A REVIEW OF THE PROCEDURE TO SUCCESSFULLY INTRODUCE A NEW VOLTAGE LEVEL TO AN ESTABLISHED NETWORK.

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INTRODUCTION

The purpose of this paper is to highlight some of the challenges that may be encountered when a change to a known methodology is made within a network.

BACKGROUND

The necessity for the introduction of a different voltage level into an already established and mature network must be considered very carefully.

Distribution networks in the UK have traditionally been built up over a number of years so inevitably some of the voltages used are no longer an industry standard. Equipment may not still be readily available so a decision may be taken to replace the equipment with a more standard voltage.

It is accepted that most problems arise when a change is made to any well-known method of working and special precautions need to be taken to avoid the pitfalls that may lie ahead. The possible pitfalls must be very carefully examined when dealing with high voltage equipment together with consideration of all the safety issues.

CONSIDERATION OF THE EXISTING SYSTEM

The current secondary distribution high voltage system in the company comprises 11kV and 6.6kV, with the majority of the system being at 11kV. This feeds distribution substations containing a ring main unit, transformer with a ratio of 6.6kV or 11kV to 0.433V and a low voltage distribution board.

Existing equipment

The equipment used on the secondary distribution system is generally of UK origin and specifically designed for UK use. The philosophy of the design has been built up over a number of years and even though the equipment currently purchased is gas insulated, the philosophy of operation has come from the previous generation of oil-filled equipment.

The methods of installation, operation and maintenance are familiar to the operational staff and the Distribution Safety Rules have been formulated with this equipment very much in mind.

Why introduce a new voltage class

The load demand on the network in the central urban area of the company is increasing with the construction of taller and more energy-demanding buildings. The increasing load demand per square metre is due to a massive increase in the power requirements of building services such as air conditioning and computer power systems compared with the needs of earlier buildings on the same site. It is difficult to change the number and physical size of the substations because of severe restraints on building substations in the central area due to the very high value of land. Also in some cases, it is impossible to lay any additional cables because the existing space in the footpaths and roadways is already taken up with utility services.

One method to resolve this issue is to increase the voltage to increase the capacity of the network.

Factors to consider when changing an existing design

a) Which is the most appropriate voltage?

An increase in voltage is required so that the maximum capacity can be realised from the equipment, but the size and cost of the equipment are also important factors. It is usually possible to obtain 24kV equipment and cables that operate at 22kV or 20kV without increasing the size and general arrangement of the equipment, also the cable and joints are very similar to the 11kV cable currently in use in the area.

b) Can the system operate in parallel with the existing network?

The 11kV network is operated in such a manner that if one feeder fails, the system can be backed up on the low voltage network and the low voltage network can be run in parallel within the same main substation area. It is not possible that a 22kV or 20kV high voltage network would be able to operate in parallel with an adjacent 11kV network, therefore the new network would be run as an island until sufficient capacity was developed to enable back up from adjacent 20kV networks.

This situation is fully accepted and the design of the network to supply customers is fully compliant with the security of supply requirements. Consideration will be given to the
provision of auto transformers at adjacent main substations to provide back-up if necessary.

c) Network design

There is an opportunity when installing a totally new network to provide a different configuration system to give additional or less flexibility and security to the network. There is obviously a cost consideration to be compared with network reliability.

For example, each leg of the network could be equipped with unit protection, but this would require circuit breakers at each substation; this provision would add very significantly to the cost and perhaps more importantly to the size of each distribution substation. If this network is to operate in the same manner as the existing 11kV and 6.6kV networks, then the protection systems should remain much the same. The requirements for the security of supply remain identical to those for the 11kV network and therefore there is no necessity to increase the level of security by installing a more sophisticated network. The system will use standard IDMT and earth fault relays at the primary substation with a relay simulating time limit fuses controlling the 24kV circuit breaker protecting the transformer at each distribution substation.

d) Control and Scada

A control scheme to operate the ring switches at each distribution substation on the 11kV network has been introduced and is currently being rolled out. This is also undergoing an enhancement to introduce automation into the scheme so that the network is automatically resorted in the event of a fault.

The new 22–20kV network will also be required to have the remote control and later the automation facility. Each substation will be required to have the scada remote terminal unit and the ring main unit will have actuators fitted to the two switches.

