INCREASING QUALITY OF SUPPLY OF EDP THROUGH OPTIMAL AND STRATEGIC DISTRIBUTION AUTOMATION DESIGN

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ABSTRACT
This is a joint paper between EDP Distribuição (Portuguese Distribution System Operator) and KEMA Consulting (Dutch based international consultant, specialized in energy), which describes the decision, development and expected benefits regarding EDP’s Distribution Automation (DA) project.

The DA project team felt the need to innovate in some aspects. Decisions are based on the balance of technical performance (outage minutes reduction) and economical performance (DA deployment total costs), related through the monetary value of Energy Not Delivered. The optimal number of DA devices and optimal locations are determined with two types of new tools.

The first is a heuristic easy to use tool applied for most of the feeders. The second tool is based on genetic algorithms and dedicated reliability analysis (electrical and geographical computer model); it is used for rules extraction and validation of the first tool. Outcomes are also used to benchmark the results per feeder in order to achieve an investment portfolio based on relative marginal benefits. Validation for a pilot network shows that both tools yield consistent results.

EDP intends to start a field pilot before the progressive roll-out.

INTRODUCTION
Anticipating regulation and future improvement obligations, EDP has made a strategic decision to increase the quality of supply of their customers and this goal is well defined in the Business Plan, which also defines strategic priorities like CAPEX reduction, OPEX optimization and Human Resources reorganization. This strong pressure, to improve the company’s performance and efficiency, points naturally towards network and business process automation. EDP started some years ago implementing remote control (and some local automation) in MV networks with very good initial improvements, but then the results started to show technological saturation and limitations of the solution; this evidenced the need for a new system integrated approach.

In this context, EDP launched a complete DA project covering power quality indicators evaluation, new equipment specification (including new local automation and preparing the next step of centralized automation), communication protocol standardization (SCADA and RTUs) and wireless communication infrastructure, quality assurance, development of application guidelines, international practices assessment, commissioning and maintenance policy (risk analysis based as part of the asset management), reliability training and DA roadmap.

Alongside, EDP launched also the Protection System project, involving the definition of the new electrical network protection philosophy, which has a high level of interaction with DA.

THE EDP MV SYSTEM
The MV system consists mainly of 70,000 Km of 10, 15 and 30 kV overhead lines and cables. The 6 million customers are served from about 400 HV/MV substations and 4,000 MV feeders. Figure 1 shows an example feeder. See [1] and [2] for details. The main Quality Indicator used in Portugal is the TIEPI (Time Interruption Equivalent Power Installed), defined as the total of power interrupted times duration, divided by the total installed power. This indicator resembles CAIDI. EDP TIEPI value for the MV system was 111 minutes in 2007. For the economic justification of investments the END (Energy Not Delivered) is used, with a monetary weighing factor in € per each kWh not delivered. In this project a value of 1,50 €/kWh was used, but this value is changing in time.

Figure 1: Example of EDP MV network

DA CONCEPT
The new DA concept is based on Reclosers fault breaking devices, with an auto-reclosing function to eliminated momentary faults. They operate similar to the circuit breakers in the substations and have to be coordinated with...
those according to the protection settings. Using more Reclosers reduces the isolated part of the feeder into smaller sections. When the protection sets limits to the consecutive number of Reclosers in series, some of them are used as Sectionalisers, monitoring line voltage and currents, and isolating automatically faulty network portions (coordinated with the substation reclosing cycles). Timers are configured exactly with the same parameters, independently from the relative Sectionaliser position in the network. Figure 2 gives an example of DA devices placed in a feeder.

**New MV DA devices**

Highlights of the fault breaking device are: “Intelligent” state of the art Recloser, with two automation modes (Recloser and Sectionaliser), to be used in NO and NC positions, equipped with voltage and current sensing, integrated Protection, Remote Terminal Unit and Communication to a Dispatch Centre.

**Fault Circuit Indicators**

In addition to DA-Reclosers, Fault Circuit Indicators will be used to reduce outage time (not outage frequency). The specification states: overhead line mounted, low cost, easy to mount, no communications and local light indication based on dI/dt characteristic.

**OPTIMAL LOCATIONS FOR DA DEVICES**

Since many MV feeders have long lengths, many branches, uneven distributed load and some additional switchgear, rule-of-thumb rules like “use Recloser halfway” are insufficient to achieve least cost investment plans. Because the number of DA devices influences the optimal locations as well, the DA allocation is inherently complex. Figure 3 shows an example. This means that a sequential approach, identify the first and than the next, will lead to sub-optimal outcomes. To obtain optimal and practical solutions a tool called KOLDA was developed. In addition, and in order to validate KOLDA, a second tool was developed, Genodal.

**KOLDA - Heuristic Optimal Location of DA**

Basis for the tool KOLDA (KEMA Optimal Location of DA) is a user-friendly Excel procedure, with minimal input (short easy fill-in tables) and a “top-down step-wise” approach. It can be applied per individual feeder. For each step KOLDA:

- Recalculates remaining END, TIEPI;
- Calculates the total costs, for END and DA;
- Checks marginal benefit of extra DA-device(s);
- Reports chosen location(s);
- Stops when marginal benefits are too low;

