Electrical Power Proposals in South Australia

By Lloyd Butler VK5BR

Introduction

Over recent years, in an effort to phase out power sources which introduce carbon dioxide into the atmosphere, renewable energy sources, such as Wind Farms and Solar sources, have been gradually introduced in South Australia. By 2016, these intermittent renewable sources were generating a major proportion of the power distributed. The long established coal and gas driven base load power stations, with very long ramp-up times, had difficulty in fitting in with the down periods of the intermittent sources. In fact the base load stations found difficulty in making profit in competition with the cheaper sources of renewable energy and the variable load conditions created by the variable sources.

As a result, some of the base load turbines were put on mothballs and ultimately the coal fired stations at Port Augusta were taken out of service. As can be seen by the power source chart in the next section, there is still plenty of power but largely dependent on wind power being maintained, coincident with the power from Connectors with Victoria. Serious drop-outs of the SA power network in 2016 were possibly a result of their outage.

The article initially looks at the existing power available, and then an energy plan published by the State Government aimed at making the power system more reliable. A number of responses to the plan, by various interested Companies and Organisations, are discussed including those taken up by the Government. Comments are made on the effectiveness of the adopted plan, on its lmitations, and the need for large scale energy storage such as pumped hydro.

South Australia main Power Generator Sources & Load

South Australia main Power Generator Sources early 2017		
Wind Farm source, registered 2015-2016	1576 Mw	Total
Roof Top PV 2015-2016	675 Mw	Total
Heywood Connector	650 Mw	Electranet
Murray Link	220 Mw	Energy Infrastructure
Torrens Island Gas Thermal	A 480 Mw B 800 Mw	AGL
Pelican Point	2 x 160 Mw CCGT = 320 Mw One Gas Thermal 165 Mw	Engie
Quarantine	OCGT 216 Mw	Origin Energy
Ladbroke Grove	OCGT 80 Mw	Origin Energy

Osborne Co-Generation	CCGT 120 Mw Gas Thermal 60 Mw	ATCO Power

If all sources were running at once, Total Power Generated = 5302 Mw

Total with Connectors from Victoria turned off - 4432 Mw

Total with Wind Farms turned off - 3726 Mw

Total with Wind Farms & Connectors turned off - 2856 Mw

SA Peak Demand around 3000 Mw

On initial look at the figures, one might assume that South Australia has some 2000 Mw of power source capacity above the peak load. But the wind sometimes does not blow and there is no solar power at night. Also the power turbines of other sources have to be taken off line from time to time to carry out regular maintenance. If the wind drops out and the sun is not shining, there is barely enough power for peak load. If added to this, one of the Connectors from Victoria drops out, then South Australia is really in trouble, as happened in a 2016 system failure. With the close down of the Hazelwood coal fired power station in March 17, 2017 and the resultant loss of 1600 MW of power in Victoria, there is also the question of whether the 870 Mw of maximum output via the two connectors from Victoria, can now always be supplied.

But if a large proportion of the power generated from that excess power capacity was stored away, when it was available, it could be discharged back into the grid when some of the sources (such as the renewables) were not generating. Referring to the SA Energy Plan (discussed following), they seem to be thinking of storage in the order of 100 Mw/hr. Looking at the figures, I don't believe the storage is anyway enough. In my opinion, they need storage in the order of thousands of Mw/hrs to prevent such as the large power outages, which were experienced in South Australia in 2016.

Suppose the whole of the wind farms were sourcing a major part of the load with their 1500 Mw of power and without expectation, this dropped out due to loss of wind. To prevent prolonged drop out of a large part of the load, the 1500 Mw would have to be smartly restored by available source capacity that was not being used in the base source generators. A present problem is that the base load generators, mainly steam turbines, have very long ramp up times (hours and sometimes days). Hence they are unable to address the power drop out in the short term. The large storage (such as pump hydro), if installed, would not only replace the need for a large standby generator station but could ramp up to maximum output in minutes.

South Australian Energy Plan

Following much dialog between the South Australian (SA) Government and the Federal Government concerning problems with power generation within SA, on March 15, 2017, the State Government introduced an Energy Plan (Ref 1). The plan included the proposal for the State to take more control of power generators in the State and how their power sources were allocated. There was also a plan to allocate $550 million for a State owned power generator, which included a 250 Mw gas driven source to deliver close to 10 per cent of SA'S peak demand, and a storage which could supply 100 Mw. It was expected that the gas driven source would cost about $360 million. The power capacity of the storage in Mw/hour, to define how long the 100 Mw could run, was not stated. The government shortly went tender to have the generator in place as soon as possible.

By June 2017, five submissions of a storage battery in response to the SA Energy Plan had been short listed by the SA Government from more than 20 entries which included extensive overseas interest. The Government plan was to finance the battery from a newly created $50m Renewable Energy fund. (Ref. 17). Mr Weatherall also stated that seventy per cent of the battery's generation was to be reserved for government use and the remainder released to the market. On July 2017. the Government announced that US company Tesla had been selected as successful in its submission. On August 1, they announced that they had finalised the 250 Mw part of the plan.

Quite apart from any formal tenders being made, there were a number of proposals made public by various companies and authorities including Solaster, Solar Reserve, Carnegie Clean Energy, Snowy Hydro Company, DP Energy, Energy Australia, 1414 Degrees, Tesla and Engie. There was also the proposal put forward by the Prime Minister of expanding pump storage in the Snowy Mountains. Some of their proposals, including the successful tenders, will be discussed in following paragraphs.

On 28-8-17, Premier Jay Weatherill released guidelines for new bids to a $150 million scheme aimed at making SA's renewables more reliable, and is calling for proposals that include everything from storage to pumped hydro and power made front waste.

Acceptance by SA Government of Tesla Battery for SA Energy Plan

According to Reference 13, Tesla has built one of its biggest battery farms in Ontario, California. It is a 20 Mw system which can discharge 80 Mw hours of electricity to power 15.000 homes over four hours.

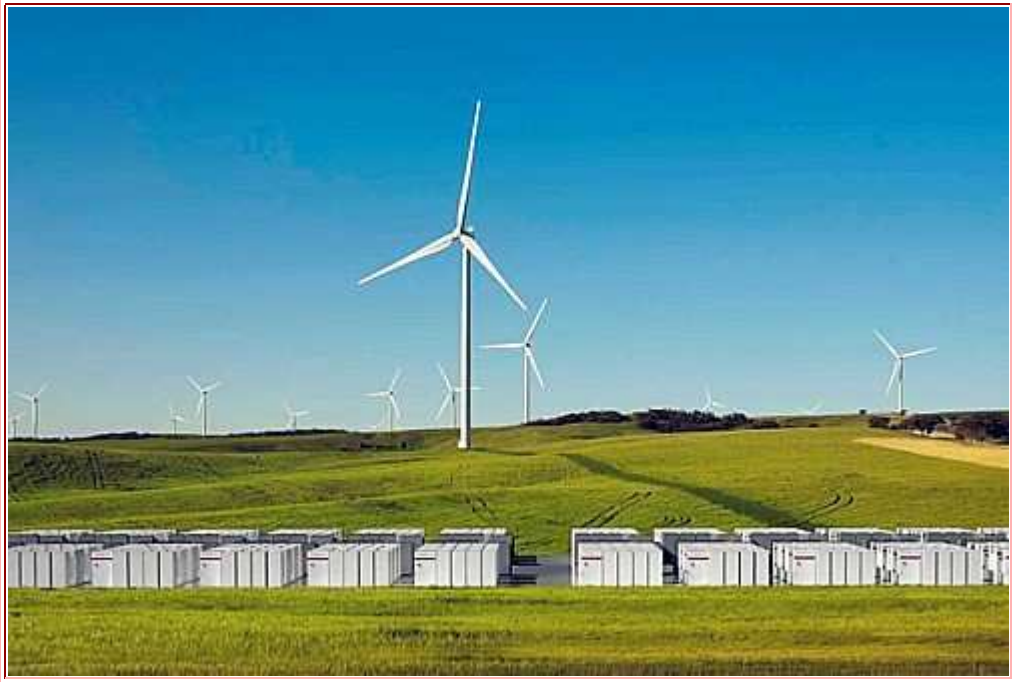
From an Advertiser column (Ref. 3), billionaire tech whiz Elon Musk, for his US company Tesla, reported that they could build the SA system (SA Plan) at a cost of up to $200 million in 100 days. It is unclear if shipping, taxes and installation costs would be extra. Mr Musk's comments, via Twitter, were prompted by a challenge from fellow tech-billionaire, Australian Mike Cannon-Brookes. In a later post, Mr Musk offered the "system" for US$250 per kilowatt/hour of capacity.