THE EQUIPMENT

The equipment currently used on the distribution networks in the UK is specifically designed for the UK and although the switchgear is designed and manufactured to the International Standard IEC 62271, it is additionally designed and manufactured to the UK ENATS 41–36 standard that enhances and adds to the IEC. More specifically, the requirement is also for compliance with the company specification that clarifies the requirements for each company. The ENATS specifies aspects which are of particular concern to the UK Heath and Safety Executive and concentrates on the safety of the equipment. The operability and safety aspects of the operation are specifically covered in respect of locking points of isolation and control and safety aspects of cable testing.

The UK specific ring main units are generally designed for a maximum voltage of 15kV and therefore unsuitable for the proposed higher voltage.

Transformers are designed and manufactured for each purpose and so do not pose a particular problem.

It is important to realise that the philosophy of operating switchgear on a high voltage network differs between the UK and most of the rest of Europe. The UK requires a greater deal of interlocking and manual-locking facilities to ensure that it is very difficult to operate the equipment incorrectly and that the risk of danger to operators and the public is minimised.

Switchgear selection

At the outset of this project it was known from the results of an initial survey of available ring main units that non-UK standard switchgear would be required because of the operating voltage. The aim of the survey was to ascertain what equipment is generally available and to check the suitability for operation on the UK system.

The survey showed that a large number of ring main units was available on a world-wide basis; this number was rapidly narrowed down to those that:

a) Incorporated a circuit breaker for the tee-off rather than a fuse.

b) Are manufactured in a country that is easily accessible from the UK to facilitate factory visits.

c) Appeared to offer the appropriate features to comply with UK requirements particularly regarding safety.

d) Are manufactured by a supplier who offers a service and spares facility in the UK.

Once the available types of switchgear had been narrowed down, a more detailed analysis of the equipment was undertaken.

Evaluation and approval of switchgear

The process of switchgear approval in the UK is somewhat simplified by the use of a Switchgear Assessment Panel. This panel, convened by the Electricity Networks Association (ENA) undertakes to assess the switchgear designed to be commonly used in the UK. The panel comprises representatives from the electricity distribution companies in the UK and assesses switchgear at the request of both the manufacturer and at least two user companies. The assessment process, if successful, leads to the issue of a
The acquisition of the required test certificates can prove to be an extended exercise as the manufacturers do not always fully understand the necessity for the examination of the certificates.

**c) Evaluation of the ability of compliance with the Distribution Safety Rules when operating**

It is important that compliance with the existing safety rules can be achieved with the new equipment. Changes to safety rules are inevitably slow and difficult to make because the consultation process is lengthy; changes are not often made to procedures as the training and experience of the operational staff relies on the strict adherence to the rules.

**d) Audit of the manufacturer**

The manufacturers of the equipment are likely to differ from those supplying the equipment traditionally used, because the equipment will be from non-UK sources. It is therefore important that the manufacturer meets the requirements of the company. Background information should be sought to verify the ability to supply other users with suitable equipment and a reference list requested from each manufacturer under consideration. The location of the factory should be checked to ensure that it is within reasonable and convenient travelling distance from the UK.

The manufacturers should be audited for their ability to provide equipment designed and manufactured to the quality required by the user company.

a) The audit includes the following criteria:

b) Design ability

c) Manufacturing methods

d) Quality systems and adherence to these systems

e) Testing methods

f) Failure record of in-service defects and failures

g) On-time delivery record

h) Service back-up in the UK

**Evaluation of other components**

The other components, apart from switchgear, required are:

a) 1 MVA transformer with dual ratio of 22–20/0.433kV

b) Cable to connect the transformer to the ring main unit

c) Cable to connect substations

d) Low voltage distribution board

e) High voltage metering unit

f) Remote terminal unit

g) Various ancillary components

**a) Transformer**

The standard method of connection of the transformer to the switchgear in the company is to attach the ring main unit directly to the transformer – these components are designed and manufactured to a common specification, allowing the flanges to fit one another. This avoids cable connection
between the transformer and ring main unit site. The low voltage board is also attached directly to the transformer from the side-mounted low voltage connections. This configuration is called a “Unit substation” and is defined on an ENA TS 35-1.

