Developing Secondary System Upgrades

A Case Study of the Waitaki 110V DC Distribution Upgrade

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Background

Increased electrification of NZ industry has pushed aging generation plant to extend their service life.

Many of these assets are now due for large scale refurbishments, requiring investment and outages.

However, fitting these works in few large outages is impractical and a staged approach is required.

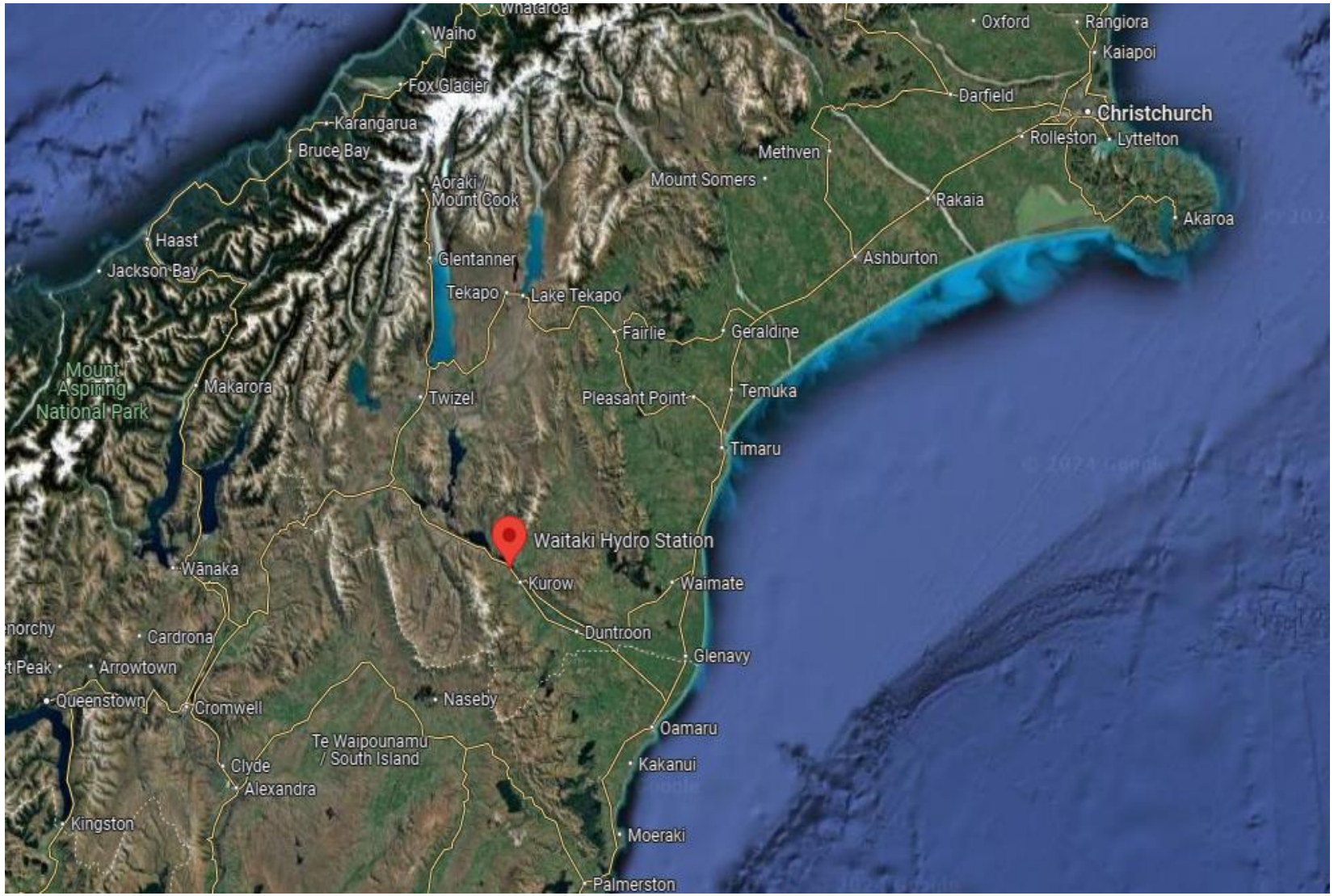
To support this staged approach, secondary systems should be upgraded to support the coming primary plant changes.

Waitaki Power Station

Located 5 minutes north of Kurow, along the Waitaki River.

First operational in 1935 with two 15 MW generators.

Additional generation was added 1940-49 and 1952-54 for a total of 7x 15 MW machines (105MW total).



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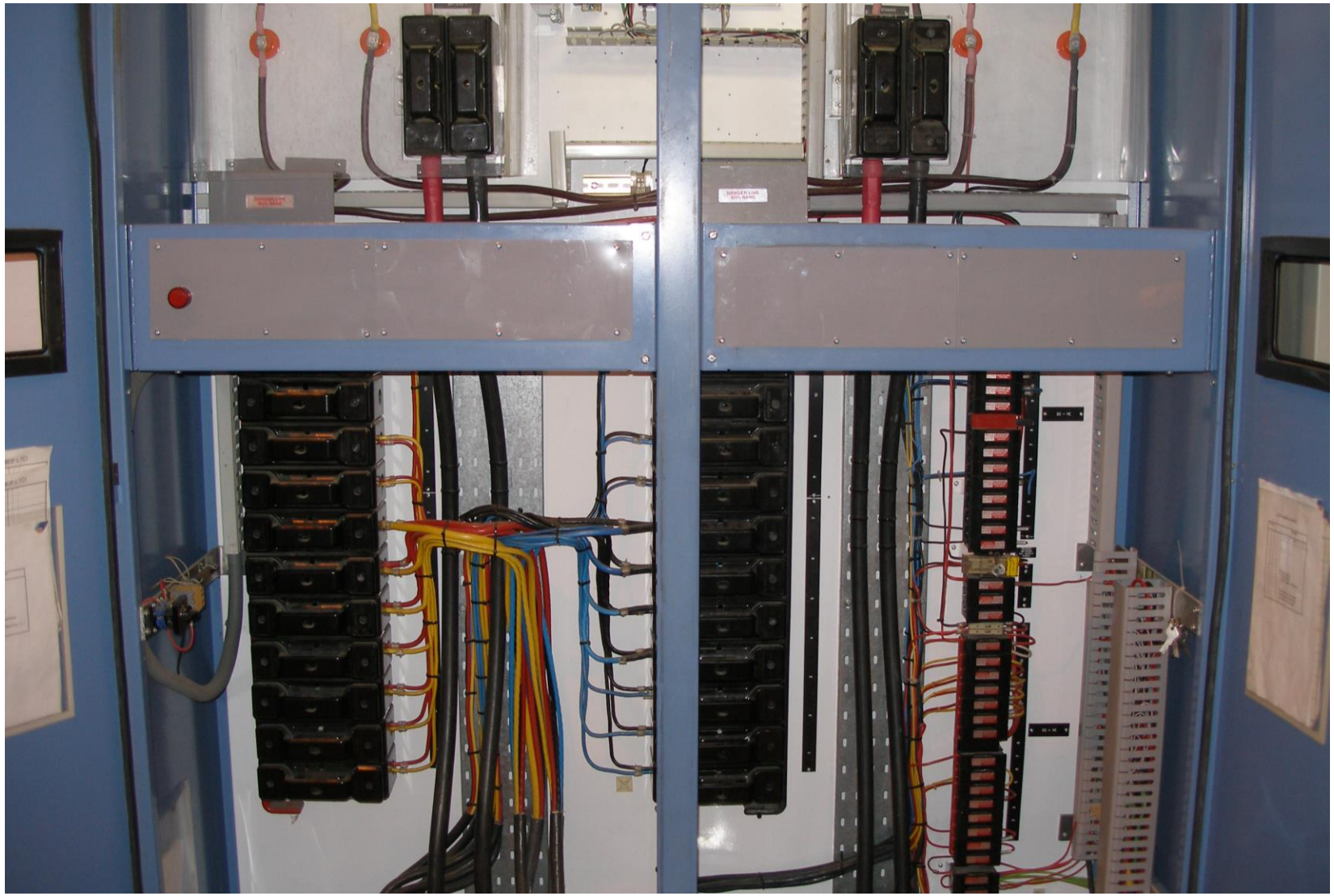
The 110V DC Distribution System