Mr Cannon-Brookes, the billionair founder of software company Atlassian, questioned whether Mr Musk could guarantee the 100Mw proposal in 100 days. Mr Musk responded that he would get the system installed and working 100 days from contract signature or it would be free. To his credit, Mr Musk achieved that time frame.

On July 17, 2017, the SA Premier Jay Weatherall announced that the company Tesla, with partner French renewable energy developer Neoen, was the successful contractor. They would build the world's biggest lithium ion battery at Neoen's 99-turbine 315 Mw wind farm located at Hornsdale, near Jamestown in the Mid North. The battery bank would provide 100Mw with a storage capacity of 129Mw/h. Elon Musk from Tesla, announced (as before) that if they don't deliver the battery in under 100 days from the contract being ticked off, it will be free.

Mr Weatherall also stated that there had been around 90 responses to the expression of interest, with 14 proponents invited to supply, and 5 shortlisted for the detailed assessment.

On August 23, 2017 a further battery was announced for the Lower York Peninsular. Electranet, the SA high voltage transmission line operator, would build a 30 Mw battery at Dalrymple substation near Yorktown, to support the grid near AGL's 91 Mw Wattle Point Wind farm. This would be connected by February 2018.



Artist picture of Tesla Proposed battery at Hornsdale Wind Farm

Temporary Back Up Generators for Acceptance for SA Energy Plan

In his $550 million energy plan announced in March 2017, the SA Premier, Jay Weatherill had proposed the installation of temporary generators before a new Government-owned generator could be built.

However, It was announced on August 1, 2017 that the SA Government has leased (& possibly buy) nine new General Electric aero-derivative turbines through US company APR Energy. TheGovernment would bring temporary back-up power generation on-line to prevent blackouts this summer (2017), before they are merged later into a permanent Government-owned power station. They also said that the hybrid turbines would initially be installed at two locations, the Adelaide desalination plant site in Lonsdale and the General Motors Holden site in Elizabeth.

The SA Government will own the plants and they would operate on diesel fuel over the next two summers before being relocated to a new site to become a power plant switched to gas. The nine new generators would be operating across two Adelaide sites by this (2017) summer. A permanent location would be chosen at a later stage. They would provide up to 276 MW (more than the previous 250 MW planned) and have a ramp-up time of 10 minutes. One report indicated that maximum output power could drop to around 200 MW in ambient temperatures above 40 degrees C. The generators would be tested monthly and only used when required to prevent an electricity supply shortfall and provide emergency back-up to help avert blackouts. Costs are not confirmed but expected to be less than $360 million. It is expected that the power plant would have a lifespan of 25 years.

General Electric TM2500 Generator - can be transported via land.

Grant for Feasibility Study for Pump Storage project in Spencer Gulf

The new 100 Mw storage output capacity battery and the new 276 Mw capacity fast ramp up diesel generators will be able to regulate against short duration variation in the outputs supplied by the wind farms. However, had they been installed in 2016, they would have been too small in power capacity to have made any difference to the outcomes of long term power outages which had occurred in that year. To improve reliability of supply in a system (such as SA), largely reliant on the intermittent output supply of Solar and wind, storage capacity in the order of thousands of Megawatt/hours are needed. Since our 100 Mw/hr battery is the largest in the world, it is clear that battery systems of thousands of Mw/hr size have not been developed nor proven to be an economic possibility.

But hydro storage systems of such capacity and with high efficiency, have been proven throughout the world. Our own Snowny Mountains system with a power output of 1500 Mw, with 9 days storage, has been running for close on 50 years of operation.

Energy Australia has received a $450,000 grant from the federal government's Australian Renewable Energy Agency (AREA) to conduct a feasibility study for a $200 million 100 megawatt project located in Spencer Gulf in South Australia. If built it would be Australia's first pumped hydro project using seawater (Refs. 9 & 10).

In the Advertiser of 17-2-17, discussions with Energy Minister Josh Frydenberg were revealed. He said a Pumped hydro storage facility at Cultana on the Eyre Peninsula could protect South Australia from power shortages that lead to load-shedding blackouts. He said work is underway to make the facility a reality. The Cultana defence site has pipelines, transmission lines and roads connected to it and it might only take a couple of years to complete.

Cultana Region of Spencer Gulf
Suitable for Pumped Storage Installation

Mr Frydenberg said that globally, 97 per cent of energy storage was in pumped hydro. "It's been underdone " he said. "We have now tasked the Australian Renewable Energy Agency (ARENA) and the Clean Energy Finance Corporation in a new funding round for large-scale storage, including pumped hydro."

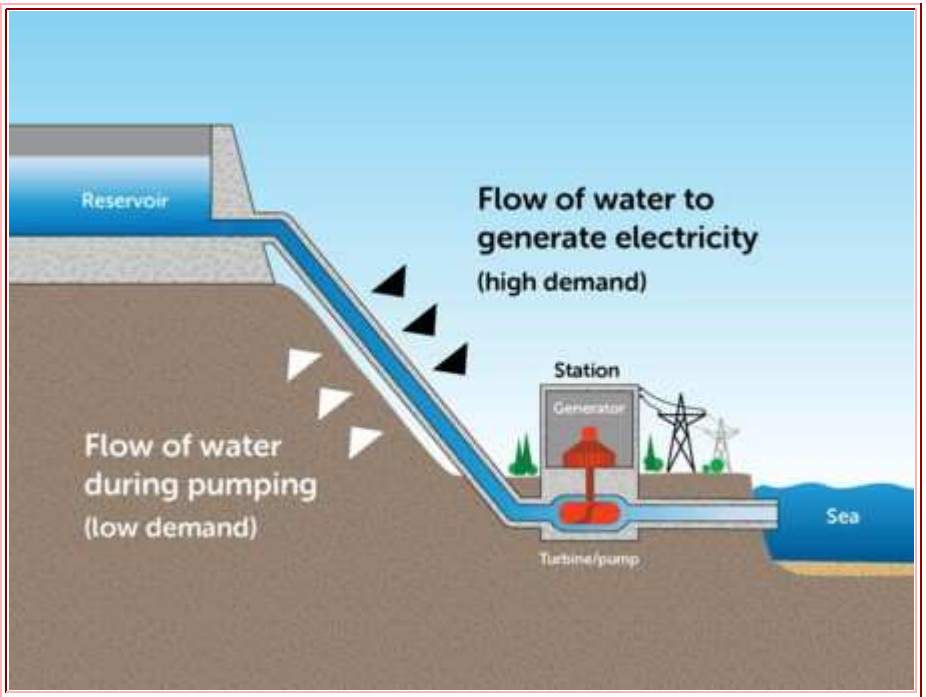
ARENA has given a grant to Australian National University Professor Andrew Blakers to research sites. He said the possibilities were almost unlimited because "you can build as many facilities as you like" (Ref 9).

"The area (envisaged) has rugged hills to the east of the gulf and there is no river in sight," he said. "We're looking for a decent volume, and a big height differential from the upper to the lower storages, ideally 400 to 500m. This form of hydro doesn't need a river. It works by pumping water front a lower reservoir to a higher one when energy from the grid is cheap , then letting the water run down again through a turbine to feed the grid when the grid price is expensive. A standard model would cost up to $500 million, but would last 50 years and be able to generate 300 Mw. If you want more output, you just make more pump storage facilities - perhaps four, five, or six,"

Professor Blakers said "You would look typically at 300 MW and a 10-hectare reservoir and that would give you a pretty good stab at stabilising the grid system. The facility could be built by a big engineering company, then run by other companies as both a generation and a storage asset. Government support would ensure the economics stack up. Usually it would take two to three years to set up a facility, but that could be fast-tracked."

