



Kauai Island Utility Cooperative

*Scope and Experiences with high
penetration IBR*

Scope of IBR on Kauai

- *Port Allen Solar – 6 MW*
- *KRS1 / KRS2 – 24 MW*
- *Customer PV – 46 MW / 11 MW Battery*
- *Tesla PV / BESS – 13 MW / 56 MWh*
- *AES Lawai PV / BESS – 20 MW / 100*
- *AES PMRF PV / BESS – 14 MW / 70*

Scope of IBR on Kauai

- *Highest Peak Load ~ 80 MW*
- *Typical Peak ~ 72 MW*
- *Typical Low Load ~ 40 MW*
- *Average synchronous renewables ~ 12 MW*
- *2021 averaged 70% , 2022 60%*

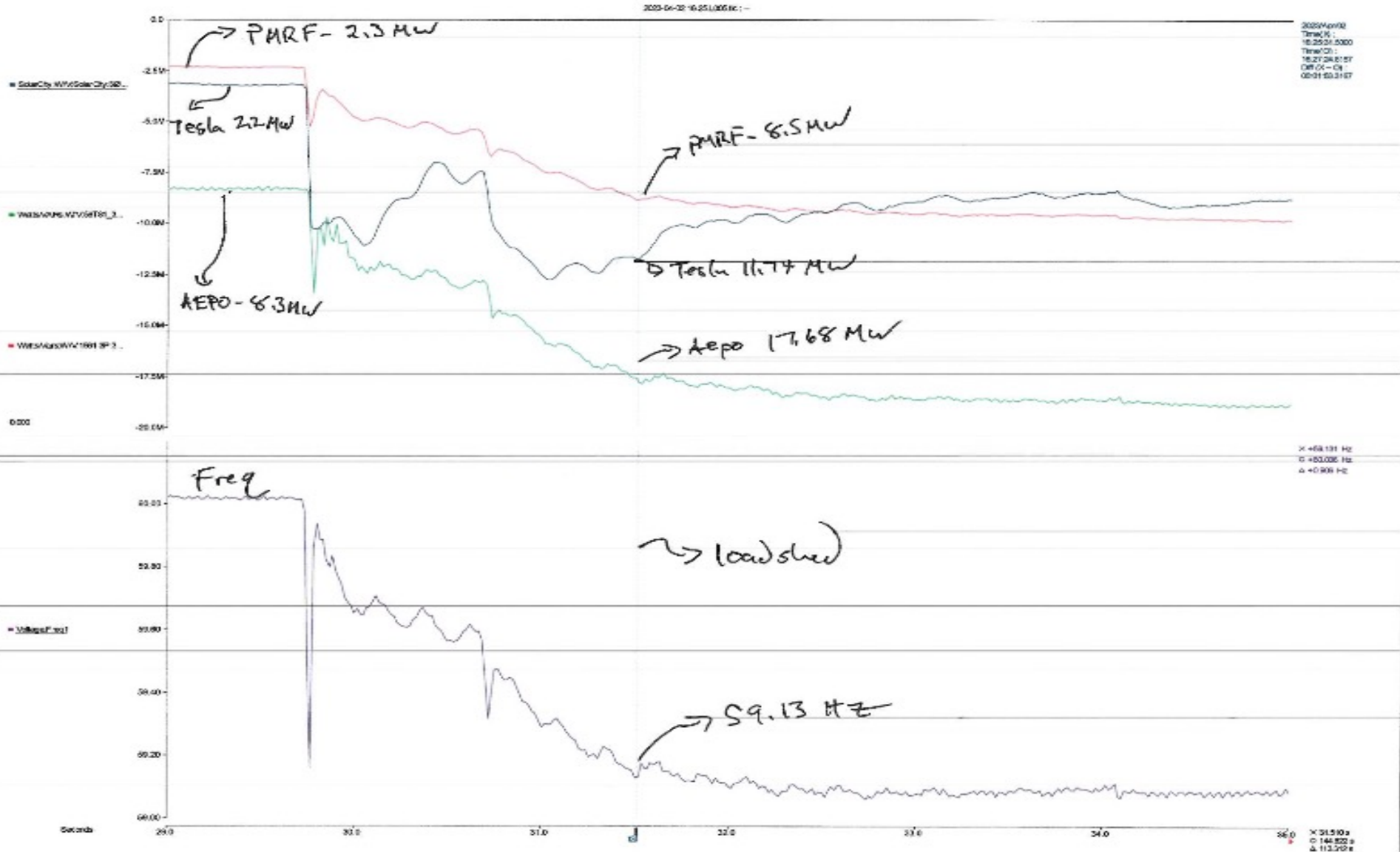
Some Recent Experiences

- *KPS Trip 4/2/23*
- *Shrimp Net Incident 4/18/23*
- *Transmission Outage 4/23/23*

