ENVIRONMENTALLY FRIENDLY, LOW COST HV/MV DISTRIBUTION SUBSTATIONS USING NEW COMPACT HV AND MV EQUIPMENT

by

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SUMMARY

The paper presents a new standardized, environmentally friendly, low cost HV/MV distribution substations. The new solution, adopted by ENEL Distribuzione in Italy, is based on the following principles, which are presented and discussed in the paper:

– Use of new simplified single-line diagrams and lay-outs. The substation is supplied from the HV subtransmission network. The “Y” single-line diagram is chosen, including one or two HV circuit breakers. The substation is usually built under an existing HV line, within the right-of-way (ROW), thereby minimizing disturbance to the environment and facilitating land acquisition.

– Almost complete prefabrication. The new type of substation is formed by three components (HV switchgear; HV/MV step-down transformer; MV switchgear), which are fully factory assembled and tested, and easily transportable to site, thereby greatly reducing cost and implementation time.

– Simplicity. The substation is equipped with only one HV/MV transformer and a compact MV switchgear section, expandible in future with another equal MV section. Auxiliary services and control circuits are all built-in in each prefabricated component.

– Use of new equipment types. The HV “Y” switchgear is mostly SF6 insulated. A new technology (patented by ENEL) is applied for the MV (20 kV) switchgear which, although air insulated, requires only 30% of the volume occupied by a conventional air insulated switchgear. This compact design allows complete factory assembling of MV switchgear in a standard size container, thereby making it easily transportable to site.

Use of this new type of prefabricated substation allows an improvement in network configuration and facilitates network extensions and operation. The following aspects are in particular dealt with in the paper:

– Choice of single-line diagram for new simplified HV/MV substations. Typical applicable simplified substation single-line diagrams are reviewed and justification is given of the selected diagram.

– Network topology improvement. The construction of new low cost substations allows an increase in the number of power injection points in MV networks, with the following benefits:

  – improved quality of service to consumers, due to the reduced average length of MV lines and reduced total length of MV lines supplied by each substation. Ground fault current is also reduced in neutral unearthed MV networks;
  – greater loading factor of transformers;
  – increase of power distribution capacity of MV networks;
  – reduction of power losses in MV networks.

The reduction of the area/load served by the individual HV/MV substations, will facilitate the application of a new network planning/operation strategy, using substations equipped with one transformer only and with full emergency supply from neighbouring substations via the MV lines in case of outage of one HV/MV substation. An important step forward for this scheme, with a great reduction of MV supply outages, will be achieved by remotely controlling the line load interrupters of the MV/LV transformer stations.

– Easier construction of substation. Construction in the available ROW of HV line, with small dimensions and complete absence of buildings, will greatly reduce disturbance to the environment and facilitate granting of permission for construction works from the public authorities and land owners. Prefabrication greatly reduces the engineering and construction works and time.

– Improvement of substation reliability. The hybrid HV switchgear with compact busbar configuration and SF6 insulated active components, is expected to improve reliability and reduce maintenance, in particular in the presence of air contamination.

The paper includes the comparison of space requirement, environmental impact and cost of new type of substation and of the conventional types, in particular concerning the MV switchgears. The feasibility of the proposed type of substation for rated voltages other than the ones used in Italy is also considered, in particular for the MV (10 to 36 kV) compact switchgears.
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SUMMARY

The paper presents a new standardized design for environmentally friendly, low cost HV/MV distribution substations. The new design, adopted by ENEL Distribuzione in Italy, is based on the following concepts, which are discussed in the paper:
- Use of a simplified single-line diagram and lay-out
- Use of new equipment types
- Very simple and compact design
- Almost complete prefabrication

The paper firstly describes the new model applied by ENEL Distribuzione for the development of the MV networks, which enables use - and takes advantage of - the new type of compact HV/MV substations.

Typical applicable simplified substation single-line diagrams are reviewed and justification is given of the selected diagram. The relevant implementation is presented for: (i) the air-SF6 (hybrid) insulated 170kV switchgear; (ii) the new 24kV metal enclosed air insulated switchgear, which is housed in a container and is very compact due to the use of circuit breakers withdrawable with vertical movement.

