IMPROVEMENT OF SAIDI AND SAIFI RELIABILITY INDICES USING A SHUNT CIRCUIT-BREAKER IN UNGROUNDED MV NETWORKS

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ABSTRACT

This document has been created after the report published at CIRED in 2005, 2009 and 2011 (Shunt Circuit-Breaker in Ungrounded Medium Voltage Systems – ref. 0028, 0875 and 0182), ref.[1].
Established in the cantons of Fribourg, Neuchâtel and Vaud, the Swiss company Groupe E currently operates its medium voltage networks in ungrounded mode.
To eliminate insulation faults, in the case of single line-to-earth fault, we use shunt circuit-breaker systems with unipolar closure connected to the MV busbars of our substations.
This system facilitates fault elimination without the necessity to open the faulty line. As for any extinction or current limitation systems, Petersen coil or earth resistance, the power quality is affected.

Initially we had favoured the operation of our networks without interruption, acting solely to eliminate fugitive ground faults, occurring in our aerial networks.
After this stage and with an increased rate of installation of the arc suppression systems (shunt circuit-breaker), we wanted to extend this philosophy across our networks, including underground systems, with the aim of maintaining operational continuity in the event of permanent ground faults

According to our estimations, this extension of the basic application must improve the quality of our supply. An improvement can be seen from analyses of the events recorded over five years and the calculation of the IEEE continuity indices, ref.[2].

However we also envisage some operating constraints. The changeover to the new operating method cannot occur without a review of the protection settings. It will also be necessary for certain installations to be adapted including the operating and intervention processes during the course of the fault clearance work installations.

The purpose of this study is to verify these suppositions.

ASSESSMENT AFTER FIVE YEARS OF OPERATION

Per our disturbance statistics, we count almost 300 faults of all types per year, of which half of them are ground faults.

From the latter, 72% are faults of a transitory nature. Using our previous operating method, the insulation faults detected in our MV distribution networks were eliminated by opening the line concerned. We wanted to reduce the effect of the occasional outages by installing shunt circuit-breakers in the MV busbars sets and, in an initial step, developed this technique only for our aerial networks.
The question then arises to extend the application to the underground networks and to pursue the continuity of the supply in the case of a permanent fault (28% of the ground faults). The improvement potential is then significant:

- Elimination of the faults, no degeneration of the unipolar fault to a short-circuit
- Securing of the fault zone (increased fault current)
- Stabilization of the network voltage (suppression of the transitory regimes)
- Improvement to the continuity of supply

It must be remembered that in a cable, a ground fault degenerates very quickly to a short-circuit between phases unless we reduce the current at the fault location very quickly, (for example with the aid of an extinction or current limitation installation). According to the studies made, the probability that this type of fault appears is close to 80% of all faults; the statistics then indicate that in 15% of cases, the fault degenerates to a two-phase short-circuit, and in 5% of these even to three-phase faults ref.[3].

The extension of the method of extinction by shunt circuit-breaker to underground systems and the pursuance of supply continuity can thus present technical or operating constraints. However, according to our estimations, it can also improve the quality of our supply.

IMPROVEMENT OF CONTINUITY OF SUPPLY DEPENDING ON METHOD

<u>Restricted operation mode: extinction of only fugitive ground faults; reminder of the operating mode.</u>

On the appearance of a ground fault, the line directional protections start and signal the presence of the fault.
Simultaneously the shunt circuit-breaker rigidly grounds

the affected phase at the HV/MV station, approximately 0.3 seconds after detection.
Two distinct cases can then occur:

1. The zero-sequence current is extinguished by the action of the shunt
2. The fault is metallic and a load current is established across the shunt.

In the first case, an automatic shunt opening is actuated after 5 seconds.
If the ground fault is permanent, the line circuit-breaker eliminates the fault opening the feeder.

In the second case, discrimination takes place by the detection of the permanent load current (active component of the IO current, exceeding approximately 25A) and the definitive opening of the shunt circuit-breaker.

Impact on the supply reliability

In this initial operational phase, we notice that the enhancement concerns principally rural networks and mainly, though with only slight effect, the MAIFI index (Momentary Average Interruption Frequency Index) according to the classification of short interruptions less than three minutes. This is quite justified since faults of this type occur principally on overhead grids, although the number of short duration faults is more important than those of long duration.

It can therefore be assumed that the application of this method favours the supply quality perceived by the customers not subject to short duration outages but having little influence on the measurement index.