Responsible for backup or main powering majority of control and protection equipment.

Considered a critical service.

Consists of 2x 230Vac/110Vdc Battery Chargers and 2x 550Ah 110Vdc Battery Banks.

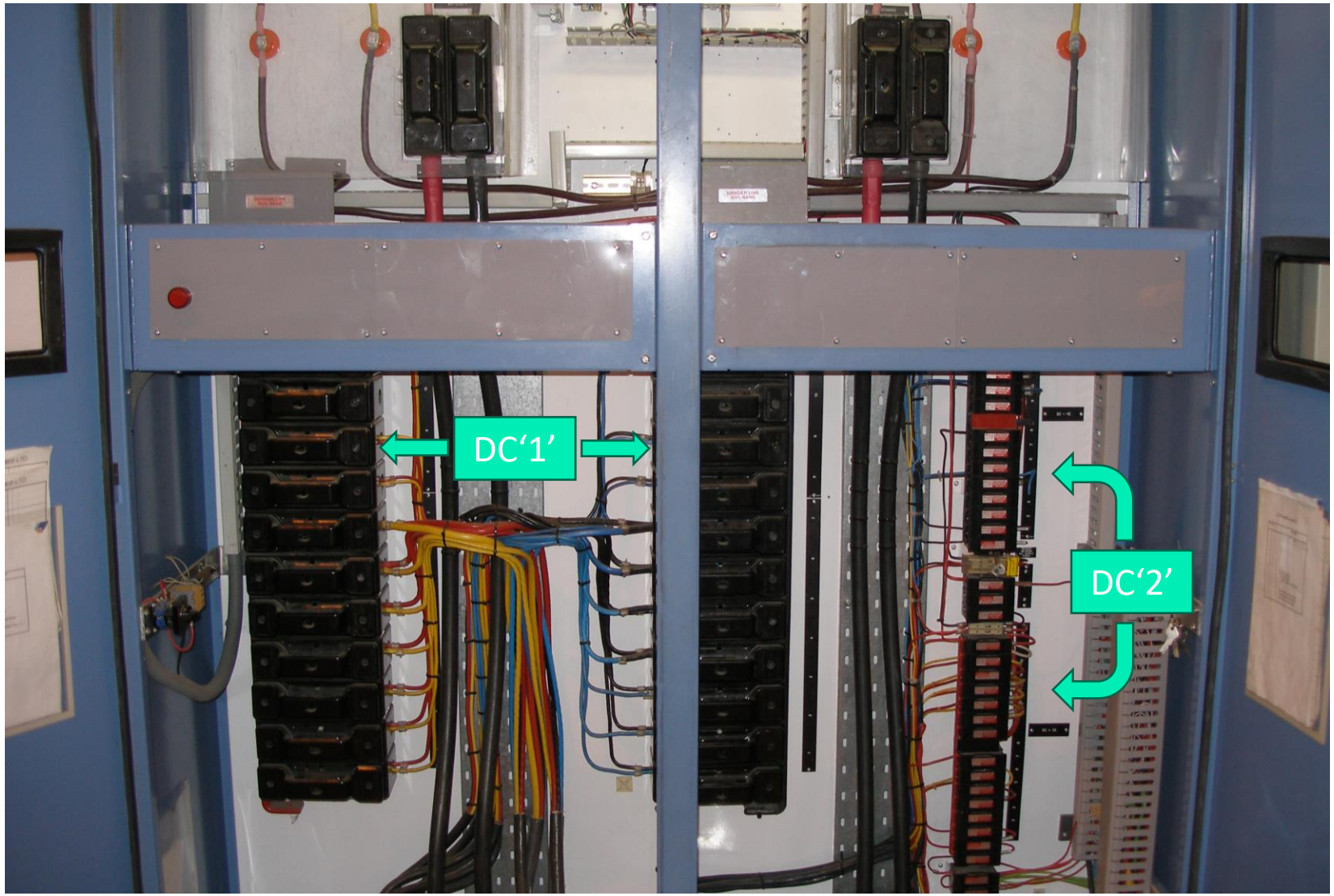
Chargers/Banks supply is paralleled via steering diodes inside the Primary Distribution Panel (PDP).



Waitaki 110V DC - Before

All sources of supply are transferred through the Primary Distribution Panel (PDP) before reaching their services:

- U1-U7 DC‘1’
  - Protection ‘1’
  - CB Control ‘1’
  - PLC Backup Supply
  - Generator Brakes
  - Excitation Control
  - Headgate Trip
- U1-U7 DC‘2’
  - Protection ‘2’
  - CB Control ‘2’
- 400V Local Service CB Control
- Revenue Metering & Comms
- Inergen Gas Release
- 11kV Switchgear ‘A’ & ‘B’



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- 11kV Switchgear ‘A’ & ‘B’

WTK 110V DC Distribution - Problems

Both separate sets of battery banks and chargers are fed through one location.

Wiring layout is confusing and difficult to add new connections.

Supply monitoring is outdated and faulty in some areas.

DC‘2’ services are supplied from the DC‘1’ bus.

Documentation is known to be out of date.

The existing PDP is a single point of failure and presents an increased risk of 110V DC loss.

Design Solutions

Templated from previous site upgrades.

Relocate one of the battery chargers to new location.

