YADLAMALKA ENERGY

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PROJECT TITLE: **YADLAMALKA ENERGY PROJECT**

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1. PROJECT DETAILS

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2. DEFINITIONS

AC	Alternating Current
AEMO	Australia Energy Market Operator
ARENA	Australian Renewable Energy Agency
BMS	Battery Management System
BESS	Battery Energy Storage System
COVID	Corona Virus Disease
BESM	Battery Energy Storage Manager
DC	Direct Current
EPC	Engineering Procurement construction
EMS	Energy Management System
FCAS	Frequency Control Ancillary Services
MW	Megawatt
MWh	Megawatt hour
MWP	Megawatt Peak
MVPS	Medium Voltage Power Skid
OEM	Original Equipment Manufacturer
PV	Photovoltaic
SAPN	South Australia Power Networks
VFB	Vanadium Flow Battery

3. EXECUTIVE SUMMARY

Yadlamalka Energy represents an innovative renewable energy initiative in South Australia, comprising a co-located Vanadium Flow Battery (VFB) energy storage (2MW – 8MWh AC) and Solar Photovoltaic (PV) farm (6MWp DC), integrated behind a DC-coupled inverter.

The VFB system is strategically designed to capitalize on South Australia's significant intraday price variations, facilitating power time-shifting from midday to peak periods in the evenings and mornings. Moreover, the project is poised to actively participate in the Frequency Control Ancillary Services (FCAS) market, contributing to the stability of the electricity grid.

Under the leadership of seasoned renewable energy investor Mr. Andrew Doman, Yadlamalka Energy has assembled a proficient team, including SwitchCo as Project Managers, Invinity Group as providers of Vanadium Flow battery technology and NGE as construction partners. The collaborative efforts of the project team have fostered a strong collegiate focus on project delivery across all disciplines.

Currently, the project is progressing on schedule and within the revised budget, with final stages of commission testing underway. This Lessons Learnt Report - No 2 delineates key recent issues managed throughout the project lifecycle. The predominant lessons Learnt encompass construction and supply chain management, as well as regulatory matters, highlighting the project's commitment to continuous improvement and optimization.

As the Yadlamalka Energy project nears completion of its commissioning phase, it remains within the confines of the revised budget. Notably, the site has been contributing to South Australia's grid since December 19th, 2023, following approval from SAPN. The official launch date is set for April 2024.

4. PROJECT DESCRIPTION

Yadlamalka Energy stands as an innovative renewable energy venture in South Australia, situated in Port Pirie, an area characterized by favourable solar radiation. The project encompasses co-located Vanadium Flow Battery (VFB) energy storage (2MW – 8MWh AC) and Solar Photovoltaic (PV) farm (6MWp DC), seamlessly integrated behind a DC-coupled inverter.

Functioning as a hybrid system, the project will provide a blend of solar power and battery storage services to the grid. Leveraging the capabilities of the vanadium flow battery, the project aims to capitalize on South Australia's notable intraday price variations, enabling efficient time shifting of power from midday to peak periods in the mornings and evenings. Additionally, participation in the Frequency Control Ancillary Services (FCAS) market will contribute to bolstering the stability of the electricity system.

The utilization of breakthrough vanadium flow battery technology promises substantial economic benefits to South Australia while supporting the transition towards a low-carbon economy. These batteries, fully containerized and non-flammable, offer reusable units capable of discharging 100% of stored energy over semi-infinite cycles, with no degradation. Notably, vanadium flow batteries present significant advantages over lithium counterparts in longer duration time-shifting applications.

ARENA's funding agreement is based on the understanding that the project serves as a demonstration initiative, producing outcomes relevant to other investors in the Australian renewables market. These outcomes include:

(a) **Reference plant:** Demonstrating the operational viability of grid-connected Vanadium Flow Batteries (VFB) to prospective developers, regulators, and investors.

(b) **Support for technical innovation:** Showcasing participation in energy and Frequency Control Ancillary Services (FCAS) markets, as well as the feasibility of providing other network support services through the Testing Plan.

(c) **Commercialization pathway:** Demonstrating the commercial viability of forecasted cash flows in the financial model using a merchant trading strategy.

(d) **Industry development:** Supporting the advancement of Vanadium Flow Batteries (VFB) usage in Australia. This involves investigating the potential to expand the existing Australian vanadium resource industry by demonstrating the feasibility of VFB utilization and linking vanadium producers with prospective VFB end-users.

