DEVELOPMENT OF RETROFIT MV/LV TRANSFORMER DESIGNS TO ACCOMMODATE INCREASED ELECTRIFICATION

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ABSTRACT

ESB Networks have developed modified MV/LV Substations for new housing scheme developments – specifically a Packaged Substation equipped with 630kVA Ester transformer which can cope with sustained peaks of up to 1MVA, and very low loss 1MVA mineral oil transformers which can be retrofitted into the space required for a 630kVA transformer.

Additionally, it has developed a prototype 200kVA 'Sidewalk Transformer' which can be installed on the public path to reinforce weak cable networks.

On Overhead networks, a 300KVA low viscosity oil Transformer which can replace a single pole mounted 200kVA transformer.

MV/LV Substations for LV networks in Domestic Housing Estates were designed in the past on the basis of a stochastic After Diversity Maximum Demand of between 1.5 and 2.5kVA per house, with the highest load in the house being the electric cooker, which was seldom on at full load for long periods. Furthermore, with the drive to increase the electrification for transport and heat, widespread replacement of existing fossil fuel vehicles can be expected, with each replacement electric vehicle (EV) having a demand of 7kVA. In addition, it is expected that there will also be widespread adaptation of Heat Pumps (typically 3.5kVA) to displace fossil fuel heating in homes.

Such widespread load additions to existing networks can be expected to impose quite significant extra loading on networks which were designed for less than 2.5kVA per customer, with the likelihood that many networks may become overloaded and require reinforcement. The utility then faces a dilemma – reinforcing in advance may prove unnecessary if the diversity associated with EV's is significant e.g. perhaps EV's only charge every third day, or load control could ensure that EV loading was matched to the available network capacity. Even worse would-be inadequate network capacity preventing EV Charging.

Accordingly, the best approach would be to develop a method whereby extra capacity could be quickly installed at short notice in existing networks thus reducing the lead time before a decision was required. However, this assumes that existing networks are capable of being uprated, which may not be the case, where packaged substations were optimized to minimize cost and hence difficult to uprate.

Similar problems arise in new Housing Estates where an optimal balance is required between the capacity originally provided and scope to increase further. As the largest Packaged Substation was 630kVA, a replacement 630kVA Ester transformer was developed which could cope with sustained peak loading of 1MVA for use where load was uncertain or where an existing 630KVA needed to cope with high peak EV loads. In cases where voltage drop would tehn be an issue a 1MVA Tap Changing Transformer with no more losses than a 630kVA was developed for retrofit.

Finally, in cases where LV cables in existing network are overloads a slimline Substation can now be installed on the public path adjacent to the LV circuits.

INTRODUCTION

The rapid introduction of the large, long duration loads associated with Electric Vehicles (~7kW) and Heat Pumps (~3.5kW) with the likelihood of and additional 3kW immersion 'booster' can be expected to pose challenges to distribution networks designed on the basis of a 2 – 2.5kW ADMD.

In the longer term it is probable that a combination of new Tariffs using SmartMeters, and the availability of local controls within networks through DSM Flexibility will slow don such growth or at least control it's diversity by up to 20%.

However there is also the possibility that new Tariffs and DSM measures could actually pose additional problems, as they will mean less diversity – instead of having the EV charging at night and the Heat pump operating most often during the day, both may be scheduled to operate intensively mid-morning (say) to absorb excess Solar or Wind production.

The approach taken by ESB Networks in addressing these challenges and the solutions developed, are described in this paper.

OVERALL VIEW OF FUTURE NETWORK DEVELOPMENT

In Fig. 1 below is a description of the possible network development paths which may be followed, and the development of different solutions for different scenarios in a manner which does not strand previous investments.