The calculations needed are based on simple formulas, like benefit is downstream load times upstream length plus upstream load times downstream length, scaled with several constants, for all combinations. Excel does that hidden from the user and presents only the optimal choice. The stepwise selection of potential points for DA-devices, dividing the feeder in several sections, is based on practical experience, supported with basic calculations. In effect KOLDA is a heuristic tool. Potential points include: cable-line junctions, major T-points, load concentrations (or laterals). KOLDA applies an automatic optimal subdivision of sections with additional DA-Reclosers. During the process KOLDA applies also DA-Reclosers at each relevant N.O.-point. The user obtains a single solution, ready to perform some fine-tuning to local circumstances if he wishes. Typical data is given as defaults, editable for knowledgeable users. The interface of KOLDA is a stepwise consistent overview of resulting decisions and marginal benefits ("decision-friendly"). See figure 4 for a screen shot.
Genodal - Genetic Evolutionary Optimization

For the validation we needed the real optimal solutions. This led to development of another tool, called Genodal (Genetic Evolutionary Network Optimization for Distribution Automation Locations). As said, optimal locations of Reclosers depend on their number; we cannot optimize locations one by one. Defining the general problem leads to:

- Find the optimal solution using cost-benefit analyses
- Optimize the number of DA-devices;
- Optimize the locations of DA-devices;
- Reliability assessment determines quality of service;
- Thousands of feeders to optimize.

Optimizing locations is a combinatorial problem with billions of possible solutions. A Genetic Algorithm solves this problem, essentially as such:

1. Create 1000 random solutions;
2. Analyze all 1000 solutions;
3. Select the best 50 solutions;
4. Create 1000 solutions, based on the best 50. Genodal uses Survival, Selection, Mutation and Inheritance;
5. Repeat from 2.

Repeating the cycle many times until convergence selects stable solutions. This algorithm has been developed by KEMA for internal use in the project. Details of Genodal are described in [3].

FIRST RESULTS AND VALIDATION

First results were obtained for a representative region with 13 MV feeders. The information for the KOLDA engineer includes only upstream and downstream load and length, indication of NO-points, line or cable type, and a one-line schematic. A typical result for a single feeder is shown in Figure 5.

Results for the area show that performance in MV service may improve to a level that is up to 4 times better when compared to initial values based on feeders with no DA at all. TIEPI can be reduced to about 25%, so there is a reduction of 75% possible. The same ratios apply for END and END-value.

The solution in this example needs about 40 DA-Reclosers, including devices for the NO-points. The Total Costs reduce to 47%, about € 1,9 million. That number is a combination of DA-investments of about € 800.000 and an END-value reduction of € 2.700.000. Of course benefits are highly dependent on the initial stage of the already existing DA deployment. Currently EDP already deployed downstream switchgear in some feeders, so the relative benefits will be smaller; EDP will use DA for further improvement.

Validation of results

Validation of results is done to demonstrate that KOLDA may be used when deploying DA further by EDP. The validation used the same input parameters for both KOLDA and Genodal. We compared 3 solutions for each feeder (“solution” meaning an optimal choice for a combination of DA-devices, number and locations, with values for END, Value of END, TIEPI):

- Result of applying KOLDA Application Guidelines by EDP engineers (as it will happen in a near future); a close to optimal “best practice” result;
- Result through Genodal (optimization); this is considered the “real” optimum;
- Recalculated KOLDA-solution using Genodal to validate calculations in KOLDA.

A validation report was compiled with detailed results: number and locations per feeder, resulting values for END, its value €, TIEPI, graphs of optimal solutions per feeder. Comparing KOLDA and Genodal-solutions shows some differences, which are combination of differences in calculations and assumptions (appearing to be small) and limitations or exceptions of KOLDA (explainable). Overall KOLDA and Genodal results are close, as shown in figure 6. Total costs vary ± 10%. This is considered acceptable for an approximating heuristic guideline. Figure 6 gives a comparison for the test area.

The conclusions from the validation are as follows:

1. The Application Guidelines (KOLDA) are suitable and can be properly used for all MV feeders in the representative area;
2. KOLDA’s results are close to the optimum values, considering number of DA-devices, DA-locations and expected values of the indices TIEPI, END and Costs;
3. Therefore EDP may trustfully use KOLDA for the further implementation of DA.

Note in figure 5 that the optimum is not sensitive to small changes. Using KOLDA in practice, this means that there is room for local adjustment without compromising results.
Innovation in DA - the MSDA concept

Compared to the chosen DA concept based on Reclosers and Sectionalisers, DA might alternatively be based on simple non-load breaking switches, communicating with a central “intelligent” unit; we call it MSDA (Master-Slave DA). Fault switching is done with the substation circuit breaker only. Fault isolation is very selectively with many slave devices switching in a non-energized condition. A low price allows many devices, yielding very small sections, and reducing times for fault locating and restoration. Advantages of the MSDA are: it is cheap, more efficient and has larger improvements. Although relying on telecom, it is robust in design; when a slave device fails due to telecom, the isolated section will just be a bit bigger than optimal, when the master device fails due to telecom, the original performance still remains. Only in the (rare) case of telecom faults performance is less improved. Mostly maximum benefit is obtained and safety is never sacrificed. The present disadvantage of the MSDA concept is that it is based on proven technologies in a combination that is new to the energy industry, thus demanding a change in staff thinking. MSDA can be used in combination with the more conventional way of applying DA (local automation), leading to a mixed concept, minimizing risks of telecom and central systems dependency. This may be another step towards Smart(er) Grids.

CONCLUSION

Making the balance of the DA-project so far it can be fairly stated that:

- DA project is properly coordinated with projects for protection and telecom;
- Specifications for DA-devices are available, DA-optimization tools are proven, the implementation roadmap is ready and the key staff is trained;
- EDP is ready to start a field pilot before the progressive roll-out of DA throughout Portugal.

Thus, EDP’s customers may expect future improvement of Quality of Service in due time, supported in DA systems.

Perspective - pilot project

The next step is the field pilot, now entering in the project planning phase.

REFERENCES