The project team comprises a blend of Australian and global energy and construction specialists, collectively driving the realization of this pioneering renewable energy endeavour.

Project Managers – Switch Co

- SwitchCo, specialist renewable energy project managers based in Victoria.

Storage Asset Experts – Invinity

- Global market leader in energy storage and manufacture of vanadium flow batteries with 20+ years' experience. Based in Canada and the UK, they bring significant technical expertise, manufacturing capability and business modelling to the Yadlamalka Energy project.

Storage Optimisation – Habitat

- UK and Australian specialist in energy trading optimisation for grid scale energy storage projects.

Knowledge Sharing – University of Adelaide

- The University of Adelaide is the Knowledge Sharing partner.

Yadlamalka Energy is developing a programme with the University of Adelaide to study energy management, economic analysis with cloud-based analytics, network deficiency analysis and flow machine infrastructure benefits.

EPC – Next Generation Electrical

- NGE is an Australian company specialising in Engineering, Procurement, and Construction services for renewable energy solutions, embodying the next generation of electrical expertise.

5. KEY LEARNINGS

5.1 Lesson learnt No. 1: Indigenous Stakeholder Engagement

Category: Regulatory

Objective: To highlight the significance of acknowledging and respecting the local Nukunu people as project developers, emphasising the importance of fostering a relationship based on mutual understanding.

Detail: In the project development process, prioritising acknowledgment and respect for the local Nukunu people emerged as crucial, underscoring the importance of fostering mutual understanding.

The project's emphasis on pioneering new technologies, rather than adhering strictly to conventional solar farm models, played a significant role in facilitating mutual understanding among all involved parties.

Yadlamalka Energy encountered substantial delays and costs related to the Indigenous Section 23 issue, which have since been favourably resolved by the South Australian Government. Consequently, the site now presents a potential additional location for future development.

A notable lesson learned from this experience underscores the significance of engaging consultants with expertise in navigating sensitive land management matters.

Implications for future projects include the necessity of early and ongoing respectful communication with local Indigenous stakeholders, highlighting the importance of fostering and sustaining positive relationships.

5.2 Lesson learnt No. 2: Project Management & Government Registrations

Category: Regulatory

Objective: The ability to achieve formal registrations in a timely manner

Detail: From a Project Management Perspective, the lessons gleaned revolve around the intricate and time-consuming nature of the various regulatory systems governed by

AEMO/SAPN, coupled with the challenge of securing the appropriate internal and external support to navigate the formal registration processes effectively.

A notable observation is the scarcity of individuals possessing comprehensive knowledge of AEMO requirements, which compounded the complexities of the project.

It became apparent that adopting a sequential approach to activities proved inefficient and led to significant time losses. Instead, the optimal strategy involves concurrently running multiple activities from the outset to expedite progress.

Unexpected obstacles, such as weather-related delays impacting SAPN connection work, underscored the importance of proactive planning. For instance, a three-month setback ensued due to high January temperatures impeding installation work, necessitating rescheduling by SAPN. This highlighted missed opportunities to advance installation bookings earlier.

Moreover, challenges emerged during the activation phase of our connection, where formal sign-offs and processes were unexpectedly required. This underscores the necessity for enhanced internal compliance planning and a proactive approach to regulatory work commencement.

Implications for future projects: Consideration and acknowledgment of regulatory complexity, emphasizing meticulous planning to mitigate potential delays, and prioritizing internal compliance readiness.

5.3 Lesson learnt No. 3: Trading Revenue & Management

Category: Commercial

Objective: Maximising project returns and revenue

Detail: The lesson gleaned from the project team's experience underscores the importance of promptly identifying the primary revenue sources available in a project, thus delineating the types of trading activities to engage in with regulatory bodies.

This early identification process necessitates a comprehensive evaluation of the requisite controls on-site and the functionalities required from both the inverter and the communications hub. The team meticulously identified 17 trading scenarios necessitating the independent control of power imports, exports, and FCAS. Each scenario entails the transmission of settings to the inverter and subsequently to the battery and solar PV systems. However, it became evident that not all scenarios could be feasibly implemented without modifications to the inverter's capabilities.

Throughout the project, we encountered limitations and devised workarounds accordingly. Ultimately, we anticipate executing most of our trading scenarios, although some will necessitate further advancement in inverter technology.

Implications for future projects: Prioritizing early focus on revenue recognition and understanding the limitations of trading systems to inform equipment design effectively.