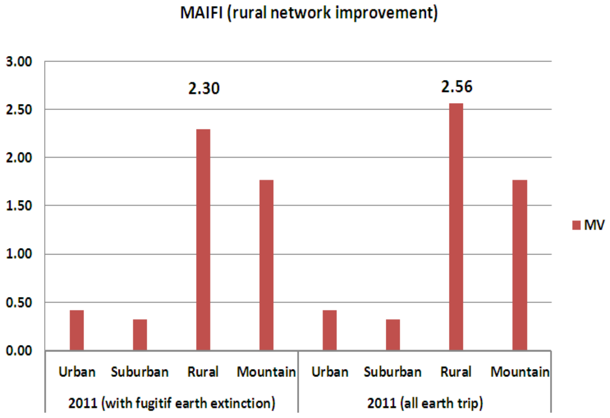

Figure 1: influence of the shunt circuit-breaker on the MAIFI continuity index (extinction of the transitory faults only in aerial networks)

<u>Extended operation mode: protection of the underground networks and maintenance of continuity of supply during permanent ground faults.</u>

The selective logic is identical to that used in restricted mode. However, to prevent a ground fault degenerating to a short circuit, the system must respond more quickly than in the preceding case. The adjustments to the protection relays must be revised.
The action of the shunt circuit-breaker is then instantaneous: reduction in the mechanism reaction time is approximately 60 to 80 ms. The maintaining of the supply can then take place. As with restricted operation, the fault current is greatly reduced at the fault location, sufficiently to avoid a breakdown of the element.

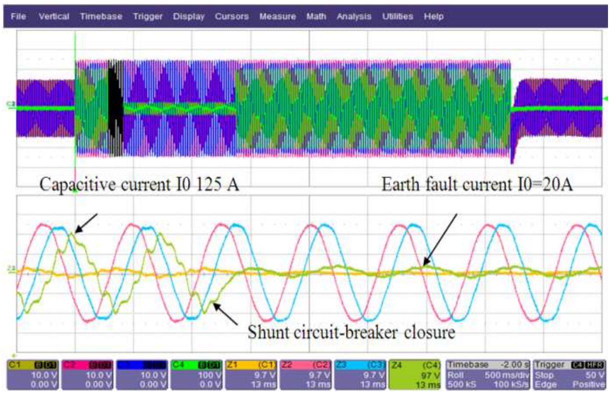

Figure 2: Permanent fault in a network with insulated ground, voltage 18 kV, reduction of the capacitive current at the fault location (test carried out with trip at 0.3 s)

As the distribution networks are provided with multiple opening points fitted with line circuit-breakers, the operator can then manually or automatically insulate the faulty area before it suffers a breakdown, destruction of the element and interruption of the supply.

The extinction is only possible if the energy dissipated in the electric arc is relatively modest, permitting a regeneration of the electrical insulation (air or insulating material).
If the current at the fault location is too great, statistics show that 92% of the ground faults degenerate as described and bring about the interruption of the supply before the operator is able to isolate the faulty section.

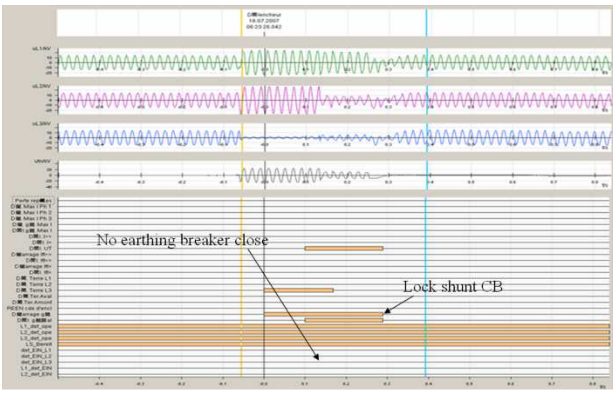

Figure 3: Ground fault degenerating to a short-circuit in a network with isolated neutral, voltage 18 kV

Impact on the supply reliability

An analysis of the performances of the extended method shows an improvement in operational continuity in urban and suburban networks, directly influencing the SAIFI indices (System Average Interruption Frequency Index) and the SAIDI (System Average Interruption Duration Index). Although the probability of a fault in an underground network is less than in an overhead one, the improvement potential is more significant than in the previous case because of the greater customer density.

