AIR – INTELLIGENT GRID AUTOMATION

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ABSTRACT

The subject of this article is addressed to Session 3, Network operation, control and protection, more precisely to medium voltage automation systems (self-healing) and communication related to grid control. It is about an ELEKTRO (www.elektro.com.br) pilot project that can reduce up to 10% local SAIDI (System Average Interruption Duration Index) with a new concept of grid automation that fits very well its geographical discontinued operational area and cities with a high volume of reclosers. The pilot is operational at Guarujá city, in Brazil.

INTRODUCTION

Since 2000's, ELEKTRO has been investing in centralized control of distribution operation through supervisory and control systems. In 2011, it started to deploy automatic restoration service systems, known as Self-Healing, that elevated distribution automation and telecommunications to an essential level for power distribution business. By the end of 2016, a total of 163 systems are in operation within a park of 1660 telecontrolled reclosers inside operational area, with an amount of 90% of this equipment communicating by GPRS to the Operational Center in Campinas city.

Those types of Self-Healing systems (now called "classic") reduce power recover from 1h30, overall time since the fault until the field teams reach and fix the problem locally, to less than 3 minutes, with no additional cost, reclosers perform both protection and automation roles. This solution works fine, with very good cost/benefit relation, but has limitations considering lower regulation goals in near future and a raising number of reclosers equipment. Limitations are 3 reclosers per system, which cannot achieve high complexity grids, no load management – impossible to apply over seasonal touristic areas or over conductors/transformers with load close to their capacity and communication is done by GPRS cellular network, which has a bad quality service in operational area.

However, always looking for improvements on these systems, ELEKTRO has been evaluating solutions since 2014 and in January 2016 the first project with new solution entered in operation at Guarujá city (supplied by Eaton Cooper), with 80.000 clients. Main benefits of this new system are reduction of power recover from 1h30 to less than 3 minutes, unlimited number of reclosers involved, which can raise number of grid segments, therefore downsizing number of clients per segment, that means a power fault disconnect less clients each event. Another benefit is the load evaluation that allows the system to operate automatically year round, analysing during a fault if the network can support a load transfer without risk, avoiding equipment stressing, increasing its lifespan and recovering as many clients as possible. Another benefit is the private fiber optics communication installed that improves reliability and availability compared to cellular carriers. Also during a fault, cellular towers are susceptible of powering off, disconnecting equipment of the operational center. That does not happen with the private fiber optics communication, assuring that we have 100% control during unexpected power fault events. Guarujá city has now a new fiber optics mesh network developed by Furukawa in Brazil called FIBERMESH, that assure very high availability for critical mission operation companies using up to four redundant ways to transfer data. This was the first project in Brazil with this new system. Results are still being measured, but 10% local SAIDI saving is expected for this project.

As a part of that big picture, in Guarujá city, there is a park of 43 reclosers, controlled by Schneider ADVC2 and Cooper Form6 relays that used to communicate by GPRS and a legacy fiber optics to the Operational Center. Therefore there was an great opportunity to upgrade the system for two main reasons, the legacy fiber optics needed maintenance and the large amount of reclosers did not fit in classic Self-Healing systems (known as Loop Automation or Loop Scheme), that can handle only three reclosers per system (Feeder, Tie, Feeder), without communication between equipment and no load management during Self-Healing operations. Also, GPRS communication, despite lower deployment and operational costs, has a low availability rate in ELEKTRO operational area. Those were the reasons for distribution automation team to start a pilot project of a new fiber optics communication and a new category of Self-Healing system.

The chosen city for that pilot was Guarujá, a reference in tourism in São Paulo state. To keep that status is important there is high quality and reliability power distribution service. The city was chosen for the project

due to large amount of installed reclosers and due to the legacy fiber optics needs maintenance. Instead of using resources for maintenance, it was more financially interesting to install a totally new infrastructure and system assets.

