Energy Networks Australia

Consultation on how best to transition to a two-way grid

First of all, I speak as a non-expert in energy management over a large electrical grid. However there are some broad principles and system realities which should be borne in mind to develop a strategy of supplying reliable electrical energy to all consumers within the grid in an environmentally benign way. Some, of these are:-

1. Renewable energy is presently in a strong uptake mode in Australia, especially domestic sized PV systems. There is also a strong environmental push for large scale renewable systems such as wind and solar farms.
2. The world generally is on an inexorable push towards renewable energy, with a number of factors driving it – declining fossil fuel reserves, rising costs of fossil fuels because of increasing difficulty in claiming them, restrictive cartel practices, reducing costs of renewable energy such as derived from PV and wind and solar farms, and environmental concerns.
3. Australia is blessed with a high potential of wind energy associated with the southern 'roaring forties'. At the end of 2017 about 4,500MW of wind had been installed, and a further 19,000 MW was proposed or committed. Since 2011 there has been an average growth of 35% in installed wind capacity. Australia is also blessed with vast quantities of solar energy. Average insolation over Australia is in excess of 4kWh per square meter per day, and greatly exceeds that of Europe and most of the United States. As of March 2018, Australia had over 7,800MW of installed PV solar power. From 2011 to 2016, PV installations have quadrupled, with an average increase of over 40% per year. With the price of PV decreasing, this rate of increasing use of PV is likely to accelerate if the grid can accommodate the variability of the resource, and feed in tariffs can be maintained at current levels, even though it may be difficult to justify new installations economically at present.
4. With good strategic planning Australia could become largely independent of fossil fuels not only in electrical and thermal power generation for industrial, commercial and residential use, but also in

transport through the manufacture of ammonia and methyl alcohol from hydrogen electrolysed from renewable electrical energy.

5. Hydrogen can be converted to ammonia using the well known Haber process. Whilst hydrogen has a very high energy density by weight, being about three times that of petrol, its energy density by volume is very low, and even when liquefied its energy density is only about ¼ that of petrol. But when converted to ammonia, the hydrogen energy content of liquid ammonia is higher than that of liquid hydrogen. This makes it feasible to use ammonia, which is easily liquefied, as a means of transporting hydrogen. Recent work by the CSIRO allows ammonia to be reconverted to hydrogen which can then be burned for thermal use, or used to drive cars, buses, trams and trains very efficiently through fuel cells. Hydrogen fuel cells are already in use in Europe in transport applications such as cars, busses, forklifts and trams. Most of these use compressed hydrogen, but with the use of ammonia in conjunction with the new technology, transport use of hydrogen should be greatly enhanced.
6. Ammonia can be liquefied just as LNG is, and exported by tanker, thus opening up a huge export market.
7. Methyl alcohol can be used as a bend in petrol, much as ethanol is used at present. It could replace ethanol which is produced from crops, thus allowing land to be used for food rather than for fuel production. This is current technology, and even if the practical application of the recently developed ammonia to hydrogen conversion proves problematic, a huge market will be opened for electrolysed hydrogen by converting it to methanol. Methanol is a high octane fuel and its use in petrol blends would allow higher compression ratios in internal combustion engines, thus making them more efficient. Methanol can also be used directly in fuel cells to generate electricity for vehicular use, thus providing an alternative to the CSIRO process.
8. Methanol is a widely used feedstock for the chemical industry. It can be converted to ethylene and propylene, which are the chemicals produced in the greatest quantities by the petrochemical industry. It is a liquid and easily transportable.