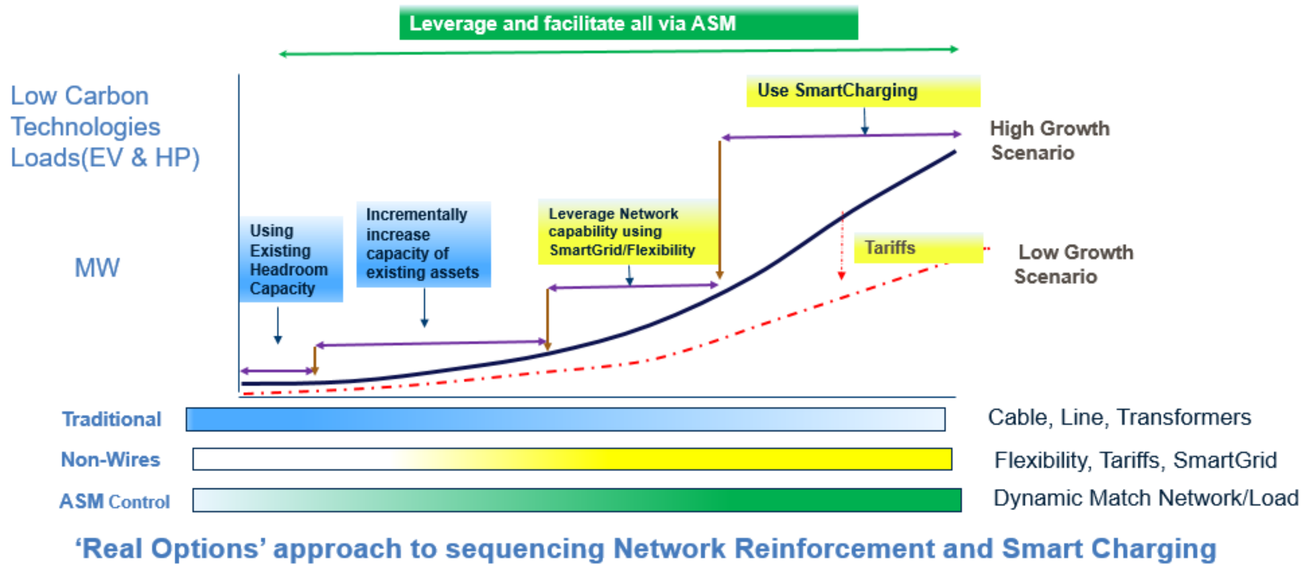

Fig. 1 Development Path for LV Distribution Networks following a 'real Options ' approach.

In Fig. 1 the possible scenarios for load growth over time are illustrated by the load growth scenarios shown, and the 'breakpoints;' on the network shown along with possible levels of additional capcity which can be added at least cost to provide an immediate solution to the particular problem.

This investment sequence also assumes that the load will not grow so rapidly that earlier investments are not required, but if this were the case the model still holds. Essentially the investments which give the largest potential increase in the capability of the system to deal with extra load are correspondingly expensive, so they would not be deployed for smaller increases where less expensive and faster solutions were available.

It is also important to understand that what is illustrated in Fig.1 is the growth in load over time and the investments which provide the capability of the network to meet that load. This may involve increasing the capcity of the network to match the load required, but equally it could involve controlling the load so that it matches the capability of the network e.g. if 200kW of spare capacity is available on a substation it could feed 30 Electric Vehicles simultaneously. However, if each EV were restricted to 4 hr continuous charging and this were allocated evenly during the day, then the same level of headroom could accommodate 180 EV's for no additional cost.

Examining Fig 1 it is seen that the pattern of network development and reinforcement is illustrated by the shaded horizontal bars at the bottom of the chart which show that reinforcements begin with traditional investments in extra capacity and then such investments decrease as Non-Wires solutions such as DSM and local control increase. The last bar shows 'ASM' which stands for Advanced System Management which describes a process whereby the capability of the network using SmartGrid control is actively matched to the requirements of load which is managed through DSM, so that the overall system is optimised by managing all flexibility available.

It is therefore seen that there is a natural investment sequence, starting with the use of already available network capacity, and this would include possible increases which may be available from re-rating network components e.g. there may be a mismatch between the Transformer rating which arises from thermal limits but which is expressed as an electrical load, so that a transformer designed for Full load rating at a design temperature of 40°C may have extra capability when used at 20°C.