5.4 Lesson learnt No. 4: Battery Thermal Management

Category: Technical

Objective: Maximise Operational Performance

Detail: The Australian climate presents considerable challenges for batteries, as they generate significant heat during operation. Early recognition of this factor prompted thorough consideration regarding the necessity of shading for our batteries.

Collaborating with INVINITY and HABITAT, extensive modelling and simulation were conducted to comprehend the climatic conditions and assess the potential need to curtail power output. Interestingly, it was determined that shading did not offer the anticipated return on investment nor substantially mitigate heat-related issues, primarily because a substantial portion of the heat load originates internally. Notably, vanadium batteries generate heat during discharge but absorb heat during charging, significantly influencing the heat load within the battery containers. In addition, the electrolyte of VFBs is water based. There is approximately 10,000 litres of electrolyte in each battery container. The thermal inertia of this large mass of water prevents the electrolyte temperature from increasing or decreasing fast, regardless of the ambient temperature. An digital model of the batteries, simulating the batteries duty cycles, daily charging and discharging times with seasonal temperature variations, allowed Invinity and Habitat to model the thermal behaviour of the batteries. This demonstrated that the batteries would operate nominally most of the year, with some capacity derating during the hottest days of the year.

Implications for future projects: Prioritising early planning to address equipment limitations and capacity constraints effectively.

5.5 Lesson learnt No. 5: OEM Manufacturer Deliver, Installation & Commissioning

Category: Technical

Objective: OEM equipment supplied delivers as expected

Detail: A significant project delay in the later stages of commissioning has been attributed to challenges in the delivery, technical support during installation, service delivery, and spare parts provision related to OEM equipment supplied to the project.

Although the key equipment such as VFBs, MVPS, DC-DC Converters and Power Plant Controller came ready to operate, once connected together as a system, getting them to works together is not a "plug & play" exercise. Fortunately for the project, most issues were limited to software interfaces (Modbus registers) and operation modes (e.g. operating margins on power and voltage envelopes) that could be fixed after proper diagnosis on site by the respective specialist engineers from each OEM supplier. However, obtaining after-sales support, especially for equipment sourced from overseas, proved to be problematic. Issues encompassed service availability, troubleshooting, commissioning, the visa application process for technical support personnel, and scheduling, as well as spare parts delivery.

Implications for future projects: For future projects, it is to be expected that significant integration work needs to be planned. This most likely translates in having specialist personnel from each OEM attending site, preferably to diagnose and remedy to equipment integration issues together. Emphasise robust supply chain management, particularly focusing on enhancing after-sales service and reinforcing backup capacity.

5.6 Lesson learnt No. 6: Test Plans

Category: Compliance

Objective: Improved clarity in reporting requirements

Detail: Difficulties have been encountered in the development of the test plans necessary for SAPN to finalize our application for FCAS services. The primary challenge has been the lack of explicit delineation of test requirements within the regulations, compounded by a limited understanding among advisors regarding the interpretation of provided guidance.

A secondary obstacle arises from the need to execute tests that deviate from standard operational parameters. Consequently, additional effort has been invested in fulfilling requirements and furnishing the requisite test evidence as mandated by regulatory bodies.

Implications for future projects: Proactive identification of the above challenges has enabled the mitigation of the risk of significant delays in the execution of testing procedures.

5.7 Lesson learnt No. 7: Unexpected Power Trips

Category: Operational Efficiency

Objective: Minimising disruptions due to power trips

Detail: The occurrence of unexpected power trips has presented challenges in the smooth execution of project activities. These trips, caused by various factors such as equipment malfunctions, grid fluctuations, or operational errors, have disrupted the excitation of test plans and hindered progress. It has become evident that proactive measures need to be implemented to anticipate and address potential power trip scenarios. A proactive and reactive ground team, in collaboration with a strong project management team, EPC and vendor team, is essential to promptly troubleshoot and resolve issues related to power trips.

Implications for future projects: Establishing robust protocols for identifying the root causes of power trips and implementing preventive measures is crucial for maintaining operational efficiency and minimising project delays.

5.8 Lesson learnt No. 8: Team Composition and Cooperation

Category: Technical

Objective: Facilitating communication among technical experts through virtual platforms

Detail: The project team comprised experts with a comprehensive range of complementary skills essential for project delivery. Cooperation was fostered through regular video conferencing sessions, facilitating effective communication and collaboration. Establishing a relationship built on trust and technical proficiency among key personnel was paramount to the project's success. Thorough consideration was given to all facets of the PV and VFB system. Engineers from each project participant convened regularly through online meetings, supplemented by occasional in-person gatherings. Restrictions imposed by COVID-19 hindered travel to and from Australia and between states for a significant duration of the project.

