

Quality of Service and Economic Assessment of a MV Distribution Network Fault Locator

João Silva




Department of Electrical and Computer Engineering, Faculty of Engineering University of Porto, Porto, Portugal (joaomiguelppsilva@gmail.com)

Abstract

The fault management process consists of several sub-tasks: fault location, fault isolation and service restoration. This work presents an assessment and evaluation of the practical aspects of the Medium Voltage (MV) Fault Locator at the Portuguese Distribution System primary substation. Eighty samples of incidents occurred at different MV network with different characteristics in Portugal were used to determine the time saving on the restoration process as well as the improvement on the quality of services indices. An economical assessment based of the use of the MV Distribution Network Fault Locator available in the Portuguese Primary Substation was done and discussed.

Author Keywords. Quality of Service, MV Fault Locator

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1. Introduction

Under the current performance-based regulation regimes, challenges are posed to distribution network operators to develop techniques that increase quality of service and reduce costs for network operation. The network regulation in Portugal currently incentivizes and penalizes operators that comply or not with their quality of service indexes. This is how performance is monitored, which captures both long and short energy supply interruptions. For this reason there is an increasing interest in the developing techniques and methodologies that can keep these indexes within regulated values and incentives further network efficiency operation strategies. Most customer outages occur in Medium Voltage (MV) networks ([IEEE 2005](#); [Louro et al. 2011](#); [Verho, Nikander, and Jarventausta 2004](#)). Therefore, to improve the quality of service delivered to customers these networks should be the focus of improvement strategies. This paper focuses on the efforts made by the Portuguese MV Distribution operator. The explanation for the number of outages in the Portuguese MV Distribution Network is due to the fact that numerous substations are manually operated, some with difficult access (geographical constraints, distance, traffic), and/or may be subjected to bad weather conditions that results in increasing access difficulty, increases failures and the number of safety issues for operating staff and nearby habitants. In order to improve customer service and satisfaction there is a need to optimize the network operation and the restoration process after a fault. With this in mind, the network operator implemented the fault location, which is expected to play an important role in shortening energy interruption time, which directly affects the quality of services indexes.

2. The fault locator in the Portuguese Distribution Network

In 2010, the Portuguese Distribution System Operator introduced the fault locator functionality, as part of the strategy to improve its network operation (Louro et al. 2011). This functionality is added to the protection units in pre-existing substations and uses the fault location method based on fault circuit impedance measurement. The communication between each substation and the operator is performed by a two-way link between the protection relays and the SCADA application existing in the network control. This way information is instantaneously transmitted between both parties (Leite et al. 2010; Moreira, Silva, and Leite 2011). The fault location is determined at the control center, combining the impedance information from the protection relay and the Network Information System (SIT). The process is illustrated in Figure 1. In case of a fault in the distribution network the current and voltage data are registered by microprocessor-based protection relays and are transferred from the substations to the SCADA system. This information is combined with the network data and as a result a possible fault location is displayed on the network's topology diagram, by coloring the determined location. For determining the fault impedance the fault location algorithm does not consider the Reactance, so the failure is considered purely resistive. The reason is based on historical data that shows that the majority of faults are resistive.

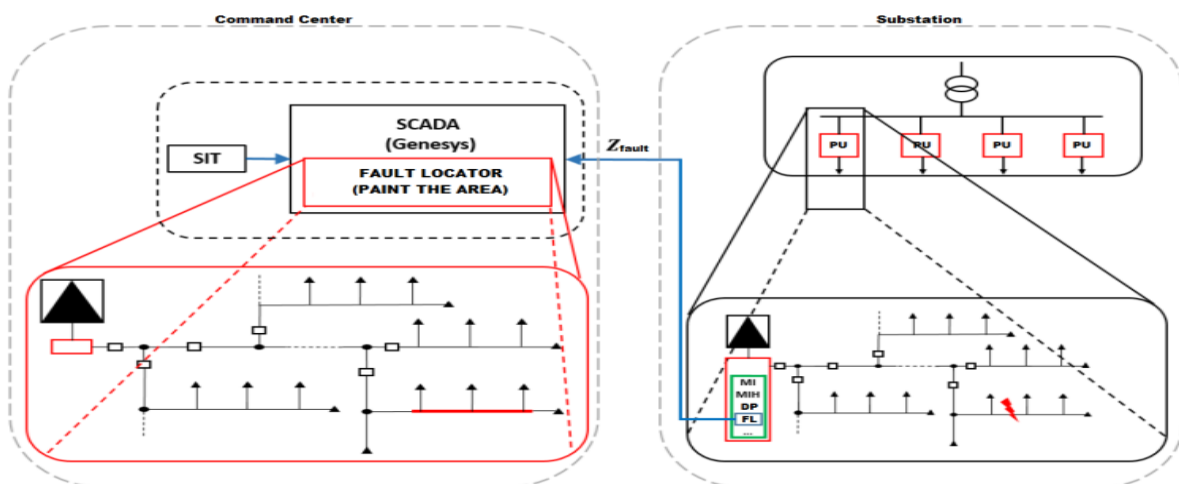


Figure 1: Portuguese MV network fault locator

After a fault location is determined, the faulty network branch is colored by using 10% above and below the found impedance value. In some cases the colored fault location consists of various branches. Based on the determined fault location the network operator proceeds to operate remote controlled protections first, to determine if the identified area by the fault locator is correct. As this is a new technology and due to the complexity of the distribution network, this fault location implementation is in its experimental phase, being used, tested and adjusted until the operator is confident in the technology. Analyzing fault scenarios where the fault locator was used, it was possible to identify 3 typical fault location scenarios (Figures 2, 3 and 4).