Segregate out the PDP into four separate cabinets:

- 2x Steering Diodes and Monitoring
- 2x Distribution (DC‘1’ & DC‘2’)

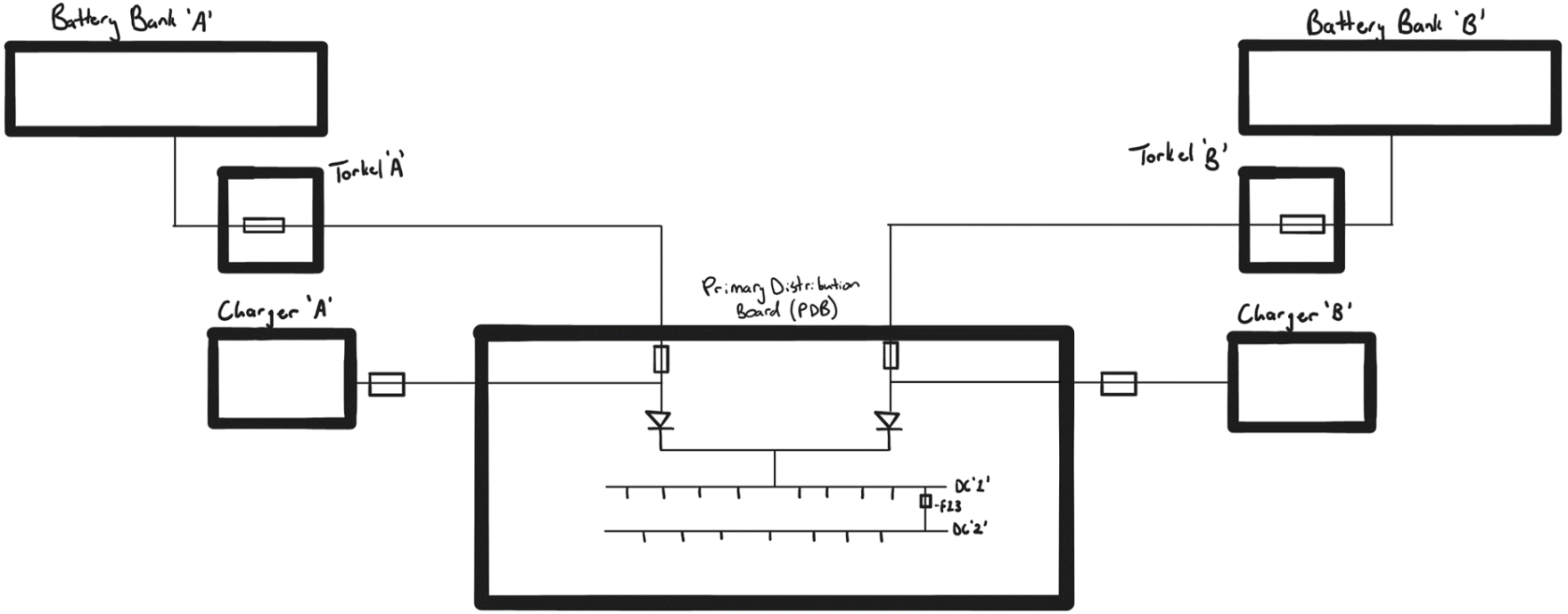
Design Solutions

The monitoring for each side of the 110V DC System included the following:

Analogue voltage and current monitoring (SCADA & dials).

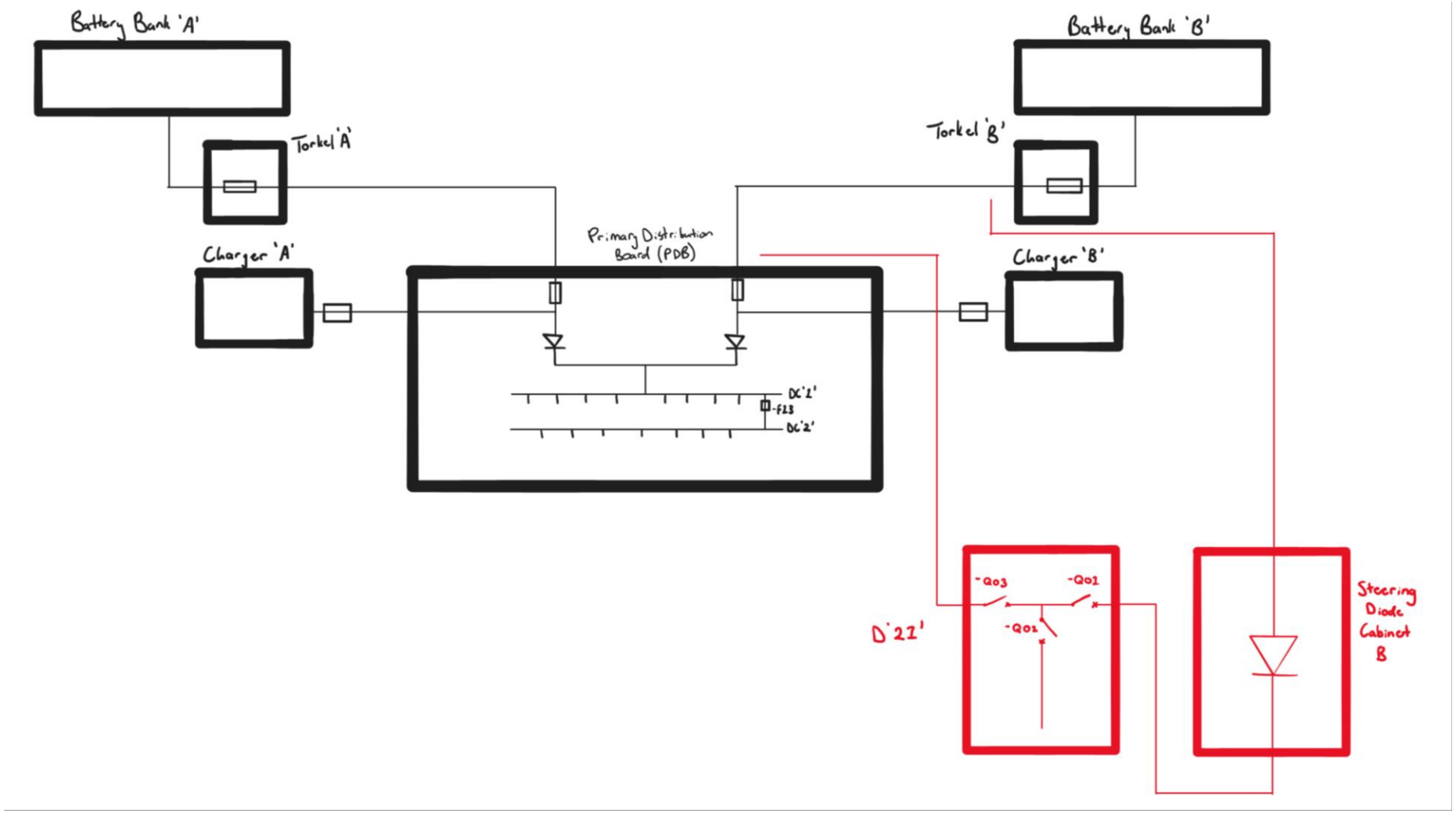
Under/Over Voltage Relays

Earth Fault Monitor with analogue IR and SCADA alarms.