The authors believe that the new largely prefabricated HV/MV substation will much contribute to improve the MV network topology, uprate the power capability and facilitate the extension of distribution networks, improve quality of service to consumers and reduce substantially the operation costs.

Keywords: substation, switchgear, HV, MV, compact design.

1. INTRODUCTION

Following the privatization and de-regulation of the electric energy market in recent years, the technical, economic and environmental requirements of network planning and operation have rapidly become more strict, as a result of public opinion, regulatory authorities and competition. On the other hand, the availability of modern network components based on new technologies and the need for uprating the power capability of networks and improving the quality of service to consumers with minimal environmental impact, has required a drastic revision in system development planning and network operation strategies by power utilities.

These new requirements are especially the case in Italy, due to the growing awareness of the public, the valuable landscape of the country and the high population density. Distribution power utilities should therefore address the following network development targets:

i) Minimizing the visual impact as well as electromagnetic field and audible noise emissions of HV/MV step-down substations and MV networks.
ii) Improvement of the quality of service to consumers, in keeping with the new Standard issued in Italy in 1999 by the Electricity and Gas Authority. Compliance with these regulations, with regards to the limitation of interruptions of power supply in particular, will require large investments.
iii) Reduction in the capital and operation cost of HV-MV distribution systems, by limiting the network redundancies, reducing construction and maintenance costs of network components and reducing energy losses.

2. ENEL'S MV NETWORK CONFIGURATION AND OPERATION MODEL

The preferential topology of ENEL’s MV networks consists of MV feeders originating at one HV/MV substation and terminating at an adjacent HV/MV substation. Each feeder supplies several MV/LV transformer stations and is normally operated radially by sectionalizing at an intermediate MV/LV station. In an emergency (fault in a MV line or unavailability of a HV/MV station), the sectionalizing point(s) is (are) relocated. A feeder tying two HV/MV stations may then have to be supplied from one terminal only. Although it is desirable to use un-tapped feeders, there are cases in which a few MV/LV stations are supplied from radial lateral lines originating from intermediate points of a main feeder.

The HV subtransmission networks are mostly operated at 132kV (Northern Italy) or 150kV (Central-Southern Italy). There are also substations supplied at 220kV. Most of ENEL MV networks are operated at 20kV.

Most of ENEL HV/MV subtransmission stations have been equipped in the past with two step-down transformers, usually rated at 2x25 MVA or 2x40 MVA ONAN (2x31.5 MVA or 2x50 MVA ONAF) and, in some cases, at 2x16MVA or 2x63MVA or 2x100 MVA. These substations were designed and built with conventional technologies, with little prefabrication. The HV switchyard outside the major towns, was an outdoor air insulated station (AIS). The MV switchgear, housed in a building, was metal enclosed, with cubicle switchgears type according to IEC Standards 298, and withdrawable circuit breakers (CBs). HV SF6 insulated stations (GISs) and, sometimes, also 20kV SF6 insulated switchgears have been used inside the major cities, with fixed CBs.

The installation of two HV/MV transformers per substation specified with an ONAF rating providing redundancy of about 50% in normal operation was justified by the requirement for quick supply restoration from the same substation of all the outgoing MV lines in the case of unavailability of one transformer. Actually, the supply of all the entire MV feeders from the adjacent HV/MV substations was hindered by the following two problems:

i) Too long a time was required by the operators for the manual on-site closing of the load interrupters at the intermediate points of several long feeders.
ii) Some long MV feeders connecting adjacent HV/MV stations had become heavily loaded due to load growth. Supply from one end only would therefore cause high voltage drops and/or the violation of the thermal current carrying capacity in some old line stretches equipped with small conductors.

