INTRODUCTION

The recent liberalisation of the electricity supply industry in Europe has led utilities to think thoroughly about how to optimise MV/LV substations for reducing global costs.

In Spain, the conclusions of this optimisation have been:

a) Cost: analysing how to reduce global costs (equipment, manpower, space, losses, maintenance, management)
b) Ensuring the continuity of electrical supply: single-transformer (protected by fuses) substations in a ring MV network (two feeders).

Consequences are:

a) To shorten low-voltage networks in order to reduce LV losses, so the MV/LV substation are closer to the customer’s load.
b) Power transformer reduction: maximum 630 kVA up to 24kV or 36kV.
c) Space reduction (surface is expensive): dimension optimisation.
d) Compact solutions: turnkey solutions.

COMPACT SUBSTATIONS

The compact substation is a global solution with three compartments (MV switchgear, transformer and LV distribution board) connected directly without cable onto a metallic chassis.

There will be three different types of compact substations:

a) Indoor compact substation: equipment with three compartments (MV switchgear, transformer and LV distribution board) on a moving (with wheels) metallic chassis.
b) Outdoor compact substation: concrete prefabricated substation with outdoor operation in order to reduce dimensions.
c) Underground compact substation: concrete prefabricated substation with outdoor operation to reduce dimensions and to improve exploitation conditions.

NEXT STEP

A) COMPACTNESS:

In order to reduce more the dimensions of the substation and the footprint (outdoor solutions), it is effective to integrate the transformer protection and switching within the transformer compartment.

B) SAFETY:

- Internal arc test: the internal arc test shows that it is interesting to use SF6 envelopes for MV switchgear separated of transformer compartment (oil) in compact substations.
- Total transformer protection: to obtain total safety of the transformer it is necessary to combine fuses and circuit-breaker (or switch with breaking capacity):
  - Fuses break high fault currents.
  - A Circuit-breaker tripped by an over-pressure relay breaks weak fault current.
- Protection of the equipment:
  - Oil leakage detector.
  - Over-temperature detector of oil.
- Selectivity with an LV relay.

C) TELECONTROL

The main purpose of the telecontrol is to obtain better quality and continuity of power supply.

D) REMOTE MANAGEMENT

The main purpose of the remote management is to have information of load evolution curves, measures exploitation events and assets installed. New technologies allow us to communicate everywhere for little charge by GSM and internet.
EVOLUTION OF MV/LV SUBSTATIONS – COMPACT SUBSTATIONS


SCHNEIDER ELECTRIC S.A. - SPAIN

ABSTRACT

The aim of this article is:
- Presenting Spanish developments in MV/LV compact substations (indoor, outdoor and underground solutions)
- Deducing the next step in the design of MV/LV substations in Europe.

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The recent liberalisation of the electricity supply industry in Europe has led utilities to think thoroughly about how to optimise MV/LV substations for reducing global costs.

In Spain, the conclusions of this optimisation have been:

a) Cost: analysing how to reduce global costs (equipment, manpower, space, losses, maintenance, management)

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Consequences are:

a) To shorten low-voltage networks in order to reduce LV losses, so the MV/LV substation are closer to the customer’s load.

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c) Space reduction (surface is expensive): dimension optimisation.

d) Compact solutions: turnkey solutions.

The EN 61330 (IEC 1330), standard on prefabricated substations, has created a good reference (specifications and tests) guide for the manufacturers to develop compact substations. A compact substation is a complete equipment (“black box”) defined by power/voltage with three compartments: MV switchgear, transformer and LV distribution board.

COMPACT SUBSTATIONS

MV switchgear has progressed from conventional equipment installed on site to cubicles tested in the factory connected by cable to the transformer, which is connected by cable to the LV board (separated components connected by cable).

The compact substation is a global solution with three compartments (MV switchgear, transformer and LV distribution board) connected directly without cable onto a metallic chassis. There will be three different types of compact substations:

a) Indoor compact substation: equipment with three compartments (MV switchgear, transformer and LV distribution board) on a moving (with wheels) metallic chassis. According to this definition, Schneider Electric has developed (in cooperation with ENDESA –GE- and UFSA –UF-).

- PLT-2 UF (up to 630 kVA – 24 kV)
- PLT-2 GE (up to 630 kVA – 24 kV)
- PLT-3 GE (up to 630 kVA – 36 kV).

The PLT components are:

- Compartment of MV/LV Transformer based on mineral oil (less than 600 litres) integral filling technology. It has been necessary to develop
a) Special transformer tank: to make direct connections to the others compartments (MV and LV switchgear).

- MV Switchgear Compartment developed with 2L+P (two 400A cable switch disconnectors and a fuse-switch for transformer protection) ring main unit (totally filled with SF6 and sealed for life in compliance with EN 60298, annex GG) cubicle. This compartment has been designed (and tested) to withstand an internal arc fault (16 kA – 0,5 s) according to EN 60298.

