Noise Management Strategies: Large-Scale BESS Projects in Australia

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Abstract - The industrial deployment of Battery Energy Storage Systems (BESS) is rapidly increasing in Australia, driven by advancements in cost-effective energy storage technologies. In Australia, significant investments are being made in BESS projects across Australia, aiming to leverage their numerous benefits, including peak load management, grid stability, renewable energy integration, and market participation. However, the proliferation of BESS projects, often situated in rural areas, presents considerable noise management challenges. This paper explores the noise issues associated with large-scale BESS projects and discusses effective mitigation strategies based on experiences from key projects in QLD, NSW, and VIC. Challenges identified include obtaining accurate noise data on new technology, close proximity to residents, and the practicalities of implementing extensive and often tall noise barriers. Effective strategies beyond traditional barriers include the reorientation of BESS units, reorganising BESS station layouts, use of acoustic enclosures and louvres, adjusting cooling fan speeds with variable speed drivers, and engaging with manufacturers for acoustic optimizations. Proactive risk management through early engagement of noise engineers in the project lifecycle is emphasized to ensure compliance with Australian environmental noise regulations and to reduce cost during design phase. This study reviews effective strategies, beyond traditional barriers, and underscores the importance of strategic planning and innovative noise mitigation to facilitate the sustainable growth of BESS projects in Australia.

1 INTRODUCTION

Battery Energy Storage Systems (BESS) are technology solutions that store electrical energy in batteries for later use, playing a crucial role in modern power systems. These systems consist of a series of batteries, inverters, and control systems that allow for the storage and release of electricity, providing backup power, balancing supply and demand, and enhancing grid stability. BESS are especially valuable for integrating renewable energy sources like solar and wind into the grid, as they can store excess energy generated during periods of high production and release it during times of high demand or low production. A Large-Scale BESS may include hundreds of shipping container size batteries and related power equipment. Operating and proposed large-scale BESS projects in Australia can be reviewed from “reneweconomy.com.au” (RenewEconomy, 2022).

Battery Energy Storage Systems (BESS) are increasingly recognized as a critical component of modern energy infrastructure, particularly in the context of renewable energy integration and grid stability. In recent years, the deployment of large-scale BESS projects in Australia has accelerated significantly. This surge is driven by the urgent need to manage peak loads, enhance grid resilience, and facilitate the integration of renewable energy sources such as solar and wind power. Moreover, as technology advances and costs decline, BESS installations are expected to become even more prevalent across regions with substantial renewable energy potential.

However, this rapid proliferation of BESS projects, especially in both urban and rural settings, introduces complex challenges, notably in the realm of noise control. As these installations are often located near sensitive receptors, including residential areas, the noise generated by the operational equipment, such as cooling systems and inverters, can significantly impact the surrounding communities. This issue is compounded by Australia's environmental noise regulations, which vary widely across different states and regions, imposing strict limits on permissible noise levels depending on the project's location and the existing local ambient noise conditions.

For instance, rural areas in Queensland often have low permissible noise levels due to the quiet ambient conditions, making the noise impact of even relatively quiet BESS operations potentially disruptive. In some regions, night-time noise limits can be as low as LAeq,15min,adj of 25 dBA, necessitating meticulous planning and the implementation of advanced noise mitigation strategies. Traditional methods, such as noise barriers, may not always suffice or be feasible due to their physical and financial constraints, requiring more innovative approaches to noise control.

This paper aims to provide an in-depth examination of the noise issues and management strategies associated with large-scale BESS projects in Australia. Drawing on Trinity Consultants Australia's practical experiences from projects in Queensland, New South Wales, and Victoria, it explores the key challenges and innovative solutions that have been either implemented or suggested to mitigate noise impacts. By outlining these strategies, the paper seeks to offer valuable insights and recommendations for future BESS developments, providing practical guidance for industry professionals and policymakers. The ultimate goal is to support the sustainable expansion of BESS infrastructure while ensuring compliance with Australia's noise regulations and minimizing the impact on surrounding communities.

2 COMMON TYPES OF LARGE-SCALE BESS PROJECTS

Large-Scale BESS projects can be broadly categorized based on their layout design, for environmental noise perspective. A large-scale BESS project can be based on either a decentralised or centralised layout. Understanding these categories is crucial for developing appropriate noise management strategies. Acknowledging each project is unique, dealing with noise issues from a centralised BESS is relatively time effective for acoustic consultants.