Transition Phases

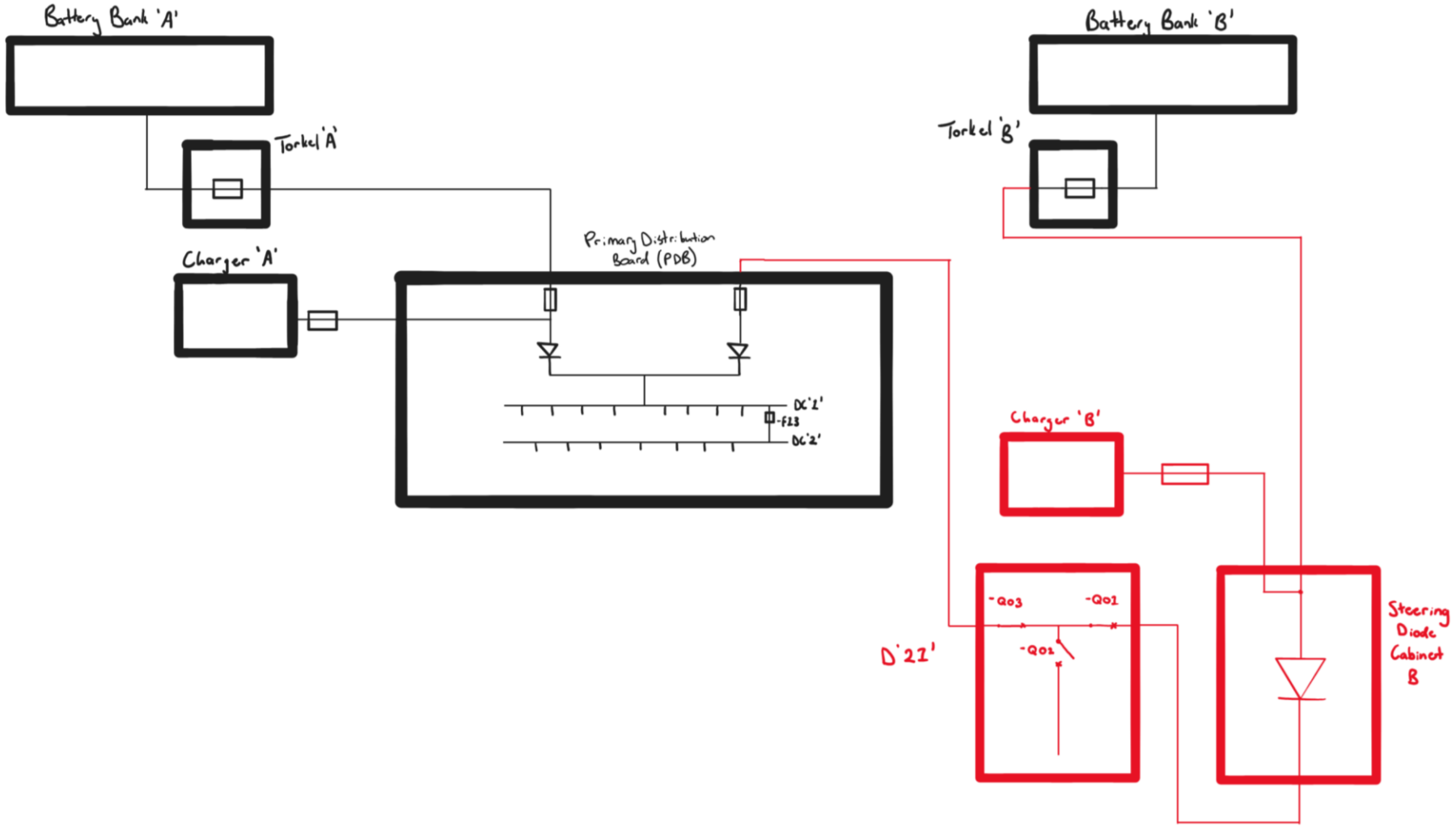
Starting from the previous configuration.



Transition Phases

Installation of SDC'B' and D21 in new location.

Run connecting cables to battery bank and temporary PDP feed.

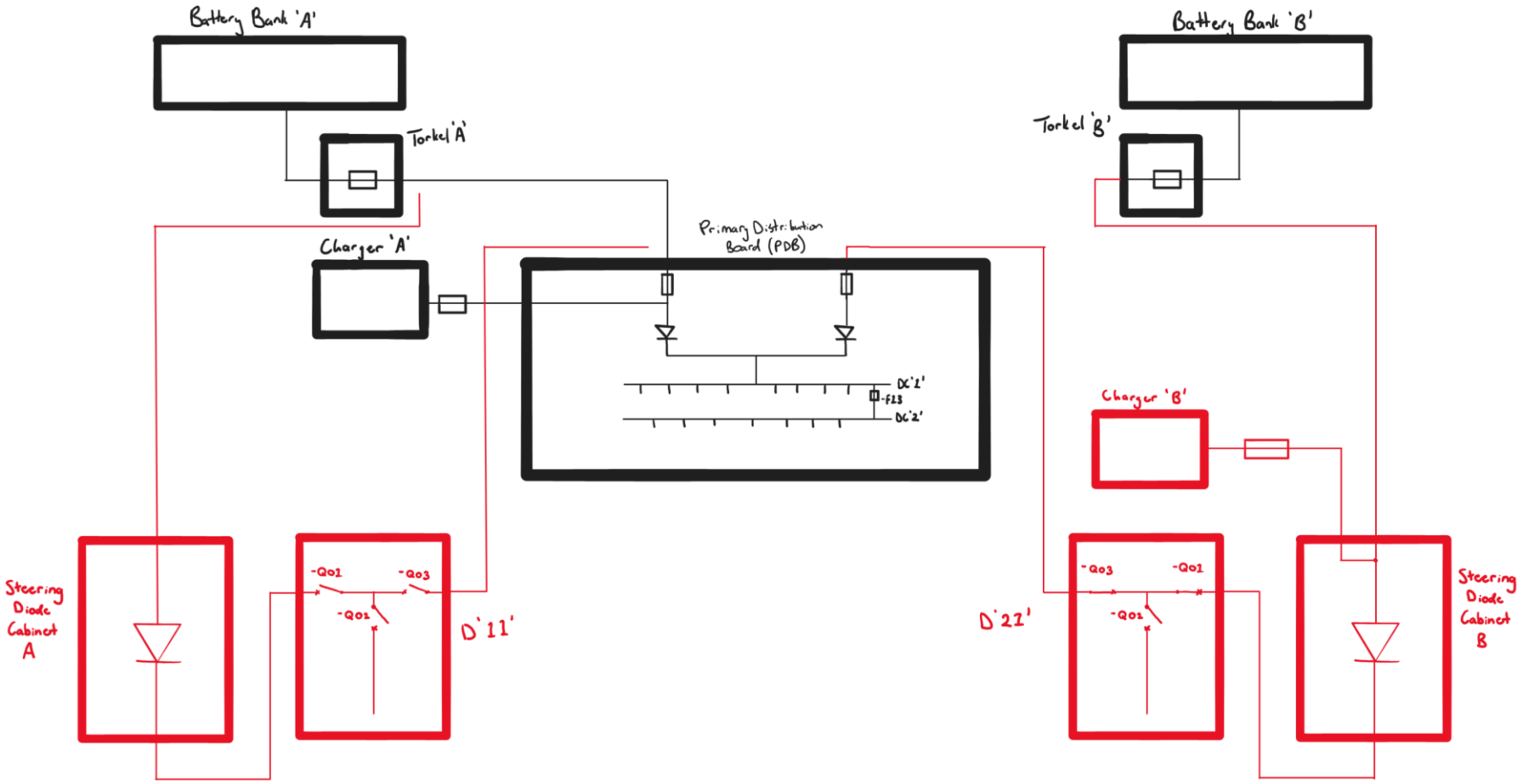


Transition Phases

Isolate, disconnect and relocate Battery Charger ‘B’ to new location beside new cabinets.