PROJECT OVERVIEW

DA, Distribution Automation, is based on FAULT LOCALIZATION, ISOLATION AND SERVICE RESTORATION. That means in order to have an efficient automation system we need to assure the basics to have conditions to be executed properly. Also, the more segmentation we have along the MV network, more efficient will be the automation. For example, a segment with 5000 clients will disconnect 5000 clients during an outage. By the other hand, a segment with 1000 clients will only disconnect 1000 clients and so on. However the more reclosers we have installed the more complex the control system will be, from the Self-Healing algorithm up to the equipment communication, which needs to have high availability and low latency to assure the system works properly. Considering that, ELEKTRO have installed 85km of a mesh fiber optics network to guarantee the communication among the equipment, a total of 43 reclosers, 3 substations, all linked to the regional office at Guarujá, where is located the automation server, responsible for reclosers automatic operations.

COMMUNICATION SOLUTION

Fiber optics mesh solution was developed by Furukawa and uses a multi-hop AODV routing that routes the package data up to 4 optics different routes, assuring communication even with multiples flaws over the network, as shown in next figures:

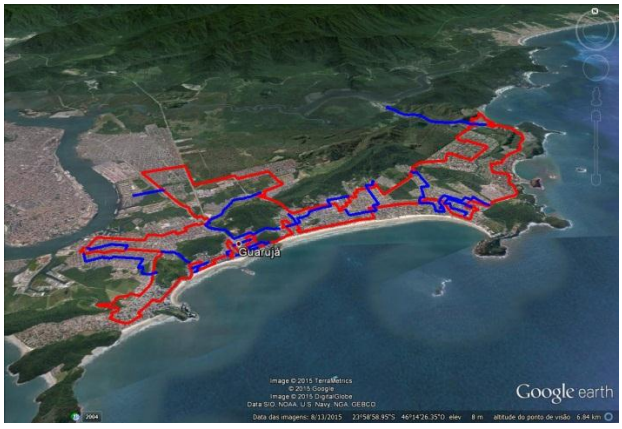

Figure 1. 85 km fiber optics pathway after project deployment on February 2016 – all the data is directed to the regional office where is located the automation server and the data link to the Operational Center in Campinas, 250 km away.

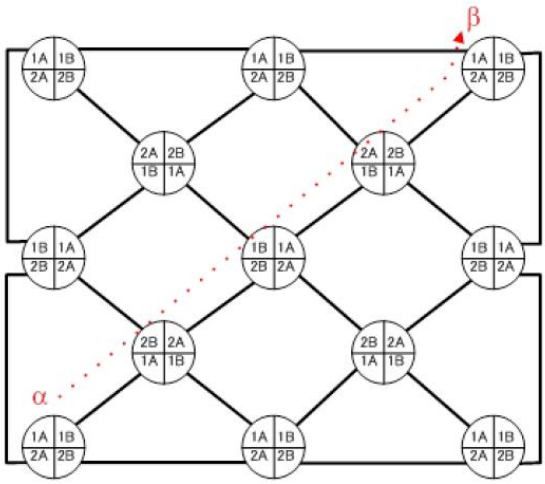

Figure 2. Example of regular data transfer from alpha to beta.

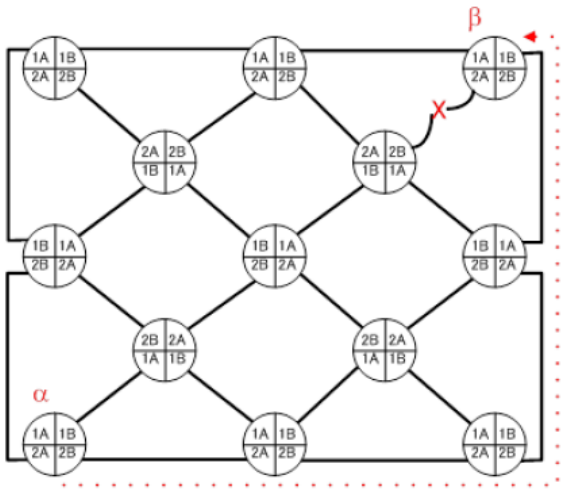

Figure 3. After the cable was brake (X), another route is automatically taken.