Examples of a decentralised and centralised BESS layout is given in **Figure 1**. In the centralised layout, all battery units and related power equipment are clustered into one location, like a battery farm. The number of batteries can vary from one to one thousand, depending on total BESS capacity and the scale of individual units. Furthermore, as batteries are placed over a large area in the centralised layout, they may act as an area source often with dimensions to the scale of several hundreds of meters. Consequently, noise barriers are not very effective for most topographic situations. In general, centralised large-scale BESS projects have required noise barriers higher than 8 m to effectively reduce noise levels. On the other hand, in the decentralised layout, small group of batteries (BESS stations) are distributed over a large area such as a solar farm. From an acoustic mitigation perspective, dividing multiple BESS units into small groups (which reduces footprints to utilise noise barriers effectively), then distributing the groups over a large area such as a solar farm (to increase distance from source to receivers), are key benefits of decentralised BESS layouts.

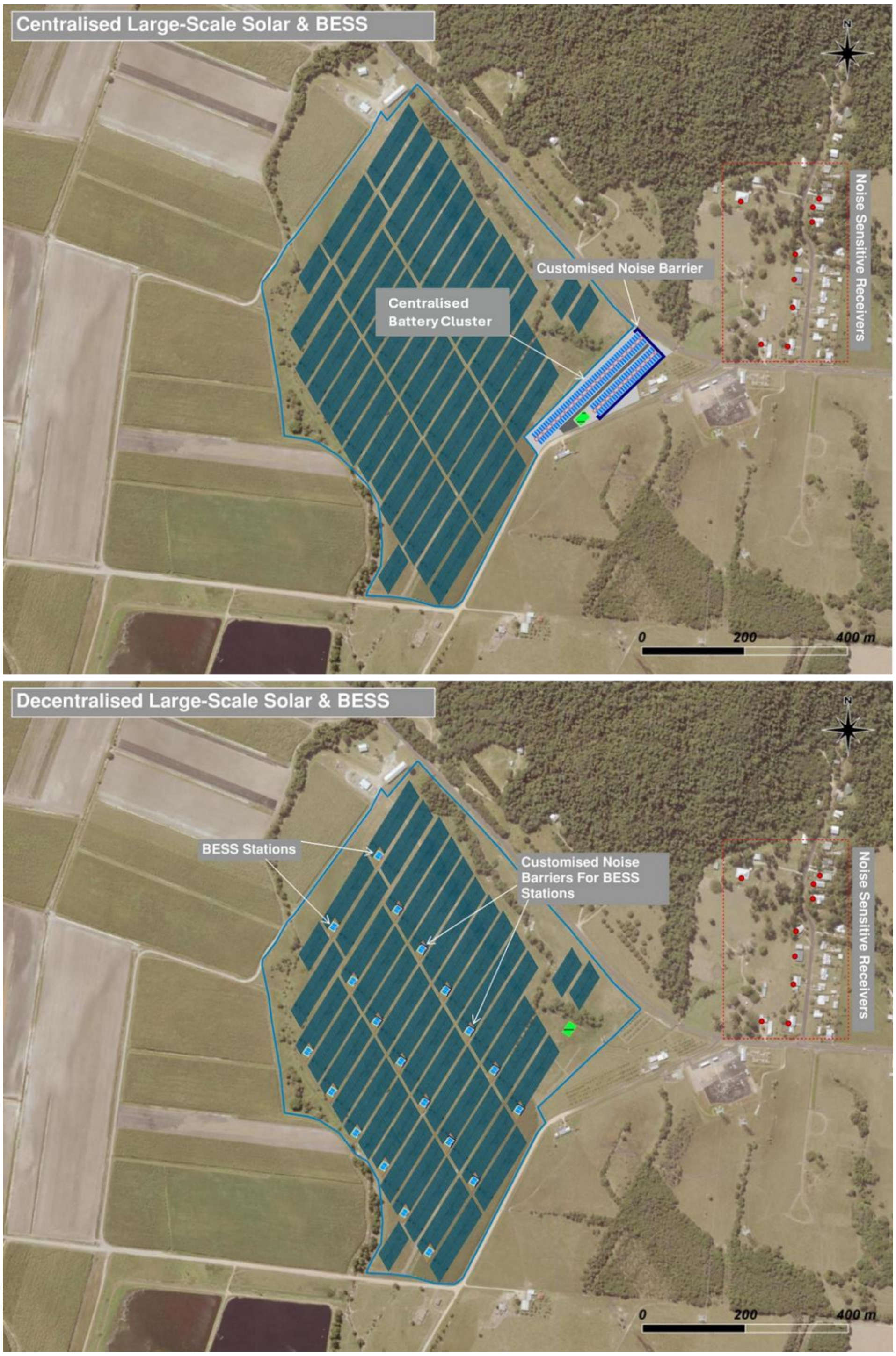

Figure 1 – Centralised (top) and Decentralized (bottom) Large-Scale Solar BESS

2.1 Centralised BESS

Centralized BESS projects involve clustering BESS units and related power equipment in a single location. These projects are typically situated near major substations or power generation facilities and are designed to handle significant energy storage and distribution tasks. Centralized BESS can be either outdoor or indoor as shown in ***Figure 2***:

- **Outdoor Centralised BESS**: Typically use container or rack-type units. These systems are exposed to environmental factors, making noise management more challenging due to the direct exposure surrounding areas to noise sources. If design aspects are be considered for each of the batteries, inverters, transformers and converters, they are required to be modelled as individual noise sources, increasing noise modelling cost and complexity. Most of the time, proponents of these projects prefer to solve predicted noise exceedances using only noise barriers.
- **Indoor Centralised BESS**: These are enclosed within buildings, often in urban or suburban areas where noise impact is a significant concern. The use of sophisticated HVAC systems in these setups can mitigate noise but introduces additional considerations regarding HVAC and outdoor chiller noise, as well as complex indoor to outdoor noise propagation. However, constructing a building over batteries and other power equipment is more effective than noise barriers.

Figure 2 – Outdoor centralized (right (RenewEconomy, 2021)) and indoor centralised (left (ElectraNet, 2024)) Large-Scale Solar BESS

2.2 Decentralised BESS