On the other hand, with the above described network configuration, each HV/MV transformer with a large rating supplies in normal operation from a half MV busbar, a large mileage of MV overhead lines which thereby adversely affects the exposure of consumers to voltage dips and interruptions. These are currently a major concern with regard to the quality of service required by the new regulations. Statistics show that about 90% of...
cumulative service interruption to consumers is caused by the MV network and MV/LV stations.

About one year ago, ENEL Distribuzione S.p.a. (ENEL Distribution Corporation) started implementing a large project for automation of the MV networks, including the remote control of the disconnectors at about 50,000 MV/LV transformer stations (which is about 25% of existing ENEL MV/LV stations). The remote control will shorten the time for locating faults on MV lines. It will also drastically shorten the time for restoring the supply of all the MV feeders from the adjacent HV/MV stations in case of unavailability of a HV/MV station, thereby solving the problem referred to in item i) above.

On the other hand, the construction of new HV/MV substations justified by the load growth and by the need to improve the quality of service of the MV networks, results in a reduction of the length and loading of the MV lines. In most of the cases, this makes it technically feasible to provide an emergency supply from the adjacent HV/MV stations of all the MV lines which are normally supplied by these new stations. The latter can therefore be realized in a simplified manner, with only one transformer, because their load can be supplied in emergency operation by the neighbouring stations via the MV networks.

Summarizing, ENEL’s trend is to change the MV network model as follows:

- **Old Model**: a few conventional HV/MV stations with two transformers with large ratings and redundant capacity, and very limited reserve from the MV network. Many long MV lines supplied by each HV/MV station and not provided with remotely controlled sectionalizing points.

- **New Model**: a large number of simplified, physically small HV/MV stations with only one transformer (16 or 25 MVA ONAN rating) and with small redundancy of transformer capacity. A reduced number of short MV lines radiating from each new HV/MV station, provided with remotely controlled load interrupters (on average, 5 along each feeder linking two HV/MV stations).

The old model considerably up-rates the loading capability and quality of service of the existing MV networks. However, it requires several new feeding points from the HV network. In practice, the required expansion of the HV network is moderate, for the following reasons:

- The HV networks are very extensive and meshed in Italy (about 45,000 km of 132-150kV lines). Most of the new HV/MV small stations can therefore be located just below an existing line, within the line right-of-way (ROW).

- Where short lateral 132-150kV lines are required for supplying the new HV/MV stations, length usually does not exceed 10-15 km. Where appropriate, use can be made of standardized compact double circuit HV lines (with insulating crossarms), the environmental impact of which is comparable to that of a MV overhead line.

- The simplified prefabricated HV/MV substations presented in the following paragraphs have a low cost and are compact and environmentally friendly.

The economic analysis has shown that the additional investment and operation costs in the HV network are far lower than the savings achieved in the MV networks.

The insertion of a HV/MV simplified new station (NS) between two existing stations (ES) is shown, in principle, in Fig. 1. A vast system, ideally assumed with a regular modular configuration, should gradually evolve in the long term as follows:

a) The total number of new simplified HV/MV stations (equipped with 1 transformer) should eventually be about twice the number of the existing HV/MV stations.

b) The length of the MV lines (Fig.1) will reduce to 50-60% of original lines and they will double in number.

c) The voltage drop and losses on the MV lines will be consequently lowered to 25%-36% for an assigned load condition.

![Fig. 1 – Insertion of a simplified HV/MV station (NS) between two existing stations (ES)](image)

d) The average loading factor of the HV/MV transformers, in normal operation at peak load, will be increased from about 50% for the existing stations, to 75% to 85% in new stations having 3 to 6 adjacent substations.

e) The mileage of MV lines supplied by each transformer will be reduced to 50%-60% of the present mileage.

f) In spite of the very little increase in mileage of total MV lines, the power distribution capacity of the network will double.

g) As most of MV public networks in Italy are operated with un-earthed neutral, the maximum ground fault current is reduced in proportion to the line mileage of networks. Self-extinction probability of phase-to-G earth faults in overhead lines is therefore increased.

h) Items b), e) and g) above, and the implementation of the remote control of load interrupters in part of the MV/LV stations, will bring along a substantial reduction of the rate of voltage dips, as well as of the rate and duration of interruption of supply to consumers.

i) The number of MV lines outgoing from the existing stations will no longer increase. On the contrary, the new stations will supply far fewer MV lines (max. 10). The congestion of MV lines near HV/MV stations will therefore diminish.