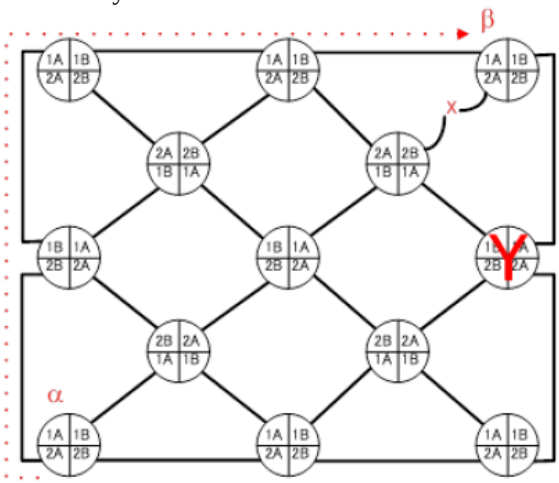

Figure 4. After equipment failure (Y), another route is automatically taken.

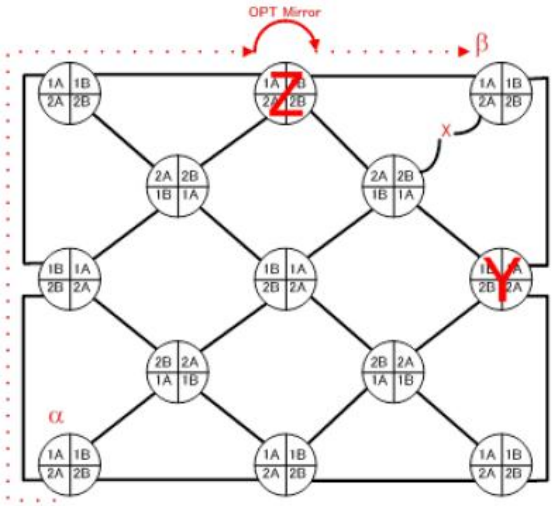

Figure 5. After an equipment power outage (Z), the optical bypass is activated keeping the route alive.

The used equipment is a router, with 100Mbps capacity, developed by Furukawa and named Fibermesh. To guarantee high communication availability, besides its mesh functionality, the equipment has also an optical bypass in case of power outage, so that the route remains alive.

AUTOMATION SOLUTION

After a market study in 2015, we have chosen Yukon Feeder Automation system to control Self-Healing. The key features that we consider to be essential for expansion were easy deployment, no programming needed, only parametrizations and there is a simulator that is possible to perform all the software tests around automatic operations, that gives reliability for field installation on the next step. We adopt this solution as a Substation Centralized or Semi-Centralized, by the fact the intelligence of the system is located at the city where the reclosers are and inside a substation (despite there is no control of the system over the substation, it is only physically located there).

This system is capable of manage a high number of network equipment, since substations transformers and feeder to MV reclosers. It is a great advance compared to traditional system we have installed that works very well for most of the locations but has limitations considering networks with more than one interconnection and load transfer limitations. These systems are named Loop Automation or Loop Scheme, depending on the manufacturer; they can make a restoration of service between two substation feeders, using three MV reclosers.

In the next figures, there are the main functions of the system. These scenarios were generated by its internal simulator, where it is possible to preview situations before real field commissioning. This is an important feature that can avoid a system malfunction due to an erroneous parametrization, also reduces field time commissioning once self-healing and load management logics can be fully tested.

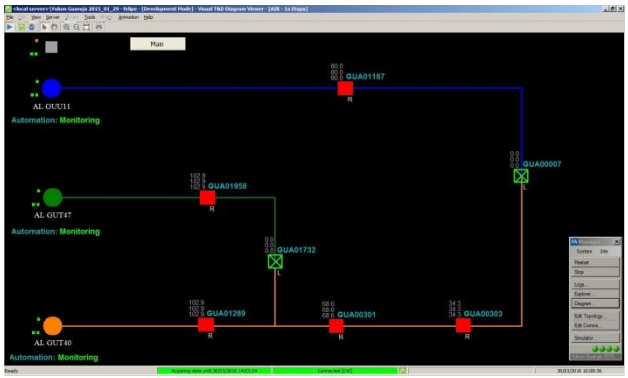

Figure 6. Normal condition. Red squares are normally closed reclosers, green squares are normally open reclosers (ties) and circles are substation circuit breakers.

