and breakers for secondary substations are capable of. This limited number of switching actions has significant impact on the costs associated with network reconfiguration. In the future this is likely to change, especially if DSOs start using network reconfiguration more actively. Technologies like static switches could radically change the costs associated with network reconfiguration and thus increase the attractiveness of using network reconfiguration. While the reduced cost would allow for much more frequent network reconfiguration, there are other issues associated with network reconfiguration that will still prevent the DSOs from frequent network reconfiguration. One of these issues is that switching actions associated with network reconfiguration under load create transients in both voltages and currents. These transients can be quite large and frequent network reconfiguration can thus lead to problems with power quality.

On the consumer side, distributed generation and demand response, and particularly their ability to provide flexibility services to the grid, could have a significant impact on the use of network reconfiguration. If flexibility services are widely available to the DSO, it could increase the use of network reconfiguration. The DSO could load the grid to a higher degree if network reconfiguration is combined with flexibility services. Flexibility services allow the DSOs to load the grid more, while still being able to deal with N-1 conditions. However, this very effect reduces the incentive to use network reconfiguration for the same purpose. Network reconfiguration on the other hand allows DSOs to utilize flexibility services from a much wider geographical area to mitigate voltage and loading issues. Combining the two would allow the DSO to increase the loading/utilization of the grid to a higher degree than either solution on its own. However, if one solution is significantly cheaper to use than the other, then the more expensive solution is unlikely to be used by the DSOs.

5 STATE-OF-THE-ART OF GRID RECONFIGURATION TECHNOLOGIES

5.1 MOST COMMON USED MV GRIDSTRUCTURES IN DENMARK

To understand the possibilities and limits, a short description of the most commonly used MV grid structures in Denmark is carried out in this chapter.

5.1.1 INTERLOOP – MV RADIALS GOING FROM A SUBSTATION AND BACK

In cities – specifically in Copenhagen, the MV-grid (10 kV) is structured in interloops from one substation, and back to the same substation. In operation, the interloop has an open switch half way, and is in fact operated as very short radials. In case of fault on cables or switchgear, the fault is isolated, and the halfway switch is closed. This is done with manual switching, where technical personnel operate the switchgear. In order to deliver reserve capacity to all the secondary substations in an interloop, the peak load on the feeder should never exceed 50% of the capacity. The interloop is illustrated below.

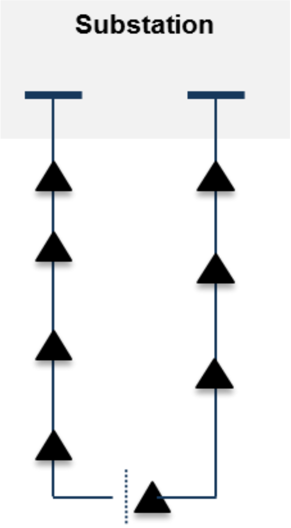


Figure 1: Interloop design for the city area.

5.1.2 MESHED – MV RADIALS IN A MESHED GRID BETWEEN SUBSTATIONS – OPERATED IN ISOLATED RADIALS

In more rural areas, all over Denmark – the MV grid is designed as a meshed grid between substations, but operated in long radials. In case of fault on cables or switchgear, the fault is isolated, and the radial will be supplied from the neighboring radials. This is done with manual switching, where technical personnel operate the switchgear. In order to deliver reserve capacity to all the secondary substations on the faulty radial, from the nearest radials, the peak load on the feeder should never exceed 70% of the capacity. The grid structure principle is illustrated beneath.

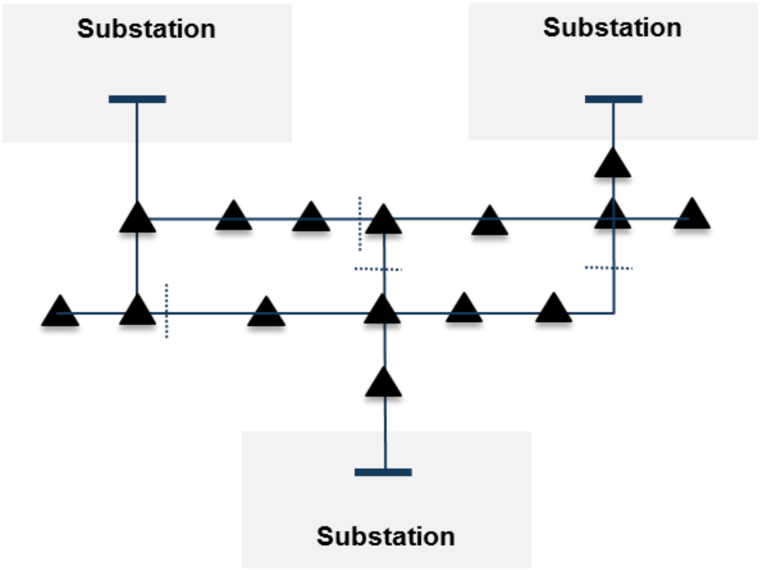


Figure 2: Meshed network design for rural area.

5.2 NEW POSSIBILITIES – GRID RECONFIGURATION BASED AND CONTROLLED AUTOMATICALLY FROM CONTROL CENTRE

5.2.1 HISTORY OF GRID AUTOMATION

A few years ago, DSO's preferred automated local reconfiguration. This was the state of art reconfiguration, and already hard for the control room personnel to accept, because they were no longer in total control with the grid configuration, but were only informed about the local automated reconfiguration.

A strong argument for local automation was also the unstable and slow wireless communication. It is desired to reconnect the customers as fast as possible, and in the statistics faults with customers disconnected shorter than one minute, did not count.

To develop automated grid reconfiguration further, both change management (develop the minds of the employees) and communication technology, has to be considered.

5.2.2 NEW CONTROLS - GRID RECONFIGURATION BASED AND CONTROLLED AUTOMATICALLY FROM CONTROL CENTRE

A third obstacle on the road to centralized automated grid reconfiguration, was of course that few DSOs were equipped with advanced distribution management systems (ADMS), that were able to conduct the necessary logic calculations, to support the reconfiguration.

All the use cases for grid reconfiguration are still as described in chapter 4.4, but of course with the total overview of the grid, not only data from the nearest secondary substations, a larger potential for optimizing the grid, concerning grid losses or voltage control, is possible, and will be developed over the coming years.

Another application in sight could be to do a programmed series of switching, to establish the MV grid reserve in meshed MV grids.

In the figure below, the characteristics of the different automation is outlined.

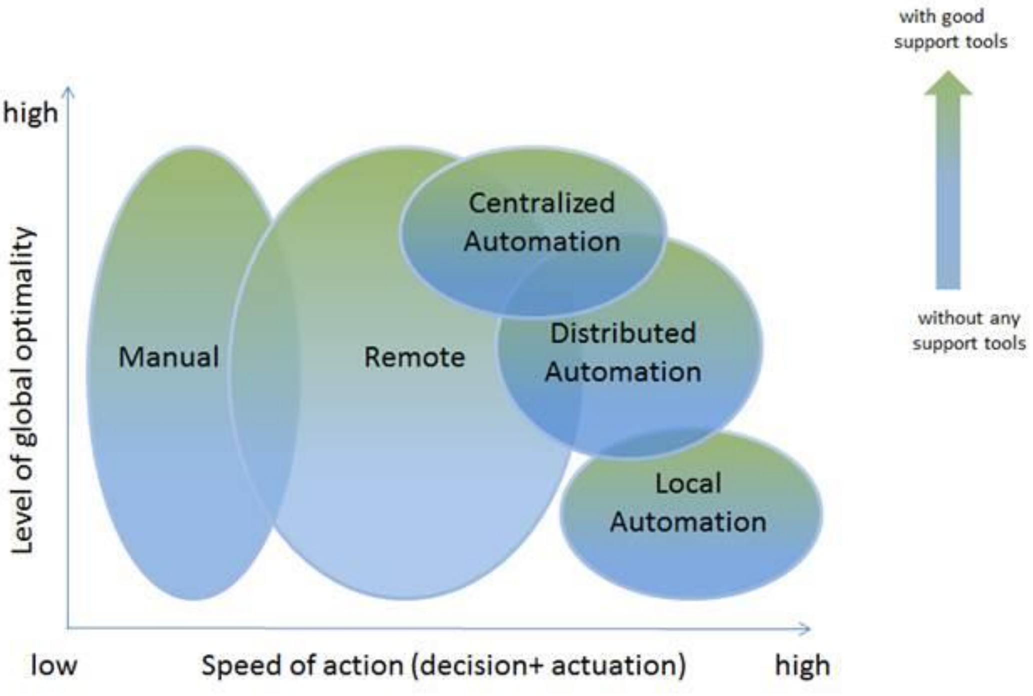


Figure 3: Comparison of different automation solutions.