### 3. CHOICE OF SINGLE-LINE DIAGRAM FOR NEW SIMPLIFIED HV/MV SUBSTATIONS

Fig.2 shows a set of single-line diagrams which have been used in various countries for the HV/MV subtransmission substations. In order to simplify the diagrams, only the CBs and HV disconnectors (DSs) have been represented, which are essential for configuring each diagram. The reader should consider current transformers (CTs) in series with each CB, surge arresters (SAs) connected to power transformer terminals, capacitive potential transformers (CPTs) and rod gaps connected to each HV line terminal, line traps if PLC communication is used, MV CBs withdrawable or provided with DSs, grounding switches on line terminals and busbars.

Diagrams have been drawn in order of decreasing magnitude of ratio R=[N of HV CBs]/[N of HV feeders] (in Fig.2, R=1 for A1 diagram; R=0.33 for B2). It is assumed that the HV line can supply the substations from either side.

Diagram A1 is also well known as the “H” scheme. It has been extensively applied in Italy in the HV/MV substations equipped with two transformers and with the line-in line-out loop connection. This conventional scheme requires one CB per each HV feeder (R=1). The redundancy of transformer capacity and of HV line capacity in closed loop operation assures continuity of supply of the MV network in case of outage of one transformer and/or one line. Although the infrequent maintenance of the DS linking the two busbar sections may require a short outage of the substation, this DS is installed because it improves operation flexibility and allows maintenance and works on busbar sections and on feeder DSs.
Diagram A2 may be applied as the initial stage of A1.

Diagram B1 allows saving one CB compared with A1. However, the permanent faults in a line cause a short outage of one transformer and relevant MV feeders.

Diagram B2 is very economic, presenting a ratio \( R = 0.25 \). It has been applied for stations with two transformers of redundant capacity tapped from one circuit of a double-circuit line. Transfer tripping signals of high reliability to line remote ends are required for an effective protection of transformers. The HV line non-transient faults cause the outage of one transformer. Application of diagram B2 subdivides the system in sections consisting of one HV line and one HV/MV transformer, protected by 3 CBs: the local HV CB, one CB on MV side of the transformer and an HV CB at remote line terminal.

Diagrams C1, D, E1 and F have the common feature of 2 CBs for 3 HV feeders, i.e. ratio \( R = 0.66 \). Diagram C2 has a ratio \( R = 0.5 \).

Diagrams C1 and C2, of North American origin, utilize DSs capable of switching on and off the transformer(s) at no-load. The rare faults on a transformer are cleared by opening the two line CBs. Normally, the line faults do not cause the interruption of load supply. The use of by-pass DSs of line CBs is justified if the interruptions of the HV lines are to be limited as much as possible. If a CB is temporarily by-passed for maintenance, a fault in the associated line will cause the trip-out of the other line local CB and outage of transformer(s). Furthermore, when a CB is bypassed, a transfer tripping signal is recommended for fast tripping of the line CB at the remote terminal in case of intervention of a transformer protection, thereby avoiding heavy damage (possibly, fire) to the transformer.

Use of the by-pass DS in diagram D allows switching of transformer with one of the line CBs, without outage of the line. Transformer protection is assured by a local CB also when the by-pass DS is closed, thereby eliminating the use of transfer tripping, which is desirable with diagrams C1 and C2. On the other hand, if the by-pass DS is closed, a line fault must be cleared at the two remote line ends and reconfiguring of line protection relays is required. As in schemes C1 and C2, a transformer fault in normal operation (by-pass DS open) causes line outage.