Decentralized BESS projects are often preferred for renewable energy sites, such as solar and wind farms. In these setups, multiple smaller groups of BESS units, commonly referred to as a “BESS station”, are distributed across the site, often in close proximity to energy generation sources like solar panels or wind turbines. This distribution helps in managing noise by spreading out the noise sources, but it also requires careful planning to minimize cumulative noise impacts on nearby sensitive receptors. Modelling and developing adequate noise mitigation for such BESS projects are relatively time consuming and often requires a trial-and-error based noise mitigation development process if noise barriers are required.

2.3 Different Unit Designs in BESS Projects

The design of BESS units also plays a significant role in noise management, making noise mitigation easier or harder:

- All-in-One Units: These integrated systems, such as Tesla Megapacks, combine batteries, inverters, converters, and cooling systems into a single container. While this simplifies installation, management and maintenance, it also concentrates noise sources into one location, which can limit noise management options. For example, if units need to be replaced with quieter alternatives due to strict noise limits, there are not many alternatives currently in the market.
- Standalone Units: In contrast, standalone units separate the battery systems from inverters and converters. These units require standalone inverters, transformers and sometimes converters, each being

an individual noise source. This design offers greater flexibility in noise mitigation, as individual components can be targeted with specific noise control measures. For example, if the inverter is the dominant noise source, noise mitigation can be focussed on that item specifically.

- Fan Locations: The placement of cooling fans significantly influences noise directivity. Fans can be located on the front, side, or on-top of BESS containers. Front or side-mounted fans tend to have more pronounced directivity, which can be leveraged in noise mitigation strategies by orienting the chiller side away from sensitive areas. Top-mounted fans, however, require taller noise barriers due to their elevated noise source, and doesn't provide any significant beneficial directivity.

3 CHALLENGES IN BESS PROJECTS

The rapid growth of BESS projects presents several challenges related to noise management. Among the key issues are obtaining accurate noise data, understanding the noise directivity and optimizing unit orientation, managing the height and effectiveness of noise barriers, and adhering to strict noise limits in rural areas. Each of these challenges requires careful consideration and innovative solutions to ensure compliance with regulatory standards and minimize the impact on surrounding communities. These challenges are detailed in following sections.

3.1 Sourcing Accurate Noise Data

Obtaining reliable noise data is critical for accurate noise impact assessments. However, manufacturers may be reluctant to provide detailed 1/3 octave, or directivity specific, sound power level data, especially for new technologies. This lack of data can hinder the ability of acoustic engineers to develop effective mitigation strategies and ensure compliance with regulatory limits.