9. The use of electrolysed hydrogen produces no carbon dioxide, thereby greatly reducing carbon emission. Conversion of hydrogen to ammonia or methanol actually requires carbon dioxide which can be extracted from the air, or from the flue gasses of fossil fuel power stations or other fossil fuel burning plants. Thus both direct burning of hydrogen or conversion to and consumption of both ammonia and methanol are carbon neutral processes, in contrast to consumption of fossil fuels which produce carbon dioxide.
10. The abundant availability of electrolysed hydrogen could spawn extensive chemical industry for the manufacture of plastics, PVC, soap, and vast numbers of household and industrial chemicals.
11. Oxygen is produced as a second stream of the electrolysis process, and this can be used in medical applications and in industry. Oxygen is used in industry for metal cutting, and in the manufacture of steel. The latter is by far the largest consumer of oxygen and is used in blast furnaces and in converting pig iron into low carbon steel in the BOS and Bessemer processes. Hence there is a large market and possibly a lucrative revenue stream for electrolysed oxygen if electrolysers are located in close proximity to steel works, or if the oxygen is liquefied for transport.
12. Ammonia is used extensively as a fertiliser, and with a growing world population, will be in increasing demand which can be satisfied with electrolysed hydrogen. At present hydrogen for ammonia is produced mainly by reforming natural gas, thus placing a strain on declining reserves of natural gas.
13. The cheap production of hydrogen through abundant wind and solar energy will enable Australia to become a major world exporter of energy and fertiliser, with great benefit to its economy.
14. The technology for the use of hydrogen, and methyl alcohol for transport use is already well developed in Europe and the US, and widespread use of renewable energy is imminent.
15. The technology for electrolysing water to hydrogen is well developed in Europe, and electrolysers of over 130MW are already in use. Conversion efficiency of electrical energy to thermal energy is in the order of 70% with the larger plants.

16. The major problem with renewable systems is that the energy flow from them is highly variable, thus rendering a large proportion of available renewable energy un-useable because of oversupply at times of low economic activity. Also, at times of excessive wind speeds, wind energy is unusable. Undersupply occurs at times of low wind speeds and at night and in cloudy conditions in the case of solar energy. The ability to store renewable energy is thus critical to their extensive use.
17. Whilst some governmental control on the installation of wind and solar farms is possible, the control of domestic PV installations is problematic. The public appears to be willing to invest in them in spite of little return, and is driven not by economic factors but by other factors such as environmental concern.
18. Given that (a) more and more highly variable energy sources will be imposed on the grid, and (b) that because of declining per capita electrical energy consumption through greater consumer environmental awareness, increasing costs of electricity per kWh, and more efficient electrical appliances such as LED lighting and inverter type air conditioning, grid voltage control will become more and more difficult in future.
19. In theory, renewable energy is desirable because it is free, but if Capacity Factor (ratio of actual energy output over a period of time to output if operating at nameplate capacity) is low, then capital charges become dominant and unit cost of power is high. Unfortunately with wind power, wind often blows when energy is not required, and often blows too strongly to be utilized, requiring blades to be feathered. In Victoria, CF is so low that AEMO will accept only about 8% of installed wind energy capacity as available supply in summer. With solar, output is restricted to daylight hours and further restricted by cloudy weather conditions.
20. The use of electrolysed hydrogen would significantly reduce the use of natural gas, thus extending limited reserves. At present natural gas is used not only as a source of energy, but also as a feedstock for the production of fertiliser, plastics and many chemicals, all of which could be replaced with electrolysed hydrogen.

21. It would be much easier to control grid voltage through active control of a relatively small number of large suppliers of renewable electrical power such as wind and solar farms than myriads of small PV installations.
22. With a suitably designed high voltage electrical grid operating throughout the nation, fed by existing fossil fuel power plants, wind and solar farms, and household PV, and operating in conjunction with the existing natural gas network and electrolysers producing hydrogen, it would be possible to control voltages throughout the grid, and allow energy to be transferred from wherever renewable electricity is being produced to wherever energy is required. The grid thus becomes the main conveyor of energy, and the pipeline (which stores hydrogen), and industrial petro chemical plants (which produce ammonia, methanol and other easily stored chemicals) the main storage systems. This arrangement would enable large scale use of renewable energy sources to the point where eventually all or most energy is sourced from renewables, leading to independence of fossil fuels and zero carbon emissions.

Technology Summary

As discussed above, large scale storage is a necessity if renewables are to be utilised to a significant extent without causing insurmountable system regulation problems. Electrical energy can be stored electrically in batteries, potentially in pumped storage, or chemically through conversion to gas. The costs of these technologies vary considerably, as does their practical capacity.