Diagram E1 has been identified as the most suitable for the new simplified HV/MV ENEL’s substations. Use of a CB on transformer HV side facilitates switching and protection of the transformer. Forced or planned outage of the line terminated only with a DS causes the temporary outage of the transformer and of supplied MV feeders. This event will be rare since the HV lines are relatively short, and high-speed single-pole reclosure is expected to avoid transformer supply interruption in most line faults.

As described in the following paragraphs, the HV part of E1 diagram stations is a prefabricated module. By adding a second equal modulus, the station is extended as shown in diagram E2.

The latter is an “H” diagram as per A1, however the two sections of HV busbars are tied by two DSs in series, thereby eliminating the above reported maintenance shortcoming of diagram A1.

Diagram F is complementary to E1, with a \( \Delta \) instead of \( Y \) scheme. Normally, one of the two DSs of the transformer is open. The scheme then behaves like E1 in the case of line or transformer faults. However the outage of either of lines for maintenance can be arranged without interruption of transformer supply by preconnecting the transformer to the line which remains in service by means of the DSs (switching with DSs is possible if line CB is blocked in closed position); the transformer DSs could be used for by-passing the line CB for maintenance.

The layout of a \( \Delta \) scheme (F diagram) is more complex and costly than layout of the \( Y \) scheme (E1 diagram). Furthermore, duplication of scheme F does not realize the “H” scheme as per A1, because the busbar tie DS is not available. These considerations have supported the choice by ENEL of the E1 diagram.

It is foreseen that up to 5-6 simplified substations with E1 diagram can be inserted in a HV line terminating at two supply substations. The iteration feasibility of scheme E1 along a line stems from the fact that a line or transformer fault should normally cause the outage of no more than one HV/MV substation.

Diagram G has been used extensively in various countries for small tapped substations along HV lines. Ratio \( R = 0.33 \), i.e. very low. The merits and limitations of G diagram are well known. Diagram G is also applied by ENEL, in the cases where there is only one simplified station tapped from a line terminating at two supply stations. Contrary to scheme E1, scheme G is not to be iterated along a line, in order to avoid the simultaneous outage of more than one HV/MV station.

4. USE OF NEW EQUIPMENT TYPES

4.1 HV Switchgear.

An important distinguishing feature of substations is the type of insulation and enclosure of components. New equipment using hybrid (SF6–air) insulation has been preferred due to the following advantages:

- very compact design;
- fast and reliable installation at site;
- no live parts within the reach of maintenance or service personnel;
- easy replacement in case of failure;
- reduced needs for civil works (a building is usually not required).

Stimulated by ENEL’s requirements for this new type of substation, some major manufacturers have developed a switching equipment design which is simple, requires minimal maintenance.
and can be more effectively integrated in the HV subtransmission networks.

Fig.3a shows the circuit schematic of the "Y" HV hybrid insulation switchgear. Compared to the E1 single-line diagram of Fig.2, the only difference is the omission of the DS busbar side of line CB, because in the case of failure or major overhaul, the affected single-phase modulus is replaced with a spare unit. Single-phase non compartmentalized SF6 enclosures are accepted, because in case of internal failure one complete phase is replaced with a spare unit and transported to the factory for repairs. Fig. 3b shows a 170kV "Y" switchgear with two CBs. The 3 sets of 170kV bushings can be polymeric. They form the interface with the incoming and outgoing line and transformer.

CBs, DSs, CTs, CPTs and grounding switches are combined in a compact SF6 completely pre-assembled enclosure. Conventional air insulated surge arresters are connected to the transformer HV terminals.

The "Y" switchgear includes remotely controlled motor operated DSs with built-in earthing switches. An interlocking system assures reliable operation.

4.2 MV Switchgear

A new-design (ENEL patent) of air-insulated compact MV switchgear, allowing 68% reduction in volume compared to a conventional air insulated switchgear is applied. As a consequence, the whole MV switchgear can be factory-assembled and housed in a container whose size (2.75 m high, 2.5 m wide and max. 12 m long) does not present transportation problems.

