Engineering Challenges and Innovation in Power Engineering - Perspectives from my 2008/09 Vocational Employment Experience

by Genevieve Beart

For most people, using electricity at home, work or in any way is as simple as flicking a switch or pushing the power button on a remote control. Little thought is given to how this same electricity was generated, transmitted, distributed and finally sold to them. In fact, all these stages, which fall within the context of power engineering, only seem to come under scrutiny when these same people flick their switches, and nothing happens. Indeed, life with electricity appears unremarkable, but trying to manage without it causes individuals, neighbourhoods and communities to grind to a halt. The power industry must function with the reality of this decidedly human backdrop. The concerns of producing and delivering electricity safely and efficiently to customers are further complicated by global issues. Climate change raises concerns about the carbon dioxide emissions of the power industry, and limited resources, carbon especially, require new engineering solutions be developed. Financial constraints cause companies to search for more economical ways in which to meet customer demand. In essence, the combination of customer demand and limitations of resources bring to light the one main issue facing the power industry in the 21st century - sustainability.

My vocational work experience was undertaken at Melbourne-based SP AusNet which owns all of Victoria's transmission network and the eastern half of the state's distribution network. Consequently, this essay will focus on some of the problems and solutions in the fields of network maintenance and design of these two networks from both an operational and strategic perspective. Furthermore, the response of SP AusNet to the problems posed by climate change will be considered and what individuals, companies and governments can do generally to ensure a sustainable future for both the power industry and the environment will be discussed.

Before commencing work at SP AusNet, I had very little knowledge of the challenges facing the power industry. I knew that there was pressure on the government to close down many of the power stations using brown coal due to high levels of pollution, but I had not understood the immensity of such a task and the ramifications such an action would have upon the entire state grid. Furthermore, I had not considered issues such as climate change and lack of resources from any other perspective than that of power generation. My experience at SP AusNet has allowed me to gain insight into how these issues affect electricity distribution and transmission. Additionally, working at SP AusNet has shown me how immediate problems, such as power outages, are dealt with, as well as how long term tasks, such as designing a new terminal station, are tackled.

Climate change is perhaps the largest challenge facing the power industry in the 21st century. SP AusNet's *2008 Sustainability Report* detailed the company's carbon footprint. It was estimated that SP AusNet emits 2.83 million tonnes of carbon dioxide (CO_2) a year - a value which is equal to the emissions of about 314,000 households[1]. A breakdown of these emissions showed that 66% were associated with

[1] SP AusNet. 'A Summary of Our Carbon Footprint Findings', *2008 Sustainability Report*, July 2008, p. 9.

SP AusNet's transmission network, 27% related to the distribution network and 1% were linked to the use of sulphur hexafluoride (SF_6) in both the transmission and distribution systems[2]. The vast majority of emissions in the transmission and distribution networks were due to line losses. As the power losses in lines vary with the product of the line's resistance and the current squared, a greater current results in a greatly increased power loss. Although the problem of line losses cannot be fully eradicated, SP AusNet is employing a couple of methods to try and reduce these losses. Firstly, more and more electricity is being transmitted at higher voltages with the rationale that a higher voltage corresponds to a lower current and hence reduced power losses. Furthermore, older conductors are being replaced with new ones of lower resistivity.

The emissions due to SF_6, as mentioned above, need careful consideration. Whilst SF_6 is considerably more pollutant than CO_2 it is highly effective as an insulator in electrical switchgear. SF_6 is used, for example, to quench the arcs associated with opening and closing circuit-breakers. It is a more effective insulator than air because of its higher dielectric strength, meaning that considerably smaller electrical clearances are required for operation of the switchgear. Additionally, switchyards using SF_6 as an insulator can be physically smaller. The ability to build smaller switchgear, in turn, comes with the advantages of easier access to equipment during maintenance and furthermore a reduced environmental visual impact because of the relatively smaller size of the switchgear. Despite these positives, it cannot be denied that SF_6 is extremely pollutant and a contributor to climate change. As such, it is necessary to consider safer alternatives to SF_6. One possible option is the use of a vacuum as insulation for switchgear. Vacuums are already in use in a number of zone substations around Victoria. For example, at Clyde North Zone Substation, where I was able to visit, all of the 66kV switchgear is vacuum insulated and indoors. Not only does this substation design reduce greenhouse gas emissions, but it also increases the integrity of the state grid. Having indoor switchgear means that the environment can be easily moderated and controlled with problems of overheating that may occur on extremely hot days in outdoor switchyards no longer an issue. While this approach is suitable for lower voltages, it is not suitable for all switchgear. The size of 500kV transformers and associated equipment remains very large at present and hence it is not economically feasible (while suitable space remains for the development of outdoor switchyards) to invest in indoor switching at all levels of the electricity network. However, as technology continues to improve, and demand continues to increase, the future may see a gradual reduction in the size of switchgear to the point where entirely indoor switchyards become the norm.

