NEW CONCEPTS FOR AUTOMATION OF MV/LV SUBSTATIONS. FUNCTIONS AND PRODUCTS: SOLUTIONS

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INTRODUCTION

The MV network is responsible for 85% of the Quality of Supply problems affecting the final customer. Automation of MV Network pretends to, efficiently and reliably, solve contingencies, whilst minimising the consequences of faults and outages, in both extent and duration [1,2,3]. Operation of switches and breakers in MV/LV Substations, strategically located in the Network, is the basis to achieve this goal. The current criteria to construct, maintain and operate the facilities will not be an option in the near future.

The different electric network topologies, operation criteria, growing operational complexity and more restrictive power delivery requirements, demand new products and solutions to make fault location and isolation more efficient; and that due to their low cost and ease, can be widely used. It is necessary to make fundamental changes.

MV/LV AUTOMATED SUBSTATION DESCRIPTION

From the automation requirements point of view MV/LV substations consist mainly of several switching devices with electric driven mechanisms, a Remote Terminal Unit, communication equipment, a power supply with a battery and interconnections. All these elements are shown in Figure 1.

![Figure 1: MV/LV Automated Substation](image)

By means of the digital inputs and outputs of the Remote Terminal Unit, the status of the switches (open/closed) is detected and the operations of opening or closing the switches may be performed. Also, analogue inputs are connected to the sensors in order to measure the current and voltage of the lines. The power supply includes a battery that allows the proper working of the system in the event of no LV supply.

The following table shows the main signals used in the MV/LV automated Substation.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubicle</td>
<td>Load-switch status (open/closed)</td>
</tr>
<tr>
<td>Control</td>
<td>Load-switch command (open/close)</td>
</tr>
<tr>
<td>Earthing switch</td>
<td>status (open/closed)</td>
</tr>
<tr>
<td>Cubicle</td>
<td>Phase-phase and Phase-earth fault indication</td>
</tr>
<tr>
<td>Sensors</td>
<td>Medium Voltage presence indication</td>
</tr>
<tr>
<td></td>
<td>Load current measurement</td>
</tr>
<tr>
<td>General</td>
<td>Substation operation status (remote/local)</td>
</tr>
<tr>
<td></td>
<td>Substation Alarm (cubicles, battery, etc.)</td>
</tr>
</tbody>
</table>

TABLE 1: MV/LV Automated Substation Signals

LIMITATIONS OF CURRENT PRACTICES

Task on Site

Currently, the practice for automation of MV/LV Substations has several limitations [4]. The reliability of the installation is clearly compromised by the following on-site works.

Wiring signals. Each switching device has several wires connecting the cubicle with the Remote Terminal Unit. Typical numbers for a load-switch feeder are 9 wires for control, 4 wires for current sensors and 4 wires for voltage sensors. It means that a MV/LV substation with 3 feeders needs more than 100 points to be connected on site.

Installing current sensors. Current sensors are used for phase-to-phase and phase-to-earth fault detection and load current measurement. They are installed around the Medium Voltage cable. In order to properly detect the zero sequence current the earth screen of the cable has to pass through the sensor twice. Otherwise, phase-to-earth fault indication will be incorrect. The number of current sensors for each switching device is 3, and they are placed in the cable compartment. It means that during the installation process the voltage in the line has to be interrupted in order to earth the cable.
Installing voltage sensors. Voltage sensors are used for Medium Voltage presence indication, reset of fault indication and polarisation of directional fault detectors. The sensors are mainly capacitors coupled directly to the live part of each phase. The small value of the capacitor makes the coupling impedance very high and therefore the signal of the sensor, a few microamps, is extremely dependent on the wiring. So, dealing with these signals the length, path and type of the interconnection wires are critical.

Setting parameters and checking. Every function of the MV/LV automated substation affected by the task on site has to be checked. Otherwise, there is no guarantee of its correct operation. So, all the control signals wired between the switching devices and the Remote Terminal Unit have to be checked; load-switch status, load-switch command, and the earthing switch status.