Opposition energy spokesman Mark Butler has described pumped hydro as an exciting opportunity to transform the system, and State Energy Minister Tom Koutsantonis has also talked it up. Mr Frydenberg said the answer to SA's woes was technology. "We need to ensure SA doesn't become an island and that you have more baseload power generation in your own state. When events such as a one in 50 year storm, or 8000 lightning strikes, or the hottest weather occurs, the system is stable and resilient enough to ride through these disturbances.

Most diagrams showing pump storage illustrate the need for an upper and lower water store. However if the facility is by the sea, the sea itself can be used instead of of a lower reservoir or tank, saving considerable construction. This certainly applies to Spencer Gulf.



Pumped Storage from the Sea

It is of interest that the University of Melbourne Energy Institute (MEI) has carried out a survey of pumped hydro projects with particular reference to the States of Australia. As a result of this, MEI produced a report dated February 27, 2014 (Ref 14). In surveying costs for pumped hydro projects globally, they found capital costs as low as $100 to $200 per kWh of useable energy stored. By comparison, they noted that chemical battery makers were aiming to be on the market in 2025 for capital costs in the range of $200 to $500 per Kw/h of usable energy stored.

The MEI report also located possible coastal sites around Eyre and York Peninsulars in South Australia which might be suitable for pumped hydro installations.

EnergyAustralia chief executive Catherine Tanna has said that Australia is perfect for a pumped hydro venture. Ms.Tanna said: "What is required is to find a site for pumped hydro that has water, but also a site that has the right geography and topography, such as elevation and proximity to transmission".

Upper reservoirs such as these could store water ready for power generation (ANU)

In February 2018, on behalf of the Australian Government, ARENA announced $453,000 in funding to Energy Australia to conduct the initial feasibility study into its proposed seawater pumped hydro energy storage (PHES) facility in Cultana. The study, totalling $1.1 million was led by a consortium of Energy Australia, Arup and the Melbourne Energy Institute. The knowledge sharing report was produced by Energy Australia for ARENA.

The study found that the project would be technically viable with an optimal capacity of 225MW with storage capacity of 1,770MWh with eight hours of storage, the equivalent of more than 126,000 home batteries. The study found the facility would cost $477 million, and would be economically viable based on several revenue streams. Subject to further engineering design, economical modelling and planning approvals, the project could be operational by 2023.

Snowy River Pump Storage Expansion at Tumut 3

The Snowy scheme, built between 1949 and 1974, consists of 16 dams, 145km of tunnels and 80 kilometres of pipes and aqueducts. There are four power stations with 17 generating units and one pumping storage station. The Snowy Hydro scheme is 58% owned by the NSW Government. The pumped hydro station in the scheme is Tumut 3 which uses water for hydro power from the Talbingo Reservoir which is released into the Jounama Pondage. Water in the Pondage is pumped back into the Talbingo Reservoir for storage.

The present capacity of the Tumut 3 pump storage, in conjunction with the Talbingo Dam, is as follows:

Storage Power Output 1500 Mw
Storage capacity 921,400 Megalitres
Discharge with the Six Turbines - Total 1132.7 - cubic metres/sec
Time to discharge full capacity - 9 days
Power Storage - 324,000 Mw/hrs

Talbingo Reservoir with its Tumut 3 Power Station
Dam and Jounama Pondage in the background

On February 24, 2017, Snowy Hydro met with the Australian Renewable Energy Agency (ARENA), which is working with Snowy Hydro on the feasibility study to expand the Snowy sheme. At an earlier Senate hearing, Snowy Hydro CEO, Paul Broad, had noted that the concept of added pumped storage was not new, and was the subject of a memo to the federal government in 1966. But he said the new initiative did not come into frame until quite recently, prompted by significant changes in the electricity market. He said "The question of pumped storage really didn't get back on our radar until about 12 months ago".

On March 15, 2017, Prime Minister Malcolm Turnbull flagged a $2 billion investment to expand the Snowy Mountains Scheme to add an extra 2000 megawatts capacity of renewable energy from the scheme's current output of 4000 megawatts. The "Snowy Mountains Scheme 2.0" would involve building new tunnels and power stations but no new dams would be built. On March 16, Mr Turnbull travelled to the Snowy Mountains to make the announcement that the Government would bring the "leadership and money" required to make the expansion vision a reality.

Prime Minister Malcolm Turnbull revealed the plan to increase the current 4,000 megawatt output of the scheme by 50 per cent, which the Government would claim is an "electricity game changer" and will help prevent power shortages in the eastern states.

It will require three new tunnels being built along a 9km stretch to link the two reservoirs, one to send water through the turbines, one to pump water back up to the higher dam and another for overflow. The Government will conduct a feasibility study this year (2017) looking at four different sites. However, the government's preference is to link the Tantangara reservoir and the Talbingo reservoir. The Tantangara reservoir will be the base for the turbines to generate the new electricity.

A further report on May 24, 2017 indicated that the cost of the project could increase to double the $2 billion investment first quoted. It was also noted that a major upgrade to the poles and wires would be needed to transmit the extra electricity created.

The added storage facility would be a splendid addition to the eastern part of the National Power grid, in the light of closure of many coal fired stations and the need to regulate the changing power output levels delivered by the newer renewable energy sources.

There was an interesting comment on TV Channel 24 (ABC) 20-6-17 comparing Pumped Hydro with Batteries:
A gentleman from the Snowy Mountains Authority was interviewed about the Snowy Scheme 2.0 proposal of expanding the pumped hydro scheme, increasing by 2000 Mw. He said to do this same capacity with

batteries would cost 60 to 100 times that of the pumped hydro.

If and when completed, the Snowy Scheme 2.0 will provide an excellent buffer in NSW and Victoria to control anticipated interface problems between slow ramp up base source power stations and renewable sources in those States. Perhaps to a lesser extent, coupled via the Interconnectors to South Australia, it could also improve stability of the grid in that State.

In a report dated 27-9-27 (Ref 22), it was noted that Federal Energy Minister Mr Freydenburg had pointed out, that Murray Hydro Power in NSW had recently been used to fill in power gaps created by wind farms, such as those in SA. But it was also noted that SA Energy Minister Mr Koutsantonis pointed out that, in the recent months, SA had been a net exporter of power via the Connectors to Victoria. These facts together seem to well justify the need for more storage via Snowy Scheme 2.0 to iron out the intermittent power coming from the Wind Farms.

On 28-8-17, the Prime Minister announced that construction of Snowy 2.0 was expected to be commenced in the following year (2018). This would create 5000 jobs and be fast tracked to provide peak power at 350,000Mw/Hr, and supply half a million homes for a week. Mr Turnbull confirmed a new $8 million accelerated agreement between the Australian Renewable Energy Agency (ARENA) and Snowy Hydro had been reached to drive planning for the construction of the project. It was also anticipated that he might also anounce that ARENA and Snowy Hydro would examine the next pumped hydro projects inluding nine in Tasmania under consideration.

Snowy Hydro's independent Board of Directors has approved the Snowy 2.0 feasibility study, which was released on 21-12-17. This confirms that the Snowy 2.0 pumped hydro expansion project is both technically and financially feasible. With significant input from leading experts in economics, engineering and geology, the comprehensive study provides a base case design and a strong investment case that exceeds Snowy Hydro's stringent investment hurdles to progress to a final investment decision in 2018.

SA Government announcement of Planning for Pump Storage

On February 7, 2018, the SA State Government announced planning and proposals for five Pump Storage installations in the State, with a value approaching a total of $2 billion (Figures quoted have been taken from various newspaper reports):

1. Proposed storage in a disused quarry in the Adelaide suburb of Highbury by Tilt Renewables. Nominal output 300 Mw, Nominal storage 1250 Mw/hr. Cost around $400 million. The storage will make use of an existing reservoir. During Installation Phase, about 200 to 300 jobs expected.

2. Proposed storage by Altura Group at Goat Hill, 12 km west of Port Augusta. Output 230 Mw, Storage 1840 Mw/hr. Cost $410 million, 200 jobs.