SP AusNet recognises the vital importance of tracking their carbon footprint as climate change is a large risk for the company. If temperatures continue to rise and extreme weather conditions such as storms, droughts and bushfires become more common, as predicted by reports, there is a greater risk of damage to all of SP AusNet's assets. Bushfires, for example, may result in more power outages and storms may reduce the lifespan of transmission lines. As such, if appropriate measures are not taken, climate change has the potential to financially cripple a company due to increased expenditure on maintenance and on the replacement of assets. These issues

[2] SP AusNet. 'A Summary of Our Carbon Footprint Findings', *2008 Sustainability Report*, July 2008, p. 9.

are already being considered by SP AusNet in the planning of new zone substations, the refurbishment of older terminal stations and the maintenance of lines state-wide.

Designing with an eye to the future is an important stepping stone to tackling the problem of current and future resource limitations. Melbourne is Australia's most rapidly growing city and is predicted to continue expanding in years to come[3]. As such, the demand for power will rise with the population, especially in Melbourne's south-east growth corridor. Consequently, plans for new zone substations and even a new terminal station in the south-east are both being developed and implemented. However, it is not enough to build a terminal station to meet current requirements. Instead, an 'ultimate plan' that looks at the long-term requirements for the station needs to be developed. This plan needs to specify the highest level to which a terminal station could be potentially expanded to, in 10, 20 or even 30 years. For the future, a long-term strategic approach is required to ensure terminal stations can be built and maintained without the waste of current, functional assets and resources. An ongoing question is maintenance and whether faulty assets should be repaired or replaced. The answer to this dilemma is generally determined on a case by case basis, through consideration of cost, type of problem and predicted lifespan of the asset in question.

In a society that is increasingly conscious about the use of fossil fuels and carbon dioxide emissions, and their contribution to global warming, there is a push towards the use of renewable resources in power generation. There are several wind farms connected to the power grid but the relative amount of power generated from these sources at present is small in comparison to the more traditional mode of generation. The vast majority of Victoria's electricity generation is concentrated in the Latrobe Valley, with Morwell, Loy Yang, Hazelwood and Yallourn Power Stations all in this same area and all brown coal powered. Loy Yang A Power Station, for example, generates 2050MW[4] of the state's base load electricity supply. This production represents more than 20% of the state's power. From a figure such as this, it is easy to see just how much of the state's continued electricity supply relies upon fossil fuels. Transition to greener power sources will remain a great challenge with many diverse issues needing to be considered.

The fact the all the state's major power stations are geographically close is something of a double-edged sword when considering the integrity of the state grid. On the one hand, having such a concentrated location for power generation means that if a new station is required, due to soaring energy demands, the infrastructure and resources (i.e. brown coal) are already in place to accommodate such needs. However, on the other hand, the geographic proximity is also a threat to the integrity of the state grid. For example, a natural disaster such as a bushfire could potentially endanger a number of power stations at the same time and hence compromise the power supplies of the entire state. The question of whether to further develop the Latrobe Valley requires serious consideration. The infrastructure, currently in place, utilises 500kV transmission lines originating in the Latrobe Valley as the crucial backbone of the state grid. Hence, new power stations developed in the area can link into the state network without the huge expenses associated with connecting to the grid that remote

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[3] T. Colebatch. 'Melbourne Tops Nation in Growth', *The Age*, 28 February 2007, accessed 22 February 2009, http://www.theage.com.au/news/national/melbourne-pushes-boundaries/2007/02/27/1172338625778.html

[4] M. Murphy. 'Victoria Unplugged', *The Age*, 3 February 2009, p. 9.

power stations would face[5]. However, in the long term, with community pressure to turn away from fossil fuels, the need to ensure uninterrupted supply and such a heavy reliance upon localised brown coal may prove problematic. Clearly, substantial financial investment will be required to meet future energy demands[6]. These pressures suggest that the development of power stations (and associated infrastructure) at other geographical locations is essential but will require much innovation.