KPS Trip 4/2/23

- *NREL has done a thorough analysis*
- *Pre-trip island load ~ 64 MW*
- *KPS load ~26.2 MW*
- *Other Synchronous load ~ 20 MW*

KPS Trip 4/2/23



KPS Trip 4/2/23

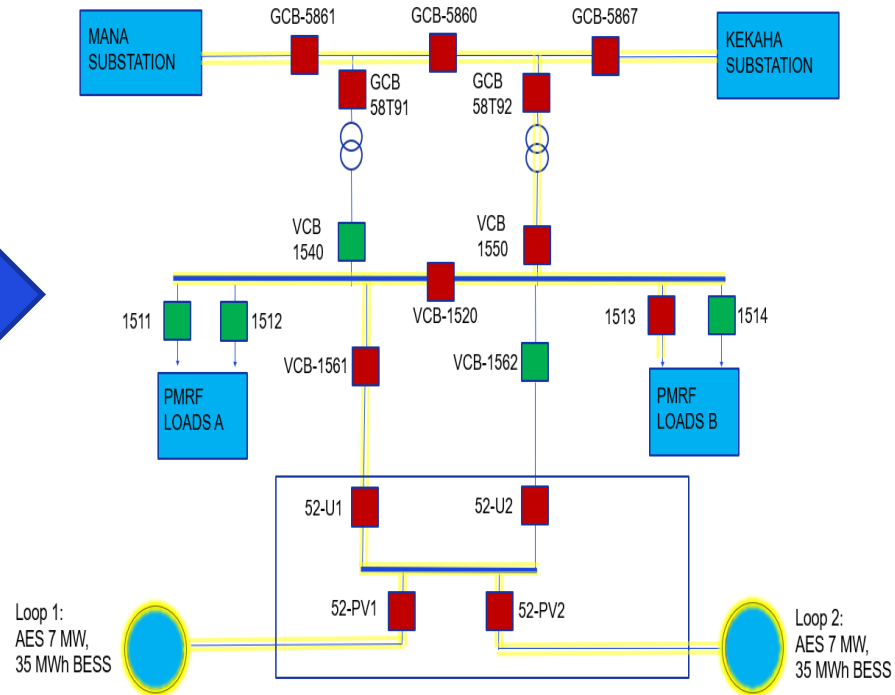
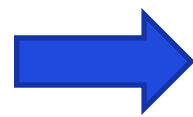
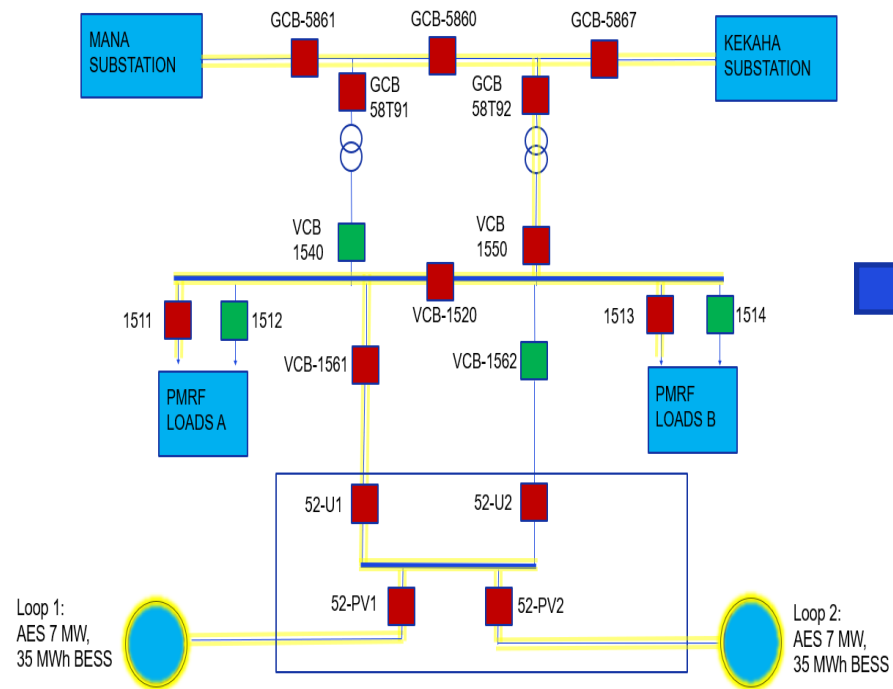
- *Load shed 1.3 MW*
- *Oscillations were much improved from past*
- *Why did we load shed at all?*
- *AGC and/or site response also questionable*

