Electricity Losses – Do They Matter?

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Mankind is naturally wasteful. Faced with plenty he chooses low hanging fruit with little thought of replacement, often spoiling its original value. Does this matter? Not really, provided the fruit continues to grow in season with little effort and minimal competition. There is plenty for all. Nature provides.

To some extent Australia, the "Lucky Country", epitomises this mindset. We Australians enjoy sun, water, minerals and energy in abundance. So why should it matter that we waste much of these resources through inefficiencies?

Losses get more serious when populations increase, competition arises and resources, previously free – like water for example – command real prices in competitive markets. Capital is invested in the means for creation and distribution of developed end products in forms called for by that market.

Losses matter much more as systems – water, energy, food, transport – become more sophisticated and more capital and job intensive. So it is with electricity. The product is certainly sophisticated: precisely controlled voltage, fixed frequency, absolute stability, unquestioned reliability and other desired attributes now command serious market value. Of course losses matter! They translate to money and are inevitably painful to the customer.

Some claim that losses of electricity generated from 'free' renewable resources – the sun, wind and waves – are costless. Nothing could be further from the truth. Today massively costly infrastructure, especially for 'free' renewable energy sources, is invested to bring electricity to its customers. Needed capital can only be paid for through sales. It clearly follows that electricity lost is income foregone to the supplier and thus is an invisible extra cost to customers. That the cost of electricity is growing fast, and forecast to continue growing, is abundantly evident to those who pay the bills.

So electrical losses must be minimised, but how? Who pays? Why? At what point along the pathway from source to end use? And with what resources?

Classic economic theory claims that the stick of intelligent regulation plus the carrot of unconstrained markets provides for the best directed and most efficient allocation of resources. It makes no sense at all, for example, to allocate substantial land, labour and capital to generate electricity from free abundant energy services such as the sun, wind and tides if the notion of 'free energy' translates to needless losses along the customer pathway.

However the measurement of and accounting for such losses and the provision of market signals to help minimise them, as technology can, is quite a different matter. This is ably demonstrated by Harry Colebourn in his recently cited EESA 2010 Conference 'best paper' entitled "The cost of losses for future network investment in the new network regime". Colebourn's scholarly work guides us through the varied nature of electricity losses from energy source through generation, transmission and distribution to the customer for today and into the foreseeable future.

Colebourn shows us first how losses are categorised as no-load or 'shunt' and load or 'series'; in other words losses that occur continuously in a live system, whether loaded or not, and losses which depend directly on the load and its magnitude - the I^2R losses we recall from university lectures. He then identifies these losses following the electricity pathway from generation through transmission, distribution and end use, calculating the Long Run Marginal Cost (LRMC) of losses for each step (although constrained in his analysis to New South Wales. The results are illuminating.

Nationally, according to published data, some 7% of electricity generated is consumed in internal losses and auxiliaries consumption at the power station, with the balance being net 'electricity sent out'. Losses following in the national transmission system are also substantial, typically another 7% through the step-up transformers, switching stations and the nearly 40,000km of high voltage overhead and underground transmission lines and cables (220kV up to 500kV) that interconnect and span Australia's states. A further 7% - 9% or more, depending on numerous local factors, is lost in lower voltage more scattered customer distribution systems, typically from 132kV down to 240V single phase at the average domestic customer's meter.

Conventionally the power from large coal, gas fired or hydro generators is supplied at around 25kV and immediately stepped up to a higher voltage through the adjacent power station transformers for direct feed into the transmission system. This minimises losses at the first step of the customer pathway although at this stage values are still low, especially for base load power. This is not the case for many renewables which, through low source intensity, are generally distributed widely and remotely in much smaller generation units. Wind farms typify this paradigm which introduces a further loss factor, which my colleague John Sligar in a recent a submission to the Prime Minister's Task Group on Energy Efficiency described as an 'assembly network'. This submission pointed out that with low wind generator terminal voltages of say 600V, and lower from solar panels, the 'assembly network' is far more widespread, comprising inverters, long medium voltage feeders and numerous relatively small transformers before grid voltage is attained. Average losses in the assembly network, depending on topography and line lengths, can be significant with estimates of 5% - 10% or more being quoted. But, given the 'squared' loss multiplier for current flow, it follows that losses at system peaks are firstly much higher than the average and, by definition, occur when electricity value is at its highest. The world of losses and quantification of their value in terms of revenue foregone is indeed complex.

