Knowledge Sharing Report

5(A) – Civil works

Project Name:	*AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Civil Works

KEY LEARNINGS

The Nyngan Solar Plant site is very flat making drainage difficult due to the minimal fall able to be achieved. During the execution of the civil works, we experienced above average rainfall which at times severely impacted the works, schedule and budget. Inclement weather was identified during the project planning phase of the project, however, the degree of rainfall did have an impact on logistics, materials deliveries (both local and interstate), transportation, internal site road condition and development, laydown yard activities, and the opportunity to use heavy tracked equipment, trenchers, cranes, etc. Rainfall affecting these activities resulted in delays until the saturated ground was able to dry out through standard dewatering and pumping activities.

Within the project site, civil scope included internal access roads on the perimeter of the site as well as internal PCS block alleyways, along with car parks, two laydown areas for storage of materials, all of which required continual maintenance through the timeline of the project. Maintenance requirements for civil works included grading, leveling, dust abatement, application of dust inhibitor (Canola oil and Dustex were trialed, but while longer lasting were ultimately less cost effective than water), and dewatering when localised flooding occurred.

A critical component to the civil works was the establishment of the water download pipe area, along with the provisioning of remote water provided by pipeline and a dam for reticulation located just outside the northern boundary of the Nyngan project site.

The Broken Hill site has an undulating landscape sculpted by flash-flooding. The attached aerial photograph shows the different aspects of the civil works package: fencing, preparation of hardstands and laydown areas, establishment of the construction water supply, roads, cut and fill, and armoring of new and existing drainage channels.

The civil works were completed prior to commencement of structural and electrical activities.

Large infrastructure projects, such as solar plants, which are approximately 250 and 140 hectares (under arrays) at Nyngan and Broken Hill respectively, depend on reliable access in order to progress different construction activities.

First Solar had given these issues some thought and through judicious use of local contractor yards, storage locations, and delayed commencement, was able to manage project risk and maintain continuity for the most part. Good project management execution can ensure multiple plans are in place to deal with most events that can be an impediment to project execution.

For example, in order to minimise impacts from inclement weather at Nyngan, which could otherwise cause material delays, access roads and alleyways needed to be maintained throughout the construction period – particularly once tables had been installed and there were open trenches limiting access to a single point for many construction areas.

Finally, the consideration of local site conditions in designing mounting structures to work with the site topography reduces the civil works cost, as this provides opportunity to minimise the required cut, fill, levelling, drainage etc. Despite the civil package having the smallest value compared to the structural and electrical works (less than 10% of the total contract price), civil costs at both Nyngan and Broken Hill exceeded $10 million, and therefore cost savings can be significant.

IMPLICATIONS FOR FUTURE PROJECTS

- Installation of weather-proof access roads to be prioritised at the project start in order to avoid delayed or out of sequence delivery of equipment and materials, and potential for civils re-work due to local rains. This lesson was learned at Nyngan and implemented at Broken Hill.
- Upfront design work on mounting structures and layout to consider the local topography of the site can result in significant cost savings associated with civil works.
- Develop clearly defined and documented Scope of Works (SOW) and Divisions of Responsibilities (DOR).

KNOWLEDGE GAP

The civil works for a solar plant typically requires the application of common engineering practices.

However, given the significant land usage required for large scale solar PV installations, upfront consideration of civil work scope and cost ensures not only suitable civil design for operations of the plant, but that the impacts of ongoing maintenance and weather-related delays are mitigated to ensure construction schedules and budgets are maintained.

SUPPORTING PHOTOGRAPHS

PHOTO: Aerial photograph showing different elements of the civil works package.

Knowledge Sharing Report

5(B) – Structural works

Project Name:	*AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Structural Works

KEY LEARNINGS

Significant learnings were made relating to the transportation and installation of structural components across the Nyngan site.

In the attached aerial photo, posts can be seen on the side of the internal road adjacent to the arrays where they will be used. The posts were delivered from offsite directly to the locations, eliminating the need to move them from a central stores area to the work site.

Tele-handlers needed only to travel short distances to move the materials from this pre-staging point to the exact location in the array where the structures were installed. First Solar accounted for this vehicle movement when designing the minimum width of alleyways and perimeter roads.