- LV distribution board compartment (630A or 1.000 A) with manual disconnector and four or three line feeders protected by fuses. It has been developed (and tested) according to EN 60439-1.

- MV direct connection between the MV compartment ( switch-fuses function) and the transformer compartment. This connection is made by fully field-controlled bushings.

- LV direct connection between the LV distribution board and the transformer compartment. This connection is made by an internal busbar (not cable).

- The transformer is protected:
  - by fuse-switch combination for short-circuit faults (there are three metallized sealed chambers for fuses in the MV compartment).
  - by a thermometer (in the transformer compartment) connected to a switch-on opening release in the MV compartment to protect over-load faults.

Advantages of these solutions are:

- Surface reduction: from 11 m² (MV/LV substation with separated equipment) to 6,2 m² (walk-in type substation) or 4 m² (externally operated substation).
- Installation improved: PLT with wheels that ease the installation.
- Global solution type-tested and factory assembled.
- Reducing LV looses, electromagnetic perturbation (smaller LV current loop) and LV faults using direct short LV connections tested in factory.
- All the operations are performed from front face, even the access to the tap changer of the transformer compartment.

b) Outdoor compact substation: concrete prefabricated substation with outdoor operation in order to reduce dimensions.

According to this definition, Schneider Electric has developed (in co-operation with ENDESA –GE- and UFSA –UF-) three compact substations:

- EHA-2 UF (up to 630kVA-24kV)
- EHA-2 GE (up to 630 kVA –24 kV)
- EHA-3 GE (up to 630 kVA – 24 kV)

The EHA components are:

- Concrete envelope (kiosk) with oil tank, light and vent grilles.
- The indoor compact substation PLT (without wheels).
- Indoor earth system.

It is necessary to ensure an easy, safe and reliable externally operation, so the main tests of the compact substation (with all the components – PLT inside), based on EN 61330, are:

- Dielectric tests (PLT-2 –24kV / PLT-3 – 36 kV) inside the kiosk.
- Temperature-rise test (feeding the MV compartment of PLT up to rated current with LV in short-circuit). According to EN 61330, EHA is class 10.

Advantages of these solutions are:

- Reduction of surface (visual impact): EHA-2 UF has less than 4m² and EHA-2GE or EHA-3 GE have less than 6 m².
- The footprint (necessary surface to exploit the kiosk) is simplified by one only access door (one only operating face).
- Turn-key solution assembled and tested in factory.
- It offers all the indoor substation advantages.
c) Underground compact substation: concrete prefabricated substation with outdoor operation to reduce dimensions and to improve exploitation conditions.
Schneider has developed (in co-operation with ENDESA and UFSA) two types of underground depending on ventilation:

- ESH : horizontal grids (up to 630 kVA - 24 kV)
- EHSV : vertical chimneys (up to 630 kVA - 24 kV or 36 kV)

The EHS components are:

- Underground concrete envelope (kiosk) with oil tank, light, water pipes (EHSH) and grids or chimneys of ventilation.
- The indoor compact substation PLT (without wheels),
- Indoor earth system,

The main tests of the compact substation (with all the components – PLT inside), based on EN 61330, are:

- Dielectric tests of PLT (PLT-2 –24kV / PLT-3 – 36 kV) inside the kiosk.
- Temperature-rise test (feeding the MV of PLT up to rated current with LV in short-circuit): According to EN 61330, EHS or EHSV are class 10.
- Waterproofing on the cover.

Mechanical overloads on the cover have to be ensured by calculation (simulation with finite elements software) or test:
- Static load : 5.000 Kg
- Dynamic load (a fire engine running exceptionally - 30 Km/h - on the ESH cover) : 5.000 Kg

Advantages of these solutions are:

- The visual impact disappears.
- Reduction of civil works due to the dimensions of EHS (surface inferior to 10 m²)
- Turnkey solution assembled and tested in factory.
- It offers all the indoor substation advantages.

NEXT STEP

1. COMPACTNESS

In order to reduce more the dimensions of the substation and the footprint (outdoor solutions), it is effective to integrate the transformer protection and switching within the transformer compartment.

Indeed, integrating protection and switching in the transformer enables to reduce the size of MV switchgear; and it is clear that integrating protection and switching in the transformer increases the height of the transformer but not its ground dimensions.

With this type of solution it is possible to design a 2.7 m² (surface) kiosk up to 630 kVA – 24kV.

2. SAFETY

Safety is a decisive aspect to be considered because of the human factor both in exploitation and maintenance.

2.1. Internal arc test.

The internal arc test shows that it is interesting to use SF6 envelopes for MV switchgear separated of transformer compartment (oil) in compact substations.

