MAXIMISING BENEFITS TO CUSTOMERS FROM DISTRIBUTION LOSSES MANAGEMENT – AN ESBN PERSPECTIVE

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ABSTRACT

Electrical Losses on Networks are an unavoidable consequence of the Transmission and Distribution of electrical power. In Ireland where over 30% of customers live in rural networks, Distribution system losses represent 7.5% of GWh distributed and thus constitute a significant component of the overall cost of electricity to customers.

Accordingly in such situations Utilities are required by Regulators to achieve improvements in losses where this is economically advantageous to customers, as it is the final customers who the ultimate winners/losers on the chosen investment decisions.

In ESB Networks all investment decisions incorporate the capitalized value of losses, so that the Total Cost of ownership is included in all cost/benefit analyses. Furthermore by capitalizing the losses consistently at the same discount rate across all voltage levels, there is no sub-optimization of investment in any one part of the network – in contrast, adopting simple set limits of losses for (say) Transformers alone would produce sub-optimal savings.

BACKGROUND

ESB Networks is the Asset Owner of the Transmission and Distribution networks in the Republic of Ireland. Ireland is a small country with an area of some 70,000 sq. km. The population is just under 4.5m and there are approx. 2.3m electricity customers. The system peak load is at circa 5,100MW.

Over 30% of the customers live in rural areas, most in the country side in separate dwellings.

A total of 80,000 km of MV overhead lines and 50,000km of LV network is required to serve this dispersed customer base, along with over 200,000 pole transformers. Furthermore as 60% of the MV network is composed of single phase spur lines connected to main 3-phase lines, over 90% of the 200,000 Overhead transformers are single phase.

LOSSES ON ESB'S DISTRIBUTION SYSTEM

In Fig. 1 the estimated energy flows including losses on ESB's Networks at the various voltage levels are shown. This assessment of distribution losses is developed by measuring the energy flows at transmission to distribution interface substations and at distribution connected generation sites which are increasing in number. This gives the total input to the distribution system. The measure and estimated consumption of customers is subtracted to yield the total distribution system losses.

Load flow studies are carried out to establish the loss rates for the various levels of the network. For LV networks these are based on analysis of representative samples of network fed from Urban and rural MV/LV substations. Staring with the energy flows into the system, the losses at the various voltage levels (and the losses at the downstream level in the system) can be calculated using the loss rate.

The total losses allocated in this manner will not match the total system losses determined by subtracting the measured input and outputs. The difference is attributed to commercial losses which are presumed to arise at LV.

As can be seen from Fig. 1, about 6% of losses are on the Distribution Networks and a further 2% on the Transmission Networks.

CRITERIA FOR LOSSES RELATED INVESTMENT

Essentially with investments in loss reductions there are a number of variables; the quantity of kWh which will be saved, the value of these losses, the marginal cost of plant to supply at peak, and the cost of capital. The quantity of kWh that will be saved is specific to the proposal that is being considered. However the same cost of losses and discount rate is applied to all investment decisions. These are determined by the ESBN asset strategy team.

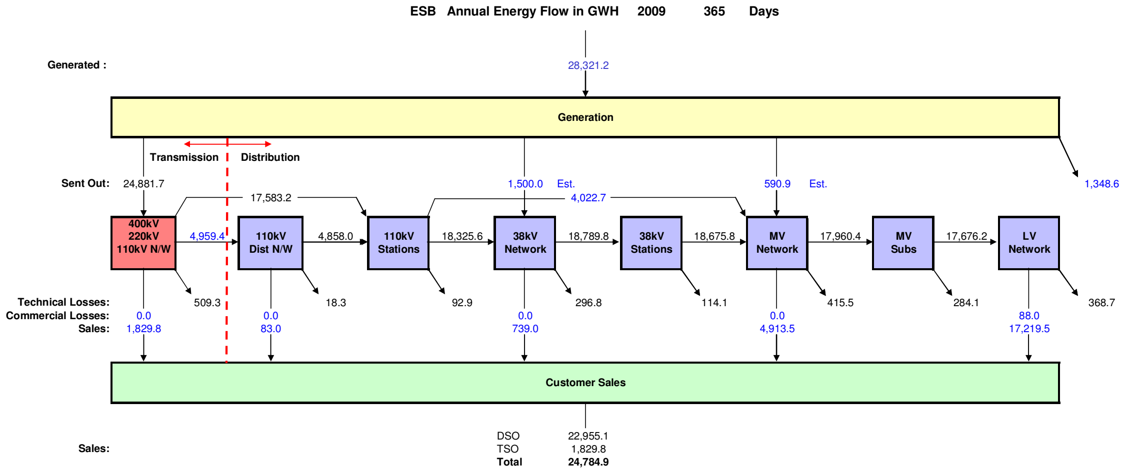

Fig. 1 System Losses in ESB Networks

Cost of Losses

The cost of losses is made up of an Energy component relating to the kWh of losses created and a Demand component related to the contribution of losses to the System Peak and the associated extra Network and Generation investments over the next 25 years.