Proper alignment of structures was achieved by installing the end posts within an array, prior to the internal posts. This provided a fixed point for controlling the line and height via laser. This approach also enabled electrical works, including underground trenching, to commence as early as possible. Note that although Nyngan and Broken Hill use the same folding table structure, the post installation at Broken Hill was more complex due to 15% of posts encountering rocky formations, reinforcing the impact site conditions play in project execution.

Strict quality control during installation of posts and tilt brackets ensured fewer issues arise later. If the posts are properly installed then table and module installation is relatively simple and repetitive. For example, at Broken Hill, with its undulating landscape, in order to ensure ease of table and module installation there were limits on the number and extent of gradient changes within a row. Each individual post height was determined from detailed topographic surveys, reviewed and signed off prior to post installation. Once installed, post spacing, alignment and angle are all checked to ensure that the structures they support will be easy to install.

Tables at Nyngan were installed using normal tele-handlers (refer to attached photo) moving perpendicular to the rows. Thus the tables were presented to the workers parallel to the rows minimising worker handling. At Broken Hill machinery had to move parallel to the rows because of the drainage channels, so to avoid workers lifting and turning while carrying the tables side-loading forklifts were used.

First Solar found that dedicating teams to particular activities (such as post, tilt, table installation) improved efficiency as the team was able to establish a routine. However, workers within each team were still required to regularly rotate tasks in order to avoid repetitive strain injuries, as well as errors resulting from repetition of tasks.

The tenderers for the Broken Hill contracts were given access to Nyngan where they viewed the different activities and had access to personnel to ask questions.

At Nyngan four post driving machines (three in operation and one on standby) were sufficient for the works. At Broken Hill, the sub-contractor supplemented the three machines provided by First Solar with an addition three of their own. The machines were serviced and inspected every hundred hours, with approximately 2-3 hours downtime – minimal impact on cost and schedule.

IMPLICATIONS FOR FUTURE PROJECTS

- Importance of upfront planning with respect to transportation logistics, for the direct delivery of equipment to work zones to increase installation efficiency and reduced internal transportation requirements.
- Structural works execution planning to reduce installation timeline, increase installation quality through post alignment methodologies, installer specialisation and ongoing quality checks should be considered upfront and assessed throughout construction.
- Develop clearly defined and documented scope of works and divisions of responsibilities.

KNOWLEDGE GAP

Nyngan and Broken Hill have the advantage of using similar module structures allowing for direct transfer of installation methodology and lessons learned from site to site, and installer to installer. Although any project will allow a methodology and routine to develop throughout construction, new racking systems will often require a ramp up in installation efficiency at the beginning of construction as installers learn a new installation technique.

SUPPORTING PHOTOGRAPHS

PHOTO: Aerial photo showing staging of posts adjacent to arrays where they will be installed.


Photo: Pre-staging of end tables to the work area


Photo: Pre-staging of harnesses to the work area

<u>Knowledge Sharing Report</u>

5(C) – Electrical works, including solar PV module installation

Project Name: *AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Electrical Works (including module installation)

KEY LEARNINGS

The solar modules are shipped as 50 modules per pallet. Each module pallet was staged close to the area in which they were needed for installation, similar to pre-staging of the structural materials. This boosted installation efficiency and also provided traceability and cross-checking that modules had been correctly allocated, as the module pallets were scanned in the pre-staged location.

Use of a template bar during module install was useful to ensure correct module spacing. Over time the module installation crews achieved significant productivity increases through development of a working system. One module crew would move ahead and temporarily place modules in the bottom 2 rows. This was quicker than installing modules directly from the pallet. Productivity increased from 160 to 300 modules per person, per day. Depending on crew size, this translated to a total module installation of between 6,000 to 11,000 modules per day.

The same module install crew transferred from Nyngan to Broken Hill in order to take advantage of the skills already learnt.

The development of bespoke wheeled chairs and trolleys (see attached photo) for the module termination crews increased productivity while providing a more ergonomic work environment.

Most high-volume tasks involving modules and other electrical components unique to Solar PV have been designed to be carried out by semi-skilled labour rather than trained electricians. Other electrical tasks are similar to those in other applications, e.g. cable terminations, and it is more efficient to use specialist sub-contractors than to hire and train staff specifically for the project.

