

# ENERGY SUPPLY QUALITY: A GLOBAL AND INNOVATIVE RESPONSE.



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*This article present GLOBAL and INNOVATIVE solutions worked out to answer the concerns of ENERGY DISTRIBUTORS operating three-phase networks in terms of CUSTOMER SATISFACTION, SAFETY and RESPECT FOR THE ENVIRONMENT.*

- *GLOBAL: they concern both the handling of the MV neutral of HV/MV SUBSTATIONS and the design of MV/LV STATIONS.*
- *INNOVATIVE: With the aim of providing solutions at optimum cost, this overall vision leads to the calling into question of conventional equipment. Initiated by Electricité de France, the themes discussed remain sufficiently general for the reader to be able to extract from them the aspects more specifically relevant to his concerns.*

## 1) Energy distributors' commitments.

Attaining a high level of customer satisfaction must be achieved within the context of a general cost-cutting policy. While regulation bodies publish comparative statistics concerning the numbers and durations of power failures, distributors must manage their network with a margin for manoeuvre limited by the amount of investment which can be envisaged and their operating constraints.

One major concern is human safety, which is guaranteed in accordance with IEC recommendations 60479-1 "effect of current passing through the human body". In addition to these basic safety requirements, there are requirements concerning the quality of the supply, such as the values of overvoltages of a duration of less than 5s transmitted by coupling of the MV/LV earths, which IEC 60364-4-44 limits to 1430 V ( $U_0 + 1200$  V). European Directive 89/336 concerning Electromagnetic Compatibility (EMC) makes it compulsory to comply with the interference limits and the insulation and emission levels of the equipment. IEC 60664-1 and 60071-1, dealing, for LV and MV respectively, with coordination and levels of insulation in accordance with operating constraints, complete this brief overview of standards.

## 2) Burial of lines in a rural environment: A decisive improvement.

Overhead lines, exposed to severe weather conditions, are the subject to momentary faults, untimely MV fuse blowings frequently attributable to short-circuits on the links between the line and the transformer. Growing awareness of the need to protect the environment and people's increasing sensitivity to their living environment make the visual impact of pole-mounted equipment difficult to tolerate. Taking a risk – however minimal – of an explosion or fire in a wooded environment or dielectric extrusion – is now seen as grounds for refusal by legislators. In addition to this there are the drawbacks of old installations with large numbers of complicated items of equipment, and disproportionate LV network lengths with respect to MV lines, for oversized powers distributed on multiple outputs. Whenever the accessibility and the nature of the soil permit, the progress of trench cable laying automation leads to Costs similar to those of building overhead networks. The additional savings obtained when taking into consideration the reduction of energy losses, and the simplification of maintenance and operation, tip the scales clearly in favour of starting wide-

scale burial programmes. Thus, in France, the proportion of buried networks has gone from 20 to 30% in less than 10 years, a change accelerated still further by the application of a legal requirement which prohibits the building of new overhead lines in densely-populated areas.

## 3) Fault current management.

The increase in the proportion of buried networks, because of their high capacitance, makes compliance with all the constraints listed in paragraph 1 problematic, whether in an isolated neutral system or a system with solidly earthed neutral. One standard means of improvement consists in compensating via an induction current, by connecting the neutral of the MV network to the earth via an Arc Suppressing Coil (ASC).

### 3-1) Drawbacks of operation under maintained fault

The question then arises of the advisability of maintaining the supply when a fault does not disappear "by itself". While one might at first be inclined to consider such an arrangement satisfactory in terms of customer satisfaction, a more in-depth look into the question leads one also to consider constraints such as the rise to the voltage between line withstood by the healthy phases, for periods of up to 2 hours: on old networks whose equipment has not been sized accordingly, the occurrence of a double fault degeneration then necessarily leads to tripping on the HV/MV substation. To avoid dangerous pace voltages, the poles must be earthed by the line equipment connectors, provided of course that they are accessible. Finally, high capacitive currents do not always allow the acquisition of machines sized for permanent operation to be envisaged from an economic point of view.

### 3-2) Guiding principles

- Adopt the resonant earthed system by Arc Suppressing Coil so that the majority of faults, now less energetic, are converted into self-extinguishable phenomena.
- Eliminate the triggering of the zero phase-sequence protections of the HV/MV substation on these "transient" faults
- In the now rare cases of permanent faults, do not maintain the supply but endeavour to locate these faults and eliminate them rapidly.

### 3-3) Responses to these choices

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**3-3-1) Step-tuned Arc Suppressing Coil, adjusted by means of vacuum contact breakers, actuated by a monitoring and control system linked to a system of permanent examination of the network**



*Example of machine in service, sized for neutral currents between 80A and 600A in 40A steps, applied for 10 seconds. A minimum active component of 20A is always retained to ensure the functioning of the current protections.*

Of compact design and unaffected by bad weather, the technology used provides good mechanical strength and instantaneous silent configuration. The offer includes the coiled equipment, its electronic interface and the study of the impact on the HV/MV substation.