3.2 Noise Directivity and Unit Orientation

The directivity of noise from BESS units, particularly those with front or side-mounted fans, can significantly impact noise propagation characteristics. Optimizing the orientation of these units to minimize noise exposure is the first step of noise management without noise barrier. However, this requires a detailed understanding of the noise characteristics of each unit and careful planning during the design phase.

3.3 Height and Effectiveness of Noise Barriers

Noise barriers are a commonly used mitigation measure, but their effectiveness is often limited by practical considerations such as height restrictions, cost, and visual impact. In many cases, the height required to achieve sufficient noise reduction is not feasible due to regulatory or community concerns. For example, some local councils in Australia limit noise barrier heights to 8 meters (and often lower), which may not be adequate for centralised large-scale BESS projects with elevated noise sources. On the other hand, noise barriers are often not a solution if the required reduction exceeds 8 dBA. A combination of noise mitigation methods (barriers and other measures) may be necessary.

3.4 Strict Noise Limits in Rural Areas

Rural areas in Australia often have lower permissible noise levels due to low ambient noise levels. This presents a significant challenge for BESS projects, particularly those located on agricultural lands where nearby residences may be highly sensitive to noise. In some cases, BESS proposals may not be viable for a particulate site due to noise impacts that cannot be mitigated in a reasonable/feasible way. Unfortunately, acoustic engineers are often external consultants who are not engaged early enough in the design process to provide sufficient input in site selection or design to achieve compliance. Proponents may be advised by acoustic engineers that their BESS proposals are not acceptable due to high level of noise impact. Sometimes this conclusion may be identified after non-acoustic consultants have finished their assessments and provided necessary evidence for approvals on all other aspects.

4 MITIGATION STRATEGIES: BEYOND THE BARRIER

Given the challenges associated with traditional noise barriers, alternative strategies are necessary for effective noise management in BESS projects, including but not limited to the following:

4.1 Reorientation and Relocation of BESS Units

Leveraging the directivity of noise sources by reorienting BESS units can significantly reduce noise impact on nearby sensitive receptors as illustrated in ***Figure 3***. For instance, orienting fans or noise-emitting components such that they are facing away from residential areas may help mitigate noise without the need for extensive barriers, if the exceedance is only a few dB. In addition to reorientation, moving BESS units and related power equipment as far from noise sensitive receivers as possible is also an effective approach. Although, the option for relocation is not as easy for decentralised BESS projects, it could be feasible for centralised BESS projects.

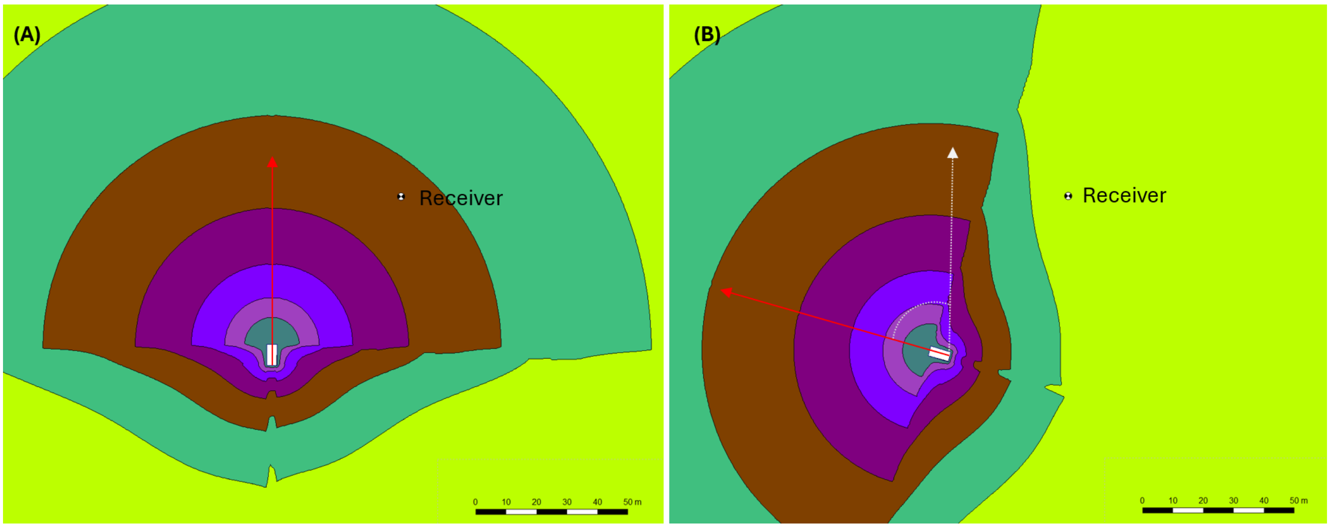

Figure 3 – Noise mitigation by reorientating a BESS container with cooling units at front: (A) Base model, (B) Mitigation model

4.2 Acoustic Enclosures and Louvres

Installing acoustic enclosures around noise-generating components, such as inverters and cooling fans, can effectively reduce noise emissions. Acoustic louvres can also be used to control noise while allowing necessary ventilation. Furthermore, some BESS manufacturers provide BESS containers equipped with optional acoustic attenuators.