With the drainage channels at Broken Hill, once tables were on and the cable trenches were dug, there was no access to some rows, so modules were placed in the rows prior to the digging of the cable trenches.

IMPLICATIONS FOR FUTURE PROJECTS

- Importance of upfront planning with respect to transportation logistics, including planning for direct delivery of equipment to work zones to increase efficiency of installation and reduced internal transportation requirements.
- Improvements can be made in sequencing and planning of the structural and electrical works such that the two works packages can proceed simultaneously, without obstructing access to any of the work areas.

- Module installation work methods to increase installation efficiency and quality can be carried through to future projects, including installation tooling, work staging and ergonomic assistance.
- Ensure access to materials throughout the build, given trenching and natural topographical features, to allow work to progress along multiple fronts.
- Develop clearly defined and documented scope of works and divisions of responsibilities for specialist sub-contractors.
- The protective bags covering the module pallet deteriorate over time with high winds and rain. This required the pallet to be re-covered and presents an opportunity for packing improvement.

KNOWLEDGE GAP

Electrical installation activities unique to Solar PV are not complex and there is growing local experience in Solar PV electrical installation.

Logistical approaches to improving efficiency are not unique to Solar PV.

BACKGROUND

Nyngan and Broken Hill required the installation of approximately 1.36 million and 677,760 solar PV modules, respectively. Modules are connected in series into strings; the strings from (typically) three rows are combined at the combiner boxes. The output from (typically) eight combiner boxes feed into a single inverter, and two inverters with their transformer form a single array with a generating capacity of approximately 1.3 MW.

The AC collector and Back of Plant (BOP) system is similar to that of a wind farm.

As the technology is relatively straight-forward the main construction concern is logistics. Hence considerable planning is required to ensure that the equipment is ordered, delivered and installed progressively. This is to ensure that there are no inefficient movement of equipment at the factory, port, road transport depot and on site. Poor logistic management can significantly delay construction. This planning will include the best port and road network for the delivery method and ensures roads and accesses are maintained properly to accommodate the high traffic movements, hence reducing any delays to the construction program.

SUPPORTING PHOTOGRAPHS

Photo: Three x Wheel Chair for Enabling Connection of Modules

Knowledge Sharing Report

5(D) – Community Engagement

Project Name:	*AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Community Engagement

KEY LEARNINGS
Stakeholder interest

Community engagement is critical to the successful delivery of large infrastructure projects such as the Nyngan and Broken Hill Solar Plants. Support from the local communities and key stakeholders for the Nyngan and Broken Hill Solar Plants has been very positive overall, with the communities highly engaged and supportive of the projects.

This involved early engagement with the community and key stakeholders as part of developing the plan which has required a focused effort to implement.

The Nyngan and Broken Hill Solar Plants generated significant interest within the local community and also at a regional, state and national level. Senior key stakeholders, political dignitaries, interest groups, community groups and media outlets were all very keen to visit the solar plants during the construction, which in turn generated further interest from other stakeholders and interest groups.

To accommodate these requests (where possible) during the construction phase of the project required significant effort and time in order to coordinate with construction activities at site. However, it was through facilitating these visits that knowledge sharing of the project, and more broadly, information on renewable energy, has helped to enhance the reputation of those involved with the project. These visits provided an opportunity to not only showcase the solar plant, but also the local community and businesses which provided further economic benefits and hopefully future benefits in the long term.

Worker behaviour in host communities

Worker behaviour reflects on the individual, their organisation and also the project. Consequently, it is critical that workers understand that we are guests in the local community and need to be respectful.

For the Nyngan Solar Plant, the Contractor established a “solar village” to provide additional accommodation for the construction workers. This was located in the town centre, which helped to provide increased economic benefits to the community. As part of initiatives to normalise relationships between solar plant workers and the Nyngan community an open day and BBQ was held at the solar village; to help the community “visit the village” and “meet the team”. This helped for the local community to better understand the project and see what was happening for themselves.

For the Broken Hill Solar Plant the local police were encouraged to participate in the ‘toolbox’ talks and inductions to ensure everyone understood their expectations for visitors working and living in Broken Hill.