Next comes the area of most interest to this paper, which is the addition of incremental capcity to existing assets, particularly through the increase in transformer capacity in existing Substations and the addition of new substations to inject power into existing circuits so that expensive relaying of cable is avoided.

As about 70% of the overall costs of the electrification of heat and power arise from network reinforcement from the MV/LV Transformer and LV system, this is an important area.

However, there are limits to the ability to uprate the network traditionally, and these arise not from physical issues but instead from economic ones – it simply becomes better value to provide the load capability required through the use of Tariffs, Flexibility, and Smartgrid.

Tariffs are an area which is intuitively understood – customers respond to price signals. However, the signals have to be meaningful and significant enough to drive behaviour when required. Tariffs could also be driven by issues such as the availability of renewable generation at low prices, where the low price signal in the market then encourages customers to switch on loads/generators, but without the involvement of any centralised control system, resulting in a loss of diversity.

Non-Wires solutions are ones where the Distribution System Operator (DSO) has control either of the operation of it's own network to increase capability (e.g. dynamic re-sectionalising in response to increased load) or where the DSO may purchase Flexibility/DSM directly from other customers in order to meet local load requirements.

Smart Charging is under the control of the customer and is associated with how the customer decides to operate their own loads.

Both Non-Wire and Smart Charging solutions are sub-optimal on their own as the synergies between them are lost by operation in isolation, and this is where Advanced System management comes in to match the capability of the network under DSO control to the scope for Customer load pattern changes provided by Smart Charging. Such a combination operates over both systems, releasing synergies and resulting in optimality.

PROVIDING INITIAL CAPACITY THROUGH THE USE OF INCREASED TRANSFORMER SIZES AND NEW SUBSTATIONS:

It is seen form Fig. 1 that the optimal initial response to load growth can be provided by increasing transformer capcity in existing substations and by the introduction of new substations to split the existing cable network and reduce cable loading.

Transformer substations typically have more capacity on their circuit outlets than transformer capcity installed e.g. a typical package substation would have 4 LV outlets each with a capacity of 200 – 250kVA, yet have a transformer size of 400kVA.

Being able to increase the transformer size in a packaged substation is difficult due to the space limitations which may exist, yet is a very inexpensive way of providing extra capacity.

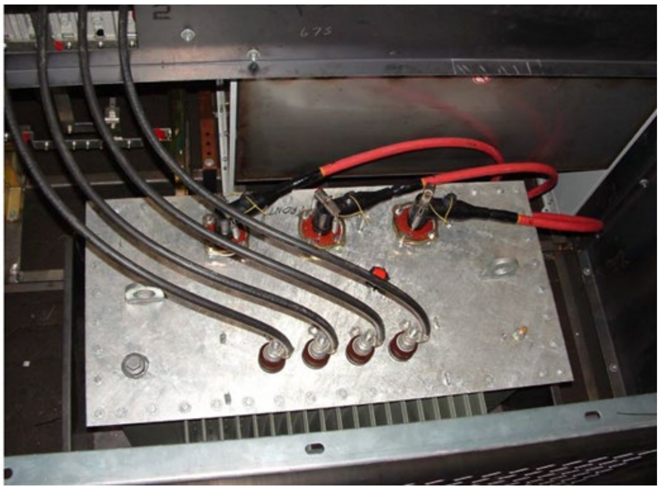

Fig. 2 Existing Transformer in Packaged Substation

Uprating this substation requires that the new, larger capacity transformer fits into the space available which , as can be seen from the photo, is quite limited.

Two approaches were developed:

(a) 630kVA Ester Transformer

As Esters can operate at higher temperature it is possible to have a higher power density so that the transformer can fit into the space available. As the peak load that may occur on the substation may only occur for short periods, the ester transformer is well capable of such excursions, even for long periods and without loss of life.

Fig. 3 630kVA Ester Transformer with peak capability > 900kVA

(b) 1000kVA Tap Changing Transformer

If additional power is required then a larger transformer is needed, and in such case voltage drop may also be an issue. Accordingly a 1MVA Tap Changing Transformer was developed which could also be retrofitted into newer/some existing Packaged Substations.