Shrimp Net Incident 4/18/23



Event Timeline: Pre-fault to unplanned islanding event

System configuration and power flow

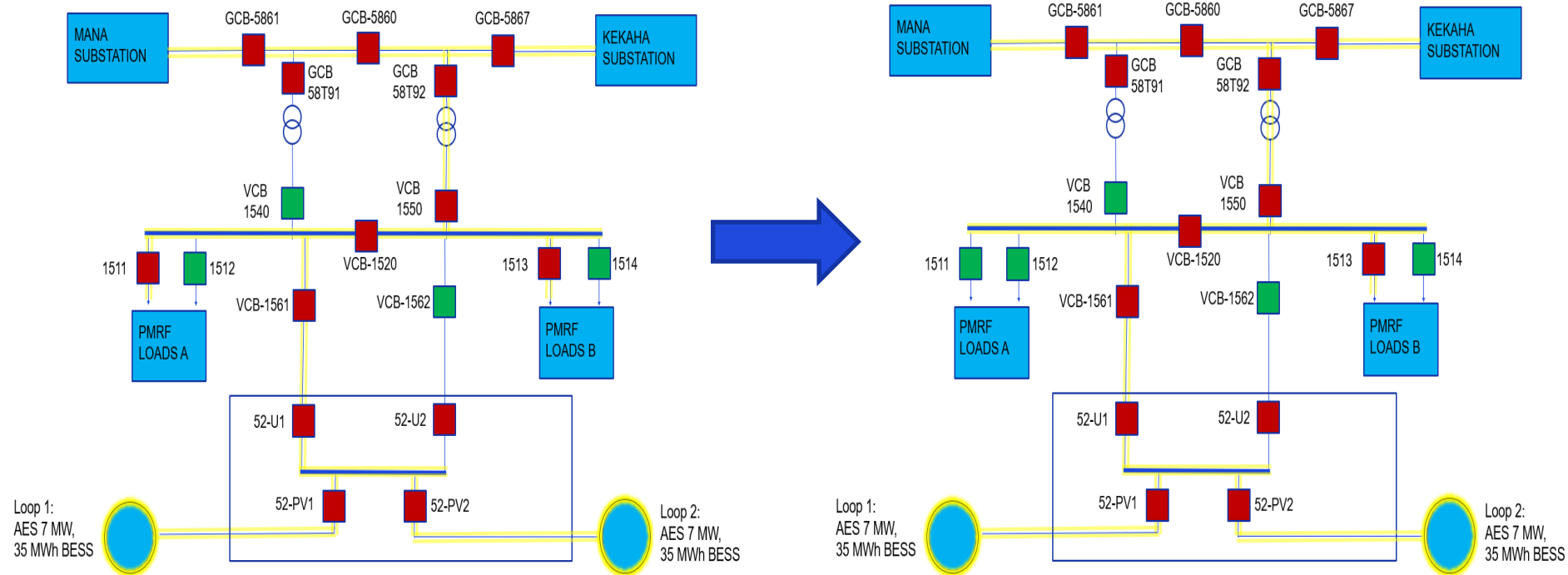


Pre-asymmetric voltage grid fault event