Community engagement meetings

Community engagement meetings were tailored to meet the requirements of the individual communities at both Nyngan and Broken Hill.

The Nyngan community were keen to be involved in a formal community consultative committee (CCC) process which regularly involved 11 community members on the committee.

However, the Broken Hill community preferred a less formal process that involved less commitment from individuals in the community, but the regular community information sessions allowed people to get involved on an 'as interested' basis.

In both cases the meetings were open to the general public, which resulted in a good mix of regulars, new community members and tourists at each meeting.

Being prepared to be flexible to meet the needs of the locals, and adjust the consultation style resulted in engaged and informed communities at both locations.

Local employment expectations

Employment opportunities in regional communities can be a difficult. As a result, major infrastructure projects like the Nyngan and Broken Hill Solar Plants create a high expectation of employment.

It is important to engage with local employment agencies early and establish a link with them and the Contractors looking to source workers. These agencies can help to match the skills of the local workers with those being sort by the Contractors.

Early engagement will also provide an opportunity for any project specific training. Local employment benefits both the local community, the Contractor and the project.

Advertising for local workers needs to consider a range of channels. For example, local print media, flyers in local employment agencies and supermarkets, radio and websites were used. It is important that all enquires are responded to in a timely manner and applicants kept informed of any changes.

IMPLICATIONS FOR FUTURE PROJECTS

- Similar to other large infrastructure projects, it is critical that experienced community engagement personnel are allocated to the project at an early stage.
- In addition to allocating appropriate numbers of experienced community engagement professionals within the EPC *and* developer teams, co-ordinated upfront planning is required to ensure timely, best practise delivery of community engagement.
- As large-scale renewable projects are typically located in regional areas consideration needs to be given to the distance and time required to deliver the community engagement activities.
- Trust is built up if the same person(s) build and maintain relationships with local businesses and community leaders, attend the local AgFair and open days, and facilitate site visits.
- Allow flexibility with community engagement activities. What might work in one community, might not be suitable for another community. The formal CCC meetings held in Nyngan were changed to a more informal engagement approach for Broken Hill.
- Develop a local employment participation plan to help manage local community employment expectations.
- Be aware of the impact on a local community that the increased worker influx can have on small communities. This needs appropriate resources to manage.
- Controlled visits of the solar plants and (Nyngan) solar village helped with community engagement with locals being able to better relate to the project.

KNOWLEDGE GAP

Development of the Nyngan and Broken Hill Solar Plants has signalled the birth of large-scale solar in Australia. This generated significant interest within the local communities, as well as with key stakeholders, media and the wider community on a national level and provided an important knowledge sharing opportunity.

As large-scale renewable projects become more common broader interest may wane. However, since such projects are typically located in regional areas, interest in projects will be proportional to the likely economic impact on the community and their interest will be on how the specific project will affect them.

ADDITIONAL PROJECT INFORMATION

Nyngan Solar Plant
https://www.agl.com.au/about-agl/how-we-source-energy/renewable-energy/nyngan-solar-plant

Broken Hill Solar Plant
https://www.agl.com.au/about-agl/how-we-source-energy/renewable-energy/broken-hill-solar-plant

Broken Hill Solar Plant aerial video
https://www.youtube.com/watch?v=GHQnlQsX3KQ

Jeremy Buckingham MP, Greens Nyngan Solar Plant video
https://www.youtube.com/watch?v=tqcX-H2OZKc

SUPPORTING PHOTOGRAPHS

Photos: Examples of community and key stakeholder participation Nyngan and Broken Hill solar plants

Knowledge Sharing Report

5(E) – AEMO Generator Registration

Project Name:	*AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	AEMO Registration

KEY LEARNING

The inverter is the generating unit for a solar PV plant, however bidding Nyngan's 154 inverters into the market is impractical. Hence Nyngan is registered as a cluster of generating units with AEMO (Australian Energy Market Operator) such that market bidding is for one generator and not 154.

Broken Hill was similar, with two parallel blocks of 40 inverters, combined into a single generator.