Connect charger to SDC‘B’ and liven.

Connect new DC distribution temporary feed to PDP.

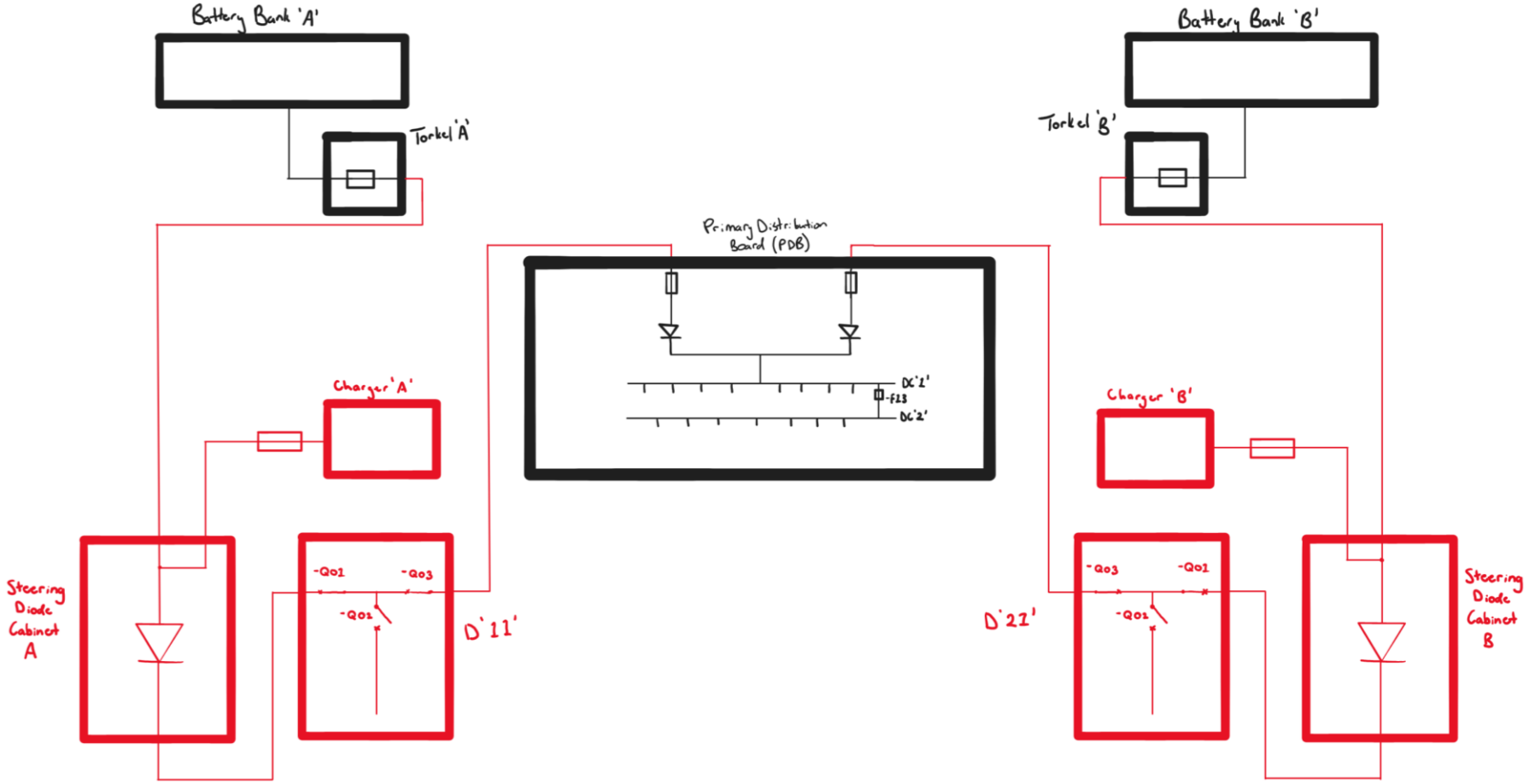


Transition Phases

With new space available:

Installation of SDC'A' and D11 in new location.

Run connecting cables to battery bank and temporary PDP feed.



Transition Phases

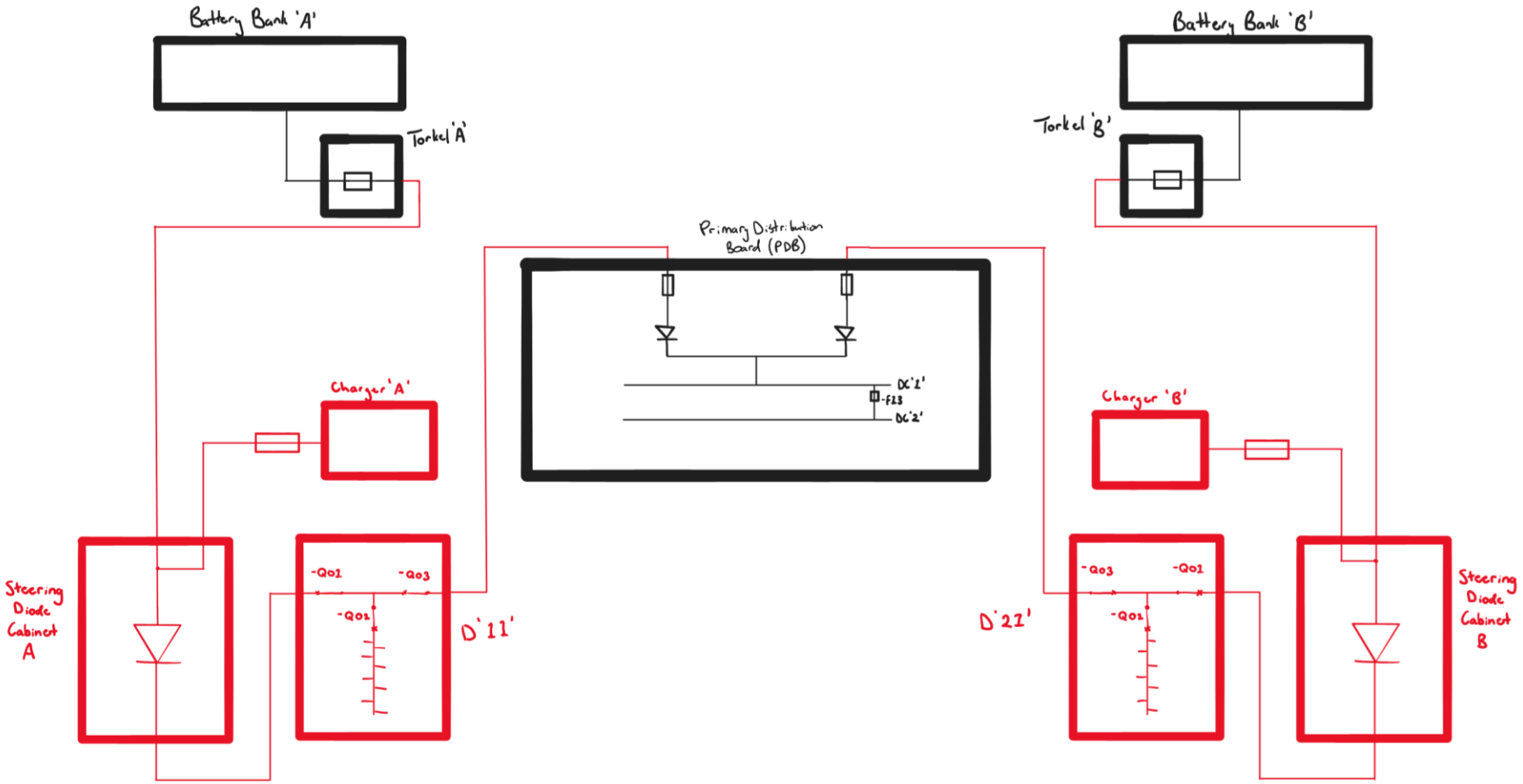
Isolate and disconnect Battery Charger 'A'.