3. Proposed storage by Rise Renewables, N/E of Pt Germain, adjacent to high voltage transmission lines and existing Baroota Reservoir. Output 200-230 Mw, Storage 1600 Mw/hr. Cost $406 million, 100 jobs.

4. Proposed storage by Energy Australia at Cultana, north of Whyalla. Output 225 Mw, Storage1770Mw/hr. Cost $477 million.

5. Proposed storage by GFC Alliance (Sanjeev Gupta) at the Iron Duchess Mine site in Middleback Ranges. Output 90 Mw, Storage 390 Mw/hr. Cost $170 million, 100 jobs.

It is pleasing to see that the Government has caught up with the one need in our newer Renewable Power system to make the system reliable. However it is expected that it will take several years following planning approval to catch up with completion. If all completed, the total power output would be 1045 Mw with a storage capacity of 6850 Mw/hr, which means that the system could maintain that output for 5.5 hours.

The cost estimates quoted for the five pump storage projects add up to $1863 million. How this is financed, and what proportion might be expected from the tax paying sources, does not appear to be to be defined.

Proposed changes to Adelaide Base Source Power Stations

Added to the proposals initiated by the SA State Government, several update proposal have been announced relative to the existing base source gas operated power stations.

On 7-6-17, AGL, the owner of Torrens Island power stations announced that it would replace the ageing thermal 480 Mw A station with a new 210Mw fast start station costing $295M (Ref 18). The A station had been running unecomically partly off line and the fast ramp up of the new station would be better able to operate in conjunction with the variable output levels of the renewable sources. The older A and B stations had been running well below capacity. The company had previously also considered the possibility of a battery system reducing the risk of a devestation black-out hitting the State. However this idea had been dropped when the South Australian Energy Plan had been released.

The new 210Mw power station will be built alongside the Torrens Island facility and will use 12 reciprocating engines. These units are capable of operating at full capacity within five minutes of start, providing a rapid response to changes in renewable generation supply. Construction was expected to begin within months of June 2017 with full operation due to start in early 2019. The power station, to be known as the Barker Inlet Power Station, will replace two of the four Torrens Island A turbines.

Torrens Island Power Station

Announced in the Advertiser 22-2-17, the management of Pelican Point Power Station, Engie, is giving consideration to the addition of an extra 300 Mw of extra gas fired power generation, depending on favourable conditions in the Electricity market. (Ref 12) This would add to the present 479 Mw which the station can generate.

Pelican Point Power Station

Some other Good Power Supply Proposals which were tendered.

A number of other good power proposals were given publicity during the time the SA Government submitted its plan. Whether some of these will still go ahead is yet to be seen. However, I think it is well worth while to include a number of these proposals for added information. For several years, the people of Port Augusta have bartered for an energy storing solar based power plant to replace the coal fired power stations anticipated to close down with Leigh Creek running out of coal. In following paragraphs there are several submissions tendered along these lines. These follow a previous solar thermal system, examined previously by Alinta, but abandoned by Alinta in 2015 as not ecomomically viable. (Ref.16)

It was also reported in the Advertiser of 25-5-17 (Ref. 15), that Energy Minister Josh Frydenberg had confirmed the Government's commitment to back a solar thermal plant at Port Augusta. It comes as the Australian Renewable Energy Agency (ARENA) puts out a request to market for industry participants to provide information on the costs and benefits of the system. Mr Frydenberg said that the Government had shown its commitment of the project by putting $100 million on the table.

Solastor - Pt Augusta

Australian company Solastor is one of several companies which have put foreword proposals on solar power stations to replace the drop out of power caused by the closure of Port Augusta coal fired power stations (Ref 5). On June 7, 2016, the chairman of Solastor, John Hewson met in Adelaide with SA Premier Jay Weatherill, SA member for Grey, Rowan Ramsey, SA Environment Minister Ian Hunter and federal Environment Minister Greg Hunt.

On June 8, the Advertiser reported that Australian company Solastor, could build a Solar Thermal plant, initially 100 Mw, of sufficient capacity to replace the output of the coal fired plants. Energy from the sun, directed by concave mirrors, would be stored at 800 degrees C in graphite blocks. Steam to drive a turbine would be generated by water running past the blocks.

The Advertiser reported that SOLASTOR would build a one megawatt demonstration plant at Port Augusta by the end of 2017 and connect it to the existing grid as a first step to its proposed $12 billion solar

thermal project. Year 2017 has arrived and gone and we have moved into 2018 with no further announcement of a demonstration plant. We have to assume that the Company has gone cold on the project, particularly in the light of competition from Solar Reserve who have also planned to build a Solar Thermal plant at Port Augusta.

The Sydney-based company, owned by Momentum Energy Resources and Solastor, is chaired by former Liberal leader John Hewson. As revealed in the Advertiser, Dr Hewson announced the project, which has in-principle support from Federal and State governments.

Dr Hewson said the full-scale plant, producing 110Mw power in winter and 170Mw in summer, would be able to store a week's worth of energy, making it more efficient and cost-effective than existing, renewable energy projects which can only supply intermittent power to the grid.

"We're not wanting to raise expectations falsely because we still haven't finalised the land, the finance (or) the approvals process, but we've started them all," Dr Hewson said. "We have no doubt it can be done, otherwise we wouldn't have announced it."

Dr Hewson said Solastor had not factored any grants into its "conservative" business case but would seek assistance through the Clean Energy Finance Corporation, with other funds likely to come from a consortium of banks.

Solastors project will have modules, each with 86 computer-controlled concave heliostat mirrors, that reflect the sun's energy into tower mounted solar thermal receivers. This receiver comprises synthetic graphite which is heated. The heat is transferred to stainless steel tubing systems containing water that is pumped through for conversion to steam which drives a turbine.

The full-scale project is expected to power more than 200,000 homes.

Solastor chairman John Hewson, Grey MP Rowan Ramsey, Premier Jay Weatherill, state Environment Minister Ian Hunter and federal Environment Minister Greg Hunt in Adelaide, June 2016.

Solar Reserve - Pt Augusta

In August 2016 (Ref 2), it was also reported that an American company, Solar Reserve, was interested in building a pilot 110 Mw solar thermal plant at Port Augusta to be followed up by five others over the next 10 years. They pointed out that the combined outputs would be equivalent in capacity to the Heywood Connector with Victoria. Possible sites for the five could be Leigh Creek, Woomera, Whyalla and Roxby Downs. Storage proposed was the use of molten salt (as for the Alinta proposal) with a storage time of 10 hours.

The following extracts are from an article introduced by Giles Parkinson on 23 February 2016 - **SolarReserve proposes 110MW solar tower and storage plant for Australia:**

The US solar tower and thermal storage technology developer SolarReserve has operated its first-of-its-kind Crescent Dunes plant in he US at its full capacity of 110MW, and is now targeting Australia as its next market.

The company said recently said that it had proposed to build a 110MW plant with eight hours storage just north of Port Augusta in South Australia, and had submitted the plan to the state government's tender for low-carbon energy.

SolarReserve said that Australia, with the highest average solar radiation per square meter of any continent in the world, is an ideal location for this advanced technology.

We refer to solar towers and storage relation at Crescent Dunes in Nevada, and to Sener's Gemasolar 19.9MW plant in Spain. These have the potential to radically change the nature of energy markets because they do not need fossil fuels, offer zero emissions energy and because of their storage facilities, can deliver electricity whenever the grid operator, or the utility, wants it.

In the Federal Budget announced in May 2017, the Government made available up to $110 million for an equity investment, if required, to accelerate and secure delivery of a solar thermal project in Port Augusta, SA.

Solar towers and storage Crescent Dunes in Nevada

In Nevada, with 10 hours of storage, power is delivered into the Las Vegas grid from around noon to midnight. However, in South Australia, power might be delivered in the highest priced part of the market when demand is greatest. It is likely to target the afternoon and evening peaks in summer, and not run in the morning. In winter, it could target the morning and winter peaks only.

SolarReserve says its proposed plant could supply Port Augusta and neighbouring towns with reliable solar power, day and night. It says the project would also create much needed jobs and economic development in the Port Augusta region, and would provide South Australia with new baseload power generation.