6 SIMULATION-BASED VALUE IDENTIFICAIOTN FOR GRID RECONFIGURATION

6.1 THE GRID MODEL

6.1.1 10KV GRID IN THE "NORD"AREA

The "Nord" grid in the northern area of Zealand supplies urban and suburban as well as rural districts. The grid is supplied from the 132 kV grid either through a 50 kV ring structure down to 10 kV or directly through 132/10 kV transformers. 60 primary substations are situated in the "Nord" grid. The 0.4 kV grid in "Nord" is made and operated as a radial grid. Thus there are no interconnections between the LV radials, supplied from the secondary substation transformer. For illustrative purpose, the grid applied in the study is a partial part of the 10kV grid in the "Nord" grid. As illustrated in the figure below, the selected 10 kV grid is supplied by three primary substations GIL, HBY and NOR. Within this modelled area, 461 loading points are supplied with electricity via 7 feeders, 382 10 kV cables, 315 two-winding transformers. Each cable offers the possibility of being switched on/off at both ends. Today, under normal operating conditions, there are 28 normally-open switches in the modelled area, ensuring the grid is operated in a "radial" manner. The grid is modelled in NEPLAN [3] which is also the simulation tool applied in various studies in this report.

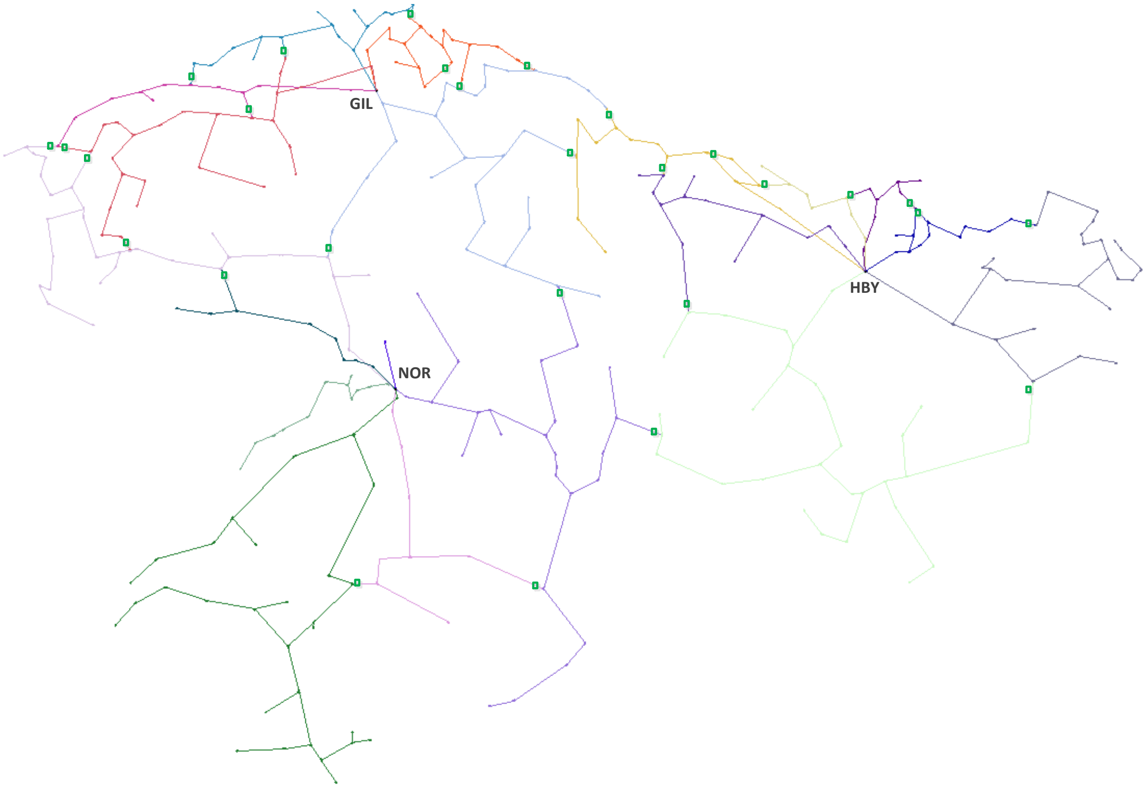


Figure 4: 10 kV grid supplied by the primary substations GIL/HBY/NOR with 28 normally-open switches.

6.1.2 CURRENT OPERATION STATUS

An overview of the operation status of the studied 10 kV grid area is presented in Figure 4. The analysis is based on a load flow study that involves 12 daily load profiles from 2013 with 15 minute resolution for each day. As indicated by the load energy curve (i.e. the daily energy consumption) and the maximum load curve (i.e. the peak load in a day), the grid has peak load in winter around Christmas time and light load in summer. The peak occurring in October could be due to the fact that the selected area is close by the coastline of northern Zealand with many summer houses which are used in the vacation period. With respect to the load factor (**LF**) (i.e. the average load divided by the peak load in one day), the LF values for load profiles in spring and summer are relatively much higher than the rest of the year, implying the load fluctuates much less in spring and summer than in the other seasons. With respect to the energy losses along the network (including all network elements), the ratio between the energy loss and the amount of energy for loads lies between 2.9% and 3.4% over the year 2013.

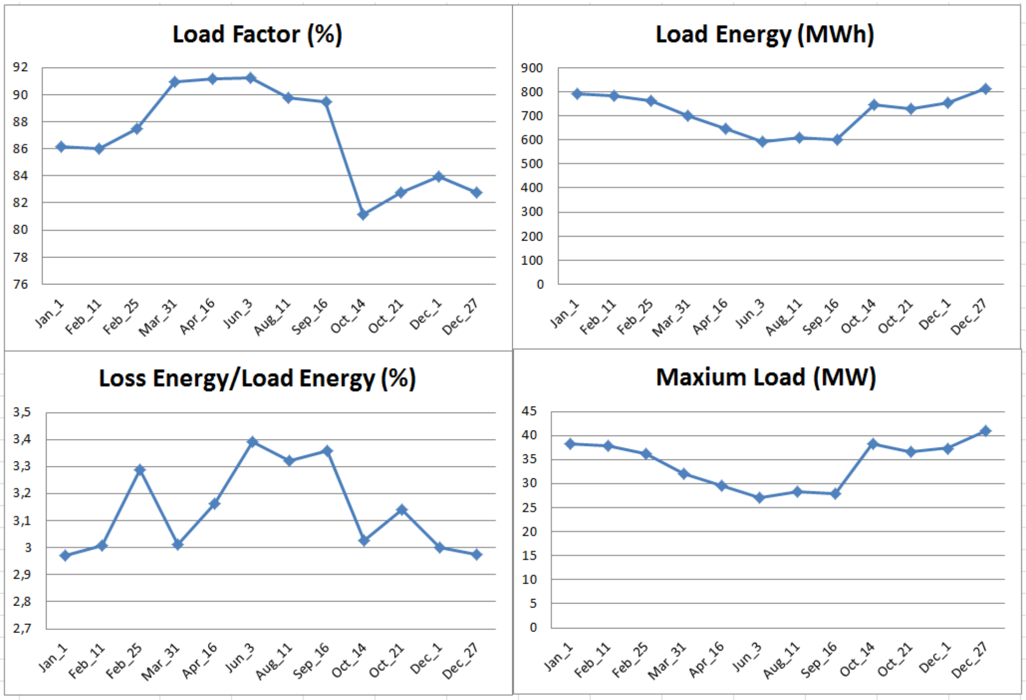
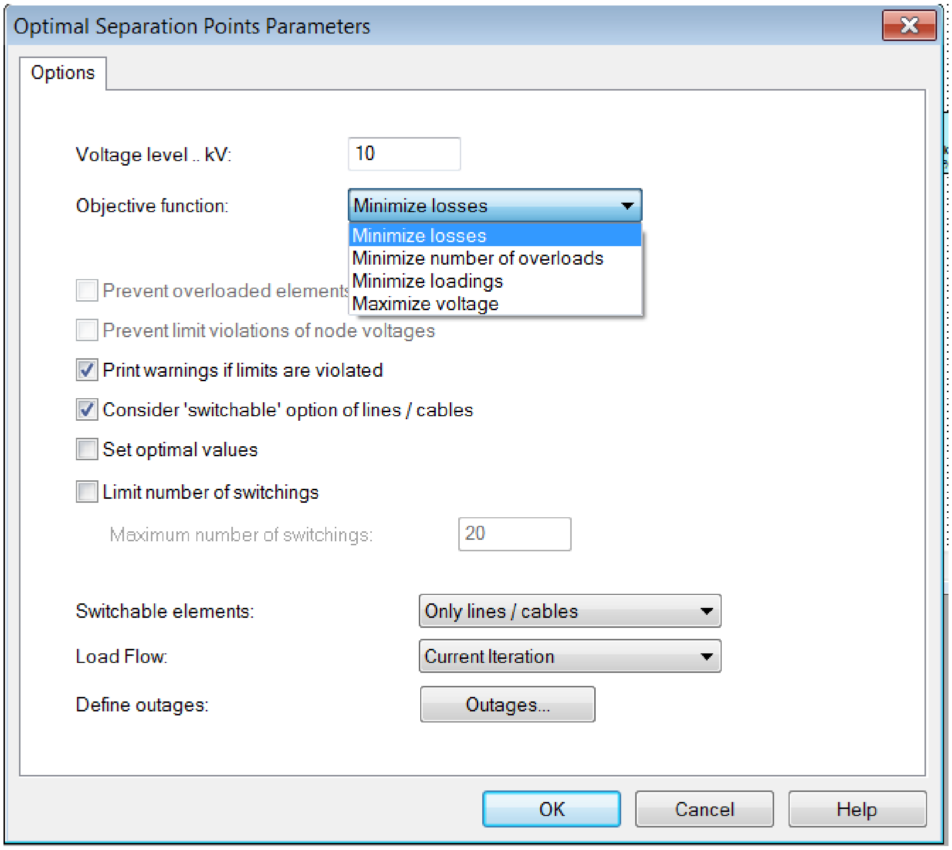


Figure 5: Overview of the present operation status (based on load profile data in 2013).