Domestic Batteries - Cost of these batteries varies from about $1000-$3000 per kWh

Large scale Network Batteries - Hornsdale SA installation of 129MWh about $350 per kWh

Pumped Storage cost varies with site – Snowy 2.0 installation of 350,000MWh about $20 per kWh. Though cost per kWh is reasonable, capital cost for this type of installation is very high, and capital in Australia would be found with considerable difficulty, probably only from government sources. The time frame in planning and building such an installation is long, in the order of a decade or more. Another consideration is that sites for large scale pumped storage are limited, thus restricting their application. The cost of Snowy 2.0 is estimated to be in the order of $6B, including transmission lines.

Power to gas – Existing natural gas pipelines can be utilized at virtually no cost, and would provide about 2,000GWh, or about six times the Snowy 2.0 capacity. The power to gas possibility involves little storage cost, and would only require that excess electrical energy from wind and solar be injected into the existing gas distribution network. It would then be used wherever required by the system. With extensive utilisation of the hydrogen in thermal and industrial process and in transport, the quantities of hydrogen injected into the existing natural gas network would decrease over time, to the point when ideally it would be negligible.

Storage Comparisons - At present domestic batteries to store PV energy are not economical, and are installed mainly for environmental and security of supply reasons by enthusiasts. But even if their cost could be halved to $500 - $1,500/kWh, they would still be extremely expensive compared to pumped storage. In addition they would have to be maintained and periodically replaced, thus adding to their operating and disposal costs. Control of these systems, if taken up extensively, would probably have to be active, and with millions of them scattered over the network, active control by network distributers could be problematic, even with aggregation.

Network batteries would have economical advantages over domestic batteries, would be much easier to control, and would enable greater use of renewables, but their storage capacity is still very limited on a network scale, and they are about 18 times more expensive than pumped storage. Storage capacity of the Hornsdale installation, though huge compared to domestic installations, can supply 50,000 homes for about one and a quarter hours only.

Electrolysers of 200MW capacity and more can be readily supplied at this time. They can be installed for voltage control in industrial areas where there is a need for hydrogen feedstock, in urban areas where PV generation is causing voltage control difficulties, or adjacent to large scale renewable energy sources. The hydrogen produced can be used directly, converted to ammonia and/or methyl alcohol and stored as such, and/or it can be stored in existing natural gas pipelines. A 200MW electrolyser could convert almost 5GWh of excess electrical renewable energy into gas in one 24 hour period. Ten 200MW electrolysers would be able to convert to hydrogen half of the full output of all wind farms installed in Australia by end of 2017. If hydrogen gas is injected into existing natural gas pipelines, the amounts injected may have to be monitored and existing corrosion control measures calibrated to prevent possible hydrogen embrittlement of steel pipelines.

Recommendations

From the above discussion it would seem to be economically and practically advantageous to pursue the Power to Gas path, especially considering long term implications in regard to supply of fossil fuels and to environmental wellbeing. In order to facilitate the introduction of electrolysers for the control of grid voltage and for meeting future energy demands in an environmentally friendly way, the following actions should be taken:-

1. Conduct laboratory experiments to investigate the extent and methods of control of hydrogen embrittlement of mild steel gas pipelines.
2. Conduct a network analysis to determine required capacity of electrolysers and where they would best be placed to minimise transmission line and pipeline augmentation costs, in order to control existing renewable energy installations.
3. As for item 2, but at say 5 year intervals using projections of renewable energy use up to approximately 2050
4. Conduct cost estimates of items 2 and 3
5. Investigate and promote industrial use of hydrogen as a chemical feedstock
6. Investigate and promote manufacture of ammonia as fertiliser and for energy export
7. Investigate and promote manufacture of methanol as a feedstock, for transport and for energy export
8. Investigate and promote patterns of urbanisation to facilitate efficient and environmentally friendly energy use, with special regard to intensive

industrialisation to attract population growth away from existing major cities, into regional areas.

From the above investigations, a rational strategy for energy supply and regulation into the medium and long term future can be formulated. It is imperative to look at the “big picture”, not only the matter of grid regulation, but also environmental factors, declining supplies of fossil fuels, development of more manufacturing industry for the economic wellbeing of the nation, and improving patterns of urbanisation away from large cities to the regions where renewable energy abounds.