PMRF feeder breaker 1511 opens under fault

Event Timeline: Pre-fault to unplanned islanding event

System configuration and power flow

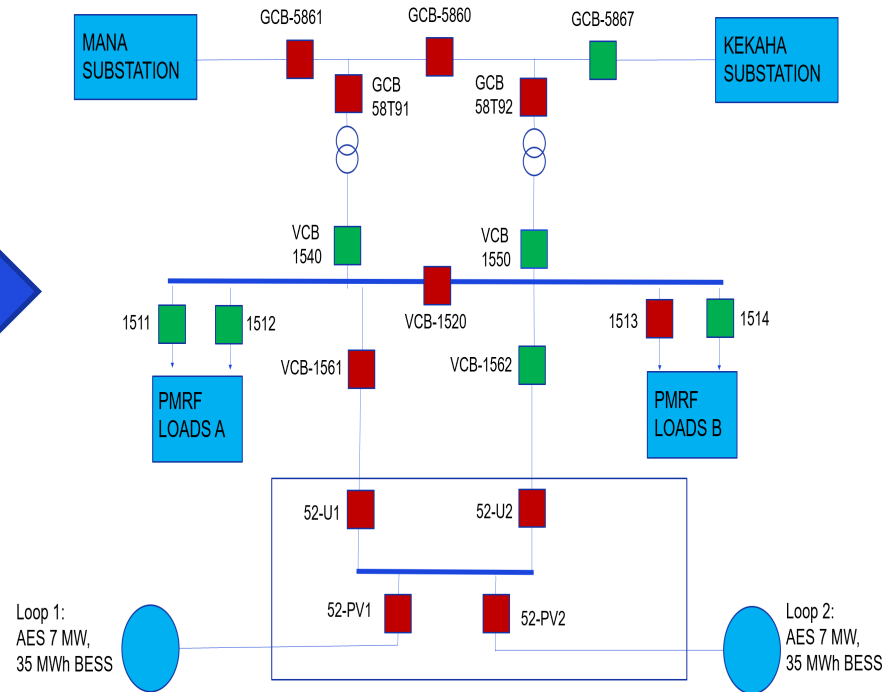
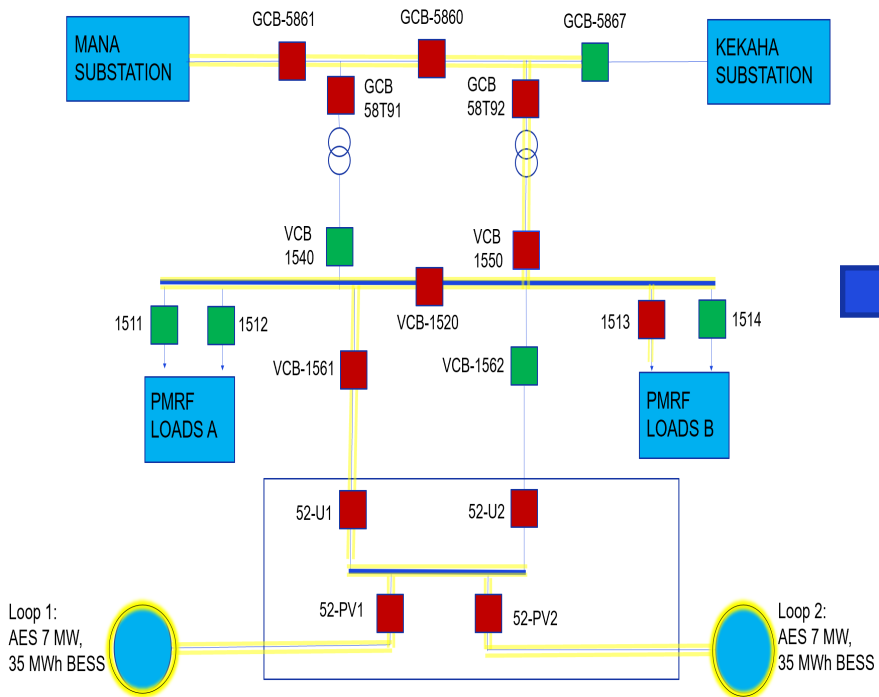