Connect charger to SDC'A' and liven.

Connect new DC distribution temporary feed to PDP.

Transition Phases

Migrate each DC circuit over to D11 & D21 under dedicated outages.



Circuit Migration

Each circuit needs to be migrated from the PDP over to either D11 or D22. Coordinated outages are required for safe transition.

24 cables to be migrated.

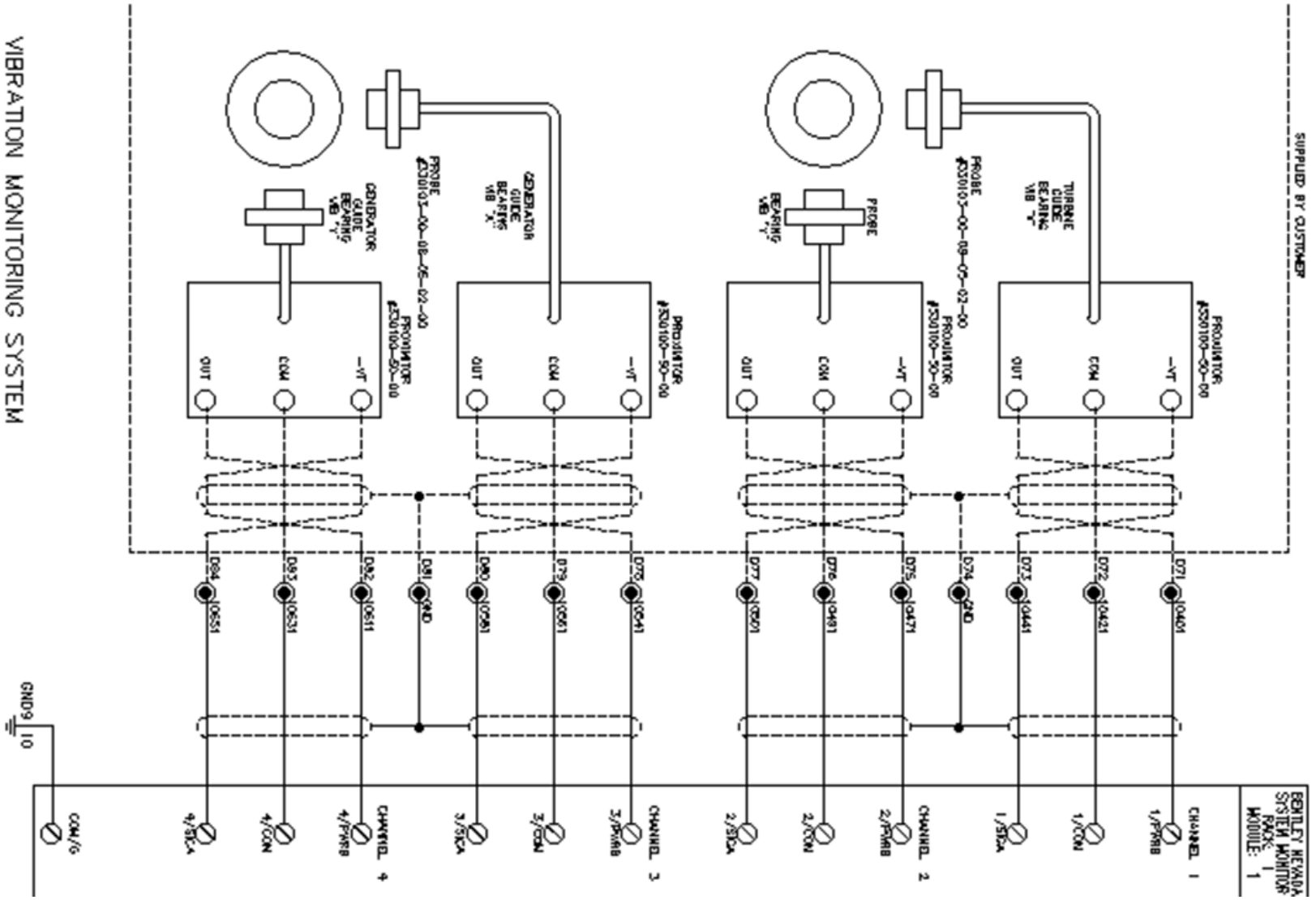
11 different outages required.

Some equipment was too critical to take out of service, so temporary bypasses were included.

Circuit Migration - Issues

Generator Creep – Unit 5

Shortly after removing 110Vdc fuses to U5, the machine began to creep. While no persons were working on the unit at the time, there was nothing explicitly preventing them. Work was suspended until a site operator could manually trigger the generator brakes to stop the machine.



Circuit Migration - Issues

The 110Vdc migration of U4 supplies was completed in conjunction with a 6-monthly service.

During this outage, the main 400Vac supply to the machine was isolated alongside the 110Vdc, de-energising the dual supplied PLC. The PLC was quickly livened again.

When the unit was restarted following the completion of the work, it tripped due to high turbine vibration.

Circuit Migration - Issues

Mystery Cables

In preparation for the circuit migration, each cable was identified by its cable number and traced to each service.

There were an additional cables found that did not appear on drawings.

These were determined to supply Transpower's equipment in the two 11kV Switchrooms.

An extension to the programme has been planned to migrate these circuits over to a dedicated Transpower supply.

Finishing Off

Once all circuits have been transferred, after six weeks of commissioning, it’s time for a break before connecting the distribution tie and closing out the project.

But…

The Unexpected

The following Monday, site maintenance staff are completing some planned testing of 110V Battery Bank ‘A’.

They accidentally isolate BOTH Bank ‘A’ and Charger ‘A’ at the same time. The tie circuit had yet to be connected.