6.2 ALGORITHM FOR FINDING THE OPTIMAL SEPERATION POINTS IN A NETWORK

“Optimal separation points” is a function offered by NEPLAN to assist the distribution operator/planner in finding the optimal separation points when network reconfiguration is under request. As illustrated in the figure below, this function offers several objectives, e.g., Minimize losses, Minimize loadings, to meet different users’ objective.



Voltage level .. kV: 10

Objective function: Minimize losses

☐ Prevent overloaded elements

☐ Prevent limit violations of node voltages

☑ Print warnings if limits are violated

☑ Consider 'switchable' option of lines / cables

☐ Set optimal values

☐ Limit number of switchings

Maximum number of switchings: 20

Switchable elements: Only lines / cables

Load Flow: Current Iteration

Define outages:

Figure 6: Screenshot of the “Optimal Separation Points Parameters” panel taken from NEPLAN.

As concerns the theory part for this built-in algorithm, the goal of this procedure is to eliminate all network meshes by changing the network topology. Usually, there are a considerable number of possible topology states. The procedure chooses one topology that meets the objective (e.g. minimizes network losses), considering all active constrains and without creating isolated sub-systems. The procedure starts by considering all switchable elements in the selected voltage level are switched on, and then runs the following interactive processes:

1. Load flow calculation
2. Determination of the element with the lowest apparent power from all the switchable elements and elements that are not yet “worked off”.
3. Switch off the found element.
4. If the remained system contains an isolated part or if any constraint is violated, the element is switched on and is labeled as “worked off”.

The iteration continues until there is no switchable element or element that is not yet “worked off” left, resulting in a topology with the optimal separation points.

The built-in algorithm was known since 1980s [4] and has been improved over the years [5]-[6]. Due to the high complexity of the network reconfiguration problem, i.e., a constrained multi-objective, non-differentiable optimization objective, the deterministic approached used by NEPLAN might get stuck in local optimal solutions rather than the global optimal solution. However, compared with heuristic approaches [7] which can address the challenge in optimization, the built-in algorithm has quite fast speed of calculation which is extremely important when analyzing a large network with thousands of variables. Further, the built-in algorithm can usually deliver a reasonable result.

6.3 RECONFIGURATION FOR LOSS MINIMIZATION IN NORMAL OPERATION

6.3.1 AN ILLUSTRATIVE EXAMPLE

The figure below illustrates an example for an optimally reconfigured network solution with network power loss minimized, given an electrical load condition measured at a specific time instance, i.e. at 18:30 of March 31. Compared with the case before reconfiguration as illustrated in Figure 4, the reconfigured network still has 28 normally-open switches while 36 cables are reconfigured.

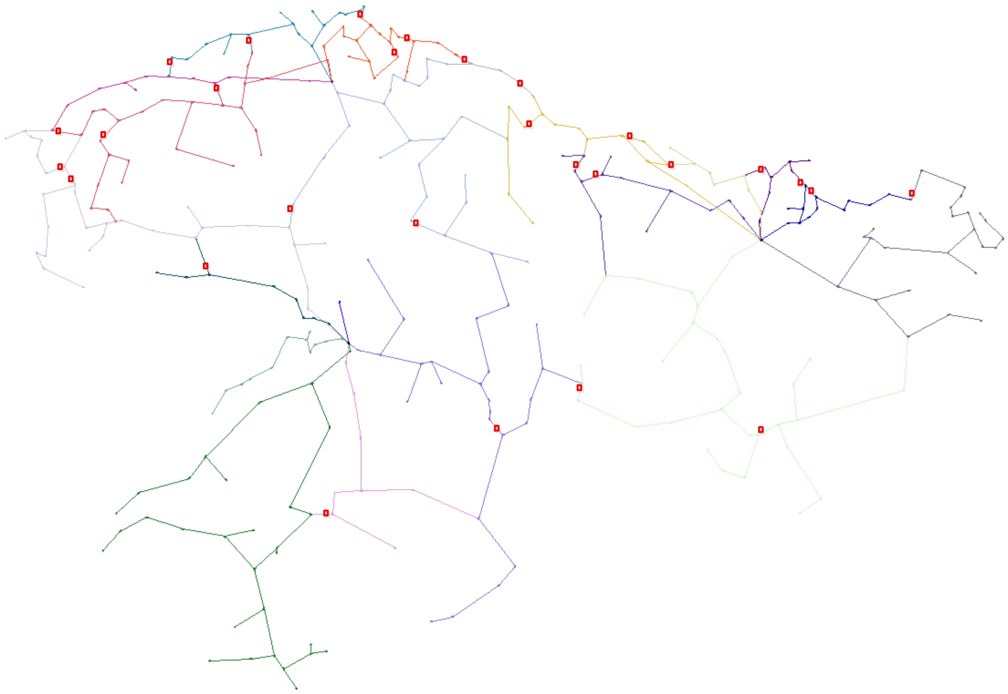


Figure 7: Optimally reconfigured 10 kV grid with 28 normally-open switches.

The table below presents a comparison of the network performance between before reconfiguration and after reconfiguration. As can be found, the reconfigured network distributes the same amount of power to the end users and reduces the power loss from 0.966MW to 0.857MW. With respect to the voltage, both minimum value (V_min) and average value (V_mean) are slightly increased after reconfiguration. As for the loading of distribution lines, its average value (LL_mean) is decreased by almost 1% after reconfiguration while its minimum value is increased by 0.02%.

Time		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)
Mar_31 18:30	Be_re	0.966	33.741	104	97.77	101.351	73.29	0.09	15,43
	Af_re	0.857	33.741	104	98.25	101.631	73.49	0.11	14.593

Table 6.1: Network performance before & after reconfiguration.

6.3.2 A MULTIPLE SCENARIO ANALYSIS

To further demonstrate the value of reconfiguration for loss reduction in normal operation, the illustrative example performed in the previous section is extended to a multiple scenario analysis. As illustrated below, the results derived from 12 scenario-based analyses are presented. Each scenario corresponds to 18:30 in a selected day. With respect to loss reduction, by reconfiguring the network, the power loss can be reduced by 10-16%. The impacts introduced by reconfiguration on cable loading are illustrated in Figure 9 and Figure 10. Although reconfiguration could increase the loading level of the maximum loaded cable for some cases, the average loading of all cables in the network is reduced by almost 2% for all cases. To achieve the loss-minimization oriented optimal topology, the number of cables being switched on/off is between 36 and 44. (detailed results for each simulation scenario is attached in Appendix-A)

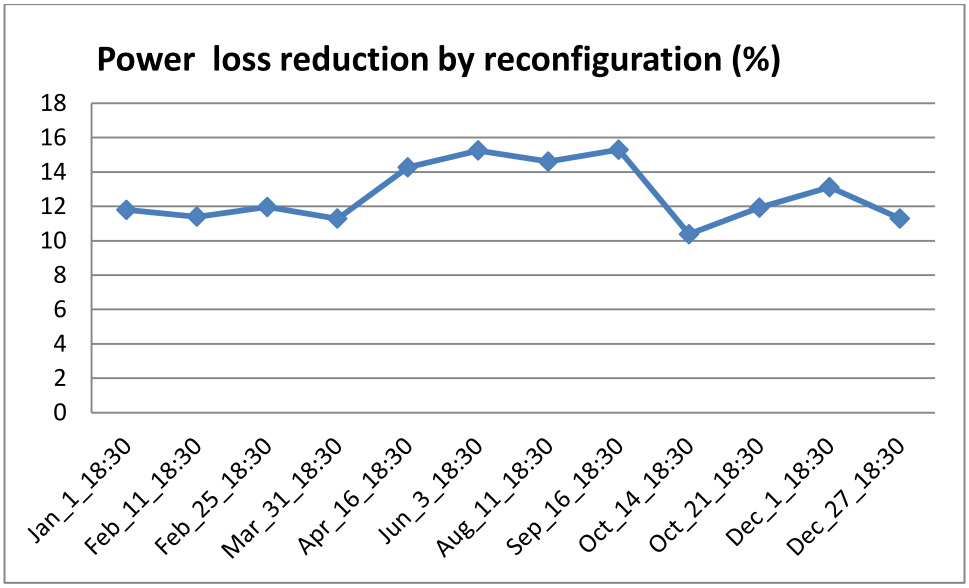


Figure 8: Power Loss reduction due to reconfiguration.