**PMRF feeder breaker 1511 closes
(fault still exists)**

PMRF feeder breaker 1511 opens under fault

Event Timeline: Pre-fault to unplanned islanding event

System configuration and power flow



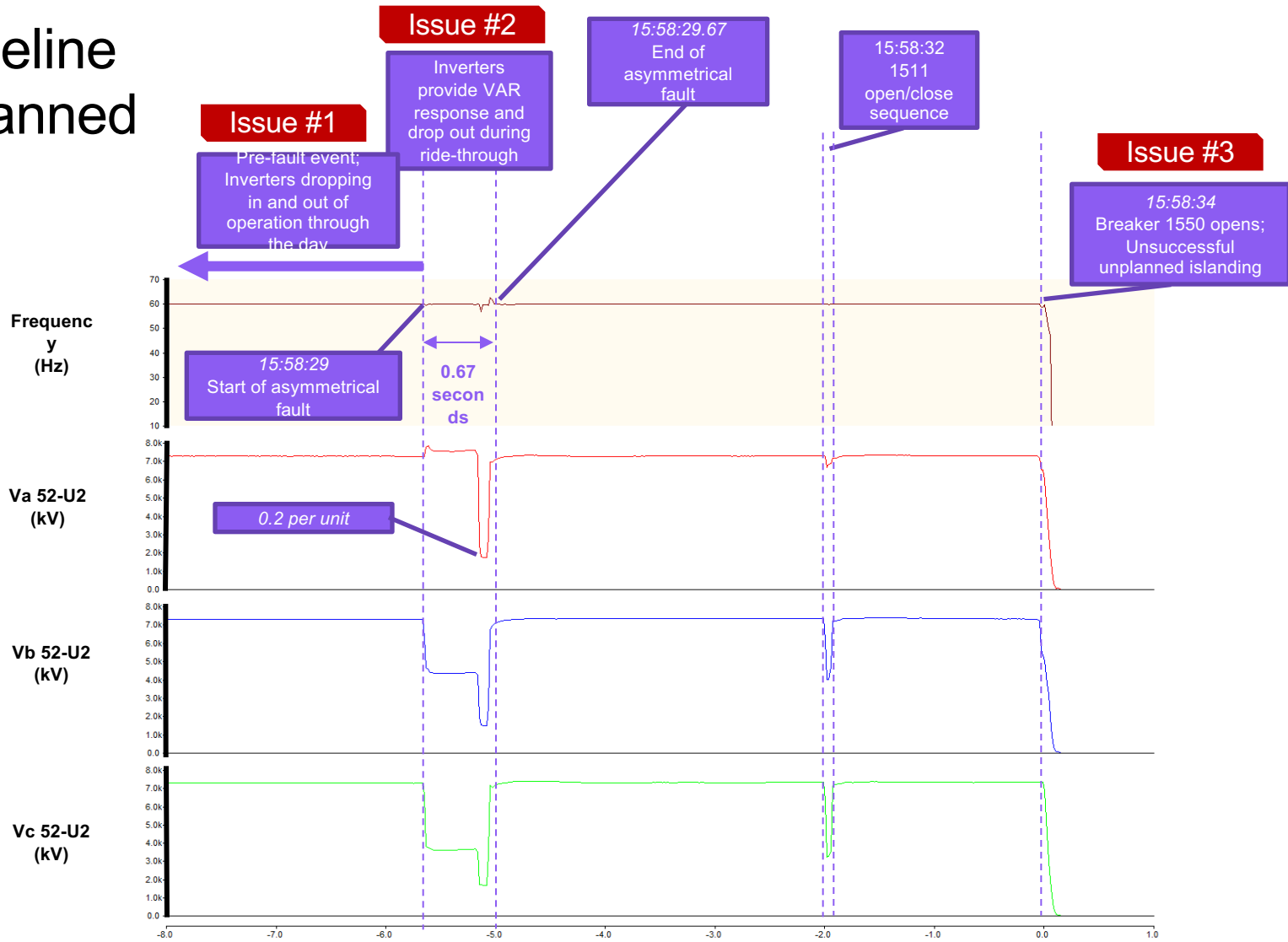
GCB-5867 opens due to transmission fault

**VCB-1550 transfer tripped;
Islanding breaker opens**

Sequence of Events – AES Kekaha

Time	Event	Issue #
Pre 15:58	Heavy rain, AES inverters dropping in and out of operation	1
15:58:29	Asymmetric voltage grid fault start; Non-compliance of ride-through and regulation requirements (PMRF feeder breaker 1511 opens)	2
15:58:32	PMRF feeder breaker 1511 closes and re-opens (fault still existing)	
15:58:34	Islanding breaker VCB-1550 opened from GCB-5867 transfer trip; Unsuccessful unplanned seamless islanding event	3
16:57	Power resumed to PMRF feeder 1513 from AES microgrid blackstart; Blackstart command not initiated by KIUC	4
16:57 – 18:53	Microgrid operation; Off-nominal microgrid frequency and voltage control	5
18:50:22	Transmission restored; GCB-5867 closed	
18:53:31	Microgrid seamless resynchronization failure over VCB-1540 and VCB-1550	6
?	1513 and 1561 opened; PMRF microgrid operation concludes	
19:06:18	PMRF feeder breaker 1513 closed; Grid power resumed to PMRF feeder 1513	
19:07:33	PMRF feeder breaker 1511 closed; Grid power resumed to PMRF feeder 1511	
19:08:51	Unsuccessful close of KIUC breaker 1561	7
?	Initiate blackstart command sent from KIUC to AES Kekaha; AES switchgear breakers 52-U1 and 52-U2 opened	

