Report

Lessons Learned Report: November 2024 - May 2025

ML-13702

Fast Charger for Heavy Battery Electric Vehicles

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The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

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EXECUTIVE SUMMARY

Fortescue WAE (FWAE), a subsidiary of Fortescue, is pioneering the development of 6MW fast chargers capable of charging 240t Battery Electric Vehicles (BEVs) in 30 minutes. This project, funded by ARENA, aims to demonstrate the operational use of these chargers in a live mining environment. The report shares challenges and lessons learned to benefit the broader industry.

Key lessons learned include:

- The necessity of early engagement with end-users to understand grid stability requirements that need to be imposed on charger design. The understanding of these requirements for FWAE's use case led to the adoption of Active Front End (AFE) technology over Diode Rectifiers, ensuring enhanced grid stability and broadening the potential use cases for the 6MW fast chargers.

- The importance of setting clear cost targets early in the design process as a means of allows for more informed decision-making and minimises the risk of significant rework. The lack of clear cost targets led to FWAE's decision to remove DCDC converters from the architecture late in the design process

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1 INTRODUCTION

1.1 Project Background

Fortescue WAE (FWAE), a wholly owned subsidiary of Fortescue, is working to develop, build and demonstrate the world's first 6MW fast chargers. These chargers will be capable of charging batteries on a 240t Battery Electric Vehicle (BEV) in 30 minutes, and will be deployed among Fortescue's mine sites.

FWAE entered into a Funding Agreement with ARENA in November 2024 to execute a project to develop prototype fast chargers and demonstrate their operational use to achieve a 30-minute BEV charge time in a live mining environment.

1.2 Objective

The objective of this report is to share challenges and lessons learnt observed to date that could be useful for the broader industry, including other individuals / organisations undertaking similar projects or considering similar opportunities.

This report is a key deliverable of the Funding Agreement.

2 LESSONS LEARNED

2.1 Grid Integration Requirements

Summary	
Title	Grid Integration Requirements
Category	Technical
Details	

Problem Statement

After completing our concept design and adopting an electrical architecture centred around the use of Diode Rectifiers, Fortescue communicated a revised set of 'grid stability requirements' that necessitated a shift to an Active Front End (AFE) architecture to meet the enhanced grid stability and support functions required. This late identification and communication of requirements led to regret and re-design work.

Background

Fortescue is working towards achieving 'real zero' carbon emissions by 2030. Part of this work includes building renewable sources of electricity generation (e.g. solar), and an electrical grid that can support transmission of electricity throughout all of Fortescue's mining operations

The design work for both the grid and 6MW fast chargers has been progressing in parallel since inception. Fortescue's new electrical grid needs to service many disparate, remote areas, and has been designed to provide electricity using a long and 'thin' transmission and distribution network. Grids of this nature lack the excess storage capacity and redundant network paths that domestic or more typical industrial grid have, and hence are inherently sensitive to sudden load changes and stability issues.

In mid-2024, it became clear that the design for the grid was not going to be intrinsically stable enough to support a fleet of 6MW fast chargers with a Diode Rectifier architecture, and that either the design of the grid or the design of the 6MW fast chargers would need to change to ensure Fortescue could provide reliable electricity to support its mining operations

A thorough options analysis was led and completed by FWAE, and it was identified that:

- It would be cheaper to change the architecture of the 6MW fast charger to use AFE technology than changing the design of the grid
- Adopting AFE technology would broaden the customer base and use case for 6MW fast chargers as a product

As a result, the concept design of the 6ME fast chargers was changed to incorporate the use of AFEs.

Diode Rectifier and AFE Technology

The key differences between a diode rectifier and AFE-based design are summarised in the table below. Key aspects have been colour coded in a 'traffic light scale' to help illustrate the differences between each technology.

Aspect	Diode Rectifier	Active Front End (AFE)
Functionality	Uses diodes to convert AC to DC	Uses actively controlled switches (e.g., IGBTs) to convert AC to DC. Allows bidirectional power flow.
Grid Support		
Harmonics	Generates significant harmonic distortion due to short current pulses.	Significantly reduces harmonic distortion by drawing nearly sinusoidal current.
Reactive Power Compensation	Not capable of providing reactive power support.	Can inject or absorb reactive power to maintain voltage levels within the grid.
Voltage Regulation	Not capable.	Regulates grid voltage by adjusting reactive power flow.
Harmonic Compensation	Not capable.	Mitigates harmonic distortion by actively shaping the input current waveform.