## **3-3-2) Directional fault detectors**

As the current of the defective MV feeder may present a value lower than the purely capacitive currents passing through the healthy ones, a new generation of detectors based on comparison of the phases, in transient state, between current and voltage according to their position upstream or downstream from the fault, replaces the old models based on current measurement.



*Directional fault detector in overhead version: a major component in the general system for improvement of supply quality*

**3-3-3) Programme of preventive and corrective actions.** Good management of the deployment of directional fault detectors distinguishes between their use for:

- Preventive operations: With the recording of momentary faults, sensitive portions of the network are identified and planned maintenance operations help to reduce the probability of occurrence of a permanent fault. They help in line burial decision-making.
- and Corrective operations: Placed near remote-controlled manoeuvring devices, the information of the versions designed to be insensitive to momentary faults, sent to the remote control centre, makes interventions quicker and more effective. For the range designed for underground networks, an electronic card option is integrated in the MV panel switch remote control module. Visual indications allows the teams to be guided rapidly in all cases.

## **4) Means to rapidly restore the power supply.**

Action in the field will be a decisive complement to the upstream corrective measures. For this purpose, mobile substations on trailers enable rapid interventions in complete safety. The TAPIR (Temporary Power Supply Transformer) comprises a 400 kVA transformer, an attached cabinet containing protections and controls, together with the cable drums



*Complete version used by Electricité De France centres. The pre-cabled transformer and cabinet assemblies can be supplied separately for later assembly.*

The changing of an MV/LV transformer is now possible without any interruption of the power supply. Easier to handle and less noisy than a generator, this mobile substation can remain in position for longer periods in a secure area without disturbing residents. It also operates as a step-up transformer, in which case it supplies an overhead transformer group isolated from its HV/MV substation. A voltage protection against phase – earth faults, adapted to temporary isolated neutral system operation, guarantees total operating safety.

## **5) Elimination of damage which may be caused by defective MV/LV transformers.**

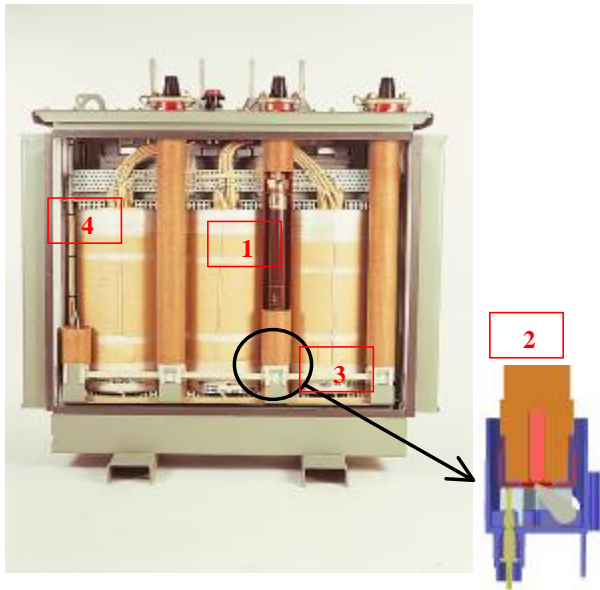
### **5-1) Objectives**

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Any manifestation of a failure must remain confined within the equipment to eliminate risks of explosion or spraying of oil. By studied coordination with the protections of the HV/MV substations, power supply interruptions are limited solely to those customers directly dependent on the faulty transformer. The guarantee of disconnection of the three phases of the network in the event of a failure rules out the possibility of a dangerous degeneration of an internal single-phase fault, and prevents the supply of abnormal LV voltages, which are potentially damaging for sensitive receivers.

## 5-2) Designing MV/LV transformers differently through the integration of a protection - cut-out function.

The system presented guarantees adaptation to the resonant earthed system by taking into account low-energy earth fault scenarios (possibility of disconnecting on values of 5 A after 250 ms). An additional guarantee of the effectiveness and reliability of the disconnection system is provided by the choice of direct handling of the fault current and not of its consequences such as overpressure or low oil level..



Cross-sectional view of an oil transformer with built-in protection - cut-out function patented by TRANSFIX. 3 fuses with strikers (1) designed for handling high currents, located in the wells filled with oil, act on a disconnection body (2), which, by mechanical coupling (3), causes the disconnection of all the phases even if only one of them is faulty. An additional striker (4), integrated in the earth circuit, enables cut-outs on low currents.

## 5-3) Association of an LV protection

The time / current characteristics of the downstream protection must be taken into account in the general coordination plan, so that only a fault occurring in the transformer can cause its disconnection. The built-in MV fuses do not require any specific maintenance and their accessibility for replacement is unnecessary. The selection criteria on which this LV protection is based, always with the aim of providing service quality, must be centred on making the LV network safe rather than preserving the

transformer. Customisation of the protection of each feeder according to the characteristics of the LV line, such as length, cross section and type (bare or insulated), is in this respect a step forward. This protection must behave reliably over a long period, under difficult operating conditions for which maintenance of complex electronic systems cannot be envisaged.