Implications for future projects: The project team maximised virtual communication channels, including video conferencing, and relied on a comprehensive repository of technical documentation to ensure seamless coordination and progress.

5.9 Lesson Learnt No.9: VFB Deliveries

Category: Supply Chain Management

Objective: Avoiding Import Delays

Detail: Thorough planning of shipping requirements emerged as crucial to avoid delays in the importation of batteries to Australia. A notable challenge encountered was the difficulty faced by the BESS partner, Invinity, in obtaining an ABN number for GST payments.

Implications for future projects: This issue has since been resolved for future projects, ensuring smoother logistics operations and adherence to regulatory requirements.

5.10 Lesson Learnt No.10: VFB Deliveries

Category: Supply Chain Management

Objective: Addressing Supply Chain Constraints

Detail: Supply chain constraints, especially concerning electronics components, were exacerbated by the impacts of COVID-19 and continue to persist to date. Electronics components for the internal DC converters of the VFBs were available in limited quantities during the pandemic. This has caused some of the VFBs to be shipped to Australia without the DC converters that were fitted on site. These components are replaceable components during the Operations and Maintenance phase, hence fitting them on site wasn’t a technical issue, only an additional task to be added on site. For the O&M phase, a stock of key spares is being constituted to ensure replacement of such electronics components do not cause any operation disruption.

Implications for future projects: Emphasise the importance of proactive supply chain management strategies to mitigate disruptions and ensure the availability of essential components for project execution. Constitute a stock of key spare parts, particularly those most likely affected by component shortages.

5.11 Lesson Learnt No.11: MVPS and DC-DC Converter Procurement

Category: Procurement Management

Objective: Managing Long Lead Items

Detail: The procurement of MVPS and DC-DC converters consistently entails a lengthy process and is prone to becoming the critical path for future projects. MVPS typically have 30 to 40 weeks lead times, due to their core power electronics long lead time power electronics components, and to the production capacity limits of the OEM. There is usually enough time in a typical project schedule to accommodate the 30-40 weeks lead times of MVPS equipment, if procurement is initiated very early in the project.

Implications for future projects: Initiating procurement during the early stages of project planning is advisable. This approach allows sufficient lead time to navigate potential challenges and ensures timely acquisition of these critical components, thereby safeguarding project timelines and objectives.

5.12 Lesson Learnt No.12: Interconnection Panels Procurement

Category: Procurement Management

Objective: Planning for Ancillary Equipment

Detail: A supply chain of standard electrical panels tailored for the Australian market has been established by the BESS partner: Invinity To connect the 41 battery units to the DC-DC converters and these to the MVPS, to the site's auxiliary power supply and to the site's communication and control network, a set of interconnection panels are required. There are 3 categories of panels: DC panels, AC auxiliary connections, and control panels. Invinity has defined panel designs to the UK standards. Functionally equivalent panels needed to be designed to Australian standards and procured. The DC and AC panels were procured from a global specialist supplier. The control panels were procured from an Australian supplier. The control panels were particularly affected by the electronic component shortages that resulted from the COVID 19 crisis. Other delays on the project masked this issue, and the control panels were delivered in time for installation to site.
Implications for future projects: It is imperative to plan for such ancillary equipment well in advance, considering the extended lead times associated with numerous electrical components. This proactive approach ensures timely availability of essential equipment, thus mitigating potential project delays.

5.13 Lesson Learnt No.13: Control Software Delivery

Category: Software Integration

Objective: Ensuring Smooth Integration

Detail: Integrating complex systems involving multiple standard equipment and software packages necessitates the engagement of a software integration specialist firm with extensive experience in large-scale energy systems. A coherent control system needed to integrate the SMA Power Plant Manager, the VFB system controllers, the Habitat dispatch engine and the controller receiving SAPN constraints at the site connection. All these different systems were existing products, some of them not offering much flexibility for any modification. It was essential first to understand the functionality and interfaces of each software package, to be able to design a site controller that would interact with all of them. A specialist energy system control company, Azzo, was contracted to do this. Using their ENRGYX platform, and with close collaboration with each of the software package suppliers (Invinity, SMA, Habitat), the team was able to create an integrated site control system that was successfully deployed. This is a complex undertaking, that needs several iterations by specialist resources. It is an essential task in the project and needs to be planned from the beginning.

