MAJOR ADVANCES IN MV/LV SUBSTATIONS

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SUMMARY

Improvements on the reliability of the components of the network, combined with a well-considered policy of cost reduction from energy suppliers, may lead to simplification of LV/MV substations in the near future.

The aim of this article is to highlight practical advantages resulting from this simplification.

- The integration of a protection/cut-off function inside the transformer itself would eliminate any external risk and disconnect all the three phases together in case of internal fault. The classical « switch-fused disconnecting device » located inside the MV board may be suppressed. The coordination between the protections of the MV substation and the ones on the LV side of the transformer must be perfectly adjusted, so that no tripping may happen without the transformer being out of order. Thus, direct access to the protection/cut-off function is not required.

The consequence of this first choice is a possible reduction of HV Board to two switch-disconnectors and one bypass switch. However, a step forward may be achieved by direct connexion of this simplified HV Board to the transformer. This apparatus attached to the tank of the transformer would then be composed of two switches disconnectors and one derivation to the transformer. Taking into account the reliability of equipments and the precision of load supply forecasts, the drawbacks of these solutions are negligible compared to potential savings.

- These general considerations also lead to the reappraisal of the cut-off function as systematically associated to each MV/LV substation. For some of the substations installed on the feeder-line, the transformer itself may have connecting points to the two incoming cables. In this case also, the statistical analysis shows that the mean duration of the interruption of supply considered for the whole life expectation of the product is not significant.

Architecture of MV substations on ring network
A: Substations without MV switchgear
B: Substation with simplified MV switchgear

All above advances would bring substantial savings, both in terms of surface occupation and cost, minimizing hence the differential of investment between overhead and underground networks.
1. INTRODUCTION

In an ever more competitive economy, energy suppliers have to pay more and more attention to optimising investments. Advances in some medium voltage network components are such that it is now possible to simplify installation diagrams, which has significant economic repercussions. With this in mind, the following contribution, based on the recent appearance of a new technical level of distribution transformers, presents interesting changes in the field of MV/LV substations, aiming to reduce the cost of connection to the MV network.

2. TRANSFORMERS WITH INTEGRATED PROTECTION/CUT-OFF FUNCTIONS

2.1 Aims

The “intrinsically safe” transformer corresponds to a new technical step consisting in integrating the protective device inside the transformer tank rather than it being external. This protection is now defined functionally, in other words with the aim of eliminating any external risk (opening the tank, propagation of an arc outside the device, fire, …), whatever the nature of the fault inside the device (surge or overvoltage, overload, faulty MV or LV circuits, etc…).

In addition a second function accompanies this internal protection, designed to systematically disconnect a damaged transformer from the MV network. So whatever the damage, the transformer environment is protected from external phenomena, and what is more, the three phases of the device being insulated from the source, there is no longer any risk of any disruption of the MV network or any risk of LV stress distribution.

We thus come back to the traditional function of the combined switch-fused disconnect switch that we find on MV panels. Finally, since the main purpose of this device is to protect against and prevent disruption on the MV and LV networks, it is not designed to be controlled either manually or automatically.

2.2 Description

Figure 1 shows the wiring diagram of a transformer with integrated protection and cut-off functions, its general arrangements are shown in figure 2.

Located just downstream of the MV plug-ins, three oil-proof fuses with strikers are placed in insulating wells. This design feature prevents any faults upstream of the fuses as well as an arc propagating between the fuses even in the absence of dielectric. There is a disconnector downstream of each fuse, reacting to the fuse’s striker, or to another phase’s disconnector, thanks to mechanical coupling. This disconnector has the same opening capacity as a switch-disconnector with a cut-off capacity of over 250 A. So three-phase insulation is always guaranteed if called upon.

In addition to this first unit, a fuse device integrated in the earth circuit of the transformer’s active part disconnects the device as soon as a faulty MV or LV earth current is detected, even for an intensity of only a few amps. Protection against weak earth faults is thus ensured (networks with compensated neutral conductors) or the faults appear in the LV transformer circuit.

A very important point is the proper coordination between all protections, ensuring that only a fault inside the transformer may be at the origin of any...
tripping. Thus, direct access to the protection/cut-off function is not required.

Figure 2: internal view of a TRANSFIX transformer with integrated protection-disconnection functions.

3. APPLICATION FOR SUBSTATIONS

For substations, the solution described above has two immediate advantages, the simplified design of MV devices and the reduced overall size of stations.