The Energy component is determined by the Load Factor (LF) and consequently the Loss Load Factor (LLF) which is much less, being proportional to the square of the LF. The LF itself is lowest at the Low Voltage on Transformers and Cables, due to diversity, but increases upstream. Accordingly any calculation of losses must take into account this effect.

In regard to the Demand component, this is related to how the peak on the item of plant concerned is associated with the System Peak, and is calculated using a System Peak Responsibility Factor (SPRF) . So the SPRF of the loads on a 15kVA transformer will have little impact on System peak as it is unlikely that their much diversified loads are likely to fully coincide with the system peak, whereas most of the peak on a HV transformer will actually occur at system peak.

The Energy component is measured in kWh, with the kWh being priced in relation to gas, including the cost of carbon. The Demand component is measured in kW, with the cost of the kW related to the marginal impact on future generation and upstream network reinforcement requirements.

Cost of Capital:

The concept of a Weighted Average Cost of Capital is well known in utilities and is usually set by the Regulator, taking into account the relative proportions of Debt and Equity within the company, the cost of Equity and Debt, and the relative business risk of the utility in relation to other companies in the same business. However this WACC is not necessarily for evaluating losses , as the risk profile on loss reduction investments can be different from the business as a whole.

Accordingly the appropriate discount Rate for Loss reduction investments is higher than the Utilities normal WACC, but below that of a Generator. In ESB's case a value of 7% is used versus a regulatory WACC of 5.95%.

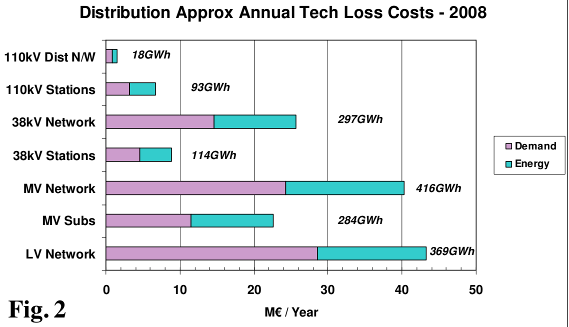

Fig. 2

Application:

By producing capitalised costs for each kW of losses at each voltage level, the cost of losses can be incorporated in all network investment decisions, from Network Planning to Procurement of Networks components, with no over investment in any one area.

MANAGING DISTRIBUTION SYSTEM LOSSES:

It should be noted that there is no overall acceptable level of losses between utilities, as the level of optimal losses depends largely on the design of the existing network, which has arisen over many years.

The opportunity to optimise losses on the system generally arises when investment decisions are being made in relation to plant or network design including the replacement of old network components due to age or overloading.

Examples of investment decisions where losses are significant include ESB's conversion of the MV Network from 10kV to 20kV Operation, and the rebuilding rather than refurbishment of an initial 500km of old Siemens 38kV line, as described below:

20kV Network Conversion:

Ebb's rural overhead 10kV networks were built in the 1950's in the expectation of a typical household consumption of 1,000kWh pa. However by the 1980's consumption was well over 4,000kWh pa, and with the larger increase in housing from the mid 1990's onwards, these networks were severely loaded, with very poor voltage regulation.

A range of possible options were evaluated, but it was clear that 20kV conversion offered the greatest benefits. The costs of 20kV conversion were little more than those of rebuilding in 10kV, yet the voltage drop was halved, thermal capacity doubled and losses reduced by 75%.

By 2010 almost 50% of the MV network in Ireland had been converted to operate at 20kV, and a further 20% is planned to be converted by 2015, reducing losses from 7.5% to 7%. It is estimated that peak losses on this 20% amount to 25MW, and that this reduction will actually pay for the full cost of conversion over 25 years.