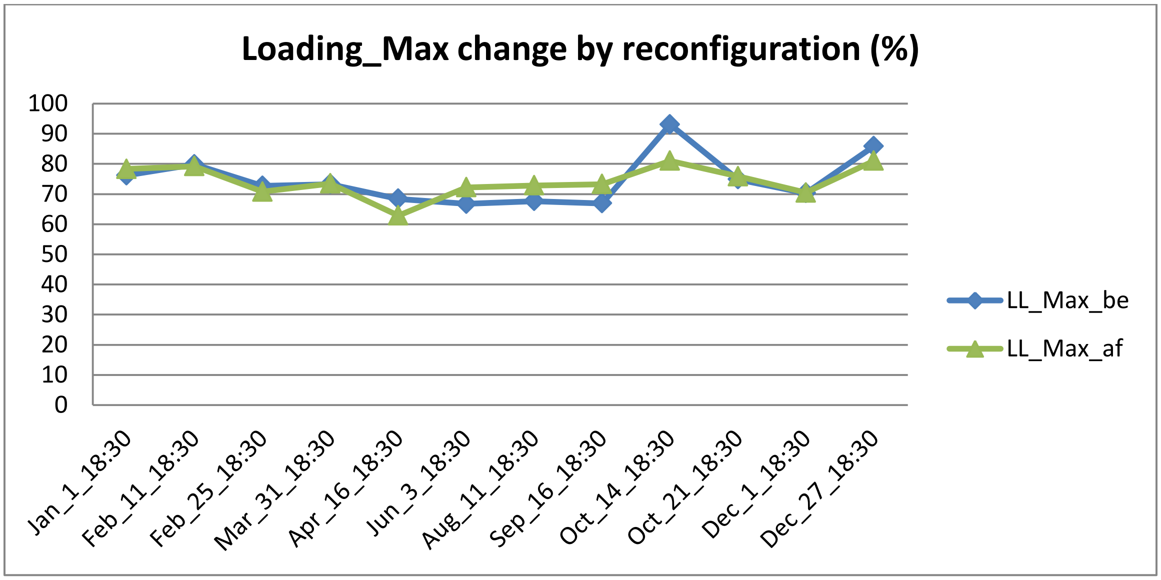


Figure 9: Comparison of maximum loading before reconfiguration and after reconfiguration.

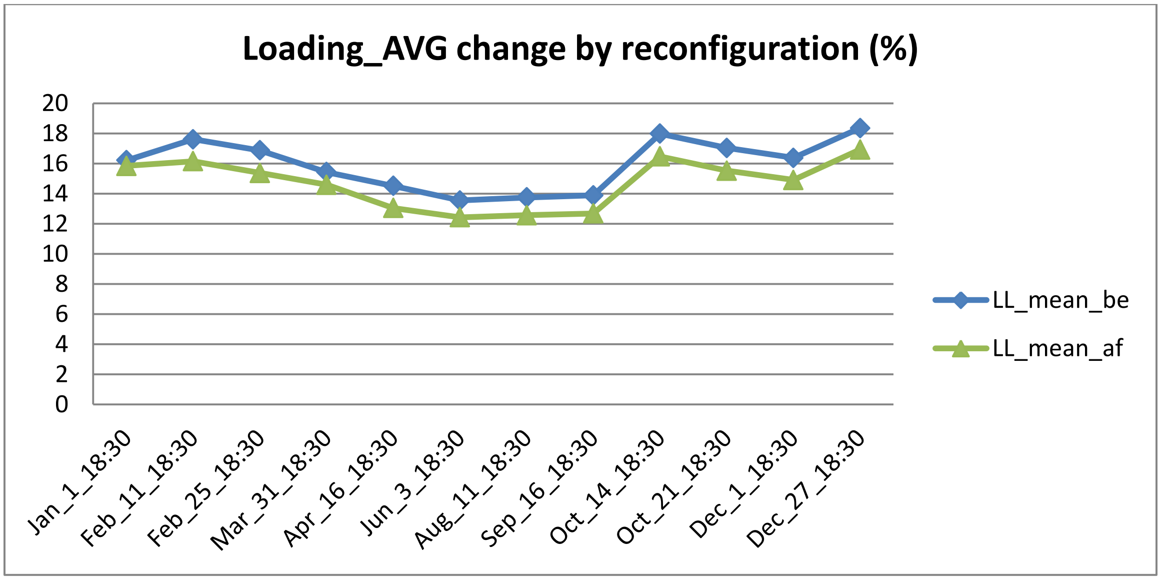


Figure 10: Comparison of average loading before reconfiguration and after reconfiguration.

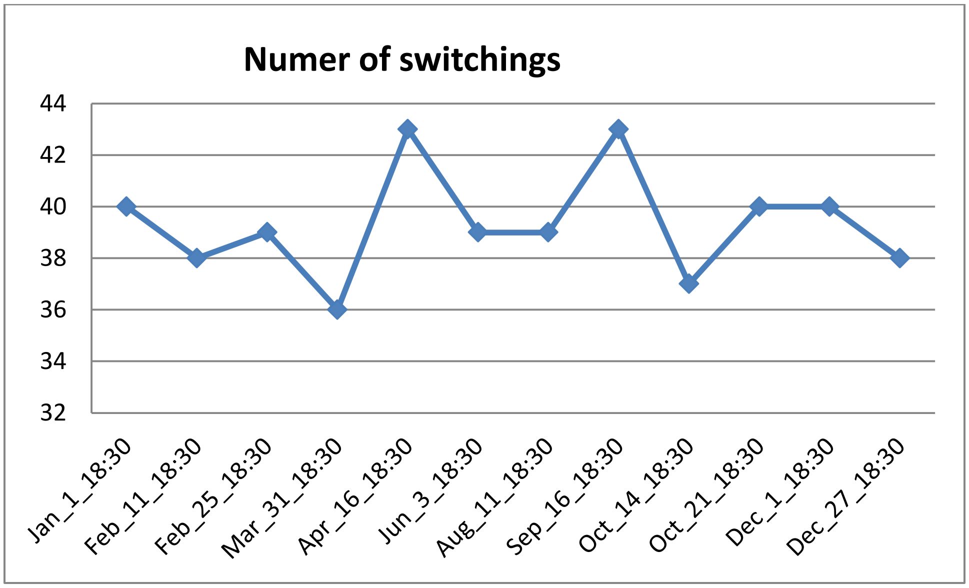


Figure 11: Number of switched cables.

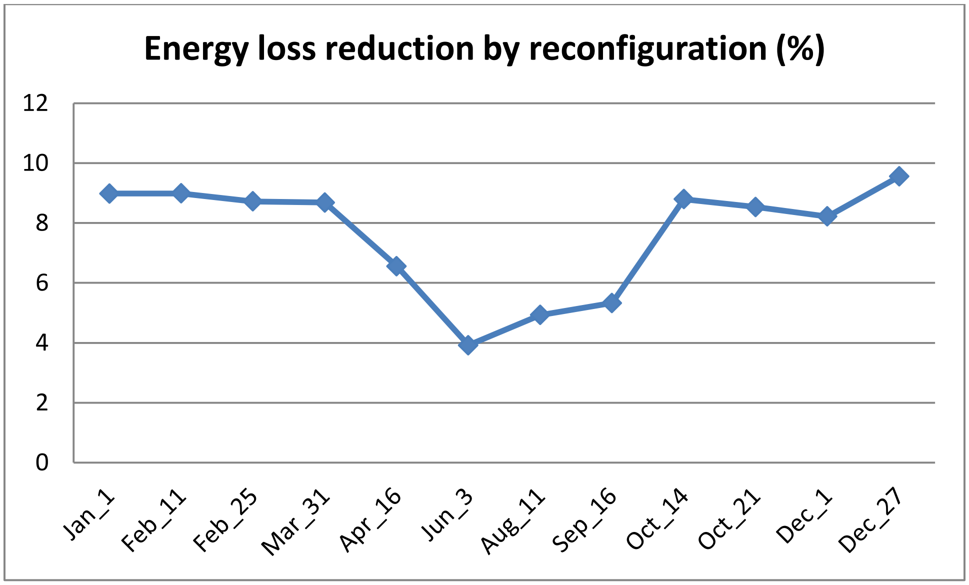


Figure 12: Energy loss reduction by reconfiguration.

6.3.3 DISCUSSION

The analysis has shown that a power loss reduction of 10-16% can be achieved by network reconfiguration under normal operation. However, this result must be put into context. This power loss reduction is only valid for the specific time instant (i.e., 18:30 when the daily peak load occurs) for which the network was optimized. If DSOs hope to achieve such a loss reduction for energy as well, they will have to reconfigure their grid on an hourly basis. If they do not, the energy loss reduction will be significantly lower. The network configurations in the scenarios were applied to the entire day and showed that the reduction in energy loss was reduced to 4-10%, as indicated in Figure 12 . If the same network configuration is applied for longer time durations, the energy loss reduction will be lower yet.

The reason for this is that the network topology after reconfiguration is only optimal for the short time period it was created for. At all other times, it may perform better or worse than the original network configuration. That being said, a loss reduction is likely even when the configuration is applied over longer time periods, because the network configurations that are used today have likely seen little loss optimization, if any.

Better results than seen here may be possible with the use of better optimization algorithms. The algorithm used by NEPLAN is fairly basic and is likely to result in a local optimum. Furthermore, it is not able to consider more than one instance of time. Better algorithms exist – both algorithms that are more likely to result in the global optimum as well as algorithms that are able to optimize over several instances of time. Use of more complex algorithms could improve both the power loss reduction for a single instance of time as well as the energy loss reduction over a longer period, such as a day.