Tom Georgis, the head of International Development, said: "As Australia moves away from coal, this is truly the only technology that has the capability of providing zero emissions and provide reliable power". In an recent interview, he told RenewEconomy. "It is ideal for what the South Australia government is looking for, bringing innovative technology to Australia at a price point that makes sense."

SolarReserve is not revealing what that price point is exactly. But it could well be around $US100/MWh, much lower than the $A200/MWh assessment made on solar thermal options by Alinta, the owner of the former Northern coal-fired power station. The Crescent Dunes facility was built at a price of $US135/MWh, with financing help from the US government, whilst the 100MW Redstone plant about to be constructed in South Africa, would deliver at around $US120/MWh (depending on the fluctuating valuation of the local currency).

This technology solves the intermittent issues experienced with other renewable energy sources, enabling the delivery of renewable baseload and dispatchable power that can compete head-to-head with traditional fossil-fired and nuclear electricity generation methods.

More definite plans for Port Aususta were announced 14-8-17. SolarReserve would build a Solar Thermal 150 Mw plant near Port Augusta which would be operational in about three years. Its standard output under normal conditions would be be 135MW, with the capability of exceeding that during the evening peak demand in favourable conditions. The project would rely on a $110 million concessional equity loan from the Federal Government, which was promised as part of negotiations with South Australian Senator Nick Xenophon on the Commonwealth's company tax cuts legislation. In the Advertiser of 24-10-17, it was announced further that the $110 million loan was being considered by three Government funding bodies.

The plant, to be built about 30km north of the town on state-owned land, would be able to store between eight and 10 hours of energy so that it could operate when the sun is not shining. The plant would feature about 12,000 billboard-sized mirrors, measuring 100sqm, arranged in a circle over an area of about 600ha. The mirrors would focus light and heat at the top of a 227m tower to be the tallest of its kind in the world. The mirrors and tower would be assembled on-site, although some parts might be imported.The design would be based on a successful solar thermal power plant in the American state of Nevada.

Construction is set to begin in 2018 and would be complete by 2020, creating an expected 650 construction jobs and 50 ongoing positions. In addition to that, the project could stimulate up to 4000 indirect jobs around the sate.

In operation, the Government would take the majority of power generated, but any power remaining would be fed into the statewide grid.

SA Premier Jay Weatherill is quoted as saying that the Pt. Augusta plant , (to be known as the Aurora), would be home to a new $650 million solar thermal power source that supplies all of the State Government's power needs and would be the largest of its kind in the world. Mr Weatherill also said this would increase market competition and could lead to lower power prices. Perhaps this is an indication of the State Government's forward thinking on the State power to expand solar thermal power stations beyond the initial pilot 150 Mw station. However, I think power consumers might like to see proof of the lower prices after completion of the pilot plant.

In the Advertiser of 24-10-17, it was announced further that the $110 million loan was being considered by three Government funding bodies.

Solar Farm DP Energy _ Pt. Augusta

It was Reported by Sophie Vorrath, 8 August 2016 (Ref 3) that a 375MW solar and wind energy park, near the site of the closed Northern Power Station at Port Augusta, was approved for development by the State Government.

Project developer DP Energy said in a statement recently released that the government's green light meant it could now deliver one of the largest and most significant hybrid renewables projects in the Southern Hemisphere, including 59 wind turbines and almost 400 hectares of solar PV arrays.

DP Energy Proposal of Wind Turbine and Solar PV Arrays at Port Augusta

It had been reported in December 2015, that the Ireland-based DP Energy had publicly floated plans to build the integrated Renewable Energy Park in September 2014, on a 5,400 hectare site 8km south-east of Port Augusta. This a part of Australia renowned for its rich solar and wind resources.

The project is one of a number being proposed for the area around Port Augusta and in the north of the state including SolarReserve's 110MW solar tower and molten salt storage project, Lyon Infrastructure solar PV and battery storage project, and even some solar farms being contemplated by Indian energy giant Adani Resources.

Following approval from the government, the challenge becomes financial backing. However the Company is confident, and is even considering the addition of storage, either in the form of pumped hydro storage or battery storage.

In May 2016, DP Energy presented its plans to the local community via two consultation sessions, and, according to DP Energy managing director, Simon de Pietro, won strong local support for the project. Overwhelmingly, the response had been positive, with many people recognising the benefits that would flow into the local community, de Pietro said in December.

One of those benefits would be a much-needed boost to employment in the region after Alinta Energy walked away from plans to replace the Northern Power Station. The $680 million project is expected to create 250 jobs over the course of its development, peaking at around 600 jobs, and winding up with the creation of 15-20 ongoing jobs. DP Energy says it plans to use local SA businesses wherever possible during the development, to maximise the local economic benefits.

Another benefit of the project would be to the local grid, de Pietro says, that by integrating different technologies, the Renewable Energy Park would be able to deliver energy when it is most needed, thereby reducing stress on the electricity network in times of peak demand and reducing the reliance on expensive peaking power.

This is because the wind resource, primarily driven by the temperature difference between the land and sea, tends to have a regular early evening peak, which is well aligned with the daily peak demand for electricity. This effect is also strongest in the summer when temperature differences are at their greatest, meaning that annual energy generation also peaks when it is most needed. Coupled with large-scale solar generation, which has a midday peak, it offers a good match to overall demand, while supporting the electricity network and placing downward pressure on wholesale prices.

De Pietro said "The Port Augusta Renewable Energy Park represents a new breed of renewable energy generation which will deliver the right power at the right time for energy consumers, and deliver economic benefit to the region and the State".

It was reported in November 14, 2017 that the Irish renewable energy developer would employ engineering firm Downer Group to develop the 150 MW solar energy component of the Port Augusta hybrid plant, with wind giants Vestas contracted to build 225 MW of wind power. Barely a week after Sanjeev Gupta announced a 1GW project to use solar, pumped hydro and battery storage, the DP company further announced a major expansion of its park, adding in another 300MW of solar and 400MW of battery storage to its plans for what was already going to be the biggest hybrid plant in Australia.

But it has also flagged plans to add a further 300MW of solar PV and 400MW of battery storage in a phase two project across the road from the farm. (The actual MWh of storage is yet to be defined). That will make a total of 1,075MW. The Company may also include 3,000 megawatt-seconds of synchronous condensors to ensure the market operator has enough "synchronous" capacity for its needs.

The two DP Energy projects join a series of other projects at the top end of the Spencer Gulf, including the 220MW Bungala PV solar project, the 212MW Lincoln Gap wind project and the 150MW Aurora Solar Reserve solar tower and storage project that will effectively double the amount of wind and solar capacity already in the state.

Solar Farm Tailem Bend - Snowy Hydro company

Another interesting power project was announced In the Advertiser of February 2017. Snowy Hydro would build the largest solar farm in South Australia at Tailem Bend. It would include capacity for battery storage back up, and built by Snowy Hydro at Tailem Bend in the year of 2017. It is anticipated to cost of more than $200 million (Ref 7). Site for the farm is located on Lime Kiln Road, Tailem Bend.

According to Snowy Hydro, the solar panels would be able to generate power for 40,000 homes and help improve the state's electricity supply, whilst creating up to 200 jobs during construction. Building of the solar farm by Snowy Hydro farm would be in conjunction with renewable energy investor Equis.

Snowy Hydro, which owns the Snowy Mountains Hydro-Electric Scheme said: The solar farm would generate up to 100 megawatts of energy and the almost 400,000 solar panels would cover 200 hectares, It added that the capacity for battery storage of up to 100 megawatts would also enhance energy security in the state. The project also includes a diesel fuelled generator producing 28 megawatts to provide backup power during periods of peak demand.

Snowy Hydro managing director Paul Broad said: "The site would be the first large-scale battery ready facility we are aware of in the state. This is an exciting opportunity for Snowy Hydro to source renewable generation in South Australia to complement our existing capacity. We have been keeping the lights on in NSW and Victoria since construction days in the 1950s and are one of the most experienced and diverse companies operating in the National Electricity Market."