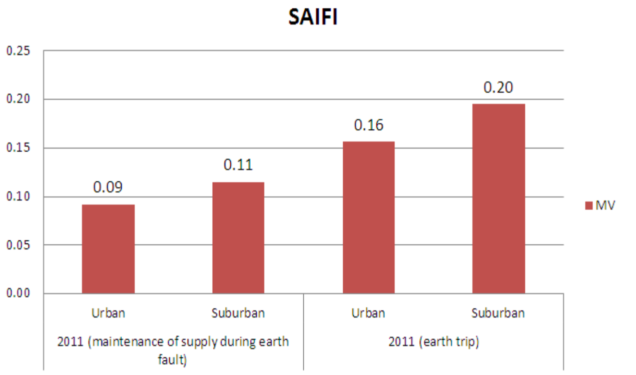

Figure 4: Improvement of SAIFI and SAIDI indices in the urban and suburban networks, by using extended method of extinction (maintenance of supply)

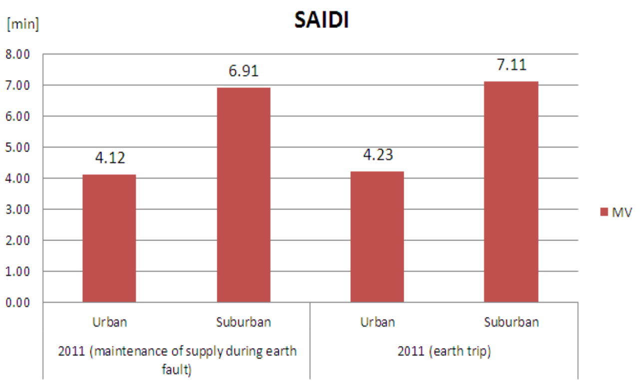

Figure 5: Improvement to the SAIDI index of urban and suburban networks by the application of the maintaining of the voltage in the case of a ground fault.

OPERATIONAL CONSTRAINTS

Compliance with the safety standards applicable to high voltage installations must be guaranteed. In the event of the functioning of a shunt circuit-breaker in closed operation with permanent fault, values of contact and step voltage must not exceed the permissible limits, ref. [4].

This requirement involves ground connectors with low impedance values which is generally the case in urban networks but difficult to realise in rural overhead lines (grounding of the MV/LV stations on masts, switch-disconnectors, lightning arresters on posts etc.). When the periphery of an urban underground network extends to the overhead networks, it is possible – if the conditions detailed above are not satisfied – to realise the definitive tripping of the aerial sector when permanent faults have occurred precisely on this latter part.

This constraint compels us to conclude that the method of maintaining the supply can only be understood for entirely underground or mixed networks, with the overhead sector guaranteeing the non-dangerous fault voltages. In the opposite case, permanent faults located in the aerial part must be eliminated by the system isolation circuit-breakers whilst transitory faults are still eliminated by the shunt circuit-breaker.

Repair of the faulty section in the case of a permanent fault

With maintained operation on a zero-sequence fault, a capacitive current is generated and concentrated in the ground connectors of the source station, but a part can be taken back to the fault location. This characteristic is not to be neglected as the localisation operations of the faulty sector and its insulation are live.

It is not recommended to proceed with these operations via the actions of the aerial switch disconnectors, as these are not designed to stand these electrical constraints. Although the closure of the shunt circuit-breaker permits this action, it is more appropriate to use the line circuit-breakers.

The advantage of maintained operation is that the duration of the power cut necessary to realise the repair work is limited solely to the faulty section. Consequently the number of customers finally affected is reduced.

In the event of the restricted method being applied solely to fugitive faults, a power supply cut is initiated in the presence of a permanent fault, 5 seconds after the appearance of the fault (faults degenerating to a short-circuit are eliminated instantly by the line circuit-breakers). Thus the intervention teams work from start to finish without the presence of voltage.

For safety reasons, mixing the two operating philosophies and the repair is prohibited.
This reflection prompts us to state that maintained operation in the case of a permanent ground fault can only be understood when our MV networks have achieved a sufficiently high installation rate of the extinction system. At that time, a development of our operating philosophy is envisaged.

CONCLUSION

By the application of the continuous operation philosophy during permanent ground fault, the ground fault extinction system improves the continuity of the service. Moreover, in the underground networks, it avoids degeneration of ground fault into a short circuit.

However, some precautions have to be considered:

- Adjustments of the protection system must be adapted to new references
- Earthing system of electrical equipment must be improved to guarantee the safety of persons and property.
- Overhead lines have to be separated from underground systems.
- Intervention procedures must be adapted during breakdown localization operations.

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