4.3 Adjusting Cooling Fan Speeds

Fans are a significant source of noise in BESS projects. By adjusting fan speeds using variable speed drivers at different times of the day, particularly by reducing speeds at night when ambient temperatures are lower, noise levels can be managed more effectively. However, estimating fan speeds at different times of the day before the commissioning phase of a large-scale BESS project requires extensive statistical weather analysis, including peak and average ambient temperatures during different seasons and times of day, as well as multiple simulations of thermal management. Acoustic engineers are often advised by the proponents' engineering team about the characteristics of the thermal management system and fan speeds, which provides guidance on the variability of noise levels during day, evening, and night periods. If the assessment period is 15 minutes or longer, it can be assumed that cooling fan speeds would vary within the assessment period. For example, fan speeds might be set at 100% for 10 minutes and then reduced to 50% for 5 minutes during the day. Furthermore, when a variable speed driver is used, fans can be further ‘calibrated’ to run at a speed that generates the least noise (e.g., 98% may be significantly quieter than 100% fan speed).

4.4 Collaborating with Manufacturers

Working closely with manufacturers to incorporate acoustic optimizations during the design phase of BESS site can lead to significant noise reductions. This might include altering fan designs, incorporating factory-designed acoustic louvres, or using quieter components. By investigating a battery unit with cooling system or a high-capacity inverter in detail during normal or maximum load operation, can identify additional noise mitigation opportunities. A high level of interrogation as to the dominant source is possible via the use of acoustic cameras. During acoustic camera readings, the covering panels of the BESS containers could be removed to identify dominant noise sources. In some instances, the compressor units or ill-designed pipework can generate more noise than the cooling fans.

4.5 Rescheduling Charge and Discharge Periods

By scheduling BESS operations to minimize activity during night-time hours, noise impact on nearby communities can be reduced during the most critical compliance hours (facilitating restful sleep). This strategy is particularly effective in areas with strict night-time noise limits; however, proponents of BESS projects typically see this as a last resort strategy to adopt. In most cases, especially for solar & BESS projects, batteries are charged during the day when the sun is shining and discharged during the evening or night period when the strictest noise limits are in effect. Therefore, preventing batteries from discharged during the evening and night period often makes a solar & BESS project redundant.

4.6 Constructing BESS Buildings

In some cases, constructing a dedicated building or warehouse to house BESS units may be a viable solution. While large HVAC systems would be required to manage temperature, the overall noise impact could be lower and more manageable than multiple outdoor containers, and a greater reduction in noise can be provided compared with a bounding fence/barrier.

4.7 Seeking Regulatory Relief

In exceptional cases, proponents may seek relief from regulatory authorities by emphasizing the national significance of BESS projects and the broader benefits they offer to the energy grid. This approach, however, is challenging and may not always be successful. There are many factors to consider in this approach, including the number of receptors affected and the extent of exceedances of the specific noise criteria. This is approach is not intended to negate noise impacts, but to seek a flexible approach to addressing the issue.

4.8 Weather-Adaptive Active Noise Management

In NSW, if down-wind adverse weather conditions occur more than 30% of the time, noise assessments and noise mitigation strategies are obligated to consider down-wind weather conditions. Depending on the distance between the source and receiver, terrain, and many other factors, the expected noise level difference between adverse and neutral weather conditions can be between up to 7 dBA. If either long-term weather data is available for analysis or the occurrence of adverse weather conditions is higher than 30%, noise mitigation for large-scale BESS projects must consider adverse weather conditions, which may result in higher noise barriers, reduced project scope, or even rejection of a proposed BESS project.

BESS sites can be equipped with on-site weather monitors that can be integrated with the management system of the BESS site. When adverse weather conditions occur or are detected by weather monitors, the entire BESS site, or a portion of the equipment, can be shut down until the weather returns to neutral conditions. This approach requires acoustic engineers to estimate noise impact under a range weather conditions and develop more sophisticated noise management plans.