Event Timeline until Unplanned islanding





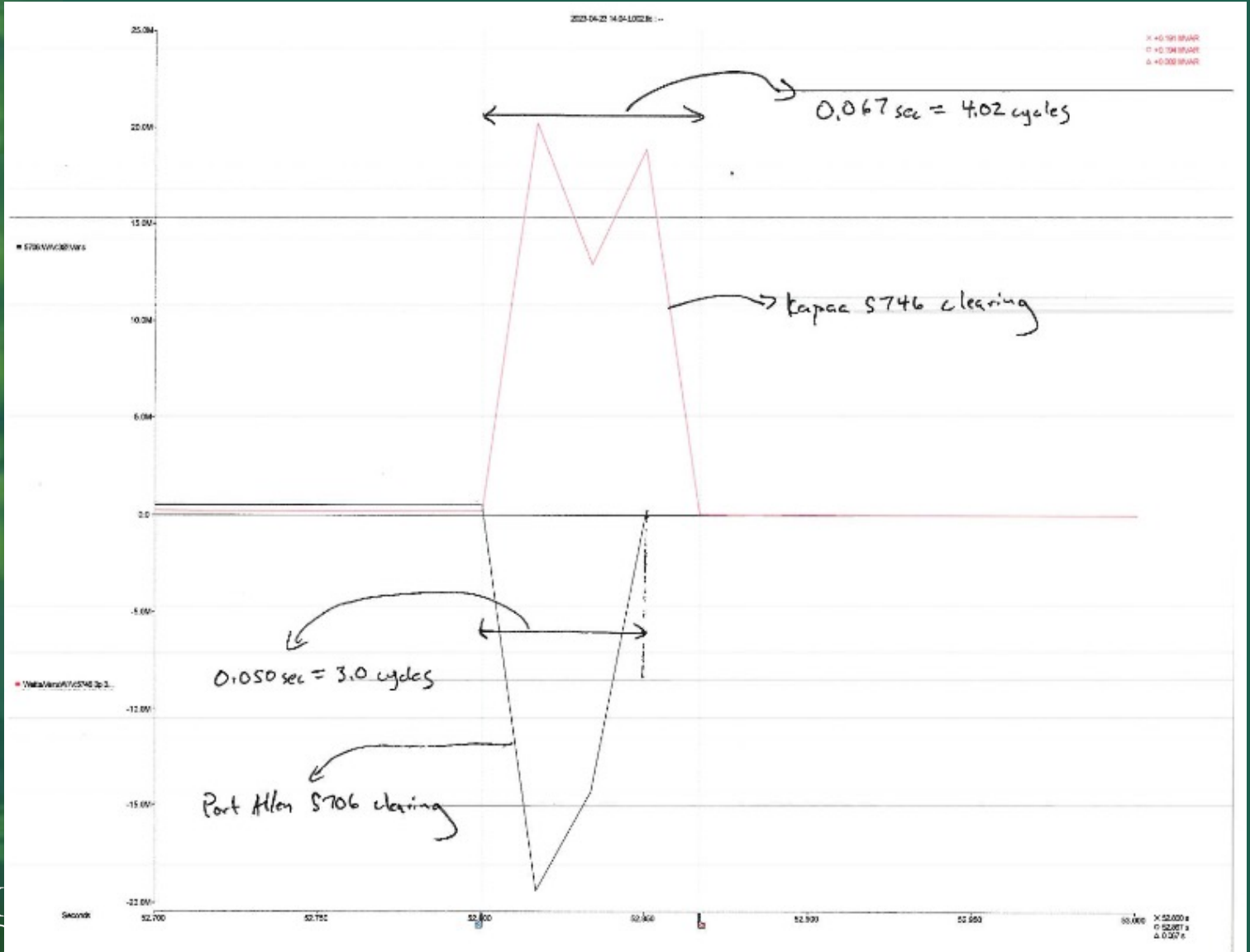
Shrimp Net Incident 4/18/23 Follow ups

- *Wire integrity / possible enclosures*
- *Modify asym. voltage error protection*
- *Procedural / communications*