However, even if better optimization algorithms are used, one should not expect the loss reduction to be significantly higher than what this study shows. MV distribution networks have been designed and expanded based on the connected loads and with N-1 criteria and limitation of voltage drop. The N-1 design criteria means that losses are already low due to the backup capacity necessary for N-1 scenarios and the limitation of voltage drop means that the network topology is already close to being optimal.

While frequent network reconfiguration could provide loss reduction similar to what is seen here, it is unlikely that DSOs would use network reconfiguration in such a way. As discussed in section 4.4.3, there are both technical and economic aspects which speak against frequent network reconfiguration. Therefore the loss reduction that is realistically achievable by network reconfiguration is likely quite low (i.e. closer to the simulated energy loss reduction than to the simulated power loss reduction).

6.3.4 PARTIAL CONCLUSION

When network reconfiguration is used for loss minimization in normal operation, the power losses can generally be reduced by 10-16%. However, the energy loss reductions that can be expected are relatively lower, being around 4-10%, as is seen by applying the optimized network configurations to an entire day. Better energy loss reductions may be achievable through use of better optimization algorithms or frequent reconfiguration, e.g. done on an hourly basis. However, it is unlikely that the reduction in energy losses can reach the reduction in power loss seen here. Given that the reduction in losses is generally accompanied by improved node voltages and line loading, network reconfiguration can be a good measure of improving both grid losses and the overall state of the grid.

6.4 RECONFIGURATION FOR IMPROVED OPERATION IN POST-FAULT OPERATION

6.4.1 RECONFIGURATION CARRIED OUT IN POST-FAULT EXAMPLES

To examine the value of optimal reconfiguration in post-fault conditions, two scenarios have been created as illustrated in Figure 13. In scenario 1, the reconfiguration is carried out after the loss of cable L-3717_2513_1, i.e., the heaviest loaded cable in this network. In scenario 2, the reconfiguration is performed after the loss of feeder L_NOR02_4055_1, i.e., one of the heavily loaded feeders in this network. In both scenarios, a reconfiguration plan is determined by minimizing the loss of the post-fault network. Results of the analysis are presented in Table 6.2.

As the studied network is designed based on N-1 criteria, in both scenarios, the loss of a line connection doesn't cause any severe problems for the network. On the contrary, the resulted network performance could be considered as even better to a certain degree. For instance, in scenario one, the loss of the cable incurs a change of load flow, leading to improved loading conditions for the system. In both studied cases, once a reconfiguration plan is performed in a post-fault condition, it can be clearly found that the system performance can be improved even more, particularly the voltage performance.

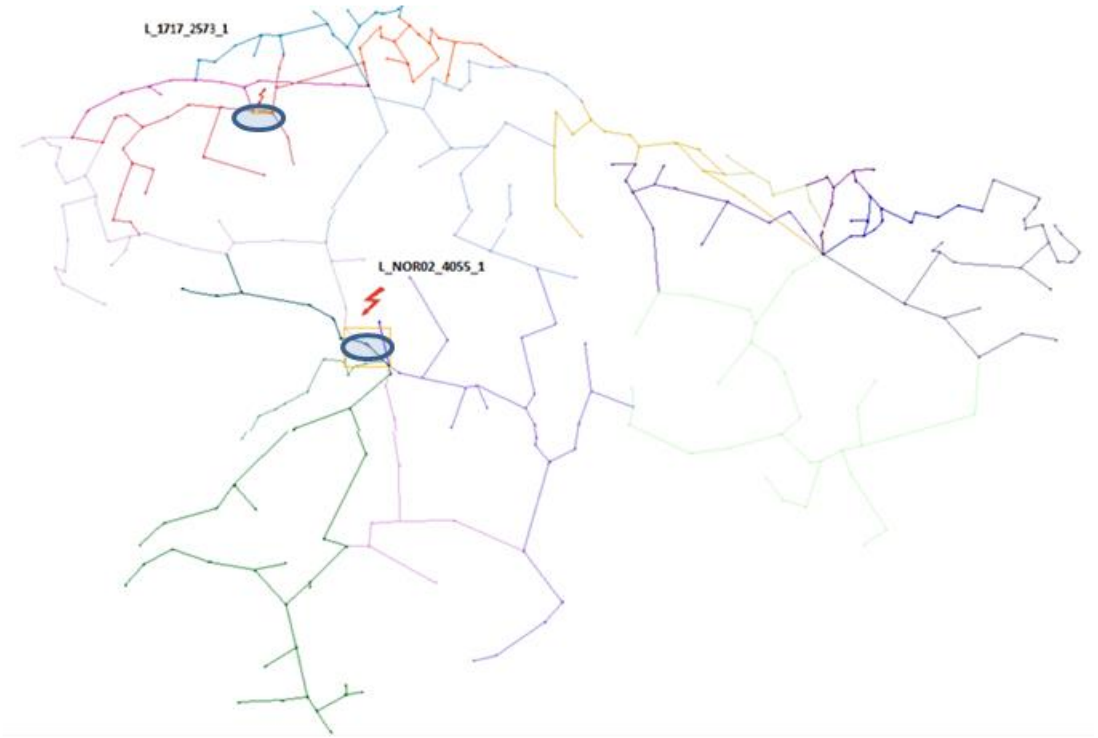


Figure 13: Illustration of fault scenarios.

	Operating condition	Loss	maxim Line loading	no. of lines with loading above 50%	V_max	V_min (10kV)	V_min (0.4KV)	loading of the outaged cable	No. of switchings
		MW	%		kV	kV	kV	%	%
Scenario 1	Before outage	1,231	85,84	64	10,4	9,634	0,361	85,84	
	After outage	1,092	77,12	52	10,4	9,634	0,362	0	
	After reconfiguration	0,95	81,01	22	10,4	9,804	0,364	0	38
Scenario 2	Before outage	1.231	85,84	64	10,4	9,634	0,361	68,24	
	After outage	1,043	83,84	40	10,4	9,634	0,361	0	
	After reconfiguration	0,933	81,01	50	10,4	9,88	0,362	0	34

Table 6.2: Network performance before & after reconfiguration in post-fault situation.

6.4.2 DISCUSSION

The analysis has shown that in post-fault conditions, the value of using reconfiguration to improve the network performance can be clearly observed. This result is also in line with what has been observed when using reconfiguration to improve the network performance in normal conditions. However, similar to applying reconfiguration in normal conditions, the derived solution is time-limited, implying only frequent optimal reconfigurations can improve the network performance over longer period at a relatively satisfactory degree.

7 CONCLUSION AND RECOMMENDATION

As a mechanism that can be directly used by the DSO without involving any demand-side participation, network reconfiguration has the potential of being used to improve both temporary and long-term network performance under different conditions.

In the Danish context, even though the current networks are very efficiently dimensioned and operated by the DSO, the potential value of network reconfiguration is still noticeable. For instance, as observed from the simulated results with data input from 2013, if an optimal recognition plan can be derived and deployed frequently, such as on hourly basis, the energy loss of the current system can be reduced at least 4%. However, to fully achieve such value requires enormous development and investment on distribution automation and optimal decision support tools. Because reconfiguration is primarily used for outage reduction in the current practice; neither distribution automation nor optimal decision support tools are commercially ready to support frequent use of optimal reconfiguration in grid operation. Further, the life span of switchgear could be another limiting factor prohibiting frequent reconfigurations, although this might be improved if solid state switches are massively deployed.

The current effort made by the Danish DSOs on improving the observability of distribution networks by having more intelligent substations and measurement devices would to a great extent support the application of network reconfiguration. Although at the present stage, it is still difficult to derive and apply reconfiguration for optimized grid operation at a system level based on these efforts, it is expected that the improved observability could better support reconfiguration applications in outage reduction and the reliability such as SAIDI etc.

Regarding other future analysis, it is recommended to further investigate the potential value of network reconfiguration. For instance, the studied Danish distribution grid has sufficient capacity of power distribution, implying there are few issues with loading and voltage. In the future, when there is a high share of DER, it is highly possible for the distribution grid to have more grid issues if reinforcement/other mechanisms are not implemented timely. Therefore, from both grid operation and grid planning perspectives, it is important to evaluate the technical-economic feasibility of using reconfiguration as an alternative/part of an integrated mechanism (such as a combined use of network reconfiguration and demand-side flexibility) for improvement of network performance on a regular basis.