The internal arc test in MV switchgear ring enables to assure safety in case of a fault in this equipment.

About the protection switch (inside the transformer), it is dangerous to break the current in the oil tank because the oil quality would be damaged with a risk to lead to a fault. Therefore it is necessary to make another tight tank within the transformer avoiding breaking the current in oil. A good solution is to break the current in a vacuum bottle.

2.2. Total transformer protection
2.2.1. Present situation

Faults downstream the substation (LV network) are eliminated by LV fuses and don’t present any risk concerning safety.

Nowadays, there are two types of transformer protection that cannot ensure total safety:

- MV fuses with strikers tripping transformer switch
- Current relay tripping transformer circuit-breaker

Fuses are very effective against short-circuit currents (internal arc within transformer tank) because they are limiting and breaking the current in approximately 5 ms.

On the other hand, for faults in windings (short-circuit between turns causing weak fault current with a gas decomposition in oil) fuses may not work as they can only break currents higher than 9 times the transformer nominal current or 7 times by the switch (fuse-switch combination). Then, with weak fault current, the transformer tank may be destroyed due to the overpressure and there is a safety hazard and pollution of the environment by oil.

A circuit-breaker (or a switch with breaking capacity) with current relay is more effective against weak fault current because the threshold is generally set at 1.5 to 1.8 times the nominal current of the transformer. However, with weaker fault currents, the safety hazard is still there. Moreover, for high fault current, the time necessary to interrupt the current is approximately 80 ms and it can lead to a destruction of the transformer tank.

2.2.2. Solution for total safety

To obtain total safety of the transformer it is necessary to combine fuses and circuit-breaker.

Fuses break high fault currents avoiding any risk of explosion.

A Circuit-breaker tripped by an over-pressure relay breaks weak fault current without any risk of tank destruction as the current is broken as soon as the pressure of the tank exceeds its normal condition.

Assuming that circuit-breaker is inside of the transformer tank, tripping by overpressure is very reliable thanks to a mechanical direct connection linking the relay and the circuit breaker.

In order to have the possibility to put out of voltage the transformer (access to LV board or operating the tap-changer), it is necessary to develop a mechanism (a lever for example) in order to switch off and on the circuit-breaker by the operator.

2.3 - Protection of the equipment

Further to people safety it is interesting to protect equipment against deterioration, especially the transformer.

a) Oil leakage detector

If an oil leakage occurs, the transformer is destroyed and there is no possibility to repair. An oil leakage detector (tripping the circuit-breaker) allows to avoid this destruction. An other advantage is to reduce the oil pollution.

b) Over-temperature detector of oil

In order not to reduce expected life of transformer or to avoid its destruction, it is advisable to protect it against an oil over-temperature. An over-temperature detector installed in the transformer tank acts to a temperature threshold and trips the circuit-breaker when the oil exceeds normal temperature.

2.4. Selectivity

When a fault occurs it is interesting to isolate the part of the network affected.

If a fault occurs in LV network downstream the substation, the LV fuses break the current only on the feeders in fault.

If a fault occurs within the LV fuse-gear, with traditional solution it is necessary:
• To change MV fuse (fuse-switch combination).
• To close circuit-breaker if there is an MV relay.

With the proposed solution within transformer tank (associating MV fuses and circuit-breaker tripped by overpressure relay), it is interesting to have a system enabling to trip the circuit-breaker without damaging MV fuses when a fault occurs in the LV fuse-gear.

Installing an LV relay within the transformer tank near the LV bushings, it is not necessary to change the MV fuses (impossible with the proposed solution) as they work only if a fault occurs within the transformer tank.

3. TELECONTROL

The main purpose of the telecontrol is to obtain better quality and continuity of power supply:

- Improving the continuity of supply: faster clearance of faults and restoration of supplies.
- Efficient exploitation of the network: distance network configuration.
- Financial saving: reducing the non-distributed energy.
- Human safety: reducing works in substation.

4. REMOTE MANAGEMENT

The main purpose of the remote management is to have information of load evolution curves, measures exploitation events and assets installed in order:

- To make network plan.
- To manage the assets.
- To know the characteristics of the substation.
- To count the number of power cuts, their duration and date.
- To have an alarm if an event happens.

Until now information of substation was not remote controlled because solutions were very expensive:

- Specific radio system
- Wire communication

New technologies allow us to communicate everywhere for little charge by GSM and internet.

To access these functions through a browser we only need:

- A modem card.
- A processing unit.
- Measures of current and voltage on the LV fuse-gear.
- A web server with a phone number to be accessed by GSM.

A local interface is not useful and maintenance is not necessary since there is no need of battery.

Therefore these functions are very cheap in installation and exploitation.

They will become an indispensable component of the substation for the utilities that want to optimise their costs.

Total protection schema