Inverters are capable of being operated in a number of control modes (voltage control, power factor control, and reactive power control) allowing them to provide grid support during operation. It is also possible to provide continuous reactive support, i.e. whilst not generating through the night as an example, which could be provided as a service to AEMO. There is additional cost for this facility and to minimise this cost it would need to be included as a technical requirement in the initial project scope.

The NER (National Electricity Rules) has evolved from an environment where generation was added to the grid through large, unique, and infrequent projects, e.g. large scale coal fired and gas-peaker plants mainly rotating machinery). The NER continues to respond to changes in the industry. Nyngan and Broken Hill registrations were based on Version 59 of the Rules; by the end of the project – two years later – the NER was in Version 75. Following the changes in the NER can be time consuming when there are multiple, smaller, generators based on a common template being installed.

In some instances the performance criteria in the NER assumes that generation is based on rotating machinery, which does not apply to solar PV.

Education was a key issue:

- The proponent – AGL, as the Principal, and Jacobs, the Owner's Engineer – having understood the inverter technology from wind farms, were able to draw on their previous experience in wind farm developments by thinking of the modules, inverters and associated transformers as analogous to a wind turbine with an inverter stage.
- The DNSP (Distribution Network Services Provider) and AEMO – educating technical assessors in inverter technology, solar energy and the implications for grid security and potential for reactive support.
- Supplier – typically foreign suppliers have little understanding of the regulatory framework and the performance inputs and information required from them. For both Nyngan and Broken Hill, First Solar (USA), the power station EPC contractor, purchased the inverters from SMA (USA), but technical inputs needed to be obtained from SMA in Germany. Performance data from these suppliers needed to be checked as, for example, power modelling originally provided by SMA was for 60hz systems not 50hz Australian networks.

- Contractor – although experienced in solar plant developments worldwide, Nyngan was First Solar's first large scale utility development in the NEM in Australia and was unfamiliar with the regulatory framework.

IMPLICATIONS FOR FUTURE PROJECTS

Discuss the potential to provide reactive services with AEMO at an early stage so that the option to provide continuous reactive support to the grid can be assessed in the context of the return on investment of the project and if beneficial then it could be included in the original project scope.

Allow time and effort to educate stakeholders, because between projects there will be changes in:

- The supplier and model of inverter.
- The Rules – as the NER Version changes or projects are implemented in different jurisdictions.
- NSPs – even within the NEM there are numerous NSPs.
- Personnel – normal turnover within stakeholder organisation between or during projects mean that previous education efforts are lost.

While the time associated with the education of stakeholders would decline with time, ARENA could accelerate the process of knowledge dissemination by:

- Documenting and making publically available lessons learned from all projects receiving funding
- Hosting knowledge-sharing workshops aimed at:
    - Understanding inverter technology and the implications for providing ancillary services
    - Streamlining the Rules for solid state generation

KNOWLEDGE GAP

Solar developments outside of the NEM would be subject to a different regulatory framework. Knowledge and experienced gained by AEMO in the technical administration of utility-scale solar developments would be limited to the NEM until diffused through active knowledge sharing activities or the movement of individuals into like organisations in other jurisdictions.

There is potential to improve efficiency by amending the Rules so that renewables projects – which lend themselves to being based on template plants – can be developed and implemented within a consistent regulatory framework.

Similarly, the NER should be reviewed so that solid state technologies (Solar PV) can be accommodated alongside rotating machinery-based technologies.

BACKGROUND

Objectives or Project Requirements

The Australian Electricity Market Operator (AEMO) administers the National Electricity Market (NEM) within the regulatory framework provided by the National Electricity Rules.

AEMO registration is required in order to be able to input electricity from a generating asset into the NEM. The registration process considers technical, principally through the Generator Performance Standards (GPS), and commercial aspects, principally through a review of demand for the electricity generated – typically demonstrated though a Power Purchase Agreement (PPA).