8 REFERENCE

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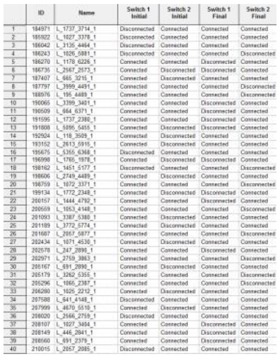
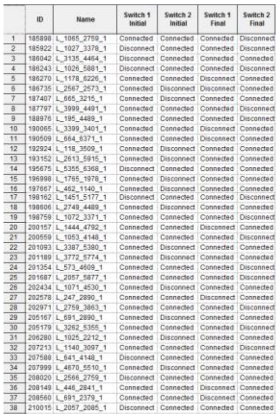
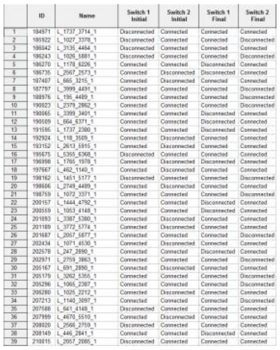
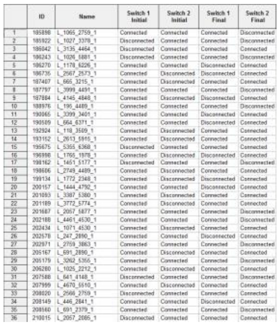
9 APPENDIX-A

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Jan_1 18:30	Be_re	1.119	37.94	104	96.67	101.17	76.17	0.09	16.219	
	Af_re	0.987	37.94	104	98.79	101.488	78.3	0.11	15.85	
Feb_11 18:30	Be_re	1.132	37.917	104	96.76	101.165	79.8	0.09	17,606	
	Af_re	1.003	37.917	104	98.25	101,476	79.19	0.11	16.158	

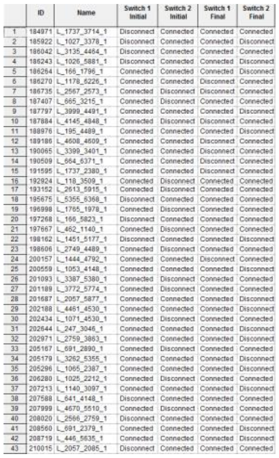
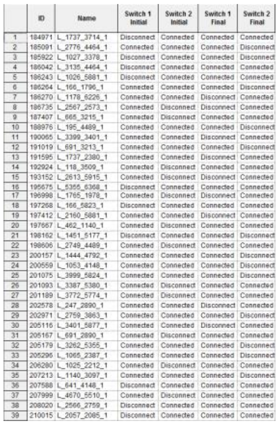
	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnected	Connected	Connected	Connected
2	185922	L_1027_3378_1	Disconnected	Connected	Connected	Connected
3	186042	L_3135_4464_1	Disconnected	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnected	Connected	Connected	Disconnected
5	186270	L_1178_6226_1	Connected	Connected	Disconnected	Connected
6	186735	L_2567_2573_1	Connected	Disconnected	Disconnected	Connected
7	187407	L_665_3215_1	Connected	Disconnected	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnected
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnected
10	190065	L_3399_3401_1	Connected	Connected	Disconnected	Connected
11	190509	L_664_6371_1	Connected	Connected	Disconnected	Connected
12	191595	L_1737_2380_1	Connected	Connected	Disconnected	Connected
13	191808	L_5096_5455_1	Connected	Disconnected	Disconnected	Connected
14	192924	L_118_3509_1	Connected	Disconnected	Connected	Connected
15	193152	L_2613_5915_1	Connected	Disconnected	Connected	Connected
16	195675	L_5355_6368_1	Disconnected	Connected	Connected	Connected
17	196998	L_1765_1978_1	Connected	Disconnected	Disconnected	Connected
18	198162	L_1451_5177_1	Disconnected	Connected	Connected	Disconnected
19	198606	L_2749_4489_1	Connected	Disconnected	Connected	Connected
20	198759	L_1072_3371_1	Connected	Connected	Connected	Disconnected
21	199134	L_1772_2348_1	Connected	Disconnected	Disconnected	Connected
22	200157	L_1444_4792_1	Connected	Connected	Disconnected	Connected
23	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnected
24	201093	L_3387_5380_1	Connected	Disconnected	Connected	Connected
25	201189	L_3772_5774_1	Connected	Disconnected	Connected	Connected
26	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnected
27	202434	L_1071_4530_1	Connected	Disconnected	Connected	Connected
28	202578	L_247_2890_1	Connected	Connected	Disconnected	Connected
29	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnected
30	205167	L_691_2890_1	Connected	Disconnected	Connected	Connected
31	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnected
32	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnected
33	206280	L_1025_2212_1	Connected	Disconnected	Connected	Connected
34	207588	L_641_4148_1	Disconnected	Connected	Connected	Connected
35	207999	L_4670_5510_1	Connected	Disconnected	Connected	Connected
36	208020	L_2566_2759_1	Disconnected	Connected	Connected	Connected
37	208107	L_1027_3484_1	Connected	Connected	Disconnected	Connected
38	208149	L_446_2841_1	Connected	Connected	Disconnected	Connected
39	208560	L_691_2379_1	Connected	Connected	Disconnected	Connected
40	210015	L_2057_2085_1	Disconnected	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	185898	L_1065_2759_1	Connected	Connected	Connected	Disconnect
2	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
3	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
5	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
6	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
7	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnect
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
10	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
11	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
12	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
13	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
14	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
15	196998	L_1765_1978_1	Connected	Disconnect	Connected	Connected
16	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
17	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
18	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
19	198759	L_1072_3371_1	Connected	Connected	Connected	Disconnect
20	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
21	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
22	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
23	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
24	201354	L_573_4609_1	Connected	Connected	Connected	Disconnect
25	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnect
26	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
27	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
28	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
29	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
30	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
31	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
32	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
33	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
34	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
35	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
36	208149	L_446_2841_1	Connected	Connected	Disconnect	Connected
37	208560	L_691_2379_1	Connected	Connected	Disconnect	Connected
38	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Feb_25 18:30	Be_re	1.045	36.287	104	97.07	101.242	72.66	0.09	16.877	
	Af_re	0.92	36.287	104	98.92	101.55	70.78	0.11	15.38	
Mar_31 18:30	Be_re	0.966	33.741	104	97.77	101.351	73.29	0.09	15,43	
	Af_re	0.857	33.741	104	98.25	101.631	73.49	0.11	14.593	

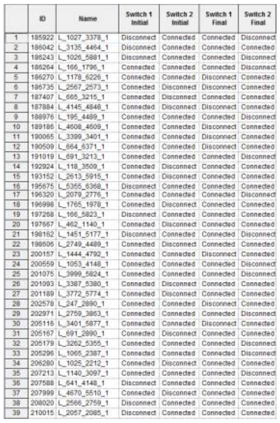
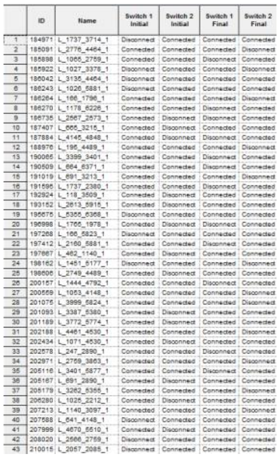
	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnected	Connected	Connected	Connected
2	185922	L_1027_3378_1	Disconnected	Connected	Connected	Disconnected
3	186042	L_3135_4464_1	Disconnected	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnected	Connected	Connected	Disconnected
5	186270	L_1178_6226_1	Connected	Connected	Disconnected	Connected
6	186735	L_2567_2573_1	Connected	Disconnected	Disconnected	Connected
7	187407	L_665_3215_1	Connected	Disconnected	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnected
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnected
10	190023	L_2379_2862_1	Connected	Connected	Connected	Disconnected
11	190065	L_3399_3401_1	Connected	Connected	Disconnected	Connected
12	190509	L_664_6371_1	Connected	Connected	Disconnected	Connected
13	191595	L_1737_2380_1	Connected	Connected	Disconnected	Connected
14	192924	L_118_3509_1	Connected	Disconnected	Connected	Connected
15	193152	L_2613_5915_1	Connected	Disconnected	Connected	Connected
16	195675	L_5355_6368_1	Disconnected	Connected	Connected	Connected
17	196998	L_1765_1978_1	Connected	Disconnected	Disconnected	Connected
18	197667	L_462_1140_1	Connected	Disconnected	Connected	Connected
19	198162	L_1451_5177_1	Disconnected	Connected	Connected	Disconnected
20	198606	L_2749_4489_1	Connected	Disconnected	Connected	Connected
21	198759	L_1072_3371_1	Connected	Connected	Connected	Disconnected
22	200157	L_1444_4792_1	Connected	Connected	Disconnected	Connected
23	200559	L_1053_4148_1	Connected	Connected	Disconnected	Connected
24	201093	L_3387_5380_1	Connected	Disconnected	Connected	Connected
25	201189	L_3772_5774_1	Connected	Disconnected	Connected	Connected
26	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnected
27	202434	L_1071_4530_1	Connected	Disconnected	Connected	Connected
28	202578	L_247_2890_1	Connected	Connected	Disconnected	Connected
29	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnected
30	205167	L_691_2890_1	Connected	Disconnected	Connected	Connected
31	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnected
32	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnected
33	206280	L_1025_2212_1	Connected	Disconnected	Connected	Connected
34	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnected
35	207588	L_641_4148_1	Disconnected	Connected	Connected	Connected
36	207999	L_4670_5510_1	Connected	Disconnected	Connected	Connected
37	208020	L_2566_2759_1	Disconnected	Connected	Connected	Connected
38	208149	L_446_2841_1	Connected	Connected	Disconnected	Connected
39	210015	L_2057_2085_1	Disconnected	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	185898	L_1065_2759_1	Connected	Connected	Connected	Disconnected
2	185922	L_1027_3378_1	Disconnected	Connected	Connected	Disconnected
3	186042	L_3135_4464_1	Disconnected	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnected	Connected	Connected	Disconnected
5	186270	L_1178_6226_1	Connected	Connected	Disconnected	Connected
6	186735	L_2567_2573_1	Connected	Disconnected	Disconnected	Connected
7	187407	L_665_3215_1	Connected	Disconnected	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnected
9	187884	L_4145_4848_1	Connected	Disconnected	Disconnected	Connected
10	188976	L_195_4489_1	Connected	Connected	Connected	Disconnected
11	190065	L_3399_3401_1	Connected	Connected	Disconnected	Connected
12	190509	L_664_6371_1	Connected	Connected	Disconnected	Connected
13	192924	L_118_3509_1	Connected	Disconnected	Connected	Connected
14	193152	L_2613_5915_1	Connected	Disconnected	Connected	Connected
15	195675	L_5355_6368_1	Disconnected	Connected	Connected	Connected
16	196998	L_1765_1978_1	Connected	Disconnected	Disconnected	Connected
17	198162	L_1451_5177_1	Disconnected	Connected	Connected	Disconnected
18	198606	L_2749_4489_1	Connected	Disconnected	Connected	Connected
19	199134	L_1772_2348_1	Connected	Disconnected	Disconnected	Connected
20	200157	L_1444_4792_1	Connected	Connected	Disconnected	Connected
21	201093	L_3387_5380_1	Connected	Disconnected	Connected	Connected
22	201189	L_3772_5774_1	Connected	Disconnected	Connected	Connected
23	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnected
24	202188	L_4461_4530_1	Connected	Connected	Connected	Disconnected
25	202434	L_1071_4530_1	Connected	Disconnected	Connected	Connected
26	202578	L_247_2890_1	Connected	Connected	Disconnected	Connected
27	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnected
28	205167	L_691_2890_1	Connected	Disconnected	Connected	Connected
29	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnected
30	206280	L_1025_2212_1	Connected	Disconnected	Connected	Connected
31	207588	L_641_4148_1	Disconnected	Connected	Connected	Disconnected
32	207999	L_4670_5510_1	Connected	Disconnected	Connected	Connected
33	208020	L_2566_2759_1	Disconnected	Connected	Connected	Connected
34	208149	L_446_2841_1	Connected	Connected	Disconnected	Connected
35	208560	L_691_2379_1	Connected	Connected	Connected	Disconnected
36	210015	L_2057_2085_1	Disconnected	Connected	Connected	Connected

