

STUDY OF SYSTEM'S VULNERABILITY DUE TO SHORT CIRCUIT FAULTS CONSIDERING PROTECTIVE DEVICES

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Abstract— The purpose of this study is to determine vulnerable areas of a pilot circuit before failure. The sags are characterized in magnitude and duration as a consequence of faults. The evaluation of the sags and the time of operation of the protection are made in the nodes using simulation tools. In this way we can find the most vulnerable areas of the system that will allow the Network Operator (NO) take action to improve power quality. One way in which the NO could improve the power quality is through the protection coordination.

Index Terms-- Sags, SAI, Relays, Reclosers, Fuses, nodes, vulnerable, protection coordination, power quality, network operator (NO), short circuit.

I. INTRODUCTION

This paper summarizes the study of vulnerability of a network of medium voltage distribution (13.8kV). This will be for balanced and unbalanced electrical faults, characterizing voltage sags in magnitude and duration.

On the eve of a regulatory framework in Colombia, which includes the sags, it becomes increasingly important to characterize and understand the vulnerability of electric systems for these events.

It is possible that the Colombian law will apply a classification as it is shown in the figure 1. Where: type of events Moderate (M) should be hold by users, type of events Severe (S) are negotiable between the operator and the users and Critical events (C) are total responsibility of NO. Therefore, if it is know the division of these events in voltage in these three groups in an electric network, it could help to make decisions to improve power quality.

In the present paper it will be study the possibility of improving the power quality by using the ability to adjust the operation of some protective devices, such as overcurrent protection relay.

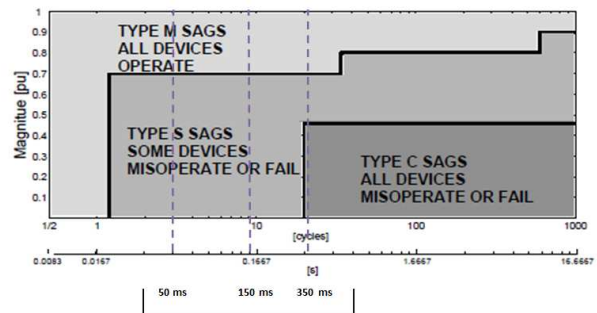


Figure 1: Classification M, S, C [1]

Similarly, the Sags Activity Index (SAI) has been applying to determine the vulnerability of a node in comparison to others.

The interpretation of the SAI it could be seen in table 1.

Range SAI	Interpretation
$1,00 \geq IAS > 0,70$	Acceptable
$0,7 \geq IAS > 0,25$	Possible customer conflicts
$0,25 \geq IAS \geq 0,00$	Unacceptable

Table1: Interpretation of SAI values [1]

II. SYSTEM DESCRIPTION

This study was performed in an electrical distribution system with a rated voltage of 13.8kV, as shown in Figure 2. This system consist of an electrical substation 110/13.8kV and 13 circuits.

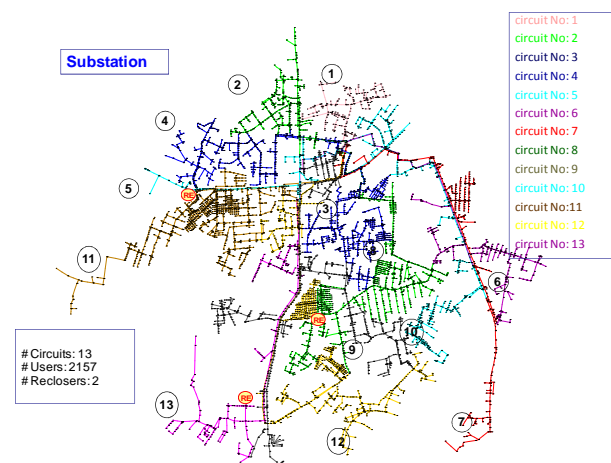


Figure 2: Diagram of substation

The main electrical characteristics of the substation are:

- It is connected by three lines of 110kV.
- The configuration of the substation from the side of 13.8 kV is double bar.
- It has two transformers of 50 MVA connected in DYN11 solidly grounded.
- The short circuit current in any of the bars of 13.8 kV when the coupling is closed is 24 kA (With the two transformers operating).

The main electrical characteristics of the feeders are:

- 13 radial circuits in 13.8 kV.
- Lines are modeled in sequence components taking into account the effects resistive and capacitive.
- The circuits have an average length of 6.82 km.
- Loads are modeled as constant impedance with a three-phase star connection.
- Users of this system are residential and industrial.