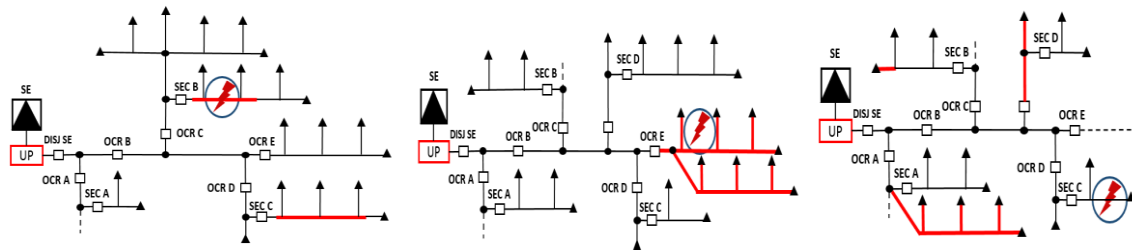


Figure 2: The Fault Locator determines the right fault location, by identifying 2 distinct branches

Figure 3: The fault locator finds the exact location **Figure 4:** The Fault Locator misses the exact fault location (left to right)

The first scenario illustrated in [Figure 2](#) is an example of when the fault locator determines the location correctly, despite identifying two distinct sections. On the other hand, there are scenarios when the location matches exactly the one found by the algorithm ([Figure 3](#)). [Figure 4](#) illustrates a fault location miss. The fault locations' performance is assessed in terms of distance error between the actual fault location and the algorithm's calculations. The fault locator is a tool to support the network operator's decisions. By suggesting a fault location it focuses the operator's actions, reducing the number of maneuvers and interruption time. Although, the confidence the operator has in the tool will affect the tool's overall performance. This behavior was observed in the analyzed sample scenarios. The quality of services of electric power is divided in three components: continuity of supply, voltage quality and commercial quality. The continuity of supply characterizes the number and duration of interruptions of energy supply and is measured on an annual basis through indices. These indexes were used to determine the impact of the fault locator on the quality of service. The indexes are the following: i) Momentary Average Interruption Frequency Index (MAIFI), which is the average number of momentary interruptions that a customer would experience during a given period (typically a year). ii) System Average Interruption Duration Index (SAIDI), which is the average outage duration for each customer served, iii). Average Interruption Time Weighted by the Installed Capacity (TIEPI) which is the equivalent interruption time related to the installed capacity (used in Spain and Portugal) and iv) Energy Not Supplied (ENS) ([Jacinto and Resende 2011](#)). The regulation in Portugal ([ERSE 2013](#)) defines momentary or short interruptions to be an outage of less than 3 minute in duration.

3. Fault location impact on the MV distribution network operation

The fault locator's impact was determined by analyzing 80 real permanent faults samples where it was used. The impact was determined by simulating the operator procedure without the fault locator, which was based on operator experience, and comparing the results against the samples. The impact on quality of service was quantified by calculating the indicators in both cases. Based on the analyzed sample, the fault locator successfully identified the fault location in 63 cases, representing a 79% hit rate and 21% miss rate (corresponding in 17 misses). [Table 1](#) summarize the impact on the quality of services indices when the MV fault locator is in use. Among the 63 successful faults location cases, 23 there were not a SAIFI or TEIPI improvement and in 52 there was no MAIFI index improvement either. However, in 7 cases there was an improvement greater than 40% in the MAIFI index. The use of the fault locator has lead to a reduction of 8 minute per incident.

Quality of Services (QoS) Indices	QoS indices reduction for the 80 incidents considered		
	Minimum	Maximum	Average
SAIDI	1.21%	38.60%	6.29%
MAIFI	8.97%	66.67%	5.31%
TIEPI	1.05%	38.51%	6.28%
ENS	1.05%	28.93%	5.22%

Table 1: The use of MV fault locator impact on the Quality of Service indices

4. Economic impact

To determine the economic impact of the fault locator the following values were assumed:

- Cost of the Fault Response Team (two members): 25 € per hour per member;
- 0.20 € per km travelled;
- Price of Energy not Supplied: 1.5 € per kWh.

The fault locator allowed a reduction of 8 min per incident by the fault response team, which meant energy interruption savings of 6.67€ per incident. There were savings on the distance traveled by the response team, which were on average 7.2 km per incident, which lead to a total travel saving of 1.8 € per incident.

To calculate the Energy not Supply without fault locator (ENS_{wfl}), Equation 1 was use, which resulted in 94.5€ saved per incident.

$$ENS_{wfl} = \frac{TIEPI \times ENS}{T} \quad (1)$$

Where ENS stands for Energy not Supply with fault locator, TIEPI stands for Equivalent Interruption Time and T stands for Time Interval.

The total average savings are 103 € per incident. Knowing that the average number of incidents per year in Portugal in the MV network is about 1,000 incidents, the savings may go up to 103k€ per year. These results show that there are definitely advantages in using the fault locator technology firstly because it uses existing equipment in the network (protection units in the substations and the operator systems) and secondly because it leads to economical savings and energy service interruption reduction.

5. Conclusions

Given the incidents sampled, the MV fault locator successfully locates the fault in 79% of the times. From these 63 cases, only 64% lead to improvements in the quality of service indices analyzed (SAIFI, MAIFI and TEIPI). The use of the fault locator has lead to a reduction of 8 minute per incident, helping increase service quality and fault management, which again reflected in improvements of SAIDI, TIEPI and MAIF indices. The fault locator may lead to savings of 103€ per incident. Additionally, the success in locating faults in the network contributes to increasing the life cycle of the network's assets. As faults are located in less time, which means that equipment is subject to abnormal operation for a shorter period of time. As this is a new technology and due to the complexity of the distribution network, this fault location implementation is in its experimental phase, being used, tested and adjusted until the operator is confident in the technology. These results prove to the operator that there are advantages in pursuing this development.

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