As the overall Substation was only designed for the temperature rise associated with a 630kVA transformer, this issue was overcome by designing the transformer so as not to have more losses than would occur on a 630kVA transformer.

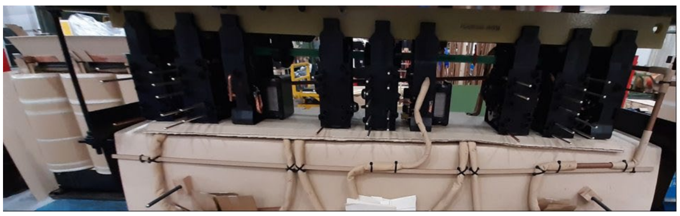

Fig. 3 Tap Changer in low loss 1 MVA Transformer.

Two interesting points emerged during the design:

(a) The Tap Changer could not be installed in the Ester type transformer as the Tap Changer had not been tested for operation at the higher temperatures involved

(b) The Transformer is single ratio as it was not possible to have select winding taps suitable for operation at both 10kV and 20kV. However, as most usage is expected in 10kV areas this is not an issue

Note: As ESB are converting the MV System form 10kV to 20kV, all transformer are dual ratio with the MV Windings operating either in series or parallel to give either 20kV or 10kV operation.

In newer substations the number of LV Outlets have been increased from 4 to 6 to facilitate less circuit loading, less voltage drop, higher SC levels and greater resilience due to improved standby. This extra circuit capacity then allows normal 630kVA Transformer to be uprated to 1000kVA and offloaded should the requirement arise in the future.

The reduced losses on the extra cabling involved is paid for by the reduction in circuit losses.

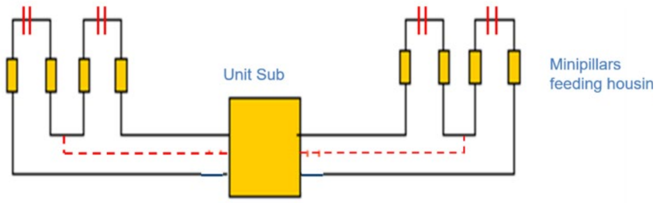

Fig. 4 Schematic of Unit Sub and Cabling

As can be seen from the above, the addition of two extra LV Cables allows for an improved network design and has low cost in 'greenfield ' sites where the ground is already open for cables to be installed.

In mature areas where no substation sites are available and where LV Cables may be inadequately sized the use of a 'Sidewalk ' Transformer of 200kVA is being prototyped.

This would be installed on the public sidewalk or grass verge due to it's small size and allow local reinforcement.

The current prototype has no switchgear and is limited to tail fed applications but resin switchgear may be compact enough to be installed and low looping into the main MV circuits.

A photograph of the prototype is shown in Fig. 5 and is similar in size to the Telecom cabinets seen on urban/sub-urban streets, so likely acceptable to public.

Fig. 5 Prototype Sidewalk Transformer 200kVA

Interestingly, TEPCI in Tokyo have significantly smaller units, equipped with 6.6kV RMU's on every street in Tokyo, with the RMU being about 600mm wide!

Overhead Networks:

Currently the largest Single Pole Transformer size is 200kVA, but recently ESB have introduced a single pole 300kVA unit which can be accommodated on the same pole as was used for the 200kVA, thus minimising upgrade costs where loads develop.

Fig. 7 200kVA Pole Mounted Transformer

The new 300kVA Transformer can replace the existing 200kVA in situ and provide increased capcity where required.

CONCLUSION:

Providing extra load capacity by uprating transformer sizes and introducing new substation s to split existing feeders rather than uprate cable networks is a low cost approach which is fast and economic to cope with increased electrification.

Furthermore, as other approaches are developed, the existence of these investments is not stranded as they are all standalone and have no legacy requirements.

Note: All Transformer shown produce by
Kyte PowerTech in Ireland