Process undertaken:

Registration typically follows the following process:

- Site determination – undertaken by the project proponent
- Preparation and submission of a connection enquiry – a request to connect to the NSP

- Response to connection enquiry – the NSP will respond with conditions, including a list of non-contestable (must be undertaken by NSP) and contestable works required prior to connection. The cost of these works will usually be borne by the project proponent. At Nyngan these included the Essential Energy switchyard, extension to the existing 132kV overhead line and provision of a Static VAR (Variable Resistance) Compensator at Nyngan substation. At Broken Hill a potable water line and existing 22kV line needed to be diverted around the solar plant.
- Technical studies are undertaken by the project proponent to establish the GPS.
- Submission of the GPS to the NSP and AEMO for their acceptance, which usually follows a series of reviews.
- Preparation and submission of registration documentation – this can happen in parallel to the GPS as the GPS only has to be finalised by the time registration is approved.
- Registration also involves a series of reviews and is usually granted following the monthly meeting of the AEMO panel, but this can be expedited.

SUPPORTING INFORMATION

- Refer to the companion document to this one on Generator Performance Standards
- AEMO Registration – Information on Network Connections: http://www.aemo.com.au/Electricity/Network-Connections
- AEMO Registration – How to Register: http://www.aemo.com.au/About-the-Industry/Registration/How-to-Register/Application-Forms-and-Supporting-Documentation/NEM-Generator

Knowledge Sharing Report

5(F) – Grid connection – energisation

Project Name:	*AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Grid Connection

KEY LEARNINGS

First Solar has found no special requirements for the grid connection of the PV Plant outside of what is normally expected for a new generator. The PV modules essentially behave as DC power supplies. They are connected to the inverters, step up transformers, collector system and then switchgear. From the inverters onwards, there is little difference between the solar plant and other types of inverter output generators, e.g. wind turbines.

The design and implementation of protection settings and the SCADA system needed to be coordinated between multiple vendors (inverters and relays in particular). Often this will be done overseas before the equipment arrives in Australia for installation.

As part of AEMO registration and negotiation of the GPS, there was an extended period of discussion with AEMO and the Network Service Provider (NSP), as they familiarised themselves with the inverter technology and the impact of solid state generation on network stability. During this time, the parameters of the inverters changed significantly. A coordinated effort was required to ensure that any changes to the inverter parameters due to performance requirements was captured and programmed into the inverters prior to commissioning.

At the Nyngan Solar Plant Essential Energy's (NSP) concerns over a white powder found on the surface of some aerial conductors had the potential to delay the commissioning of the 132 KV connection assets. This conductor was procured by the contractor from an Essential Energy approved supplier. Following lengthy discussions, a compromise was reached whereby the commissioning took place on time, but the conductors were required to undergo a thorough testing regime.

At the Broken Hill Solar Plant the design for the rail crossing of the dual circuit 22kV overhead line went through the rail operator's (Australian Rail Track Corporation) rigorous review process. In order to expedite the approval of the design it was necessary to accept conservative standards (1/1000 year wind loading) – compare the attached photographs of final Broken Hill 22kV installation and the 132kV installation at Nyngan.

IMPLICATIONS FOR FUTURE PROJECTS

- To ensure a smooth transition from installation to the grid connection, it would be beneficial for the EPC contractor to appoint a dedicated protection system coordinator to interface between AEMO, the NSP, and the protection equipment manufacturers/ suppliers.
- Poor co-ordination of inverter performance will slow the commissioning process and create delays in energisation.
- Quality assurance of materials from the factory to site, and storage on site needs to be managed to ensure materials procured are of the right standard and are not damaged or degraded prior to installation.

- Start early, allow time, and assign personnel to manage engagement with stakeholders that provide approvals; delays can adversely impact the overall project.

KNOWLEDGE GAP

There is no real knowledge gap concerning grid connection. However, managing the requirements of all the stakeholders is a critical aspect that requires attention and should not be underestimated.

SUPPORTING PHOTOGRAPHS

Photo: New 132 kV line at Nyngan


Photo: New 22kV lines crossing over the railway at Broken Hill

Knowledge Sharing Report

5(G) – Generator Performance Standards

Project Name: *AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants)*

Knowledge Category:	Technical
Knowledge Type:	Construction
	Generator Performance Standards

KEY LEARNING

Development and approval of the Generator Performance Standards (GPS) took about 12 months after the first submission to the Network Service Provide (NSP). This process was about 6 months longer than what one would expect where the technology is well understood. Additional direct costs for the Proponent's team, i.e. ignoring lost opportunity and Contractor costs, would have been of the order of $250,000 for each site.