D11 (DC‘1’ distribution) is de-energised.

Waitaki suddenly becomes much quieter.

The Unexpected – Station

Site Overview 30 seconds before 110V DC failure.

The Unexpected – Station

Site Overview 90 seconds after 110V DC failure.

The Unexpected – Station Impacts

At the time 110V DC‘1’ was de-energised, U1, U4 U5, U6 & U7 were online and generating at 15MW. U2 & U3 were offline.

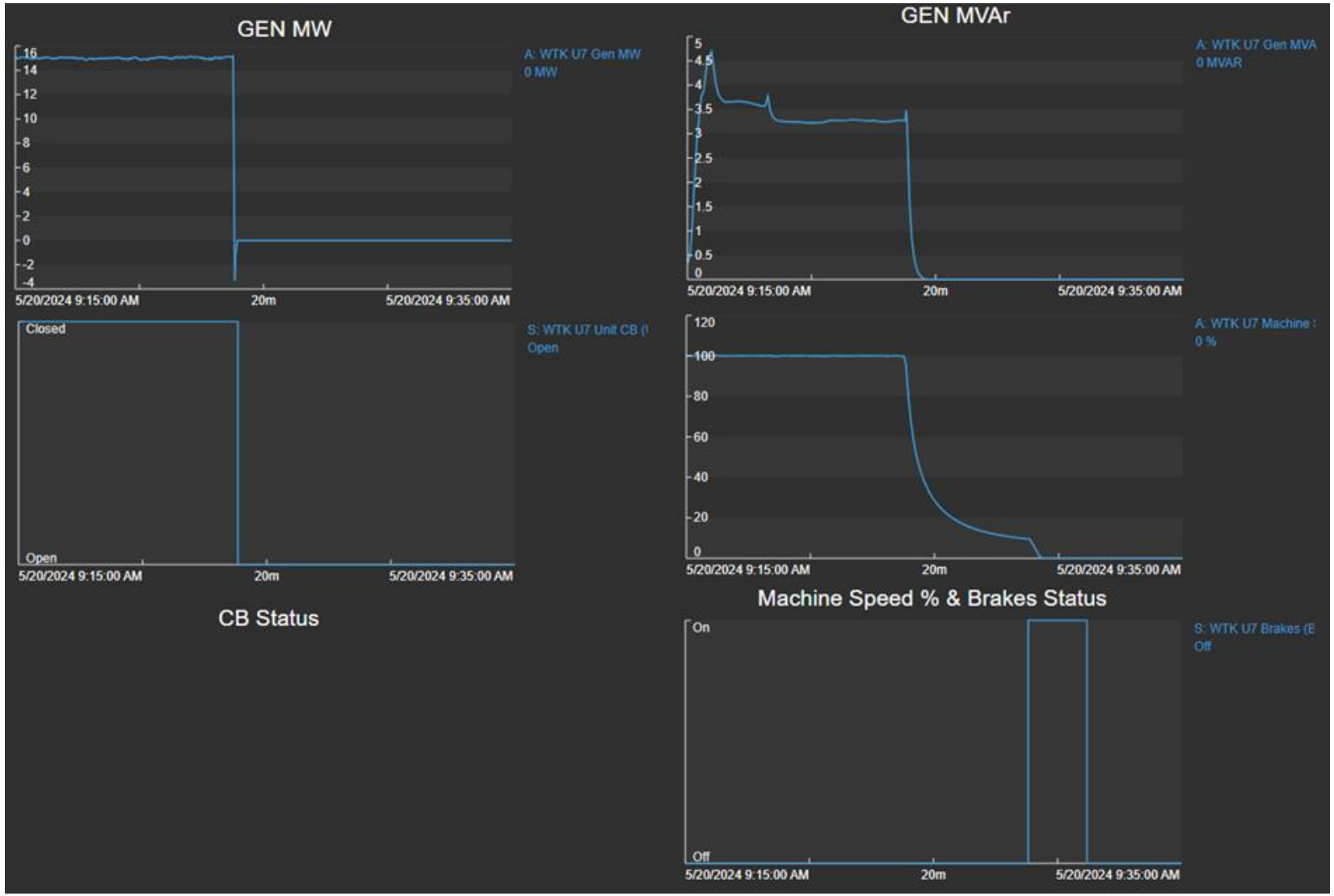
U2 & U3 began to creep, being pushed around by their HP lubrication oil.

U1, U5, U6 & U7 were able to safely disconnect on their second attempt following the failure to open the CB during their “Electrical Shutdown”.

Remote control of the Local Service 400V CBs became unavailable.

Revenue metering (all units and station aggregate) were de-energised.

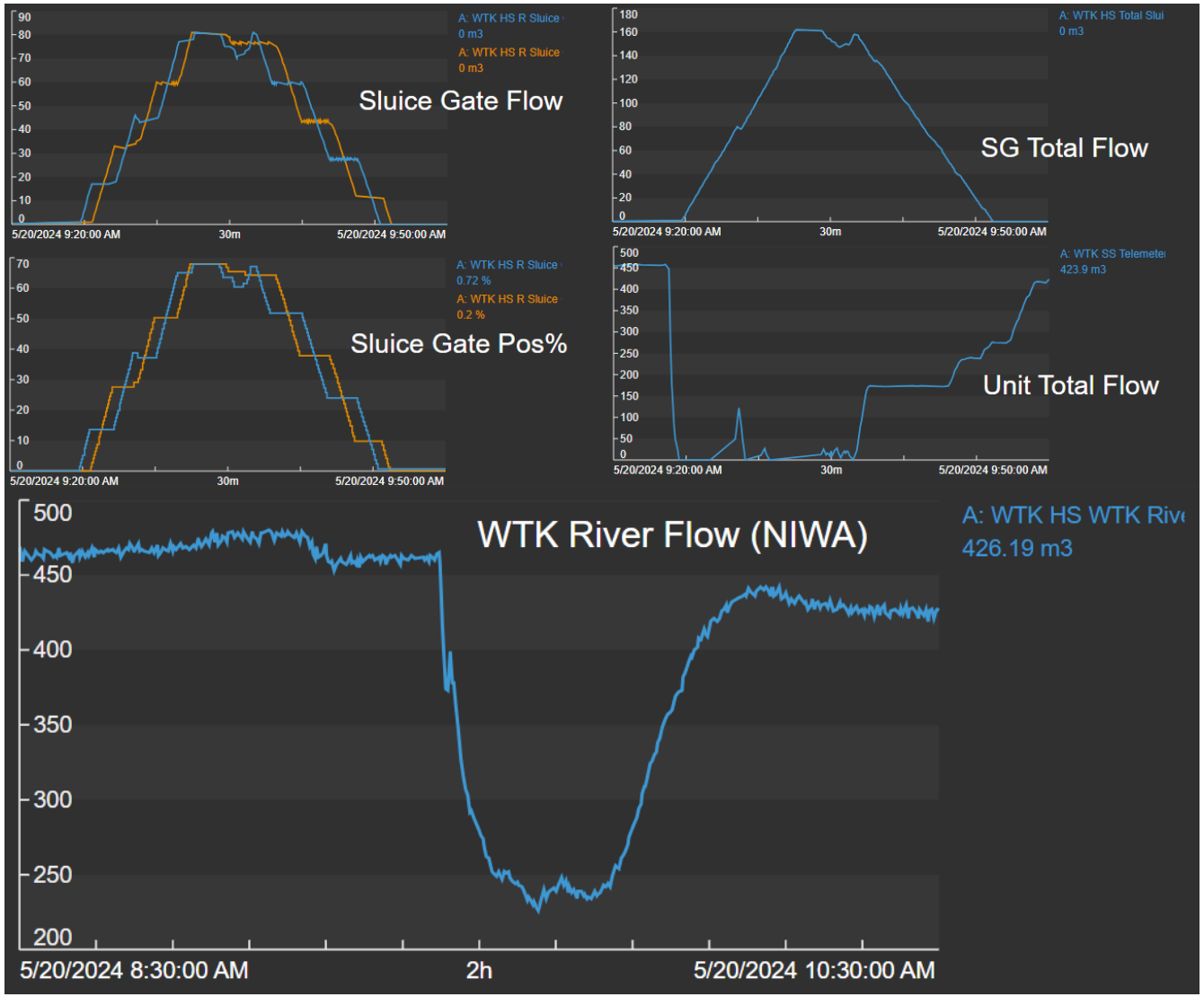
The station trip was caught by site operators, who were able to restore Bank ‘A’ and Charger ‘A’ after 5 minutes.