Mr Broad explained that the solar plant was designed to maximise the amount of electricity generated in the late afternoon, when demand for power was typically greatest. He said: "The solar farm represents a significant strategic investment in South Australia by Snowy Hydro and demonstrates our commitment to growing both our generation business and our Lumo Energy business, which services around 50,000 electricity customers in the State." He said: "We are pleased to be working with Equis to deliver more renewable energy to South Australia, backed by reliable fast-start thermal capacity."

It is important that this unique generation facility at Tailem Bend is also 'battery ready' with the ability to install up to 100 megawatts of large scale battery storage on the site. (The battery storage capacity in Mw/hr was not included in the address).

Mr Broad said construction would begin shortly, subject to relevant approvals. Solar power would be online from early 2018, followed by diesel power. The Tailem Bend project would be located on land already owned by Snowy Hydro and would provide the company with access to 264 megawatts of generation capacity in SA. The company already operates 136 megawatts of fossil fuel capacity at Port Stanvac and Angaston and would add a further 28 megawatts of diesel generation at the Tailem Bend site from 2017. The solar farm would also help power an expansion of the Snowy Hydro retail business (Lumo Energy) in South Australia.

It was also announced in January 2017 that the Snowy Hydro company was partnering in the Tailem Bend venture with Singapore-based renewable energy developer Equis. It appears that they expect completion of the Solar Farm in 2018.

An article in the "Advertiser" 15-2-18, annnouced that construction of the Snowy 127 Mw Solar Farm (called Tailem Solar) would start that month. They expected to be delivering power to the grid in the first quarter of 2019. An area of the site would be reserved for a battery installation with storage up to 110 Mw/hr. Developer Equis said it was also planning to develop Tailem Bend 2 (110Mw) adjacent to Tailem Solar with construction expected to start this year.

Artist Sketch of proposed Solar Farm at Tailem Bend

Power Storage in Silicon at 1414 degrees C

The following is an interesting development of research in energy storage. On Tuesday April 11, 2017, the Advertiser published the following article in their Business Journal - **SA energy storage system at fraction of Tesla's cost** by Luke Griffiths (Ref 8):

An innovative Adelaide company 1414 Degrees has attracted private investment from the other side of the world as it edges closer to a public float that would help fund large-scale energy storage systems.

Executive chairman of 1414 Degrees, Kevin Moriarty said a significant portion of the recently raised $2.5 million would go towards the installation of a 10Mwh storage system at a South Australian hydroponic farm. The storage would be charged by wind and biofuel.

A feasibility study for the project would be completed later this month (April 2017) and $2 million has been earmarked for project installation, which is expected to start late in the month..

But Dr Moriarty said that the 1414's plans go well beyond the "small-scale" system of 10 Mwh storage and cost a fraction of that for lithium batteries. In consideration of the success of a prototype developed at the company's onsley base, Dr Moriarty said 1414's method of storing energy, is applicable for larger grid-scale systems. The stored energy, produced as electricity from such as wind or solar, is stored as molten silicon which can be tapped at any time.

1414 Degrees Chairman Kevin Morriarty

The device stores electrical energy by using it to heat a block of pure silicon to melting point 1414 degrees Celsius. It discharges through a heat-exchange device such as a Stirling engine or a turbine, which converts heat back to electrical energy, and recycles waste heat to lift efficiency.

The company has engaged engineers to work on Thermal Energy Storage System (TESS) devices and to develop large-scale energy storage systems.

A 200 Mwh TESS will be the main component of these systems, which Dr Moriarty estimates would each cost around $7 million to produce. To give some context, Tesla founder Elon Musk recently provided, via Twitter, a rough quote of $33 million for a 100 Mw lithium battery storage system. (In a later quote, he gave a figure of US$250 per kW/h).

And following interest from property developers, Dr Moriarty said 1414 is planning 800Mw/h systems for deployment in energy grids by late 2018. This will would secure the network even if transmission is disrupted by storms or other events. What people are looking for is something that can take a whole suburb or shopping centre, either off-grid, or with reliable power sourced mainly from renewables. "That is exactly what we offer," he said.

Following its recent capital raising, which attracted investors from the UK, US, and New Zealand, 1414 is now planning to raise between $5 million and $20 million via a midyear public float. "We have been are aiming to get a prospectus out in by mid-June 2017. Obviously a lot of work would be done before then." Dr Moriarty said.

"Our experienced technical team would build the first 200 Mw/h storage module during the next 12 months with additional fueling from the IPO."He said 1414 decided against submitting a non-conforming bid as part of the State Government's push for a government funded, privately operated 100MW storage battery."

Dr Moriarty added "An advantage of our low-cost storage technology is that it does not reduce in capacity and require replacement as with batteries." Perhaps this development will lead to cheaper bulk power storage than is available now in batteries, pump storage and molten salt. One thing that has worried me is how the storage is achieved. He doesn't seem to have explained the technique of how the large amount of electrical energy raises the block of pure silicon to the 1414 degrees or why silicon was selected for storage.

But the selection might well be explained by the high latent heat at the silicon fusion temperature of 1414 degrees. For silicon, latent heat of fusion is 1926 Kj/Kg compared to copper at 205 Kj/Kg and salt (sodium chloride) as around 1000 Kj/Kg. Salt was used for storage in the Spanish Torresol Solar Thermal plants and the USA Solar Reserve Solar Thermal plants which would require about twice the weight of salt to that of silicon for a given latent heat storage. Another factor which was pointed out by Dr Moriarty was low cost of the silicon. Silicon is the second most abundant element in the earth's crust. The cost to mine it appears to be around US$1000 to US$2000 per tonne. By comparison to other possible storage elements, is apparently not expensive.

In April 2017 Dr Moriarty had indicated that a proposal" had been submitted to the State Government, but had declined to elaborate. However responding to the State's $150 million additional scheme announced on 30-8-17, Dr Moriarty told the Advertiser that his company would bid for an up to $15 million slice of the renewable energy fund, which could take its cutting-edge silicon storage power plant prototype from the lab and into the market.

Quoted in the Advertiser 23-12-17: The State Government had already announced a $1.6 million grant for 1414 degrees Celsius to trial new silicon thermal storage technology at SA Water's Glenelg Wastewater Plant. SA Water chief executive Roch Cheroux said the trials would last for several months, with the total cost of the renewable energy initiatives to be determined by the success of the trial.

Operations at Whyalla

In July, 2017,international company GFG Alliance, run by British industrialist Sanjeev Guptas, signed a deal to buy the Arrium steelworks and mining operations at Whyalla, proposing to protect the jobs of an estimated 5500 workers.

The company has also taken a major step towards realising its Australian energy ambitions. In September 2017, GFG Alliance, through its energy division, SIMEC Energy, also reached an agreement with ZEN Energy to establish a strategic partnership and acquire a majority stake in ZEN. Company ZEN is a prominent emerging Australian energy company providing businesses and households with affordable, reliable and tailor-made solutions. The State Government has provided a bridging contract for its energy supply needs to the formed company SIMEC ZEN. It is proposed that the retailer will provide 80 per cent of the Government's electricity needs in 2018 and 100 per cent in 2019, in the period before the Aurora Port Augusta plant comes on line in 2020.

Also announced in September, associated with the revival of Whyalla steelworks by GFC Alliance, is a proposal by Indian energy giant Adani to build a 140 Mw Solar Farm 10 Km north of Whyalla (Ref. 23). The proposals are to tap into the 132Kv power network between Whyalla Central and Cultana substations. It is understood that Adani is also looking into accompanying battery storage options. It is proposed to commence the project in 2018, with the aim to generate power by early 2019. Formal agreement, between the Whyalla City Council and the Adani Group, has been reached to access land for the development of the $200 million solar farm.