4.9 Returning to Day 0 and Revising Thermal Management Strategy

All challenges discussed in this paper can often be simplified by returning to Day 0 of the design process and reassessing the thermal management approach. In large-scale BESS projects, there are many low-capacity thermal management systems with fans for each piece of equipment. Historically, the authors of this paper have dealt with more than two thousands of individual noise sources in a single large-scale BESS project. Often, the main challenge is the sheer number of noise sources, and reducing and managing a smaller number of noise sources usually results in an easier noise mitigation design process. From the basics of mechanical engineering, the same capacity for thermal management can be achieved with a few large-scale cooling units rather than multiple small thermal management units for each battery unit, inverter, converter, etc.

It is important to note that increasing the capacity of a cooling system does not necessarily lead to a proportional increase in sound power level. Considering noise emissions from a central cooling system during the design phase can result in lower overall noise levels.

To explain this idea further, a central cooling plant with factory noise attenuation can be designed to replace integrated cooling units on batteries and other equipment. For example, the transformation of thermal management into a central system for a BESS station with eight battery containers and related power equipment is shown in ***Figure 4***. This method can make the BESS noise problem more manageable because, when noise barriers are not effective enough, the next step is to seek available noise attenuators for cooling fans. However, such attenuators are either not effective enough or are costly due to the number of batteries and other power units in a large-scale BESS project. To overcome this, designing central high-capacity cooling units with acoustic attenuation and noise emissions in mind from the beginning of design process can be a very feasible approach. Although acoustic engineers may not be in a position to accurately estimate the additional cost or cost-benefit of converting the thermal management system to a centralized unit, it is reasonable to suggest that making some of the proposed BESS projects (with effective noise control) DA-approval ready would likely justify the cost.

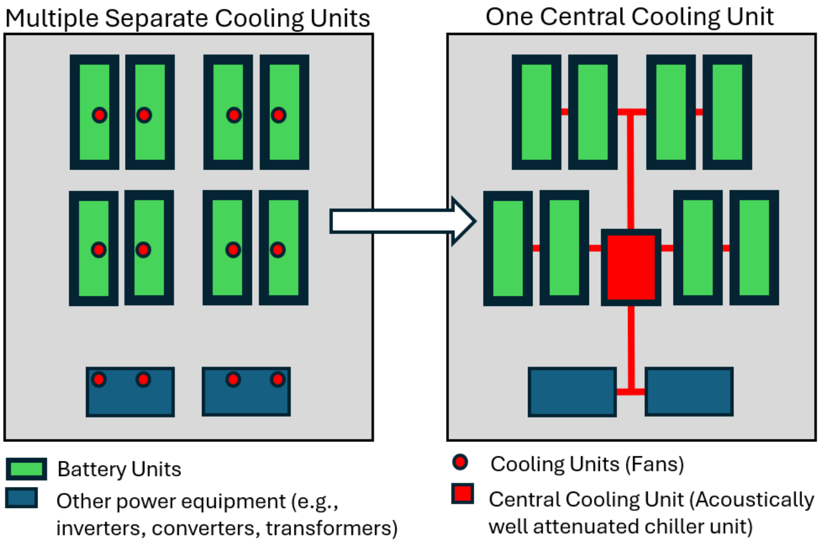

Figure 4 – Revising thermal management system into a high-capacity but acoustically well attenuated central cooling unit - An example of a typical BESS station layout for decentralised large-scale BESS projects

5 CONCLUSION

As Australia continues to expand its renewable energy infrastructure, the deployment of large-scale BESS projects will play a crucial role in achieving national energy goals. However, the noise generated by these systems presents a significant challenge, particularly in regions with stringent noise regulations and low ambient noise levels. This paper has highlighted the importance of understanding the various types of BESS projects and their associated noise management challenges.

Effective noise mitigation requires a multifaceted approach that goes beyond traditional noise barriers. Strategies such as reorientation and relocation of BESS units, placing BESS units indoor environment, and collaboration with manufacturers for noise optimization are essential. Additionally, innovative solutions like weather-adaptive noise management and centralising thermal management strategy can further enhance noise control.

Proactive risk management, including the early engagement of acoustic engineers, is vital to ensure that noise impacts are adequately addressed from the outset. By adopting these strategies, the industry can better manage noise impacts, ensuring compliance with environmental regulations and promoting the sustainable growth of BESS projects in Australia.

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