Table I - Main technical characteristics of HV switchgear

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
<td>170 kV</td>
</tr>
<tr>
<td>Power frequency 60'' withstand voltage</td>
<td>325 kV</td>
</tr>
<tr>
<td>1.2/50µs lightning-impulse withstand voltage</td>
<td>750 kV</td>
</tr>
<tr>
<td>Rated short-circuit breaking current and rated short-time current</td>
<td>31.5 kArms, 1s</td>
</tr>
<tr>
<td>Rated short-circuit making current</td>
<td>80 kApeak</td>
</tr>
<tr>
<td>Rated current</td>
<td>1250 Arms</td>
</tr>
</tbody>
</table>

Fig.4 Compact 24kV switchgear housed in a container: a) single-line diagram; b) cross-section of a withdrawable 24 kV CB with vertical movement (left: disconnected; right: connected); c) photo of a switchgear (protective doors open and closed, respectively)
The unloading of the container from the truck is easily and quickly made by an on-board hydraulic system. The containerised switchgear is therefore immediately ready for operation at site. It is merely necessary to set up the container, fit the external parts and make the connections. Large cost reductions are therefore achieved in engineering, manufacturing and assembly.

Major features of the MV switchgear cubicle are: the presence of equipment for telecommunications (PLC or other), auxiliary services cast-resin dry-type transformer, air conditioner, 110Vdc dry-type batteries, battery chargers and local supplies located in the container walk-in.

The single-line diagram of the standardized MV switchgear is shown in Fig.4a. Switchgear is made of two sections, assembled back-to-back, which are connected by copper busbars. It includes 1 incoming 1250A transformer feeder, 11 outgoing 630A line feeders, 1 PT cubicle, 1 CB cubicle which can be used as the tie-breaker to the 2nd MV switchgear if the substation is extended. One CB cubicle is used as shunt CB for the selfextinction of phase-to-Ground arcs in lines where the MV network is operated with the neutral un-earthed. If a Petersen coil is installed instead of the shunt CB, this is located near the transformer.

The main electrical characteristics of the 24kV switchgear are shown in Table II.

<table>
<thead>
<tr>
<th>Table II - Main technical characteristics of the 24kV switchgear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated voltage</td>
</tr>
<tr>
<td>Power frequency 60 Hz withstand voltage</td>
</tr>
<tr>
<td>1.2/50µs lightning-impulse withstand voltage</td>
</tr>
<tr>
<td>Rated short-circuit breaking current and rated short-time current</td>
</tr>
<tr>
<td>Rated short-circuit making current</td>
</tr>
<tr>
<td>Rated current, busbars</td>
</tr>
<tr>
<td>Rated current, feeders</td>
</tr>
</tbody>
</table>

The MV switchgear consists of metal enclosed air-insulated cubicles with internal power arc withstand capability (IEC 60298). It includes (Fig. 4b) a withdrawable vacuum CB having lateral operating mechanism for vertical movement. This new solution allows CB sectionalising by vertical movement of the interrupting unit. A central service truck is used to remove the CB completely from its cubicle.

All the protective relays, as well as monitoring and control devices of each feeder, are located in a metal-enclosed LV compartment on the top.

<table>
<thead>
<tr>
<th>Table III – Dimension (mm) of 24kV and 36kV container housed switchgears</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Operating voltage (kVrms)</td>
</tr>
<tr>
<td>Height, including protection</td>
</tr>
<tr>
<td>Height, without protection</td>
</tr>
<tr>
<td>Width of cubicles</td>
</tr>
<tr>
<td>Depth of cubicles</td>
</tr>
<tr>
<td>Width of switchgear</td>
</tr>
<tr>
<td>Container: Width</td>
</tr>
<tr>
<td>Height</td>
</tr>
<tr>
<td>Length</td>
</tr>
</tbody>
</table>

Fig. 4c shows a 24kV switchgear. The container is installed on a concrete foundation on 4 feet. Each long side is provided with steel doors horizontally hinged at the bottom and top of container. In the open position (top photo) these doors create a front working platform and a roof, respectively, for operation and maintenance. The bottom photo shows the doors closed in normal operation.