Some Conclusions

Looking at the power source figures at the start of the article, I don't believe a shortage of total power is the problem which leads to system instability. The problem is being able to store surplus power so that it is used to maintain power to the full load when there are troughs in the amount of power being generated. Suppose the 1500 Mw of wind farms suddenly dropped out due to lack of wind, or wind speed exceeds 90 Km/hr, or the 650 Mw Heywood Connector trips out. The thermal base load stations can't ramp up quickly to take the load and a major part of the grid trips out. Storage in the order of 1000 Mw/hr plus is needed. Neither the standby battery storage of 100 Mw/hr nor the 275 MW standby generator would be able to hold the grid stable in the event of these losses of power. The possibility of such an event was close on Thursday January 18, 2018 ,when the ambient temperature increased to 42 degrees C and the total wind wind power generation dropped to117 Mw. (Ref. 24). At the time, SA became reliant on 31% of its power (or 732 Mw) from Interstate via the Connectors.

The large scale installation of wind farms and solar generation across Australia is calling for power storage on a large scale and as soon as possible. Considering the present state of storage technology, this seems to be best provided by pump storage.

Pump Storage seems a very straight forward system. The alternating current is fed directly in the electric pump which I understand can be the same machine as the hydro power turbine which re-generates alternating current. By comparison for batteries, the AC power has to transformed down to a low voltage and rectified to DC. On release of the DC power, this has to be reformed into AC with an Inverter. The idea of building a storage with many thousands of paralleled chemical batteries, to be able to release thousands of Megawatts over extended periods, might be hard to achieve and be expensive. Also I am yet to hear of battery storage of such high capacity actually working anywhere in the world.

The proposal for large scale pump storage using sea water in Spencer Gulf to support the many installed renewable energy sources in South Australia would seem to be of higher priority than building more generating capacity as proposed in the SA Energy Plan. Also the idea to increase the storage capacity in the Snowy Mountains scheme by 2OOO mW (over many days) is an attractive proposal to support wind farms and solar systems which replace the many coal fired stations being closed in the Eastern States. The project could circumvent potential power outages such as those experienced in South Australia in 2016.

According to Reference 14, the overall power energy efficiency of energy used in pumping and then retrieving the energy used for the pumped storage system varies between 70% and 80%, with some sources claiming as high as 87%. Also there are no battery storage systems in existence which can match the storage capacity of large pumped storage system. For example the Snowy Mountains Tumut 3 system can discharge 1500 Mw for nine days from its fully pumped up storage. To service a large grid system it stands out as the way to go rather than mess about with batteries. That is the order of pump storage we could well do with in the Spencer Gulf of SA. I also refer to a statement by the Federal Energy Minister Josh Frydenberg (ref 10), He said that globally, 97% of the energy storage systems were pumped hydro..

Federal Energy Minister Josh Frydenberg said he welcomed the storage investment of Tesla but it was small compared to the scale of the problem the State Government had created. The new battery is 129Mw/hr compared to the 1000Mw/hr of storage at the Cultana pumped hydro project in the Upper Spencer Gulf and the 350,000Mw/hr additional storage we would get from Snowy Hydro 2.0. I endorse those remarks.

I have mentioned before, that there is an inherent hazard in the method of synchronising the frequency and phase of the AC waveform of the many small power sources tapped into the grid. For the system to work as it is, there has to be one large source (such as a base power station) to provide the reference and act as a sort of sink which sets the parameters. The multiple small power sources, such as wind farms and solar, tap across the grid to pick up the reference and lock in their outputs feeding the grid to the parameters set. If the system expands to the situation where large base sources are phased right out and replaced with all smaller sources, unable to provide the sink, the grid system will become unstable. If that situation occurs, the large scale hydro based storage could also provide the reference.

Concerning some of the ancilliary power systems which have been included in the article, the solar powered plants described for the Port Augusta region would seem to be good proposals, particularly those with supportive storage such as the use of graphite blocks or molten salt. The proposal to build a solar farm by the Snowy Hydro Company at Tailem Bend is also an interesting one, particularly as their past interests have been associated with hydro systems. Whether some of these proposals will go ahead is yet to be seen.

The idea to provide energy storage by heating pure silicon to melting point at 1414 degrees Celsius is another idea worth keeping on the radar. Mr Kevin Moriaty says, it will provide storage at a fraction of the cost of lithium batteries. Large scale development of a commercial model of this method of energy storage might be revolutionary but perhaps a few years away.

Solar Thermal power generation, as a partial replacement for the phased out coal fired stations at Port Augusta, was previously discarded by Alinta Energy as not financially viable. It seems that Solar Thermal is now back on the books with Solar Reserve. Workers, made redundant in the power industry at Port Augusta, will be pleased with that development.

Summary of new SA power sources installed or to proceed since early 2017

Wind Farms- DP Energy 225Mw, Lincoln Gap 212 Mw, Adani (GFC Alliance) 140 Mw - Total 577 Mw

Solar PV - DP energy (150 Mw + 300 Mw + 300 Mw), Bungala 220 Mw, Tailem Bend (Snowy) 100 Mw, Adani (Whyalla) 140 Mw - Total 1210 Mw

Solar Thermal - Aurora (Solar Reserve) 150 Mw

Deisel Generation - 276 Mw

Gas - Torrens Island - Fast Start 210 Mw replaces A Station 480 MW - Result Minus 270 Mw, Pelican Point possible addition of 300 Mw, Total 30 Mw

Energy Storage - DP Energy (400 Mw + 400 Mw), Aurora (Solar Reserve) 110 Mw (8-10 hrs), Tailem Bend (Snowy) 100 Mw, Tesla 100 Mw 129 Mw/hr - Total 1139 Mw (mainly short term capacity except for Aurora)

If all these planned power sources are completed and run together, the gross addition is 3353 Mw. If added to the early 2017 maximum figure, (which without Interstate Connectors, is 4432 Mw), we get a result of 7785 Mw. If the long term pump hydro storage of 1045 Mw being planned is added, the result is 8830 Mw. The peak load in SA is little more than 3000 Mw. So if all the wind farms are engaged and we have day sun, we could feed up to 6000 Mw to the eastern states. (Of course, this is limited by the capacity of the two Connectors, 870 Mw.)

Using both the battery and pump storage, our long term (several hours) holding ability will be 1045 Mw and short term (one hour) holding ability will be (1045 plus 1159) Mw = 2204 Mw.

Some Final Remarks

The Need for Large Energy Storage.

My assessment of SA power generation capacity with all sources providing maximum possible output during 2016 was 5300 Mw. Maximum possible load was a little over 3000 Mw. Operating with a reasonable wind, the wind farms alone were capable of over 1500 Mw output.

Possible dropouts such as occurred in 2016 are the 1500 MW from the wind farms and failure of power via the 650 Mw Heywood Connector. Also we know that 675 Mw from Roof Top PV is not there at night. Dropout, in particular that due to the windfarms, can be quite random. Fast regeneration of power is needed from some other source to fill the dropout gap. Existing Base Load generators are slow to rampup and hence the need for fast rampup storage. Hopefully, the storage capacity should be large enough for output to fill the dropout gap over a time frame equal to any anticipated duration of dropout. To be realistic, we are probably looking at energy storage in the order of thousands of megawatts output to be maintained over many hours, or at least over sufficient time for rampup of Base Load generation if available.

But in SA to protect against power dropout, we are getting a Lithion Ion battery of 100 MW output level and storage capacity of 129 MW/hr, publicly billed as the largest lithion ion battery in the world. If that is so, it only demonstrates how limited in size these batteries are in solving the energy storage need of a large scale renewable power grid such as a large wind farm network. Larger battery type storage has not been demonstrated throughout the world. Had this battery been installed in SA in 2016, I fail to see how it could have made any difference in quelling the power outages experienced in SA during that year.

SA is also getting nine mobile diesel/gas generators by December 2017 to provide a total 276 Mw of emergency power in the event of power shortage from existing sources. Considering the maximum possible output of 5300 Mw from those existing sources, this power shortage might have been addressed by energy storage had it been available.

Trying to build up energy storage on the scale that is needed with batteries seems a lost cause. The only real solution is pump storage. The pump hydro will take several years starting from now, but it should have been started coincidental with the progressive installation of wind farms to maintain a continuous energy supply. The need for storage was always obvious just as we have always needed reservoirs to store the water from rain.

