

# PMU-Based Grid Islanding Solution

**Why PMUs with Teleprotection & CCU Outperforms the Standalone Under-Frequency-Relay Grid Islanding Solution**

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*Securing the Power Grid | Thermal • Hydro • Solar • Wind*

IEEE C37.118 Synchrophasor • IEC 61850 GOOSE • GPS/NavIC Timing • ROCOF • Phase Angle Protection

# PRESENTATION AGENDA



## Valiant Communications PMU Grid Islanding Solution

01

### The Grid Islanding Challenge

*Why modern grids need intelligent islanding*

02

### Global Grid Failure Case Studies

*Spain/Portugal 2025 • India 2012 • South Australia 2016 • Europe 2006*

03

### Limitations of Standalone Under Frequency Relays

*Why frequency-only protection is insufficient*

04

### Valiant's PMU + Teleprotection Solution

*Architecture, triggers, and dynamic perimeter control*

05

### Comprehensive Feature Comparison

*PMU+CCU+Teleprotection vs. Standalone UFR*

06

### System Components & Architecture

*VCL-PMU-30, DTPC, CCU, NTP, NAS*

07

### Why Valiant — Benefits & ROI

*Technical superiority, End-to-end solution*

# THE GRID ISLANDING OBJECTIVE

## What is Grid Islanding and Why is it Critical?

### What is Grid Islanding?

- Grid Islanding is the deliberate isolation of a defined region of the power network from the national grid, allowing it to continue operating independently on locally generated power.
- In an event of grid failure — caused by fault, overload, renewable fluctuation, or cyber-attack — critical zones such as hospitals, defence facilities, water treatment plants, and data centres must remain powered.
- The aim is: protect downstream consumers, preserve generation equipment, and enable rapid reconnection once the national grid recovers.

### Under/Over Frequency

Grid drops below 47.9 Hz or exceeds threshold

### ROCOF Prediction

df/dt trend predicts imminent frequency collapse

### Phase Angle Deviation

The Phase Angle in any zone deviates beyond permissible threshold

### Cyber Attack Detection

Hostile manipulation triggers any of the above

# CASE STUDY 1: SPAIN & PORTUGAL BLACKOUT — 28 APRIL 2025



Most Severe European Blackout in 20 Years — UFR-Based Defence Failed to Prevent Cascade

**50M+**

People Affected

**15 GW**

Generation Lost in 5 Seconds

**90 sec**

Grid Collapse Time

**12–16h**

Restoration Duration

## Sequence of Failure

1. 12:03–12:22 — Two inter-area oscillation episodes at 0.2 Hz and 0.63 Hz undetected as threats
2. 12:30 — Renewable generation (solar+wind) = 78% of supply; grid inertia critically low
3. 12:33 — Two consecutive generation loss events in SW Spain; 15 GW lost in 5 seconds (60% of demand)
4. 12:33 — French interconnector decouples; Iberian grid isolated; cascade of overvoltage disconnections
5. 12:33:30 — Under-frequency load-shedding relays activate but insufficient to arrest collapse
6. Outcome: Total blackout of Spain + Portugal; black start required from hydro + gas plants

## Why UFRs Failed

- UFRs only monitored local frequency — no phase angle or ROCOF-predictive capability
- No wide-area situational awareness: each relay acted independently
- Overvoltage cascade (not just underfrequency) was primary trigger — outside UFR detection scope
- No centralized data analysis capability was available to predict and pre-empt cascade
- Solar inverter disconnections (inverter-based resources) not handled by static UFR settings

# GLOBAL CASE STUDIES: UFR FAILURES THAT LED TO GRID COLLAPSE



Three major blackouts where standalone Under-Frequency Relays proved inadequate

## IN India Northern Grid Blackout — July 2012

- 670 million people affected (9% of world population) was affected
- 32 GW generation capacity offline
- UFR load-shedding scheme installed but failed to perform as designed
- States bypassed UFR trips under political pressure to overdraw power
- No centralized wide-area monitoring; relays acted independently only on local frequency.

### Key Lesson:

UFRs are only as effective as operator compliance. Without centralized enforcement and wide-area data, they are routinely bypassed.