At the substation there are three protection elements that are capable of breaking the circuit under load, which are:

- Relays (13, one for each circuit)
- Reclosers (3)
- Fuses type VS and K

III. CONTENT

A. Simulation of faults

The faults were simulated in PSS@SINCAL in an automated manner. Three-phase, Two-phase and One-phase ground-fault were made (solid earth fault) . These failures were performed on all nodes in the system (7236), where results were observed in the nodes of interest (loads).

B. Duration of events

The classification of the events according to their duration is shown in Table 2 and Figure 3.

RANGE (ms)	CUMULATIVE FREQUENCY	NEGATIVE CUMULATIVE FREQUENCY
0-50	23%	100%
51-100	29%	77%
101-150	51%	71%
151-200	64%	49%
201-250	73%	36%
251-300	83%	27%
301-350	88%	17%
351-400	91%	12%
OVER 450	100%	9%

Table 2: Total fault clearing time

The expected value of clearance times of events is 150 milliseconds; this can be seen in Figure 3. Moreover, in Table 2 it could be seen that 77% of the events are clear in times exceeding 50 ms and 12% are cleared at times greater than 350 ms.

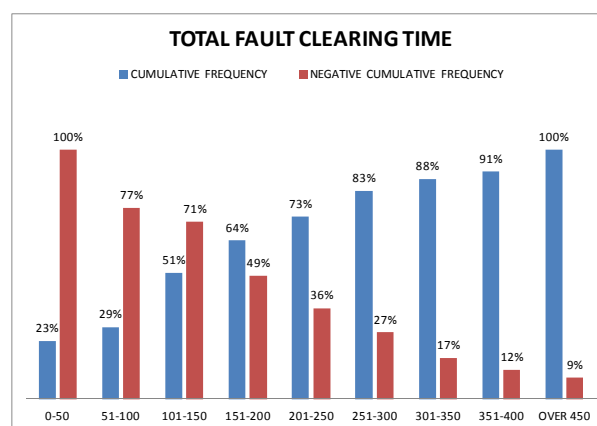


Figure 3: Total fault clearing time

C. Sags analysis

A Table 3, analysis could be made as following:

Of the total simulated faults, regardless factors such as the place where made, robustness and configuration of the system, 45% of faults can cause noticeable sags in the network.

From the simulated faults throughout the system, the relay clears the 79.9% of faults, followed by fuses with 17.3% and reclosers with 2.8%. In the case of the bar at the substation, these values decrease to the point which there is not sags type C.

The sags: M, S y C have a presence in the system of 65%, 33% y 1% respectively.

D. Classification of SAI

As it is indicated in Table 4, it could be made the following analysis:

71% of users have a SAI acceptable. The 6% have potential conflicts with users and 21% are unacceptable.

Users more vulnerable to failure are shown in Figure 5 and represent 22% of the loads. These users belong to the circuits 8, 10 and 12 as shown in Table 5.

EVALUATION OF SAI	System
Acceptable	72%
Possible customer conflicts	6%
Unacceptable	22%
Total	100%