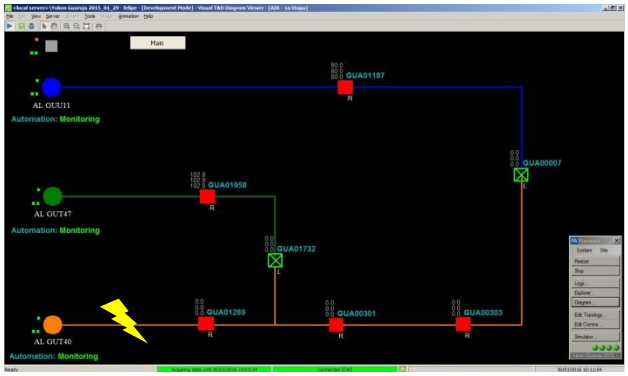

Figure 7. A fault condition is simulated at the yellow lightining.

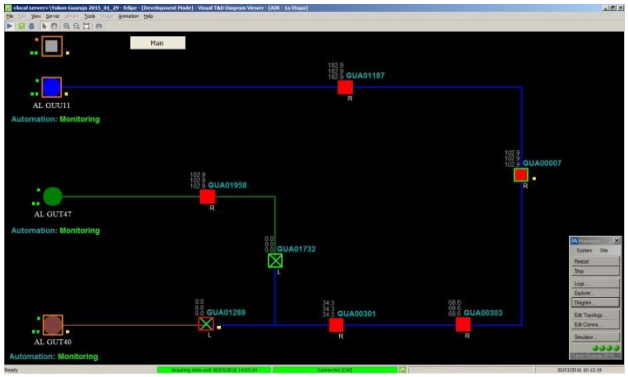

Figure 8. Fault is located, isolated and the service is restored by a tie point.

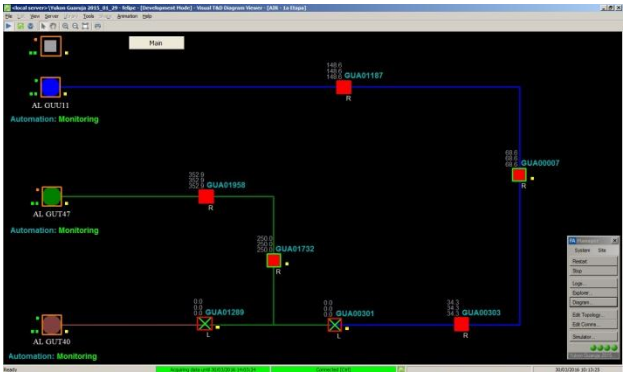

Figure 9. After a while, load increases and another tie is closed to split the load, avoiding an overload at the substation or at a conductor.

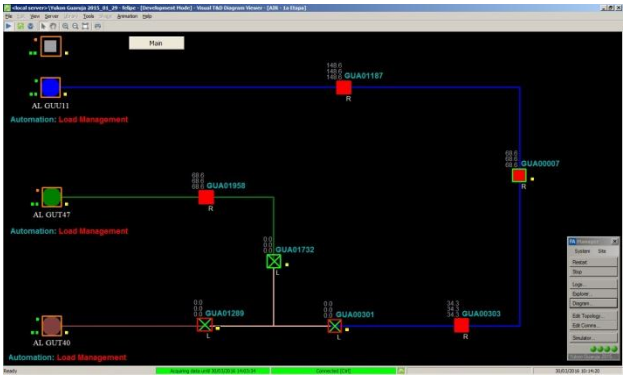

Figure 10. After a while, load increases again and there is no option unless shedding part of the load, avoiding again a substation or conductor overload.