## AU South Australia Blackout — September 2016

- Storm-triggered line faults caused voltage dips; 9 wind farms auto-disconnected
- 456 MW generation lost instantly; Heywood interconnector tripped (613 MW)
- Low grid inertia (inverter-based renewables) caused RoCoF too fast for UFRs to respond
- Under-frequency load shedding activated but could not arrest freefall
- Entire state blacked out in minutes.

### Key Lesson:

In low-inertia grids with high renewables, ROCOF rises so fast that static UFR thresholds are triggered too late. Phase-angle and ROCOF-predictive monitoring is essential.

## EU European Grid Split — November 2006

- E.ON switched off 380 kV line over River Ems for ship passage — inadequate N-1 analysis
- Continental European grid split into 3 asynchronous islands within minutes
- 15+ million households affected across Germany, France, Italy, Belgium, Spain
- Frequency diverged across zones; UFRs could not coordinate across split grid
- Morocco–Spain interconnectors tripped at 12:33 due to low frequency.

### Key Lesson:

Grid split events create phase-angle divergence between islands. UFRs cannot detect or respond to inter-zone phase deviations — PMUs with wide-area monitoring are required.

# LIMITATIONS OF STANDALONE UNDER-FREQUENCY RELAYS

Why Frequency-Only Protection is Dangerously Insufficient for Modern Grid Islanding



## Local View Only

Protection relay monitors only its immediate zone. No awareness of grid-wide conditions, phase angles, or cross-zone frequency divergence.



## Reactive — Not Predictive

UFRs react only after frequency crosses a static threshold. ROCOF-based prediction (that can give milliseconds of early warning) is absent or rudimentary.



## No Phase Angle Detection

Phase angle deviation — the primary indicator of inter-zone grid instability and the most dangerous cyber-attack vector — is completely undetectable by UFRs.



## No Dynamic Perimeter

UFRs cannot dynamically grow or shrink the island perimeter based on real-time load vs. generation balance. The perimeter of the proposed island is fixed at commissioning.



## No Wide-Area Coordination

Each relay acts independently on pre-set values. No centralized decision-making, no big-data analysis, no GOOSE-based coordinated trip commands.



## Blind to Renewables

Wind and solar inverters disconnect on voltage/frequency transients, not on UFR commands. UFRs have no mechanism to manage inverter-based resource behaviour.



## Cyber-Attack Blind Spot

A coordinated cyber-attack that manipulates phase angles without triggering under-frequency will completely bypass UFR protection.



## No Analytics or Data Logging

No historical data, no post-event root cause analysis, no predictive maintenance insights. Basic event logs only.

# VALIANT PMU + TELEPROTECTION + CCU

*A Unified, Wide-Area, Intelligent Grid Islanding Solution*



## Wide-Area PMU Monitoring

VCL-PMU-30 at every substation streams Frequency, ROCOF, Phase Angle, Load & Voltage at 50 frames/sec via IEEE C37.118. Complete grid visibility at all times.



## Microsecond Teleprotection

VCL-TP DTTC issues trip commands over an SDH / IP/MPLS / MPLS/TP network with <5ms back-to-back transmission. Centralized trip coordination is executed at the CCU level — not relay-by-relay.



## Smart Central Control Unit (CCU)

VCL-CCU processes data from all PMUs in real-time, runs grid-islanding software, manages dynamic island perimeter, and issues alarms and commands — all within a few milliseconds.



## GPS/NavIC NTP Time Sync

VCL-2156 NTP Server with GPS/GNSS/NavIC provides <30ns time accuracy grid-wide. Ensures all PMU measurements are precisely synchronized — critical for phase angle validity.

# FIVE SCENARIOS THAT TRIGGER VCL GRID ISLANDING

Automated, multi-parameter protection — covering what UFRs cannot detect

01

## Under/Over Frequency

Grid frequency falls below 47.9 Hz or exceeds user-defined upper threshold. VCL-CCU raises alarms and issues centrally coordinated trip commands to all operative sites simultaneously.