Phase-to-phase and Phase-to-earth fault detectors have to be adjusted and tested. Current testing equipment is necessary to perform the test. Checking the correct connection on-site for voltage sensors is not possible since no reasonable testing equipment is available for that purpose.

Short-circuit Fault Detector Mis-operation

The phase-to-phase and phase-to-earth fault detectors present problems of incorrect indications depending on the characteristics of the Medium Voltage network. These kind of devices were developed for local indication lighting a lamp when the short-circuit current was detected. Mis-operations were not critical since local indication was reset after a period of time and did not have any influence in the network operation procedure. For MV/LV automated substation no mis-operation is allowed since the indication will be directly reported to the Dispatching Centre. An incorrect indication will lead to wrong operations in the network to locate the fault and will delay service restoration.

The main problems found in the traditional fault indicators are the following.

Capacitive currents. A phase-to-earth fault in a network yields a zero sequence capacitive current in all lines and cables. This means that the fault indicator has to discriminate which current corresponds to the fault and which corresponds only to the capacitance. The more cable a network has, the more capacitive current will appear in the case of a phase-to-earth fault (e.g. underground cable 18kV/30kV x 240mm² ⇒ 3Amps/kM).

Earth fault indicators are definite time devices, where time indication is independent of the magnitude of the current (e.g. 100ms for 20Amps implies 100ms for 200Amps). This means that to ensure a proper detection, the setting for the minimum detection current should be the maximum capacitive current at the point where the earth fault detector is installed. Otherwise, some indications will not actually correspond to real faults.

Figure 2: Phase-to-earth fault in a cable distribution network

Inrush magnetizing current. When a feeder is closed at the primary substation the current in the line not only corresponds to the load but also to the inrush magnetizing current of the MV/LV distribution transformers. One characteristic of this current wave is its peak value (e.g. 5 times the rated value).

Figure 3: MV/LV transformer inrush magnetizing current

Phase-to-phase fault detectors detect this current peak as a fault. In order to avoid this mis-operation these devices usually include a self-reset indication if there is load current after the peak detection. However, if after the current peak there is a trip (e.g. a phase-to-earth fault previous to the MV/LV substation) the fault detector will mis-operate and indicate to the operator an incorrect location for the fault. This phenomenon also appears when using feeders with automatic reclosing functions.
No standardisation

The topology of the substation has to be determined in advance in order to use the specific products according to the installation. This means that the type of Remote Terminal Units, sensors, relays, etc. depends on the number and type of switches and breakers in the MV/LV Substation. Moreover, the different devices used to be from different manufacturers and there is always some engineering work of integration. Each substation is a kind of small project and the level of standardisation and flexibility of substation components is quite small.

ADVANTAGE OF THE NEW CONCEPTS FOR DISTRIBUTION AUTOMATION

Description of New MV/LV Automated Substation

The new concepts are based on the functionality of the new MV cubicles that satisfy the electrical requirements and the automation requirements as a single unit assembled and tested in-factory [5]. The main automation functions are related to phase-to-earth and phase-to-phase fault detection, Medium Voltage presence detection, current measurements, switching operation and cubicle status indication, taking into account the simplicity of commissioning and operation.

![Figure 4: New Concept of MV/LV Automated Substation](image)

The cubicles, the Central Unit and the Local Bus mainly form the MV/LV automated substation. The cubicles integrate all the functionality stated above and are plugged directly to the Local Bus. This Bus is independent of the number of cubicles and it is used for the communication and supply between the cubicles and the Central Unit.

The Central Unit only includes the functions of a Remote Terminal Unit as a gateway. It takes the information from the Local Bus and translates it to the communications protocol of the Dispatching Centre. The Central Unit also includes the supply, battery and communication equipment. It is also directly plugged to the Local Bus and independent of the number of cubicles in the substation.