Table 4: Classification of SAI for the entire system

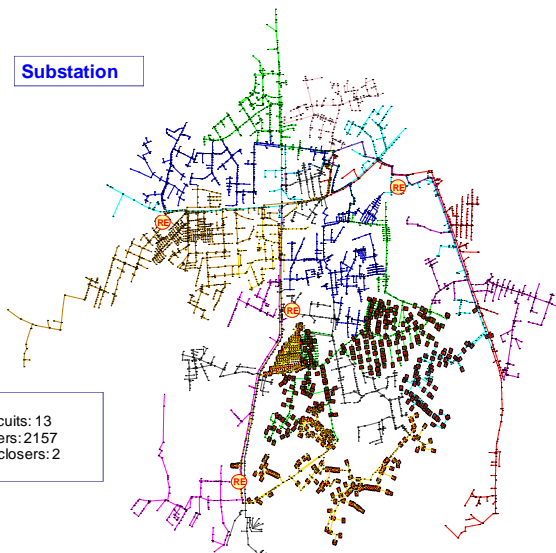


Figure 5: The most vulnerable points of the system

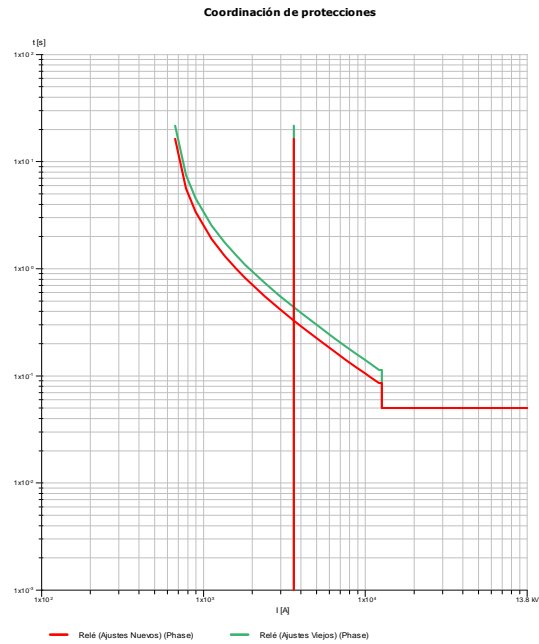


Figure 4: Characteristic curves of a relay, located at the beginning of each feeder

IV. CONCLUSIONS

Regarding to the duration of the events and the conditions of the simulated distribution system (including the protection coordination), the expected value of the events is 150ms. 76% of the events last 50 ms or more and events around 350 ms do no reach more than 10%.

The 2/3 parts of the simulated faults generate sags type M and 1/3 type S in all the system.

# SAGS/# EVENTS		45.0%											
SYSTEM					SUBSTATION				FARTHEST NODES				
	RELAY	RECLOSER	FUSES	TOTAL	RELAY	RECLOSER	FUSES	TOTAL	RELAY	RECLOSER	FUSES	TOTAL	
M	48.3%	1.0%	16.5%	65.8%	61.7%	0.9%	16.1%	78.7%	50.4%	0.8%	15.3%	66.5%	
S	30.7%	1.8%	0.7%	33.2%	21.3%	0.0%	0.0%	21.3%	30.0%	1.6%	0.7%	32.3%	
C	1.0%	0.1%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	1.1%	0.1%	0.0%	1.2%	
TOTAL	79.9%	2.8%	17.3%	100%	83.0%	0.9%	16.1%	100%	81.5%	2.5%	16.0%	100%	

Table 3: Classification M, S and C for the system, substation busbar and farthest nodes

Given the robustness of the network, 45% of faults are capable of causing sags elsewhere in the system. If the system were more robust, then the range would be higher and would have a greater number of failures that generate sags. If the system were less robust, then the number of faults that generate sags will be less.

Due to the non-existence of relays that operate with lower times than 8.33ms, any event type M manages to be outside the definition of voltage sags. For the same reason, the events type S-cannot over pass M in the delimited strip by time 21ms as the minimum time of operation of the relay is 50ms (see Figure 4). However, it could be allows sags type C and S by reducing the time of coordination of the relays with fuses and recloser as it show in the figure 6.

Protection Device	T...	Fault	Path	Zone	T...
Relé (Ajustes Nuevos)	OC		Phase		0,327 s
Relé (Ajustes Viejos)	OC		Phase		0,436 s

Figure 6: Operating times of the relays

Figures 4 and 6 shows that a collapse type C (relay with old settings), you can turn a type S implementing new settings to the relay. Therefore, it is of great convenience to the Network Operator reduce the operation time of the relays as indicated by Figures 4 and 6, as would avoid being penalized by the introducing regulatory frameworks in the country.

71% of users have conditions of acceptable power quality because they are not facing type C sags. This leads to have an Index SAI valuation over 0.7. 28% does not have it. This means that it generates conflict with the users and this is unacceptable.

Circuits with short circuit levels (less than 2.3 kA) which correspond to the last six of Table V have similar length and short circuit level measured in the last user. However the circuits 8, 10 and 12 are the most vulnerable in the system because they do not have reclosers to clear faults in less time. Figure 5 shows that the most vulnerable zone of the system is that corresponding to these circuits.

If the technology which works with relays will change, it could improve the performance of the protections. This will allows a low coordination time between the elements of the protection. Therefore this will help to improve the quality of the power in a system, due to this allow to have shorter sags in time and be less severe for the users.

Finally, if we want to improve the vulnerability of a circuit, we should install a protection element as a recloser.

Circuits	Short circuit capacity in more distant loads (A)	Length (km)	Recloser
Circuit 1	7365	2,79	No
Circuit 2	5905	3,87	No
Circuit 3	4334	4,75	No
Circuit 4	3465	5,61	No
Circuit 5	3464	6,22	No
Circuit 6	3378	6,69	No
Circuit 7	2572	8,31	No
Circuit 8	2338	8,25	No
Circuit 9	2243	7,06	Ok
Circuit 10	2069	8,15	No
Circuit 11	2054	7,48	Ok
Circuito 12	1946	9,81	No
Circuito 13	1909	9,24	Ok

Table 5: Short circuit capacity in more distant loads

V. REFERENCES

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