The power plant controller (PPC) is the controlling unit for a solar PV plant and together with the inverters form an integrated system for controlling the operations of the generator. Details of both elements are critical before the Technical Assessment (Connection) Study can be undertaken to determine the GPS. Any change in the PPC, inverter equipment or revision to the PPC or inverter modelling may impact the Connection Study and GPS.

The Proponent (AGL) is contractually responsible for the provision of the study and ultimate development of the GPS, but First Solar determined the PPC, inverter supplier, model and associated characteristics which were then used in the GPS. When First Solar changed inverters a significant amount of time and effort to amend the GPS was required. Technical matters raised by the Owner's Engineer would go via the Contractor to the supplier (via the USA to Germany) – and responses would follow the same trail back to the Proponent. This was not a very efficient way of obtaining data from SMA, the Original Equipment Manufacturer (OEM).

The technical aspects of registration are covered in part by the GPS, which is subject to review and approval by both the Australian Energy Market Operator (AEMO) and the NSP. The NSP acts as both an agent of AEMO and also has a mandate to ensure grid security. At Nyngan, initial technical studies assumed power factor control mode based on the NSP's response to the connection enquiry. Later, during the review of the GPS, AEMO and the NSP were keen to explore the consequences for the solar plant to provide dynamic grid support. This expanded the scope of technical studies required to support the GPS and extended the registration process.

Similarly, at Broken Hill the process took longer than would have been expected as the technical personnel in the NSP took time to investigate in detail the inverter technology and the implications for their network.

IMPLICATIONS FOR FUTURE PROJECTS

Consider including responsibility for the final technical studies and GPS within the scope of the EPC contract. This would eliminate an unnecessary interface between those preparing the GPS and the supplier. It would also align control and impact of changes to the inverters with the responsible Contractor.

Ensure that the PPC and inverter model is robust in design and proved as early as possible in the project to avoid delays in approval of the GPS and thus potential delays in registration and generation.

Include AEMO early in the development of the GPS to gain consensus between AEMO and the NSP on the inputs into the GPS.

KNOWLEDGE GAP
A general understanding of solar technology will in time diffuse through the local industry. However, given the range of applications, suppliers and evolution of inverter technology there is no avoiding the need to become familiar with the specific inverter technology being applied and facilitating the education of other stakeholders.

There is potential to streamline registration by making a single entity responsible for the management of the review and approval of the GPS rather than the current requirement under the NER to submit the GPS for review to both AEMO and the NSP.

BACKGROUND
Objectives or Project Requirements
The Australian Electricity Market Operator (AEMO) administers the National Electricity Market (NEM) within the regulatory framework provided by the National Electricity Rules (NER).

Part of the NER requirements is the technical assessment of the generator for connection to the grid. The Network Services Provider (NSP) is responsible for grid security, and also acts as an agent for the market operator. For a Proponent to connect a generator to a specific point on the grid, the Proponent, AEMO and the NSP need to agree on what level of performance the generator needs to attain. This is contained in the GPS. The GPS is determined by a series of technical studies (both dynamic and static) that describe the performance of the generator while it is connected to the grid. These studies also show how the grid responds to the generator’s operation.

The GPS also provides the technical input into the AEMO registration process – see the companion report on AEMO registration. Consequently, AEMO and the NSP need to agree to the GPS.

Process undertaken:
Development and approval of the GPS typically follows the following process:

- Collection of inputs, including:
    - Establishing the NER version and studies required – from AEMO.
    - Site-specific physical data – from site determination.
    - Connection and grid conditions – from the NSP’s response to the connection enquiry.
    - Inverter performance data and modelling objects – from the supplier.
    - Network models – from the network operator (AEMO).
- Modelling and other technical studies to determine the performance levels that will go into the GPS.
- Development and submission of GPS in the prescribed format to both the NSP and AEMO for their review.
- Acceptance of the GPS by the NSP and AEMO, which usually follows a series of reviews.

SUPPORTING INFORMATION

- Refer to the companion document to this one on AEMO registration.

- AER Generator performance standards information booklet
  https://www.aer.gov.au/node/21331
- AEMO Generator Performance Standards
  http://www.aemo.com.au/Electricity/Market-Operations/Generator-Performance-Standards