Commissioning Operations

The number of commissioning operations is dramatically reduced. There is no wiring between cubicles and Remote Terminal Unit. Instead, the automation interconnection of cubicles and the Central Unit are standard links to form the Local Bus, not requiring specialised personnel to perform the connection.

Current sensors. There is no need of current sensor installation since they are built in the switching devices in-factory. They are integrated in the cubicles taken into account that there is no interference when connecting MV cables. So, the installation problem of the earth screen of the cable disappears.

Voltage sensors. The capacitive voltage sensors are connected in-factory inside the cubicle. Therefore, the signal is not affected by any manipulation on site.

Testing. Sensor tests are performed in-factory. This allows for special testing equipment to thoroughly check that the complete primary and secondary systems of the cubicle are correct (including directional functions). So, on-site tests are reduced to checking the communication between the cubicles and the Central Unit.

Short-circuit fault detectors. The problems found in traditional fault detectors are avoided in this new concept. Capacitive and inrush magnetising currents are clearly identified as non-fault currents since the system uses the same techniques as modern digital protective relays. This allows us to define a set of configuration parameters not influenced by the point of the network where the substation is built.

Equipment Standardisation

Modularity (criterion) permits the building of any type of (installation) topology with the same type of equipment. The dependence on the number of cubicles and previous knowledge of the topology of the installation is no longer required. Cubicles are manufactured and tested in the same way independently of the MV/LV substation configuration, which yields a high degree of standardisation.

The Central Unit is also standard and it is the same unit independently of the number of switches and breakers of the MV/LV Substation. The Local Bus guarantees the compatibility between the cubicles and the Central Unit and it is defined with an open standardised protocol (e.g. IEC 870-5). So, the complete automation substation is made of factory-standardised equipment with no complex on-site task required.
CONCLUSIONS

Results have been obtained from a pilot substation already commissioned. The parameters to compare the different solutions are described as follows.

**Functional errors:** The number of errors detected when checking the functionality of the substation for the first time; switch status and command, fault detectors, voltage detectors, current measurements, etc.

**On-site tasks:** It is the time carrying out all the fieldwork necessary to fine-tune the substation.

**Personnel specialisation:** The knowledge of remote control systems required for personnel to perform the on-site tasks.

**Standardisation:** The degree of standardisation of the equipment used and the possibility of using it in any type of substation.

**Performance:** The performance of the system, including the correct detection of all events (e.g. earth fault indications).

**Cost:** The total cost of the substation taking into account all the equipment and the entire tasks to guarantee the correct operation of the substation.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Traditional</th>
<th>New concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional errors</td>
<td>20%</td>
<td>2%</td>
</tr>
<tr>
<td>On-site tasks</td>
<td>8 hours</td>
<td>2 hours</td>
</tr>
<tr>
<td>Personnel specialisation</td>
<td>100%</td>
<td>10%</td>
</tr>
<tr>
<td>Standardisation</td>
<td>60%</td>
<td>100%</td>
</tr>
<tr>
<td>Performance</td>
<td>70%</td>
<td>90%</td>
</tr>
<tr>
<td>Cost</td>
<td>100</td>
<td>80</td>
</tr>
</tbody>
</table>

TABLE 2: MV/LV Automated Substation comparison

All the advantages, outlined previously over traditional solutions, necessary for an automated, reliable, efficient and easy operation of the distribution network, are the main part of the new design concepts of MV/LV substations and are mainly built in to the network switching device. The number of commissioning operations is dramatically reduced, and reliability and quality are substantially improved due to the in-factory mounting and testing. A new integral product is created which is flexible and easily adapted to the different needs of operation, network schemes and communications systems.

The new concepts for automation are the result of the collaboration among some of the leading electrical utilities in the country (with more than 3,000 automated installations in MV, and growing rapidly) and the main MV/LV Substation manufacturer and provider.

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REFERENCES