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Apr_16 18:30	Be_re	0.806	29.752	104	90.41	100.249	68.4	0.09	14.518	
	Af_re	0.691	29.752	104	99.75	101.78	62.85	0.11	13.046	
Jun_3 18:30	Be_re	0.741	27.334	104	97.52	101.599	66.74	0.09	13.552	
	Af_re	0.628	27.334	104	99.53	101.836	72.21	0.11	12.434	

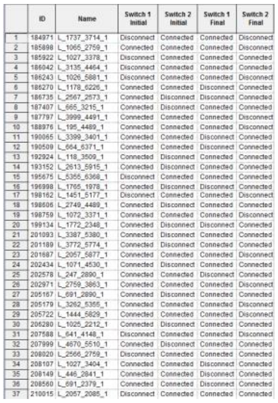
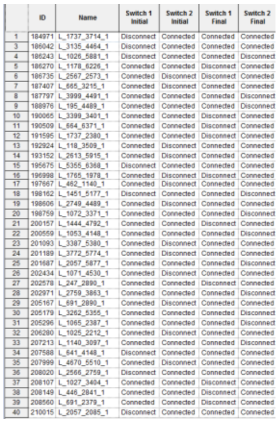
	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Connected
2	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
3	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
5	186264	L_166_1796_1	Connected	Connected	Connected	Disconnect
6	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
7	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
8	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
9	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnect
10	187884	L_4145_4848_1	Connected	Disconnect	Disconnect	Connected
11	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
12	189186	L_4608_4609_1	Connected	Connected	Disconnect	Connected
13	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
14	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
15	191595	L_1737_2380_1	Connected	Connected	Disconnect	Connected
16	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
17	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
18	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
19	196998	L_1765_1978_1	Connected	Disconnect	Connected	Connected
20	197268	L_166_5823_1	Disconnect	Connected	Connected	Connected
21	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
22	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
23	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
24	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
25	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
26	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
27	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
28	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnect
29	202188	L_4461_4530_1	Connected	Connected	Connected	Disconnect
30	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
31	202644	L_247_3046_1	Connected	Connected	Connected	Disconnect
32	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
33	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
34	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
35	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnect
36	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
37	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
38	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
39	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
40	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
41	208560	L_691_2379_1	Connected	Connected	Connected	Disconnect
42	208719	L_446_5635_1	Connected	Connected	Connected	Disconnect
43	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Connected
2	185091	L_2776_4464_1	Connected	Connected	Connected	Disconnect
3	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
4	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
5	186243	L_1026_5881_1	Disconnect	Connected	Connected	Connected
6	186264	L_166_1796_1	Connected	Connected	Connected	Disconnect
7	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
8	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
9	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
10	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
11	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
12	191019	L_691_3213_1	Connected	Connected	Connected	Disconnect
13	191595	L_1737_2380_1	Connected	Connected	Disconnect	Connected
14	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
15	193152	L_2613_5915_1	Connected	Disconnect	Disconnect	Connected
16	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
17	196998	L_1765_1978_1	Connected	Disconnect	Disconnect	Connected
18	197268	L_166_5823_1	Disconnect	Connected	Connected	Connected
19	197412	L_2160_5881_1	Connected	Connected	Disconnect	Connected
20	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
21	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
22	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
23	200157	L_1444_4792_1	Connected	Connected	Connected	Disconnect
24	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
25	201075	L_3999_5824_1	Connected	Connected	Connected	Disconnect
26	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
27	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
28	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
29	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
30	205116	L_3401_5877_1	Connected	Connected	Disconnect	Connected
31	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
32	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
33	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnect
34	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
35	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
36	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
37	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
38	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
39	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Aug_11 18:30	Be_re	0.753	27.865	104	97.57	101.575	67.63	0.09	13.756	
	Af_re	0.643	27.865	104	99.6	101.833	72.84	0.11	12.566	
Sep_16 18:30	Be_re	0.765	28.327	104	97.55	101.557	66.91	0.09	13.889	
	Af_re	0.648	28.327	104	99.45	101,825	73.25	0.11	12.691	

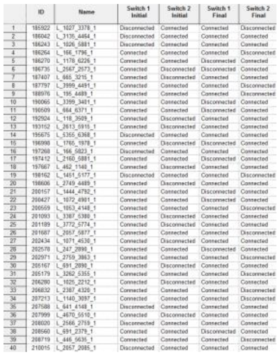
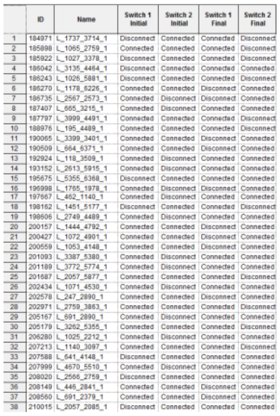
	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
2	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
3	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
4	186264	L_166_1796_1	Connected	Connected	Connected	Disconnect
5	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
6	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
7	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
8	187884	L_4145_4848_1	Connected	Disconnect	Disconnect	Connected
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
10	189186	L_4608_4609_1	Connected	Connected	Disconnect	Connected
11	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
12	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
13	191019	L_691_3213_1	Connected	Connected	Connected	Disconnect
14	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
15	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
16	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
17	196320	L_2079_2776_1	Connected	Connected	Connected	Disconnect
18	196998	L_1765_1978_1	Connected	Disconnect	Connected	Connected
19	197268	L_166_5823_1	Disconnect	Connected	Connected	Connected
20	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
21	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
22	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
23	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
24	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
25	201075	L_3999_5824_1	Connected	Connected	Connected	Disconnect
26	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
27	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
28	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
29	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
30	205116	L_3401_5877_1	Connected	Connected	Disconnect	Connected
31	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
32	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
33	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnect
34	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
35	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
36	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
37	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
38	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
39	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Connected
2	185091	L_2776_4464_1	Connected	Connected	Connected	Disconnect
3	185898	L_1066_2759_1	Connected	Connected	Disconnect	Connected
4	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
5	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
6	186243	L_1026_5881_1	Disconnect	Connected	Connected	Connected
7	186264	L_166_1796_1	Connected	Connected	Connected	Disconnect
8	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
9	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
10	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
11	187884	L_4145_4848_1	Connected	Disconnect	Disconnect	Connected
12	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
13	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
14	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
15	191019	L_691_3213_1	Connected	Connected	Connected	Disconnect
16	191596	L_1737_2380_1	Connected	Connected	Disconnect	Connected
17	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
18	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
19	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
20	196998	L_1765_1978_1	Connected	Disconnect	Disconnect	Connected
21	197268	L_166_5823_1	Disconnect	Connected	Connected	Connected
22	197412	L_2160_5881_1	Connected	Connected	Disconnect	Connected
23	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
24	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
25	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
26	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
27	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
28	201075	L_3999_5824_1	Connected	Connected	Connected	Disconnect
29	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
30	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
31	202188	L_4461_4530_1	Connected	Connected	Connected	Disconnect
32	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
33	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
34	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
35	205116	L_3401_5877_1	Connected	Connected	Disconnect	Connected
36	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
37	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
38	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
39	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
40	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
41	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
42	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
43	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Oct_14 18:30	Be_re	1.205	38.283	104	96.82	101.136	93.05	0.09	17.987	
	Af_re	1.08	38.283	104	97.51	101.453	81.04	0.11	16.472	
Oct_21 18:30	Be_re	1.065	36.611	104	96.99	101.227	74.88	0.09	17.037	
	Af_re	0.938	36.611	104	98.81	101.538	75.89	0.11	15.531	