Most energy storage systems around the world are pumped hydro. Pumped Storage seems a very straight forward system. The alternating current is fed directly in the electric pump which I understand can be the same AC machine as the hydro power turbine which re-generates alternating current. By comparison for batteries, the AC power has to transformed down to a low voltage and rectified to DC. On release of the DC power, this has to be reformed into AC with an Inverter. The idea of building a storage with many thousands of paralleled chemical batteries, to be able to release thousands of Megawatts over extended periods, might be hard to achieve and be expensive. .

The University of Melbourne Energy Institute (MEI) has carried out a survey of pumped hydro projects with particular reference to the States of Australia. As a result of this, MEI produced a report dated February 27, 2014. In surveying costs for pumped hydro projects globally, they found capital costs much lower than capital costs for chemical battery.The MEI report also located possible coastal sites around Eyre and York Peninsulars in South Australia which might be suitable for pumped hydro installations.

One other point for pump storage is that in releasing energy, it becomes a hydro electric generator with the inherent advantage that it can build up to maximum power output in minutes. This is a highly desirable feature to correct for power source variations and power dropouts.

On the practical side of looking at pumped hydro, Energy Australia has received a $450,000 grant from the federal government's Australian Renewable Energy Agency (AREA) to conduct a feasibility study for a $200 million 100 megawatt project located in Spencer Gulf in South Australia. If built it would be Australia's first pumped hydro project using seawater.

In the Advertiser of 17-2-17, discussions with Energy Minister Josh Frydenberg were revealed. He said a Pumped hydro storage facility at Cultana on the Eyre Peninsula could protect South Australia from power shortages that lead to load-shedding blackouts. He said work is underway to make the facility a reality. The Cultana defence site has pipelines, transmission lines and roads connected to it and it might only take a couple of years to complete.

New Proposals for Pumped Storage introduced: On February 18, 2018, the State Government finally announced plans for the installation of five pumped hydro systems. Refer to a new section on this proposal now added in a previous part of this report following the Snowy Pump Hydro Section. (Also Reference 25).

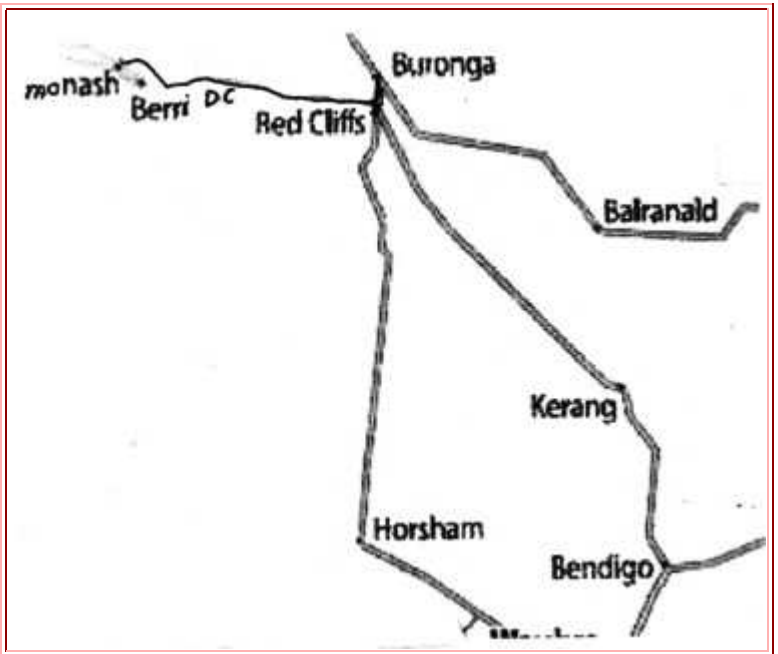
Synchronisation of the National Grid

The National Electricity Grid is indeed a lengthy operation. It streches from around Port Augusta in South Australia, around the south coast of South Australia and Victoria, and up the eastern coast of Victoria, New South Wales and Queensland as far as an area around Port Douglas. Apparently over a distance of around 5000 km, the 50 Hz AC network is shared and synchronised to a common frequency and phase reference which is the common load itself. The exception to this are the High Voltage DC links between Berri and Redcliffs and undersea from Victoria to Tasmania.

The distributed power is transmitted via random routes and reverse directions depending on the load conditions and the sources available at the time. My concern is with power which travels over long distance

to reach its destination. Electro-Magnetic energy travels in space at the rate of 300 x 1000 km/s. In a medium, such as a transmission line it travels at somewhat less a rate. In some forms of transmission line used for communiations, the velocity factor is around 0.6 and for the purposes of this discusion I will use that figure for the velocity factor in the general grid network.

On that basis, velocity in the grid is assumed to be 180 x 1000 km/sec and at a frequency of 50 Hz, the phase would shift 90 degrees at successive 900 kms from the source. A problem can be forseen when there are more than one energy route of varying length to a distributing point from a distant source and the addition of powers of differant time phase are attempted to be added. One such a point can be seen on the complete Nation Grid diagram at Redcliffs where power might be combined coming from SA, southern Victoria and eastern NSW. In this case, stability is probably already being improved by isolation due to the high voltage DC link connecting Redcliffs with Monash in SA.



Multiple power feeds connect at one point at Redcliffs
Note the High Voltage DC Link between
Monash in SA and Redcliffs

There are advantages in large networks to enable wider sharing of spare generation when it becomes available. However in USA, they have apparently had troubles with network stability in trying to operate networks too large. This has been solved by using smaller areas of connected AC with their own synchronisation but coupling the small areas together via high voltage AC-DC/DC-AC coupling systems. In other words, via a High Voltage DC Connector without the long DC transmission line.

It seems to me, that the installation of these DC couplers would vastly improve the stability of the whole network system. Perhaps each Australian State could run with their own synchronisation reference whilst still maintaining ability to transmit power between States, as required, and as they do now.

References

1. South Australian Energy Plan http://ourenergyplan.sa.gov.au/

2. Solar Reserve - Pt. Augusta http://reneweconomy.com.au/solarreserve-proposes-110mw-solar-tower-and-storage-plant-for-australia-16693/

3. Port Augusta 375MW solar and wind energy park http://www.dpenergy.com/hybrid/port-augusta-renewable-energy-park/

4.100 days to fix SA power crisis: Tesla - the Advertiser11-3-17

5. Big Project Unveiled - Solastor, the Advertiser 8-6-16

6. Whats new in Battery Storage - Carnegie, the Advertiser 1-4-17

7. Place in the sun for SA with new Power Plant - Snowy Hydro, the Advertiser 1-2-17

8. SA Storage at fraction of Tesla's cost - 1414 Degrees - the Advertiser 11-4-17

9. Pumped Storage - Andrew Blakers - the Advertiser 14-11-16

10. Watery Solution to Power Problem - Tory Shepherd, the Advertiser 17-2-17

11, Opportunities for Pumped Hydro Energy Storage in Australia - Arup-MEI Research - Melbourne Energy Institute, University of Melbourne

12. Pelican Point energy park to fire up - Advertiser, 22-4-17.

13. Powering up for the Charge - Battery Storage - The Advertiser 10-5-17..

14. Pumped-storage hydroelectricity https://en.wikipedia.org/wiki/Pumped-storage_hydroelectricity

15. $110m to back Pt. Augusta solar bid. Advertiser 25-5-17.

16. New Power for North of the Gulf and South Australia OTN, March 2015.

17. Bidders Listed for Bigest Battery. - Advertiser 01-6-17.

18. New Power Station Torrens Island http://www.abc.net.au/news/2017-06-07/agl-announces-new-sa-power-station/8596016

19. New Temporary Power Generators for SA. http://www.abc.net.au/news/2017-03-14/sa-power-energy-minister-electricity-market-plan-jay-weatherill/8351450

20. Our Battery of Batteries frees SA from Victoria - Paul Starick - Advertiser 23-8-17.

21. Energy Bill can cut Bills - Daniel Wills - Advertiser 29-8-17

22. Snowy Plugs Power Gap - Advertiser 27-9-17

23. Whyalla Solar Farm - Advertiser 27-9-17

24. Heatwave Sparks push for National Energy Plan - Advertiser 22-1-18

25. Hydro to keep our Electricity Pumping - Advertiser 8-2-18