Power Factor Correction	Not capable.	Improves power factor by adjusting the phase angle of the current relative to the voltage.
Fault Ride-Through	Lacks fault ride-through capabilities.	Can continue operating during grid disturbances, such as voltage sags or short circuits.
Voltage Sag Compensation	Not capable.	Maintains stable DC output during voltage sags.
Short Circuit Response	Not capable.	Provides short-circuit current injection to support the grid during faults.
Recovery After Fault	Not capable.	Quickly resynchronizes with the grid after fault clearance.
Fast Frequency Response	Not capable of providing fast frequency response.	Can quickly respond to changes in grid frequency, stabilizing the grid during disturbances.
Voltage Regulation	Limited to basic voltage conversion without regulation capabilities.	Can regulate grid voltage by adjusting reactive power flow.
Frequency Regulation	Not capable of frequency regulation.	Can adjust active power flow in response to changes in grid frequency.
General		
Cost and Complexity	Simple and cost-effective. Requires fewer components and less sophisticated control systems.	More complex and expensive. Requires advanced control systems and additional components.
Size and Weight	Smaller size and lighter weight.	Larger size and heavier weight due to additional components and advanced control systems.
Applications	Suitable for applications where grid support functions are not critical.	Ideal for applications requiring enhanced grid stability and support functions.
Power Quality	Lower power quality due to higher harmonic distortion.	Higher power quality with lower harmonic distortion.

Implications for Future Projects

What We Would Do Differently

In future projects, we would engage with the end-user early on to ensure we have an in-depth understanding of their grid's stability/performance characteristics, and hence identify any design requirements that should be imposed on the product to support the grid.

Doing so would help identify potential issues early on and allow a design to be created that meets all necessary criteria from the outset with minimal risk of re-work.

Implications for Future Projects or the Industry

The transition to AFE technology in this project highlights the importance of considering grid stability and support functions in the design of high-power charging systems across the industry. By integrating AFE technology, future projects can benefit by providing an improved grid support capabilities, such as fast frequency response and localised reactive power compensation. This will both enhance the efficiency and reliability of 'fast chargers', and contribute to the broader goal of such projects to support sustainable and resilient green energy systems.

2.2 DCDC Elimination & Cost Reduction

Summary	
Title	DCDC Elimination & Cost Reduction
Category	Technical & Commercial

Details

Problem Statement

After completing our concept design and working around a set of requirements to have the 6MW fast charger operate at a wide range of voltages (300 to 1800 VDC), Fortescue communicated a revised target cost for the charger that led to the removal of DCDC converters from the architecture. This late adoption of a heavily reduce target cost led to regret and re-design work.

Background

The 6MW fast charger was initially designed with a firm requirement for the operable voltage range (300 to 1800 VDC). This was done with the intent of allowing the chargers to charge a wide range of mining equipment (each of which can only accept charging power with a certain voltage range, depending on the design/capacity of its battery system), and not limiting the use case exclusively to mining trucks.

Upon the completion of the concept design, Fortescue communicated a revised target cost for the charger. Fortescue Zero led efforts to identify cost savings that could be realised while identifying impacts to the attributes and overall use case of the chargers.

Ultimately, it was decided that the DCDC converters could be removed on the condition that Fortescue accepted the reduced range of mining equipment that could be used by the chargers (1000 to 1500VDC). This decision was made on the basis that:

- The DCDC converters contributed ~20% to the total cost of the chargers
- Fortescue's expected use case for the 6MW fast charger is solely planned towards charging mining trucks haul trucks with higher capacity batteries
- Reducing the voltage range the charger operates at makes it easier to optimise the design, efficiency, and performance of the Power Electronics components within the charger

Implications for Future Projects

What We Would Do Differently

In future projects, it would be ideal to have firm cost targets set from the outset, so they can be integrated into the design process. This would allow the design team can make more informed decisions about component selection and architecture without the risk of significant re-work.

Implications for Future Projects or the Industry

The decision to remove DCDC converters highlights the importance of setting clear cost targets at the beginning of a program, and shows the benefit that can come from having mature discussions about trade-offs between cost and product performance.

This lesson also hints at the need for continuous innovation in power electronics. Developing more cost-effective and efficient DCDC converter technologies could help mitigate the trade-offs between cost and performance in the future. Additionally, standardising voltage levels across different EV equipment could reduce the need for complex and expensive converters, simplifying charger design and reducing costs.

3 CONCLUSION

FWAE has identified several important learnings relevant for the development of high-power charging systems in the mining industry, including:

- The necessity of early engagement with end-users to understand grid stability requirements that need to be imposed on charger design. The understanding of these requirements for FWAE's use case led to the adoption of Active Front End (AFE) technology over Diode Rectifiers, ensuring enhanced grid stability and broadening the potential use cases for the 6MW fast chargers.

- The importance of setting clear cost targets early in the design process as a means of allows for more informed decision-making and minimises the risk of significant rework. The lack of clear cost targets led to FWAE's decision to remove DCDC converters from the architecture late in the design process

These learnings have material implications for the industry. The late transition to AFE technology highlights the need for considering grid stability and support functions in the design of high-power charging systems, both in general terms and in each charger's specific application and operating environment. In addition, the removal of DCDC converters emphasises the need for continuous innovation in power electronics to develop more cost-effective and efficient technologies. Standardising voltage levels across different EV equipment could also simplify charger design and reduce costs.

The next steps for the program include continuing to refine the design of the 6MW fast chargers, incorporating the lessons learned from this phase. Further engagement with stakeholders will be essential to ensure that the chargers meet all necessary requirements and support Fortescue's broader goal of achieving 'real zero' carbon emissions by 2030.