3.1. Changes in MV wiring diagrams

Moving the protection inside the transformer itself means the MV panel features two line-feed switch-disconnectors and a bypass switch only, as shown in figure 3.

However, providing access to the link between the panel and the transformer imposes the following constraints:

- the safety of operational staff must be guaranteed in the event of any electrical failure in this link
- any work must be carried out after earthing and short-circuiting. Unless remote earthing is carried out at MV/LV stations in the vicinity, the earth disconnector must be kept on the bypass.

The other way of designing MV/LV substations that frees from the above-mentioned constraints is to accept the principle of a direct connexion of the MV board to the transformer. However, this would impose the reappraisal of a usual practice the justification of which is a possible further adaptation to the load, or the replacement of the transformer in case of damage without disturbing the supply.

Several aspects show today that the physical dissociation of both elements may appear obsolete:

- The means operators have at their disposal to carry out network supervision are such that demand can be accurately forecast and load adjustments reduced.
- The mean failure rate of distribution transformer for underground network is around \( 10^{-7} \) fault per operating hour, which represents one replacement of faulty equipment out of 40 units considering a period of 30 years.

In conclusion, given the current state of our networks, the demand and technology, there is no longer any justification for separating functions as it has been customary to do up to now. If this view is accepted, it is possible to devise a physical combination of the transformer and MV devices, a solution with significant economic repercussions.

In electrical terms this means making the transformer function “transparent”. The MV device distributes feeder-bypassed power, the latter no longer being medium voltage but low voltage. When this MV unit is ready, the bus bypass is no longer accessible and no longer requires a bypass switch or a DC-earth disconnector. Figure 4 shows the wiring diagram for such a layout.

Figure 3: Diagram for a line feed cut-off station with simplified MV device

Figure 4: electrical wiring diagram showing physical combination of MV devices and transformer.
In technological terms, this combination nevertheless requires two coexisting insulation techniques: The transit of network power, in the same way as the cut-off devices, can only reasonably be envisaged in a gaseous or solid insulating medium, for obvious reasons of staff safety. So these functions must be kept physically isolated from the transformer. The ideal transformer, for economic reasons, but also for reasons of compactness and insensibility to the environment, is still the transformer that is immersed in mineral oil. Its integrated protective function, created using fuses, is placed so as to do away with any vulnerable wiring that may transit the network short-circuit power in the transformer tank (see paragraph 2.2.).

3.2. Impact on station architecture

Following on from the above wiring diagram, a transformer station can be designed using three modules:

a) A base, integral to the installation location, supporting the LV feeder pillar, thus constituting the fixed part of the station.

b) An TYPE-A HV block integrating the feeder cut-off function and the transformer function, which can be moved by slinging

c) An enclosure, providing access to operational parts and allowing possible replacement of the TYPE-A HV block or LV elements.

Figure 5: Functional diagram of the MV/LV station with its three modules
A: Interface Ground / substation
B: LV feeder pillar
C: Transformer
D: HV board 2I-diagram
E: Enclosure

3.3. Operational consequences

It is nowadays accepted that the failure rate for a one-piece type 2I+P MV panel is the same as for transformers, i.e. $1 \times 10^{-7}$ per operating hour. Combining the transformer function doubles this rate, which means that on average one MV block failure out of 20 stations will be repaired in thirty years. It should be pointed out that a general improvement of reliability should be expected simplifying the MV panel will contribute to improving the current reliability rate thanks to:

- The simplification of HV switchgear (removing a switch, a disconnector and a protective function comprising fuse wells that often caused wee-known failures)
- The reduction of connecting points in the whole system
- All connexions operations made and tested at factory site

During this operation, as for any replacement of MV panels disconnecting the feeder line, earthing both cables is carried out at stations nearby. The obligation to restore LV distribution as soon as possible entails providing an independent source powering the LV load centre bus (if the LV network is not intermeshed). A disconnection method (even a DC-earth) must therefore be available between the LV load centre and the MV block. It should be noted that this is not a question of cutting off power under load, so a switch function is not required here.

3.4. Technical and economic consequences

In terms of value analysis, the advantages are:

a) For devices: removing a bypass switch, a double DC-earth disconnector fulfilling the protective function, a set of three fuse wells, a reduction in the volume taken up by the panel casing, and a saving on the pedestal.

b) Removing a MV link

c) For the outer enclosure, reduction in overall volume.