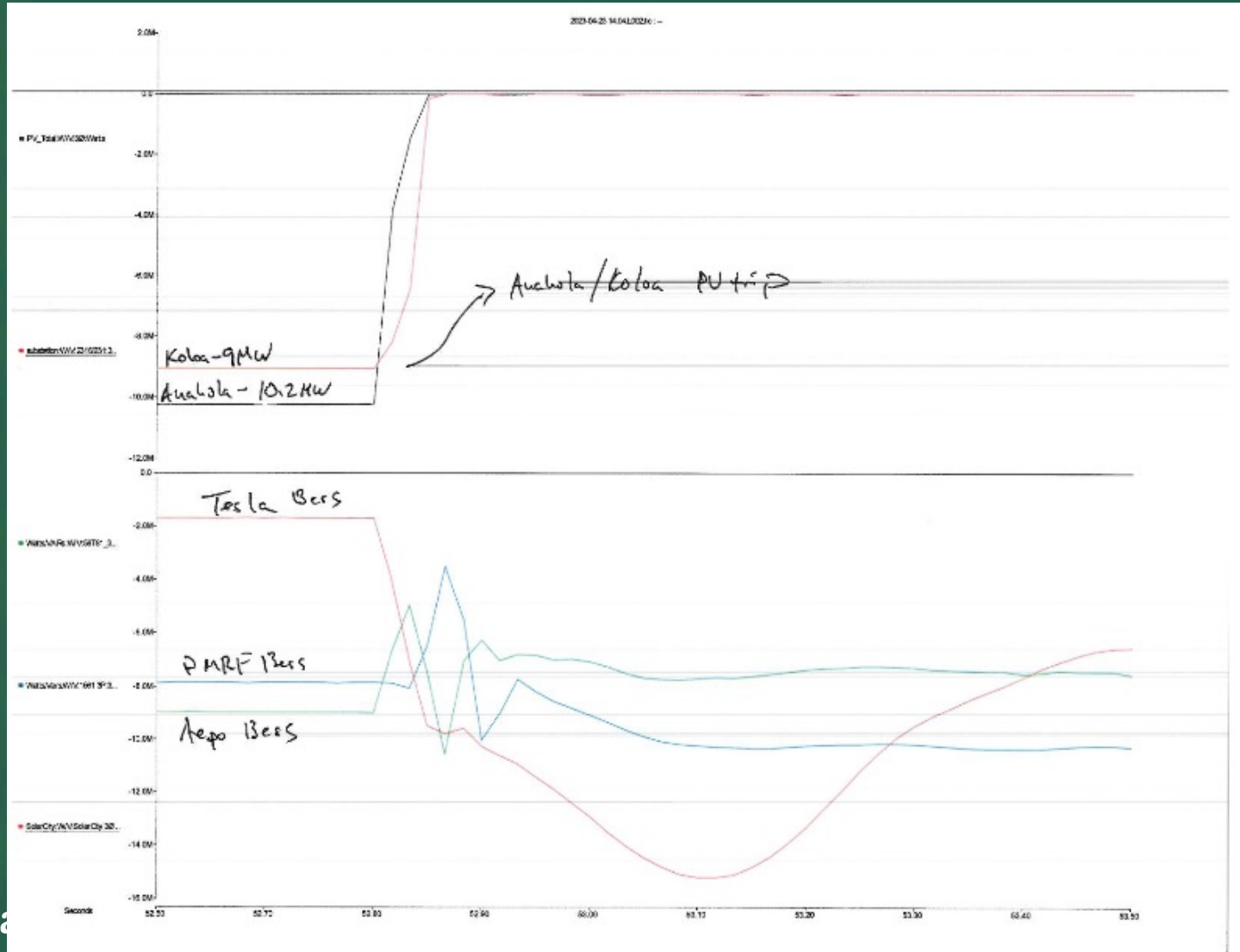
Transmission Outage 4/23/23

- *No customers lost initially*
- *Fault cleared ~ 4 cycles*
- *6.4 MW synchronous load*
- *48 MW island load / ~ 87% IBR*
- *Island was 100% renewable during fault*
- *Eventual 7.9 MW load shed*

Transmission Outage 4/23/23



Transmission Outage 4/23/23



Transmission Outage 4/23/23

- *Voltage dip caused 20 MW load loss from three solar farms*
- *Both AES sites did not fully respond with MW*
- *Synchronous Condenser responded well*