✓ UFR detects this — but only locally, with no coordination

02

## ROCOF Predictive Trigger

Rate of Change of Frequency (df/dt) indicates frequency WILL breach 47.9 Hz in the next few hundred milliseconds. VCL acts BEFORE the threshold is crossed — giving critical extra milliseconds.

✗ UFRs react AFTER threshold breach — too late for coordinated action

03

## Phase Angle Deviation

Any zone's phase angle diverges beyond permitted limits versus other zones. This is the most dangerous instability indicator — and the one completely missed by UFRs. VCL detects and acts.

✗ UFRs have zero phase angle detection capability

04

## Cyber-Attack Detection

A cyber-attack that manipulates grid parameters will inevitably trigger one or more of the above deviations. VCL's centralized analysis detects anomalous multi-parameter patterns that individual UFRs cannot see.

✗ UFRs provide no cyber-attack detection whatsoever

05

## Manual Intervention

Grid operator can manually initiate islanding for testing, maintenance, or in any situation where automated thresholds have not yet been triggered but operator judgement indicates risk. Full NMS control panel.

✗ UFRs offer no manual override or operator-controlled islanding.

## How Dynamic Perimeter Works

- The VCL-CCU continuously monitors real-time load AND generation data from every PMU in the network — 50 data sets are analyzed / per second / per site / per PMU.
- At any instant, the CCU knows exactly how much power each island segment consumes and how much is being generated.
- When grid failure occurs, the CCU calculates the optimal island boundary: which feeders to include (operative) and which to exclude (blocked).
- If the island's generation exceeds load — more loads are added (island expands) to maintain balance.
- If load exceeds generation — loads are shed in priority order (DRDO, Defence, Railways, Airport etc. feeders always protected as blocked).
- As a last resort, the CCU signals generators to reduce output or halt specific units to maintain stability.
- The entire process is automatically executed by the CCU, operating in milliseconds, with optional manual override at any time via the VCL-NMS dashboard.

## DTPC Logical AND Gate

### INPUT 1:

Under/Over Frequency OR ROCOF threshold breach signal from CCU

**AND**

### INPUT 2:

Site in OPERATIVE mode (load + generation balance allows inclusion in island)

### TRIP COMMAND

issued only when BOTH inputs TRUE

# FEATURE COMPARISON — PART 1 OF 2



VCL PMUs + Teleprotection + CCU vs. Standalone Under-Frequency Relays

Feature	VCL PMU + Teleprotection + CCU	Standalone UFR
Principle of Operation	Under-frequency, Over-frequency, ROCOF, Phase Angle Deviation, synchronized data, real-time centralized decision-making	Under-frequency and possibly ROCOF only
Real-time Monitoring	50 frames/sec: Frequency, ROCOF, Phase Angle, Load, Voltage from all sites	Local frequency only. No real-time wide-area data
Wide-Area Situational Awareness	Full grid visibility. Centralized, coordinated decision-making by the CCU executed across all sites	Local zone only. No broader grid awareness
Speed of Response	Microseconds: Trip commands transmitted and executed across all locations	Seconds: reacts only after local frequency threshold breached
ROCOF Prediction	YES — predicts imminent frequency breach; acts milliseconds BEFORE threshold is crossed	Limited or none. No predictive capability
Phase Angle Detection	YES — continuously monitors inter-zone phase deviation across the power network. Primary instability indicator	NONE — completely blind to phase angle divergence at the network level
Cyber-Attack Detection	YES — multi-parameter anomaly detection; phase angle manipulation detected	NONE — frequency-only; cyber manipulation through phase angles bypasses UFR