To get the value of losses into at least a broad context, Australian power stations of all types generated just over 250TWh in 2008-09. We may assume, very approximately, that average end to end system losses, excluding the power station and the 'assembly network' at this time, are around 15%. If the sale value is taken as a modest $120/MWh (Colebourn uses generally higher LRMC figures), then Australia wide losses cost at least $4.5 billion each year and probably more. We must bear in mind that so called subsidised 'feed in tariffs' of 60c/kWh ($600/MWh), designed to stimulate renewables investment, suggest that yet higher electricity values could be considered.

Losses, regardless of energy source, are thus far from insignificant and certainly not 'free'. Indeed, depending on the carbon intensity of the source (negligible for hydro, wind solar, geothermal and nuclear), system losses 'contribute' around 30M tonnes of CO_2 each year. Such emissions will, very soon, command their own price through tax, trade or hybrid.

In short, electricity losses are a substantial economic burden.

So much for the problem – but what is the solution? How do we reduce such losses to the economic minimum? Regulatory instruments are still blunt but effective – improvements are desirable; market forces are generally a more refined and intelligent answer – although both stick and carrot must play their part. With national losses so costly it behoves us to consider how we should invest most effectively to reduce them. What, for example, is the economic case for larger diameter low-loss copper power cables, low-loss transformers and other supply equipment and even, for example, superconducting cables in the future? What is the role for system minimum energy performance standards (MEPs), commonplace for appliances and a host of other efficiency improvement measures? What can we achieve with intelligent grids and dramatically better load control systems in our businesses and homes? This market space is still on the threshold, sorely in need of national standards and an appropriate regulatory environment that properly recognises and reflects the cost burden of system losses.

The classic means of engaging market forces is to ensure that price signals impact the person or organisation that benefits from loss minimisation investment. But does not this happen already? No - explains Colebourn; it does not! He notes for example that there is currently no direct regulatory incentive scheme for distribution businesses to minimise their system losses.

For transmission and distribution, what price signal incentives drive loss reduction investments? Colebourn takes us through the complexities of bulk measurement, LRMC calculations and settlement arrangements in the generation, transmission and distribution systems. As noted above he exposes limitations in recording and directing the correct loss prevention price signals to those who could take action, especially network owners. If properly captured, directed and analysed these signals could, where economically warranted, encourage corrective investment in, say, efficient low loss transformers, higher capacity cabling and overhead conductors, increased HV transmission voltages and more.

For consumers in the home, the apartment, the office, the business and the factory the potential for energy efficiency and loss reduction is immense. In my active energy management practice days, both in Australia and overseas, I would confidently predict 25% potential energy reductions (at least as compared to unconstrained BAU growth) with economically rational investments showing a 2 – 3 year payback or less. I would make that same prediction today; not because little has been done since the 1980's, but because advanced technologies such as low loss variable speed drives, computer based measurement and control devices, smarter sensors and faster on line analytical tools have all raised the potential for yet further efficiency gains through automatically managing consumption to programmed criteria. Energy efficiency 'beyond the meter' must inevitably reduce the ratio of overall system losses to useful load.

I conclude with just four observations on the future of electricity supply systems and their likely impact on losses. Firstly the fast rising price of electricity and its likely future trajectory must harden the case for enhanced energy efficiency and the collection and focussing of loss related price signals on system investors, owners, managers and operators. Some commentators forecast electricity price rises up to 300% by 2020, far above predicted economic growth rates of 2-3%. The critical need is to focus those signals more effectively. Secondly, without substantial 'de-bottlenecking' investment in transmission and distribution systems, the 'squared losses' attributable to system peaks, arising from home air conditioners for example, can only increase. Thirdly, a price on carbon and an increasing shortage of base load generation capacity will drive investors firstly towards gas – as is now the case - then to advanced 'clean' technologies such as subsidised renewables with storage, coal with carbon capture and sequestration (CCS) and eventually nuclear and geothermal. Significant supply system investment will be needed to cater for changing load flow patterns. Lastly electric vehicles will soon be ubiquitous. They will impact systems significantly, increasing load flows (and hence losses) but also contributing to system stability and security through their on-line storage capacity. New supply system investment will be needed as load flow patterns adjust to the shift from oil to electricity for domestic transport.

In short the substantial economic burden of electricity losses, exacerbated by growing costs, warrants more exhaustive, better informed and far sighted long term investment analysis in transmission and distribution systems. Planning horizons, often short and expediency driven, must extend to take account of the true economic impact of losses in developing core national assets. National standards (deriving from international models), far sighted policies and regulations that give due weight to the real cost of losses are all part of the solution. Colebourn and Sligar have made a sound start in articulating the problem; much more lies ahead to deliver effective solutions.