The Unexpected – Units

Unit 7 Operation during 110V DC‘1’ supply loss.

- Wicket gates begin to close during initial shutdown attempt.
- Initial CB trip attempt fails due to 110V DC supply loss.
- Secondary CB trip command given via live 110V DC‘2’ supply after CB remained closed.



The Unexpected – Sluices

Due to the loss of generation and water flow, the two dam sluice gates automatically opened to pass the consented minimum flow.

These were automatically closed once river flow was restored.

The Unexpected – Unit 4

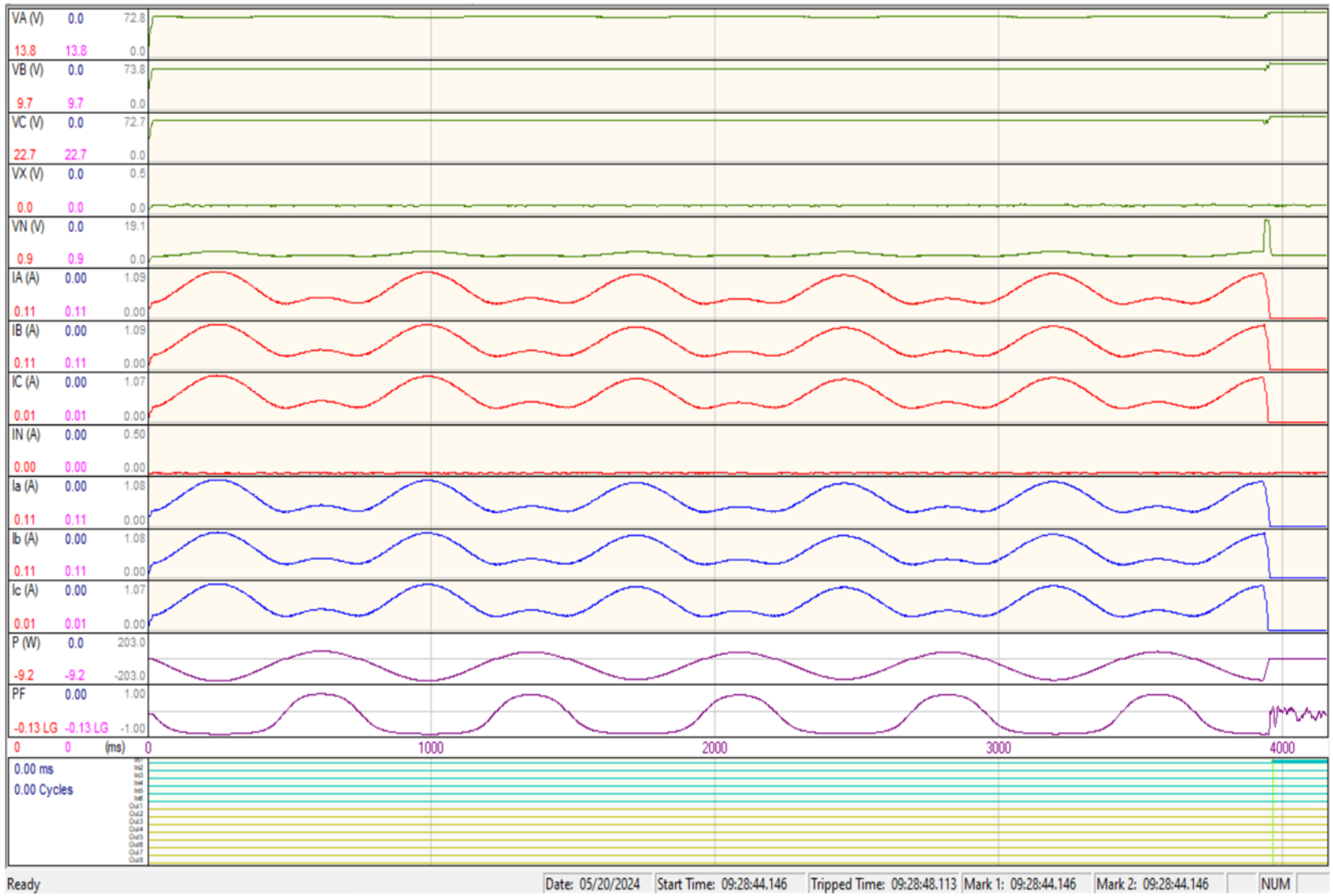
Unit 4 didn't disconnect from the 11kV bus like the other units.

U4 has two 11kV CBs (Bus A and Bus B) which rely on 110V DC powered limit switch indication.

Therefore, the PLC fails to see a closed CB and does not trigger its backup trip.

So, the generator keeps spinning with no driving water flow.

U4 became a motor.



The Unexpected – Unit 4

While motoring, U4 became unstable and started pole slipping.

The resultant power oscillations ranged -15MW to +6MW.

Causes of this have yet to be fully understood.

U4 was only tripped once the 110V DC supply was restored (5 min motoring).

The Unexpected - Response

Onsite operators were quickly able to respond to the situation, confirming that plant had safely disconnected, and river flow was maintained.

The worker completing the battery tests restored the battery bank and charger.

Each service was restored to normal operation and resumed running.

Project Learnings

Projects that affect wide-reaching systems need to have clear work controls both during and outside the project team's onsite presence.

When designing generation secondary systems, it's important to consider power failure scenarios and design accordingly.

Unless regularly tested, never assume the plant will operate as expected.

Conclusions

Secondary system upgrades require plenty of preparation, including as-building drawings and testing.

The older the site, the greater risk of unexpected disruption. Be prepared for the random.

When designing secondary systems, neve assume a power supply is guaranteed.