Implications for future projects: Initiating the software integration process early in the project timeline, following the selection of standard software packages, is crucial for seamless integration and optimal system functionality.

5.14 Lesson Learnt No.14: Battery Installation

Category: Project Execution

Objective: Overcoming Installation Challenges

Detail: All large equipment, namely the MVPS and the containerised battery units, were handled on site using a crane. Each one of the 41 battery containers weights 25 tons. They are arranged in a stacked 2 high configuration. Accurate landing of each ground level container on it's foundation pads, then positioning the 2nd level container on top of the ground level one require specialist crane operations and heavy loads handling skills. Scheduling hiring the crane required to position the batteries on site was a challenging exercise. Preparing a site lifting plan, in accordance with applicable H&S regulations was essential to the success of the operation. The solution for this project was to hire the crane and specialist operators from a local company (Max Cranes) in Port Pirie. The project was also able to use their storage yard as a temporary landing area to hold the containers prior to bring them to site. Securing support from local companies is essential for a successful installation operation.

Implications for future projects: The decision to engage local crane services from Max Cranes in Port Pirie, coupled with the utilization of their storage yard as a temporary landing area, played a pivotal role in facilitating a smooth and successful installation operation.

5.15 Lesson Learnt No.15: Battery Commissioning

Category: Training and Development

Objective: Building Local Capacity

Detail: The BESS partner Invinity is physically located in the UK, to be able to deploy technical support to completing works pose as a challenge. The VFBs were located on site in accordance with the site layout design done by Invinity and harnessed with the DC-DC converters, the AC auxiliary power supply network and the Control panels. The panels themselves were mounted at the front of the containers in accordance with Invinity's standard design. This had been done previously by Invinity in Oxford, UK for the ESO project by Invinity's field team. This experience was shared with NGE through dedicated training sessions. The installation procedure is thoroughly documented by Invinity and was implemented by NGE personnel with not particular difficulties. Since it was NGE's first installation of Invinity batteries, two Invinity customer support technicians attended site to provide guidance. During power up and battery commissioning, a system engineer from Invinity also attended site to configure all levels of the Invinity BMS: the principal Flow Battery Energy Storage Manager (FBESM), the 6 Cluster Managers and each of the 246 Battery modules inside the containerised battery units.

Implications for Future Projects: To ensure timely services like battery commissioning, it is advisable for all foreign-based vendor partners to conduct training sessions for local engineers. This empowers the team to handle common interventions and repairs post-commissioning. Utilizing local expertise proved invaluable in resolving minor issues after engineers departed, exemplified by the BESS partner Invinity.

5.16 Lesson Learnt No.16: Test Case Scheduling

Category: Project Planning

Objective: Adapting to Energy Price Constraints

Detail: Essential collaboration between the test and trading teams was required to align test schedules with periods of advantageous energy prices. Despite initial estimations suggesting a 9-day duration for all energy tests, scheduling constraints extended the timeline to 3 weeks for completion.

Implications for Future Projects: It is imperative to integrate contingencies into test schedules to effectively accommodate fluctuations in trading prices.

5.17 Lesson Learnt No.17: FCAS Test Case Definition

Category: Knowledge Management

Objective: Acquiring Expertise in FCAS Requirements

Detail: The project team encountered a significant challenge in understanding FCAS requirements, largely due to the limited expertise available within Australia. The assistance provided by AEMO experts played a crucial role in enhancing the team's comprehension of test requisites and expected outcomes. Understanding the requirements outlined in the AEMO MASS document and translating them into a practical test method for the Yadlamalka system posed a formidable task.

Currently, Australia offers three FCAS modes: Delayed, Fast, and Very Fast FCAS, each with well-defined rules, response times, and frequency ramp rates. Through collaborative efforts, the project team, including engineers from Habitat, Invinity, AZZO, and SMA, successfully defined a test procedure. Several informative discussions with AEMO experts were necessary to ensure accurate understanding of the FCAS requirements.

Implications for Future Projects
This experience underscores the importance of seeking expert guidance when encountering unfamiliar regulatory landscapes. For future projects, it's advisable to establish early connections with relevant authorities or industry experts to facilitate understanding and compliance with intricate requirements, thereby enhancing the likelihood of project success.