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Disconnect
2	185898	L_1065_2759_1	Connected	Connected	Connected	Disconnect
3	185922	L_1027_3378_1	Disconnect	Connected	Connected	Connected
4	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
5	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
6	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
7	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
8	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
9	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnect
10	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
11	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
12	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
13	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
14	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
15	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
16	196998	L_1765_1978_1	Connected	Disconnect	Disconnect	Connected
17	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
18	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
19	198759	L_1072_3371_1	Connected	Connected	Connected	Disconnect
20	199134	L_1772_2348_1	Connected	Disconnect	Disconnect	Connected
21	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
22	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
23	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnect
24	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
25	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
26	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
27	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
28	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
29	205722	L_1444_5829_1	Connected	Connected	Connected	Disconnect
30	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
31	207588	L_641_4148_1	Disconnect	Connected	Connected	Disconnect
32	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
33	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
34	208107	L_1027_3404_1	Connected	Connected	Disconnect	Connected
35	208149	L_446_2841_1	Connected	Connected	Disconnect	Connected
36	208560	L_691_2379_1	Connected	Connected	Disconnect	Connected
37	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Connected
3	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
4	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
5	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
6	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
7	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnect
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
10	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
11	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
12	191595	L_1737_2380_1	Connected	Connected	Disconnect	Connected
13	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
14	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
15	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
16	196998	L_1765_1978_1	Connected	Disconnect	Disconnect	Connected
17	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
18	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
19	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
20	198759	L_1072_3371_1	Connected	Connected	Connected	Disconnect
21	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
22	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnect
23	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
24	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
25	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnect
26	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
27	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
28	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
29	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
30	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
31	205296	L_1065_2387_1	Connected	Connected	Connected	Disconnect
32	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
33	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
34	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
35	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
36	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
37	208107	L_1027_3404_1	Connected	Connected	Disconnect	Connected
38	208149	L_446_2841_1	Connected	Connected	Disconnect	Connected
39	208560	L_691_2379_1	Connected	Connected	Disconnect	Connected
40	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected

		Loss (MW)	Load (MW)	V_max (% 10KV)	V_min (% 10KV)	V_mean (% 10KV)	LL_max (%)	LL_min (%)	LL_mean (%)	Switching events
Dec_1 18:30	Be_re	0.999	35.378	104	97.2	101.278	70.28	0.09	16.38	
	Af_re	0.868	35.378	104	99.08	101.593	70.48	0.11	14.909	
Dec_27 18:30	Be_re	1.231	39.904	104	96.34	101.079	85.84	0.09	18.357	
	Af_re	1.092	39.904	104	98.04	101.41	81.01	0.11	16.928	

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	185922	L_1027_3378_1	Disconnected	Connected	Connected	Disconnected
2	186042	L_3135_4464_1	Disconnected	Connected	Connected	Connected
3	186243	L_1026_5881_1	Disconnected	Connected	Connected	Connected
4	186264	L_166_1796_1	Connected	Connected	Connected	Disconnected
5	186270	L_1178_6226_1	Connected	Connected	Disconnected	Connected
6	186735	L_2567_2573_1	Connected	Disconnected	Disconnected	Connected
7	187407	L_665_3215_1	Connected	Disconnected	Connected	Connected
8	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnected
9	188976	L_195_4489_1	Connected	Connected	Connected	Disconnected
10	190065	L_3399_3401_1	Connected	Connected	Disconnected	Connected
11	190509	L_664_6371_1	Connected	Connected	Disconnected	Connected
12	192924	L_118_3509_1	Connected	Disconnected	Connected	Connected
13	193152	L_2613_5915_1	Connected	Disconnected	Connected	Connected
14	195675	L_5355_6368_1	Disconnected	Connected	Connected	Connected
15	196998	L_1765_1978_1	Connected	Disconnected	Disconnected	Connected
16	197268	L_166_5823_1	Disconnected	Connected	Connected	Connected
17	197412	L_2160_5881_1	Connected	Connected	Disconnected	Connected
18	197667	L_462_1140_1	Connected	Disconnected	Connected	Connected
19	198162	L_1451_5177_1	Disconnected	Connected	Connected	Disconnected
20	198606	L_2749_4489_1	Connected	Disconnected	Connected	Connected
21	200157	L_1444_4792_1	Connected	Connected	Disconnected	Connected
22	200427	L_1072_4901_1	Connected	Connected	Disconnected	Connected
23	200559	L_1053_4148_1	Connected	Connected	Connected	Disconnected
24	201093	L_3387_5380_1	Connected	Disconnected	Connected	Connected
25	201189	L_3772_5774_1	Connected	Disconnected	Connected	Connected
26	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnected
27	202434	L_1071_4530_1	Connected	Disconnected	Connected	Connected
28	202578	L_247_2890_1	Connected	Connected	Disconnected	Connected
29	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnected
30	205167	L_691_2890_1	Connected	Disconnected	Connected	Connected
31	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnected
32	206280	L_1025_2212_1	Connected	Disconnected	Connected	Connected
33	206832	L_2387_4320_1	Connected	Connected	Connected	Disconnected
34	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnected
35	207588	L_641_4148_1	Disconnected	Connected	Connected	Connected
36	207999	L_4670_5510_1	Connected	Disconnected	Connected	Connected
37	208020	L_2566_2759_1	Disconnected	Connected	Connected	Connected
38	208560	L_691_2379_1	Connected	Connected	Disconnected	Connected
39	208719	L_446_5635_1	Connected	Connected	Connected	Disconnected
40	210015	L_2057_2085_1	Disconnected	Connected	Connected	Connected

	ID	Name	Switch 1 Initial	Switch 2 Initial	Switch 1 Final	Switch 2 Final
1	184971	L_1737_3714_1	Disconnect	Connected	Connected	Disconnect
2	185898	L_1065_2759_1	Connected	Connected	Connected	Disconnect
3	185922	L_1027_3378_1	Disconnect	Connected	Connected	Disconnect
4	186042	L_3135_4464_1	Disconnect	Connected	Connected	Connected
5	186243	L_1026_5881_1	Disconnect	Connected	Connected	Disconnect
6	186270	L_1178_6226_1	Connected	Connected	Disconnect	Connected
7	186735	L_2567_2573_1	Connected	Disconnect	Disconnect	Connected
8	187407	L_665_3215_1	Connected	Disconnect	Connected	Connected
9	187797	L_3999_4491_1	Connected	Connected	Connected	Disconnect
10	188976	L_195_4489_1	Connected	Connected	Connected	Disconnect
11	190065	L_3399_3401_1	Connected	Connected	Disconnect	Connected
12	190509	L_664_6371_1	Connected	Connected	Disconnect	Connected
13	192924	L_118_3509_1	Connected	Disconnect	Connected	Connected
14	193152	L_2613_5915_1	Connected	Disconnect	Connected	Connected
15	195675	L_5355_6368_1	Disconnect	Connected	Connected	Connected
16	196998	L_1765_1978_1	Connected	Disconnect	Disconnect	Connected
17	197667	L_462_1140_1	Connected	Disconnect	Connected	Connected
18	198162	L_1451_5177_1	Disconnect	Connected	Connected	Disconnect
19	198606	L_2749_4489_1	Connected	Disconnect	Connected	Connected
20	200157	L_1444_4792_1	Connected	Connected	Disconnect	Connected
21	200427	L_1072_4901_1	Connected	Connected	Disconnect	Connected
22	200559	L_1053_4148_1	Connected	Connected	Disconnect	Connected
23	201093	L_3387_5380_1	Connected	Disconnect	Connected	Connected
24	201189	L_3772_5774_1	Connected	Disconnect	Connected	Connected
25	201687	L_2057_5877_1	Connected	Connected	Connected	Disconnect
26	202434	L_1071_4530_1	Connected	Disconnect	Connected	Connected
27	202578	L_247_2890_1	Connected	Connected	Disconnect	Connected
28	202971	L_2759_3863_1	Connected	Connected	Connected	Disconnect
29	205167	L_691_2890_1	Connected	Disconnect	Connected	Connected
30	205179	L_3262_5355_1	Connected	Connected	Connected	Disconnect
31	206280	L_1025_2212_1	Connected	Disconnect	Connected	Connected
32	207213	L_1140_3097_1	Connected	Connected	Connected	Disconnect
33	207588	L_641_4148_1	Disconnect	Connected	Connected	Connected
34	207999	L_4670_5510_1	Connected	Disconnect	Connected	Connected
35	208020	L_2566_2759_1	Disconnect	Connected	Connected	Connected
36	208149	L_446_2841_1	Connected	Connected	Disconnect	Connected
37	208560	L_691_2379_1	Connected	Connected	Disconnect	Connected
38	210015	L_2057_2085_1	Disconnect	Connected	Connected	Connected