This is offset by the transformer costing more through integrating the protection-disconnection function. The anticipated gains are:

- 25% surface area: a 630 kV station takes up no more than 3.5 m$^2$.
- a 20 to 25% saving compared to the cost of a traditionally-designed station (see figure 8).
4. SUBSTATIONS WITHOUT MV CUT-OFF SYSTEM

This new way of thinking raises a fundamental question: is it always necessary to combine the cut-off function with the transformer function? Since the transformer now has its own integrated protection, can one not then distribute access points to the feeder line in a different way from power withdrawal points?

4.1. New distribution of functions on the network

The advantage of dividing up a feeder line into as many segments as there are transformer stations is being able to isolate a cable failure whilst maintaining the power supply to all stations with no lasting power cut. There are nevertheless areas where this advantage is not mandatory, where a power cut lasting longer than with traditional systems (but nevertheless limited in time) is acceptable.

The two following comparative solutions show the merits of such an approach:
In the 1st case, corresponding to the current situation, a feeder line is made up of 20 substations, each fitted with an MV 2I+P panel, 4 of them being remotely controlled.
In the 2nd case, shown in figure 6, the same feeder line still has 20 substations, 16 being connected with no MV control system (without an MV panel), and 4 equipped with remote-control MV panels.

Figure 7. Architecture of an MV station for connection with its components:
A: Interface Ground / substation, B: LV feeder pillar
C: Transformer, E: Enclosure

4.2. Architecture of a station with no MV control system

For a station with no MV control system, the absence of an MV panel is offset by the fact that the transformer itself has connecting points to the two incoming cables.
The architecture of the station is shown in figure 7. Since network power transits inside the transformer, it is important to design the link between the two connection points to prevent any risk of dielectric failure that could cause a failure in the volume of oil in the device.

4.3. Operational consequences

There is no need to cover transformer load adjustment or equipment failure, which were dealt with in paragraph 3.2. On the other hand, line failures need to be discussed here.
For a conventionally equipped network, a cable failure generally requires the following tasks to be carried out:
- turning on the switches on either side of the failure, following the information received from the related fault detectors
- turning off the feeder line supply
- locating the faulty segment using the information provided by the fault detectors in the powered-down area
- throwing the manual switches in the stations on either side of the failure
- turning off the remotely controlled switches
The average power cut lasts approximately a minute for all the stations, and lasts approximately an hour
for the three or four stations located between the remote control switches on either side of the failure. Now for a similar network equipped with stations having no MV control system, the tasks required are (see figure 7b):

- turning on the remotely controlled switches on either side of the failure, following the information received from the related fault detectors
- closing the feeder access point
- locating the faulty segment using the information provided by the fault detectors in the powered-down area
- disconnecting the faulty segment connections at stations on either side of the failure, and earthing
- placing insulation caps on the plug-ins on the transformer side
- turning off the remotely controlled switches.

The average power cut lasts approximately a minute for the feeder line, and still lasts approximately an hour for the stations located between the remote control switches on either side of the failure. However, restoring normal power supply now entails another power-down for the stations located between the remotely controlled switches on either side of the failure, this also being around an hour, because the following tasks need to be carried out:

- turning on the remotely controlled switches on either side of the repaired failure
- reconnecting the connection points of the repaired cable segment to the stations at either end
- turning off the remotely controlled switches
- restoring the normal feeder supply point.

4.4. Technical and economic approach

Given the hypothesis of one cable failure per year for 100 km, and an average distance separating MV/LV stations of under 1 kilometre, the drawback of the concept without an MV control system compared to the traditional design is an extra power cut of around one hour per station over the whole operating period (30 years). This is offset by an extremely simple and compact station design. Its cost is estimated at half that of a traditional station (see figure 8).

5. CONCLUSION

The introduction of a protective function in MV/LV transformers, as well as progress in network component reliability, leads one to give serious thought to simplifying the MV/LV station considerably. In the first example, with feeder line disconnected, the saving on a station is estimated as being between 20% and 25% thanks to the combination of the transformer and disconnecting devices (simplified MV panel).

In the second example also reviewed herein, the diagram is modified so that most of the stations have no MV control system. The savings per station can be as much as 50% in this case. The drawback of underground networks compared to overhead networks is precisely the extra cost of the various pieces of equipment they require, including MV/LV stations. The solutions put forward in this document provide operators with ways of optimising their investment by reducing this handicap.

Références :