ABSTRACT

In this paper the author details how ESB Networks carried out a fundamental re-examination of its housing scheme design criteria, developed new design procedures, matched these to the range of network components purchased and retrained Design staff in the new approach. New housing scheme design achieve greater standardisation of the equipment required, more intensive use of assets and a more flexible network design with lower losses, better voltage regulation and improved reliability.

INTRODUCTION

ESB Networks is the Asset Owner of the Transmission and Distribution networks within the Republic of Ireland, a small country with an area of some 70,000 sq km and a population of 4m, corresponding to 2.2m ESB customers.

Demand has being growing rapidly – in 1999, the peak demand was 3,436 MW and the customer base was 1.5 million with a load growth of 6% per annum. New customers were being connected at a rate of 50,000 per annum. However by end of 2006 peak demand had increased to 5,042 MW (nearly a 50% increase) and the number of customers connected reached 105,000 per annum – i.e. had more than doubled. In fact between 2001 and 2007 580,000 new customers were connected – approx. 25% of all ESB customers.

Accordingly the connection of new housing needed to be reviewed in order to ensure design was optimal.

GENERAL APPROACH

The project had three phases – analysis of existing housing schemes, development of improved design procedures and extension of appropriate training to design staff. A five man project team (headed by the author), consisting of engineers involved in the national customer connection business initiated the process, and were later backed up by a team of experienced design staff in carrying out the training.

Housing Design:

ESB Networks housing schemes utilise pad mounted unit substations comprising a transformer (200/400/630kVA), a Ring Main Unit (kKT or kkkT), and a 5 x 400A LV panel. Larger concentrated loads such as commercial developments/apartment blocks using Night Storage Heating (NSH) may use 2 x 1000kVA indoor Substations.

All LV Mains cabling is 4 x 185 AL XLPE, all MV cabling is 3x1x185 AL or 3 x 1 x 400 AL XLPE.

House connections are via 35/25 service cable comprised of Al conductor surrounded by stranded copper wire.

All cabling is pulled in ducting which has been installed by the house builder when paths were open, with cable pits located opposite each group of 8-12 houses, where an above ground connection box (Minipillar) is installed. The Minipillar can accommodate up to 3 x 4 x185 cables and 12 service cables. Sectionalising Minipillars are also used.

Analysis

A sample of 12 recent housing scheme designs were selected from practised design staff and reviewed in detail by an experienced design engineer. Each scheme was then re-designed in an optimal way taking into account changes in network components that were readily achievable and using appropriate DCF analysis to assess the optimum initial size of plant with regard to losses, load growth and standby facilities.

Areas for improvement were grouped into three sources:

(a) Improvement in the existing Design process
(b) Improvements in the Technology used
(c) Improvements in the execution of the Designs.

Improvement in the existing Design process

(1) Non-optimal MV/LV Substation Position

This is the most critical area within the housing scheme design, as a poor substation position will result in longer cable runs, excessive voltage drop and losses. Non-optimal location also restricts the optimality of future network developments – in fact along with the extra costs first incurred, there is a series of future extra costs arising from how the poor position of the initial substation affects that of future ones.

(2) Conservative Load estimation

ESBN does not estimate customer’s loads, as it is only he customers themselves who have a full understanding of their load requirements. However there is a tendency for customers (or their consultants) to overstate actual load requirements, resulting in a higher level of capacity
requirement. This results in larger shallow costs which the particular customer pays for directly, but also drives the need for upstream reinforcement which is shared by all customers.

However upstream investments, such as a new Cable circuit, are external to the customer’s premises and can be installed as required, and, as long as there is sufficient time to make the necessary system changes, do not need to be done immediately. This means that if the design staff feel that the accumulated customer load is excessive, it behoves them to hold back on committing to any upfront investment until the actual load has been measured. This approach requires good guidelines for the Design staff in order that their decisions are not overly conservative.

(3) Complicated MV feeding arrangements

New substations need to be connected into existing MV networks, and it was evident that a desire to do the most economic job was resulting in excessively complicated networks with poor feeding arrangements.

In particular there was a tendency to use a kkkT substation type which could be looped into an existing circuit and also provide a single circuit radial feed to further substations. It was felt that this was more economic than looping in the new substations as only one run of cable was required.

(4) LV Network design

At the LV level there was excessive concern to minimise initial cabling costs and to minimise use of backfeeds on the basis that these involved extra costs. It was difficult to have a clear process to consistently produce economic, efficient and effective designs because each housing layout was different, and whilst lowest initial cost was easily calculated, longer term value creating designs were difficult to justify.

Scope for improvement was also seen to be available in the application of economic conductor sizing and the allocation of volt drop between LV and MV in urban systems.

Development of improved Design Procedures

To address the issues discovered, an MV and LV Design Guidelines manual was developed along with a set of worked examples, showing existing design and an ‘even better if’ version.

Issues that had previously required very sophisticated judgement on behalf of design staff were simplified into simple decision tables and procedures for producing optimal housing scheme designs were developed.