This method of connection is not possible with the type of switchgear available so the specification for the transformer is for a “Continental type” with all connections on the top of the transformer and with an integral corrugated tank cooling method. The transformer is also specified with a dual ratio of 22 or 20kV to 0.433kV to cater for the probably change in voltage at a later date.

A similar procedure to the switchgear approval process is carried out to evaluate the manufacturers. A full type testing programme, including a short circuit test, is specified.

A typical “Continental” transformer

Cable

The cable required does not present any change in normal methods for cable evaluation as the current contract for 11kV and 33kV cable can be easily adapted thus no further evaluation of the manufacturer is necessary. The cable type of XLPE screened is readily available as a standard, as are the screened “plug in” connectors.

Low voltage distribution board

The company’s standard LV board is selected as the most suitable for this project and thus no additional evaluation or approval is required.

Remote terminal unit

Again, the company’s standard unit is selected as being compatible with the control system – the interface with the switchgear is specified to the switchgear supplier to ensure compatibility with the actuators and indications from the switchgear.

High voltage metering unit

A number of the substations will supply customers who take their supply at 22kV or 20kV and therefore metering is required at that voltage level. The standard 11kV metering unit is designed to fit directly to the rear of the UK-style ring main unit and of course this is not available at 20kV. Therefore a separate metering panel containing the metering class CTs and VTs is required. This again requires evaluation and approval. A similar process to the switchgear evaluation and approval should be carried out.

CONSIDERATION OF INSTALLATION METHODS

Switchgear

The conventional arrangement for UK-style switchgear is for cable boxes at the side and rear of the ring main unit, situated at least 500mm above floor level. The option is also available for inverted side cable boxes to enable the cables to enter from the top of the substation; this is particularly useful in the case of underground substations.

In the case of the switchgear under consideration for the 20kV system, all available equipment uses a convention of bottom entry cable within the footprint of the switchgear. This presents the requirement for a change of design to the substation because very few distribution substations have a basement or other means of access for cables from below the substation.

The method used to permit the installation of the switchgear is to install a purpose-made plinth to raise the switchgear thus allowing the cable to be installed from below the switchgear. The traditional UK switchgear is cabled using connection lugs mechanically connected to the cable and bolted to the bushings in the switchgear cable box. This connection is then completed by moulding a heat shrink system around the connection.

In the case of the 20kV switchgear, the cable connections are made by means of “plug in” connectors and although the company has experience of this method, it is very limited in the installation of distribution substations. It is accepted however that this is a very convenient method of connection.

Transformer

The “Unit substation” method of connection is not possible with the type of switchgear available at 20kV and so a decision is to use “plug in” connectors on the transformer as well as the switchgear.

The transformer specified is thus for a “Continental type” with all connections of the top of the transformer.

The high voltage metering unit, where required, is cable connected to the “tee-off” from the ring main unit and then cable connected to the customer’s switchgear; this is all connected using high voltage “plug in” connectors.

The installation, once the above issues are understood and accepted, does not prove to be a problem

Spares
The standard 11 and 6.6kV distribution equipment is frequently installed and so there is always sufficient equipment in the company’s stores to supply spares in the event of a failure, without keeping a specific spares inventory. As this project to install a 22–20kV system is beginning in a very small way with only a handful of substations, it is essential to keep a specific spares inventory or at least one of each type of the equipment. The lead time for delivery of the equipment is extended and in the event of failure a lengthy time off-supply would be inevitable – unless backed up by temporary generation.

**Training**

When any new equipment or system is installed, it is essential that all staff involved receive appropriate training.

Training is required for installation of the equipment:
- a) Installing the ring main unit on to a plinth
- b) Installing the cable from beneath the switchgear
- c) Terminating the cables with the “plug in” HV connectors
- d) Correctly plugging in the terminating the cable screens
- e) Commissioning the protection relay
- f) Commissioning the metering unit

Training is also required for the safe operation of the switchgear; equipment will be made available in the company’s training centre to assist with this. It is very important that all staff likely to be involved with operating the equipment be trained before they are required to operate in the substations. The manufacturer will be required to produce a training package with a video simulation showing the correct operating procedure for the equipment. This package will be available on CD so that it can be used as a reminder on site if required.

**SUMMARY**

It can be understood that above procedure for installing a new system into an established mature network is lengthy. By following a thorough planned procedure however, the chances of problems with the installation and operation will be minimised.