Learnings

- *Droop / GFM seem to have helped oscillations*
- *Asymmetrical fault error could unnecessarily trip site – Kekaha*
- *Q over P Priority*

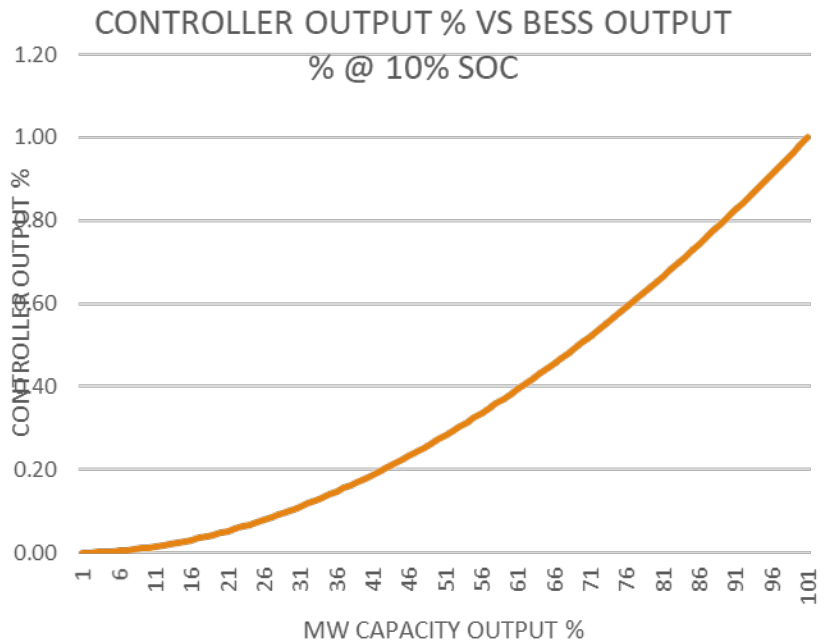
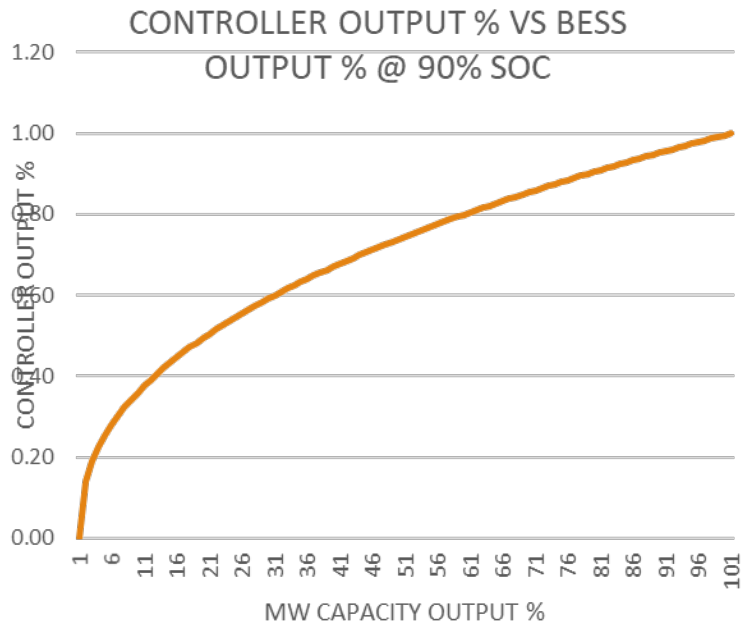
On the Horizon

- *GFM at Lawai AES Site*
- *More synchronous condensing*
- *PROTECT-IT (NREL Partnership)*

Automatic Generator Control

- *Key variables are SOC and MW avail.*
- *Prioritize BESS for response*
- *Single PID for system*
- *Emerson Delta-V*
- *Net MW setpoint to PV / BESS sites*
- *Operator tools*
- *Future: PV only sites integrated*

SOC IMPACT TO BESS OUTPUT



Dispatch Tools – Manual Operator Controls

StormGeo

Spinning Reserve Calculation

Maintenance Data

MWh Goal for next day

KPS – Isochronous Mode

KRS - Curtailment for frequency control

High and low limits for all units

Minimum BESS Output

Future Grid Activities

- *BESS only sites*
- *Add BESS to existing PV only sites*
- *New PV + BESS site(s)*
- *Pumped hydro*