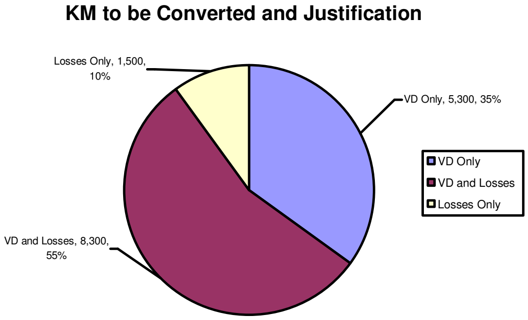

Fig. 3 Justification for current 20kV conversion

As can be seen from the above pie chart, the current 15,000km requires reinforcement mainly because voltage will be outside standard, but by converting to 20kV not alone is the network reinforced, but the investment pays for itself over the following 25 years!

Asset Replacement:

During the late 1920's Siemens worked with the ESB in building over 2,000km of 50's Copper 38kV Lines, using a combination of steel towers and wooden poles. However despite regular maintenance and refurbishment, by 2008 portions of this network had deteriorated, with a combination of problems including mid-span joint failures, corrosion on steel towers and rotten poles.

Fig. 4 Siemens 38kV Steel Tower/Wood Pole Line

The decision as to which lines were to be rebuilt and which refurbished was made on a circuit by circuit basis, taking into account the use of a new 150AAAC single pole line which had a significantly greater rating than the 50Cu line being replaced, and much lower losses.

Fig. 5 Replacement 150AAAC 30MVA 38kV Line

It was found that the optimal strategy was to rebuild 500km of Siemens 38kV line in 150AAAC, and to refurbish others, with Thermovision cameras being used to identify and replace problematic joints.

Network Components:

As well as including losses in all investment decisions, ESBN also use capitalised losses in the selection of network components such as transformers, OH lines and cables, with the sizes chosen so as to be effective in minimising losses to an economic level. Typical cable sizes in ESBN are 4 x 185 AL at LV, and 3 x 1 x 185 Al and 3 x 1 x 400 AL for MV, with these sizes influenced by their expected contribution to system losses.

On Transformers, where losses can be optimised at each tender, capitalised value of Iron and Copper losses is issued with the Tender, and the Total cost of Ownership (Initial cost + capitalised losses) is an important factor in evaluation.

FURTHER DEVELOPMENTS:

As part of ESB's R&D project with EPRI, two projects are being undertaken under the aegis of 'SmartGreen Networks', the use of more advanced, low loss, pole transformers and the Dynamic Sectionalising of networks using existing Reclosers to minimise losses.

Low Loss Transformers:

Amorphous transformers have been known for many years, but whilst common in Japan, India and China they were uncommon in Europe. The reason for this is that when amorphous core transfomers were introduced previously in the late 1970's, the impact was to drive traditional Silicon steel transformer manufacturers to reduce losses through design changes and also to reduce prices in order to remain competitive.

This meant that the reduction in losses produced by amorphous core transformers was insufficent to compensate for the higher initiial costs associated with more expensive amorphous core and larger, heavier tanks.

However the new generation of amorphous core units not alone have lower losses, but for OH Pole Mounted Transformrs are claimed to be no larger physically than existing silicon steel units.

In addition, three phase Hexaform shaped transforemers, which have been available for many decades, were known to be very efficienct but were excessively complicated to manufacture, but now, due to a breakthrough in manufacturing technology, are expected to be competitive with traditional transforemrs.

ESBN currently have 150 MV Amorphous core and 50 Hexaform transformers due for delivery in early 2011 for network trials, as this will facilitate their inclusion in the next Transfoermer Tender.

By capitalising Iron and Copper losses and issuing these with the tender, transformers which are most cost effective in achieving economic loses at the lowest price can be sourced.

Dynamic Sectionalising:

Traditionally networks have been sectionalised to maximise continuity rather than minimise losses. With the advent of 'self healing networks' and SCADA, it is now possible to sectionalise to minimise losses whilst still maintaining continuity.

The trial currently underway at ESBN is to assess the benefits of having SCADA move normally open points according to the losses savings available, and also to assess the potential for operating MV networks closed (-difficult on rural newtorks with low SC levels).

In particular, matching the sectionalising to the output of an MV wind generator is being trialled so as to minimise 'spill' up stream and hence reduce network losses as much as possible.

CONCLUSION

Including losses in all network investments is Sustainable and results in the best long term benefits for society as energy costs are minimised, CO2 emissions reduced and the use of fossil fuels unnecessarily eliminated.

In addition the 'spin off' benefits of low loss equipment are that it runs at lower temperatures and, hence, being less stressed, has longer life and greater reliability. Extra capacity is inherent in the use of low loss equipment which tends to be sized for its economic working load rather than its full rating.

So it's a virtuous circle!

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