The above-described MV switchgear has so far been realized for a 24kV rated voltage. However, a similar construction has been designed for the 36kV rated voltage, with BIL of 170kV and 50Hz-60° test voltage of 70kVrms. The breaking capacity of CBs can be 12.5 or 16kArms. A few insulating barries are used in the 36kV switchgear, for limiting the dimensions within the container sizes. Table III shows the dimensions of cubicles and container for the 24kV and 36kV switchgears.

The comparison of the major features and cost of typical 24kV switchgears (SF6-insulated, conventional metal enclosed air-insulated, air-insulated-compact) is given in Table IV. Costs are given in percent with reference to the air-insulated solution.

<table>
<thead>
<tr>
<th>Table IV – Comparison of typical 24kV switchgears</th>
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</thead>
<tbody>
<tr>
<td>Dimensions (m)</td>
</tr>
<tr>
<td>Volume (%)</td>
</tr>
<tr>
<td>Typical number of feeders</td>
</tr>
<tr>
<td>Building dimensions (m)</td>
</tr>
<tr>
<td>Building volume (%)</td>
</tr>
<tr>
<td>Internal arc withstand capability</td>
</tr>
<tr>
<td>Busbar current (A)</td>
</tr>
<tr>
<td>Cost including CBs (%)</td>
</tr>
</tbody>
</table>

5. LAYOUT OF NEW HV/MV SUBSTATION

The substation is supplied from the HV (132-150 kV) subtransmission network with the “line in-line out” scheme. As reported in section 3, the “Y” scheme is applied with one or two CBs (as per diagrams G and E1 of Fig. 2).
Fig. 5a shows the layout (plan and longitudinal cross-section) of a 150/20 kV substation, including the possible future full doubling. Fig. 5b is a 3-dimensional view of a 150/20 kV substation equipped with one 25 MVA transformer.

Due to the reduced dimensions, the new type of substation is usually built below an existing HV line, within the right-of-way, thereby minimising disturbance to the environment and facilitating land acquisition.

Power supply up-rating can be made by installing the 2nd “Y” HV switchgear, the 2nd power transformer and 2nd MV container in the substation.

The described substation consists of only three blocks of components (HV switchgear; HV/MV step-down transformer; MV switchgear) which are fully factory-assembled and tested, and easily transportable to site, thereby greatly reducing cost and implementation time. Auxiliary services and control circuits are all built-in in each prefabricated component.

6. SUBSTATION COST COMPARISON

Fig. 6 provides the cost comparison of four types of substations:

- “H” scheme (A1 in Fig. 2) GIS, with 2 transformers
- “H” scheme (A1 in Fig. 2) conventional AIS, with 2 transformers
- “H” scheme (E2 in Fig. 2) formed by two Y-hybrid HV switchgears (YHHVS), two transformers and compact MV switchgears (CMVS) in two containers (one 12 m long and the another 9 m)
- “Y” scheme (E1 in Fig. 2) with one YHHVS, one transformer and a CMVS in one container.

The breakdown of itemized costs are given for each solution, in per cent of those of the conventional AIS with the “H” scheme.

The cost of a “Y” simplified 170/20 kV substation with one 25 MVA transformer and MV switchgear in one container (12 outgoing feeders), excluding the costs for connection to HV line and to the outgoing MV lines, is about 750,000 Euro at the time of writing.

7. CONCLUSIONS

A new simplified HV/MV subtransmission substation, standardized by ENEL Distribution Corporation in Italy, has been presented. Use of compact hybrid insulated HV switchgear and a new MV switchgear design, both prefabricated, provides a drastic reduction in required land surface, low environmental impact, low cost and fast-easy implementation. These new system components and the implementation of the remote control of part of the MV/LV transformer stations will allow the application of a new model for ENEL MV network expansion. This is expected to comply with the current requirements of the public, the Regulatory Authority and market competition for an improved quality of service with minimal disturbance to the environment, and at reduced costs.

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