The consequences of soaring energy demands have already been felt in 2009, with a record demand of 10,459MW recorded on Thursday 29th January causing up to 500,000 customers to be without power in Victoria[7]. This late-January heat wave saw four consecutive days in the mid-forties with temperatures on Friday 30th January exceeding 45°C in Melbourne. Although such an extreme heat-wave is rare in Melbourne, climate change reports suggest that summers will continue to warm up and weather patterns will become more erratic in the years to come[8]. As such, the power network needs to evolve to be able to better function under extreme conditions and increasingly higher peak-demands. Dealing with peak-demands is not as simple as switching in an additional generator somewhere in the state, although, to a certain degree, this is a useful option. Record-breaking power demands are rare and as such it is not feasible to build extra generators purely to deal with peak loads. Instead, a greater emphasis should be placed upon energy efficiency and the education of the public to consciously reduce their power demands in times of peak system use. For example, solutions as simple as using more energy efficient light bulbs, turning off lights when not in a room and turning air conditioners down to a lower setting can have a marked effect on the power demand if applied *en masse*, particularly during times of peak demand. When demand exceeds available power it becomes necessary to engage in load shedding, which means that power to certain areas will be cut for a set period of time and these controlled power outages will be rotated. The alternative to load shedding is to seriously compromise the integrity of the state grid by trying to draw more power from it than is available. Hence, load shedding is used to avoid over-drawing the system and its consequence - a system black. That is, a state-wide blackout from which it could potentially take days or even weeks to fully recover. While load shedding may not be an ideal solution, above all in sweltering weather, it is preferable to a system black and at present serves the system well as an intermediate step to ensure the state grid's integrity.

Facing the energy crisis in light of surging demands and climate change is not just an issue that needs to be addressed by the power companies. Instead, solutions to the problems raised need to come from all levels of the community. At a government level legislation on emissions trading schemes needs to be further developed and implemented so as to ensure accountability for CO_2 and other emissions at all stages of the power engineering cycle. Presently, the governing body NEMMCO (The National Electricity Market Managing Company) sets targets for SP AusNet in regard to the number of minutes customers are without power supply and rewards or

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[5] R. Garnaut, 'Chapter 19 - Network Infrastructure', *The Garnaut Climate Change Review*. September 2008, accessed 22 February 2009, http://www.garnautreview.org.au/chp19.htm

[6] R. Garnaut, 'Chapter 19 - Network Infrastructure', *The Garnaut Climate Change Review*. September 2008, accessed 22 February 2009, http://www.garnautreview.org.au/chp19.htm

[7] M. Murphy. 'Victoria Unplugged', *The Age*, 3 February 2009, p. 9.

[8] R. Garnaut, 'Chapter 5 - Projecting Australian Climate Change', *The Garnaut Climate Change Review*. September 2008, accessed 22 February 2009, http://www.garnautreview.org.au/chp19.htm

penalises SP AusNet according. An emissions trading scheme developed by the government would, in most likelihood, function quite similarly to this system. Furthermore, the government needs to financially support the development of more non-coal generators by either aiding or rewarding companies that engage in producing green power, or by significantly contributing to the infrastructure required to establish such generation outside of the Latrobe Valley. Within power companies themselves, greater emphasis should be placed on extending the lifespan of assets, forward-planning and innovative engineering solutions that reduce the needless waste of resources. But, above all, it is individuals, the members of the community, who are capable of making a difference. The first step is education. Teaching the public about the issues revolving around climate change, and what they can do to ease demand on the system, is vital in moving towards a greener future for power engineering. The second step is to motivate and reward change, steps already occurring to a certain degree. For example, the government offers rebates to households who install solar panels and offers Green Loans of up to $10,000 for households working towards being more energy efficient[9].

Working at SP AusNet has given me valuable insight into the upcoming challenges that will need to be met head on in all areas of the power industry. The threat of climate change and greenhouse gas emissions emerged as the single greatest concern for the future. Tackling this problem is further complicated by resource limitations and growing energy demands from society. There is no quick and easy solution to the problems addressed in this essay. Instead, the challenges facing power engineering in the 21st century require innovative solutions from industry experts, members of the public and bright young minds. The move towards a sustainable future for power engineering in Australia is just commencing. The challenges are being recognised and individuals, companies and the government are starting to respond. The future begins now.

[9] Department of the Environment, Water, Heritage and the Arts. *Australian Government Environment Rebates*. 3 February 2009, accessed 22 February 2009, http://www.environment.gov.au/rebates/index.html

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