PROJECT RESULTS AND NEXT STEPS

After one month installed there was a considerable gain in mean communication availability of the reclosers, from 77,93% to 99,48%, that represents 79 days more during a year.

Regarding technical indicator SAIDI, it is expected to have a 0,48 hour reduction for the city in 2016, that corresponds to a 10,8% reduction compared to 2015, when SAIDI was 4,43 hours.

The first results are very optimistic and the expansion strategy is to install the new system in cities with more clients and where network are able to receive it. Also financial and technical returns will be considered as priority and telecommunication infrastructure will be changed from GPRS to a private fiber or licensed radio. There will be one automation server per city. For smaller cities, classic systems will keep being installed once they are more cost effective for that scenario.

Figure 11. Expansion strategy for next years. Private local communications and one automation server per city.

For 2017 three more cities are already selected to receive the new system with a company budget dedicated to new automation technology. These cities were chosen based on historical events, SAIDI impact, financial penalties, grid operation flexibility, project global cost, OPEX reduction (vehicles, cellular carriers, maintenance, call center), client satisfaction and equipment lifespan.

Figure 12. Reclosers controllers Schneider ADVC2 panel (left) and Cooper Form 6 (right) with Fibermesh.

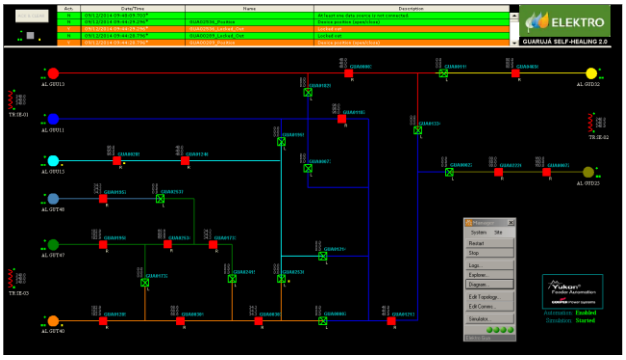

Figure 13. Screenshot from the automation server with part of the reclosers – segmented MV network with many possible automatic operations and load analysis in real-time

Scenario before the project
▪ Number of reclosers: 41
▪ Communication: 18 Cellular/GPRS, 23 legacy fiber optics
▪ Availability: 77,93%
▪ Automation technology: Self-healing "Loop Automation" classic, no communication among reclosers
▪ Maximum of 3 reclosers per system
▪ No load management or load check before operating
▪ Frequent local inspections needed to restore/reset communication

Table 1. Scenario before the project.

Scenario after the project
▪ Number of reclosers: 43
▪ Communication: 85km fiber optics with Furukawa Fibermesh
▪ Availability: 99,48%
▪ Automation technology: substation centralized Self-Healing
▪ Unlimited number of reclosers per system
▪ Real-time load management
▪ Substation integrated
▪ Smart and dynamic automatic operations
▪ Higher network segmentation
▪ Reclosers remote access for parameters maintenance
▪ Almost zero local inspections needed to restore/reset communication

Table 2. Scenario after the project.

CONCLUSIONS

The installation of a private telecommunications infrastructure, replacing cellular carriers, brings, by itself, a significant gain in reliability and availability. All this improvement together with a new Self-Healing technology, there will be a decrease of time to restore the service through automation of process that today operators do manually. Besides, automatic operations are more effective, eliminating unnecessary open/close commands, increasing safety and equipment lifespan. Also, there is an increase of number of equipment involved in Self-Healing, limited to three reclosers (Feeder, Tie, Feeder) in classic systems to an unlimited number, either for reclosers or substation feeders, for consequence, there is higher network segmentation, with less clients per segment. 80.000 clients are covered by new system so far.

REFERENCES

[1] J. Ekanayake, K. Liyanage, J. Wu, A. Yokoyama and N. Jenkins, 2012, *Smart Grid: Technology and Applications*, John Wiley & Sons Ltd, United Kingdom, 111-220