## 6) Systems in line with a general policy of improvement of rural networks

### 6-1) Evolution of POLE-MOUNTED EQUIPMENT in low-sensitivity sparsely-populated areas.

Powers are limited to 50, 100 and 160 kVA; two LV feeders are therefore economically optimal. The proposed solution combines the advantages of the integration of a protection - cut-out function with the possibilities of live work offered by specially designed resin bushings.



"TPC" 100 kVA overhead substation on Electricité De France networks. Transformer pole mounted by hanging-up arrangements, with live connection bushings and built-in protection - cut-out function.

Conventional overhead MV fuses, which are exposed and therefore a source of problems, are eliminated. Live work helps to simplify networks by reducing the number of overhead switches and terminal poles. Integration in the environment is favoured by a reduced volume of oil, and by the elimination of chairs and other supports in favour of a mounting facilitated by the reduced weight (less than 550 kg) of the equipment.

### 6-2) MV/LV "SIMPLIFIED" SUBSTATIONS to provide an economical solution for burial of lines in peri-urban areas.

The allocated power of these substations, limited to 250 kVA complies with the principles of compactness and bringing the load closer to the consumer. The transformers are equipped with a protection - cut-out function which guarantees total security despite the increase in the short-circuit power of the networks. This integration allows protection to be available even if the power supply is provided by a derivation box from an underground network. It acts effectively in case of failure, in places where the impedance of the line would mask the event for the remote fuses of an overhead-underground down lead. This advantage thus enables it, in association with disconnecting equipment upstream on the line, to economically replace the

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fuse switch of an MV panel usually located in the substation, when the remoteness of the overhead-underground down lead becomes critical. The separable connectors, pulled out off load after verification of the absence of power supply on their capacitor voltage dividers, make it possible to operate in complete safety after connection on a short-circuit earthing plate.

Two MV/LV "SIMPLIFIED" SUBSTATION concepts have been developed, in compliance with the requirements of IEC 61330 :

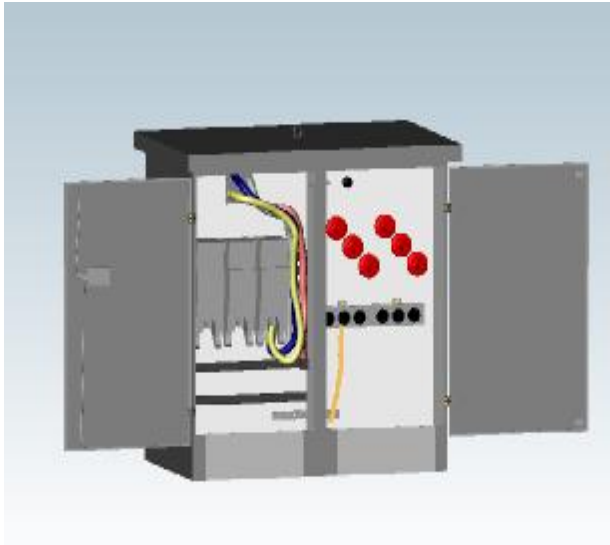
- "ECOBLOC", in which the LV panel is directly linked to the transformer. All the structures such as the oil retention vat and the enclosure are metallic, welded together with the tank containing the active part and the cooling dielectric. It is adapted for "radial" or "ring" installations, in which case the protection - disconnection function allows the power supply of the loop to be maintained if one of the substations is faulty.
- "ECOPOSTE", constituted by equipment mounted under a concrete or polyester enclosure. It comes in "radial" form, in which case it contains a protection – cut-out transformer and a fused LV panel, or in the form of an "MV/LV ring network substation" with additionally a simplified MV board comprising a switch – disconnector and an earthing switch on the network side.

possible, the integration of a protection –cut-out function totally eliminates the effect of a transformer failure on the environment. This last solution, generalised by Electricité De France for over 5 years and validated by a rigorous programme of qualification tests, constitutes the starting point for major innovations in public distribution MV/LV substations.

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If the themes presented here are relevant to your present concerns, you are invited to dialogue directly with the author of this article by e-mailing him at [thierry.grima@groupe-cahors.com](mailto:thierry.grima@groupe-cahors.com), or by sending a fax to 00.33.4.94.75.00.28 (in English, Spanish or French). You may also consult our Internet site and register your requests at [www.groupe-cahors.com](http://www.groupe-cahors.com)

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*Example of 160 kVA ECOBLOC in false cut-out, with built in protection – disconnection system.*

## 7) Conclusions

OPTIMUM SUPPLY QUALITY AT MINIMUM COST is obtained by improvements which concern all network functions. Control of the amount of investment linked to the transition to the resonant earthed system and compatibility with pre-existing conditions provide reasons for choosing an Arc Suppressing Coil definition sized according to a short-term neutral current, beyond which a fault is no longer considered to be transient. The handling of permanent faults is then based on the performance of directional fault detectors and rapid means of intervention. As the consequences of a failure must remain as limited as