Technological improvements:

Some important decisions were taken in regard to the technology which facilitated simpler designs, as well as saving money on logistics and procurement. In particular the range of pad mounted substations was restricted to 200kVA and 400kVA sizes only, on the basis that cyclic housing scheme loads allowed for a 30% increase in rating. This meant that a 400kVA could in practice feed about 520 houses at 2.3kW ADMD – however a 630kVA would have such a large feeding area that volt drop and feeder losses were likely to be such that it would not be fully loaded. However all ESB Pad mounts could still be retrofitted with 630kVA.

Also, it was decided to eliminate 630kVA Unit Subs and only to make kkkT versions available in 400kVA pad mounts, with kkkT would be avoided wherever possible i.e. the presence of a kkkT was to be considered as a sign of a possible design problem.

This meant that ESBN Tenders for Unit Substations now only needed to cover 200kVA kkT and 400kVA kkT/kkkT, reducing substation variety by 50%, from six types to three.

Load estimation and Transformer sizing:

Whilst design staff would continue to provide customers with the level of connection requested, the timing of upstream reinforcements would depend on ESBN’s own assessment of likely customer load.

To facilitate this guidelines for cross checking customer load estimates based on connected loads with diversity, w/m² estimates from floor area and comparison with the existing loads of similar customers were issued – these would highlight discrepancies for further investigation.

In particular w/m² tends only to be reliable in large developments, where a single load will not distort the calculation and where loading is uniform with area i.e. predominantly lighting and air conditioning. Typically figures of 70w/m² (no air con) and 100 w/m² (air con) are used for initial assessment as these are relatively conservative.

Comparison with typical loads, as shown in Table 1 is also useful, as is diversifying lists of installed loads, where the total ADMD is usually about 50% of connected load.

(Lighting load is same as installed load i.e. 100% Process Heating Loads 35% (- thermostatically controlled).
Space Heating – 70%, Canteens – 30% Groups of water heating loads (immersions) – 20%, Hand driers – 5%)

Coincidence of loads needs also to be considered – night security lighting should not be added to day load
The size of the initial transformer chosen is such that it has 25% extra capacity for future growth – unless this would result in a second substation.

Table 1

| Decision on whether to do a larger job now so as to avoid extra cost in the future have been rationalised using DCF and presented in a simple formula. So if the cost of a minimal job now is €6.8k followed by an uprating some years later for (say) €3.9k, as against €8.6k to do the full job now, then the ratio of €3.9k / (€8.6k – €6.8k) is calculated (2.17) and from the chart it is seen that breakeven is around year 14 i.e. if you feel that the uprating will definitely not be required before year 14, do the cheap job now – if not do the full job now. As is apparent it is much simpler to make a judgement about whether something will/will not happen over a period than do DCF cashflows!

Table 2

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<th>MV Feeding Arrangements</th>
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In the MV Design Guidelines it was established that the goal was to have direct MV feeders between HV substations as this led to a flexible and orderly development of the network. In support of this all new cabled MV/LV substations would be fed via a Double Run of cable, thus avoiding the need for outages for increasingly large loads which were a feature of single cable feeds.

Use of kkkT RMU’s was abandoned except for particular network configurations (Fig. 2)

Fig. 1

Extension of MV Cable Network – Development in progress, each new station is looped into last cable section

Fig. 2

Dangers of using kkkT Switchgear in MV Designs

Fig. 3

Poor Extension of MV Cable Network – Initial station fed from kkkT, and network extended in hope of eventually being able to loop somewhere. In many cases this proves impossible e.g. developer does not proceed with next phase etc. 1.5MW on a tail has been seen but record is 15 substations on a tail – adding in an extra substation can then require outages of up to 14 substations.

LV Housing scheme design

(1) Place the MV/LV substation at the assumed electrical ‘centre of gravity’ of the development

(2) For the LV Housing scheme design, start by looping all houses with 4x185 cables on both sides of the road. Look at connecting new network to existing network and try to get direct Substation to Substation feeders.

Failing this loop back into original substation. This creates loops which when later split into new substations will create substation to substation feeders.
(3) Draw LV Schematic to clarify the proposed network and then adjust it to get rid of extra cable which is not giving much benefit. Add in extra cable to complete loops or worthwhile interconnection. If there are long runs of cables in parallel then the substation is not optimally positioned and should be relocated.

Fig. 5 Original Design Example - Optimal design below:

Note the lack of cable crossings, the interconnection with existing networks and the looping of tail feeds. For small extra amounts of cable good interconnection and topology is achieved, increasing reliability, reducing losses and facilitating economic expansion, as the capacity in existing subs can now be tapped, resulting in subsequent Unit Subs being located further away (- these types of design readily lend themselves to accommodation of DG, as they can be configured to minimise voltage rise.) In this particular example the actual amount of cable in the improved re-

design was significantly less than in the original due to optimal substation position and improved circuit layout.

Whether or not is economic to run two cables, one on each side of the road and then loop then instead of just running one cable along the road and providing teed connections to Minipillars on the opposite side was also analysed.

Fig. 6

Minipillars on both sides of the road, feeding up to 12 houses each

The result of the analysis was that where there were more than 45 houses expected on either side of the normally open point, then losses savings alone would justify looping, and improved standby and more flexible network development would justify method A.

Fig. 8

Single Circuit possible when interconnecting to existing Network:

Double circuit to facilitate extension into adjacent Housing development (e.g. end of cul de sac shown by dashed line).

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