# FEATURE COMPARISON — PART 2 OF 2



VCL PMUs + Teleprotection + CCU vs. Standalone Under-Frequency Relays

Feature	VCL PMU + Teleprotection + CCU	Standalone UFR
Dynamic Island Perimeter	YES — continuously adjusts island boundary based on real-time load vs. generation balance	NONE — fixed perimeter set at commissioning
Renewable/DER Integration	Full integration with solar, wind, DERs. Monitors inverter-based resource behavior	Limited. Designed for legacy synchronous generators only
Adaptive & Predictive Capability	Advanced algorithms + centralized big-data processing. Adaptive thresholds	Reactive only. Fixed pre-set thresholds, no adaptability
Operation Mode	Fully Automatic WITH manual override option via NMS dashboard	Not automated. Operator must manually configure; no remote coordination
Data Logging & Analytics	Comprehensive: ~1GB/day per PMU. Long-term storage for root cause analysis. VCL-9090 NAS provided as an adjunct to the CCU, with up to 480TB of data storage	Basic event logging only. No analytics
Scalability	Highly scalable: add PMUs/sites without redesign. 22+ sites in Punjab scheme	Limited. Each relay independent. No system-level scalability
Reliability & Redundancy	Dual CCU (primary + DR), dual NTP, dual NAS. Never a single point of failure	Single-point measurement. No redundancy architecture
Made in India (Atmanirbhar Bharat)	100% — All VCL components designed, developed and manufactured by Valiant Communications Limited.	Primarily imported components from overseas manufacturers

# SAMPLE STUDY: PUNJAB GRID ISLANDING SCHEME



Rajpura Thermal Plant (2x700 MW) + Ranjit Sagar Hydro (4x150 MW) — 22 Sites — Northern Grid Isolation

22

Substations  
Connected

1.4 GW

Generation  
Capacity

50 fps

PMU Data Rate  
per Site

<2 ms

GOOSE Trip  
Latency

## Scheme Operation

- VCL-PMU-30 at each of 22 substations streams Load, Frequency, Phase Angle, Voltage to Central Site via IEEE C37.118 over dedicated transmission links.
- VCL-CCU at Central Site processes 50 frames/sec from all sites; makes island formation decisions in real-time
- When frequency drops below 47.9 Hz (or ROCOF predicts breach), CCU sends GOOSE packets to VCL-TP, DTPC stack
- DTPC issues trip commands ONLY to sites in OPERATIVE mode — protecting DRDO, Defence, Railways etc. feeders (always BLOCKED)
- Dual VCL-2156 NTP Servers at every site provide GPS/NavIC timing to <30ns for PMU synchronization
- VCL-9090 NAS stores ~1GB/day/PMU for long-term archiving, root cause analysis, and fault pattern study.

## Network Architecture

<b>Protocol:</b>	IEEE C37.118 (PMU data) + IEC 61850 GOOSE (trip commands) + DTPC Stack
<b>Transport:</b>	IP/MPLS over dedicated transmission channels
<b>Redundancy:</b>	Dual CCU (primary + DR site); dual NAS; dual NTP per site
<b>Timing:</b>	GPS/GLONASS/NavIC, <30ns accuracy, IRIG-B outputs
<b>Connectivity:</b>	Transmission Network Agnostic. Can use SDH / IP/MPLS and MPLS-TP transmission links.

# VALIANT SYSTEM COMPONENTS



All components are Designed and Manufactured by Valiant Communications Limited

## VCL-PMU-30

*Phasor Measurement Unit*

Compact, comprehensive PMU. Streams 50 frames/sec of Frequency, ROCOF, Phase Angle, Load, Voltage. IEEE C37.118 Synchrophasor. Installed at every substation. Built on CEA guidelines.

## VCL-CCU

*Smart Central Control Unit*

High-performance server managing IEEE C37.118 data from all PMUs in real-time. Runs grid-islanding software. Manages dynamic island perimeter. Includes VCL-NMS.

## Transmits Trip Commands over an SDH / MPLS/IP / MPLS-TP Network

Transmission Network Agnostic. Transports Trip Commands efficiently over SDH / IP/MPLS or MPLS-TP networks. Bridges CCU commands to remote teleprotection stacks. Broadcast — no handshake delay.

## VCL-TP DTPC

*Digital Teleprotection*

Up to 8 Binary I/O channels. <5ms back-to-back transmission over IP/MPLS/E1/Optical IEEE C37.94 fiber interface. Issues and receives TRIP commands across all locations simultaneously.

## VCL-2156

*GPS/NavIC NTP Time Server*

GPS / GLONASS / NavIC time receiver. <30 nanosecond accuracy. IRIG-B outputs. Dual-server deployment per site for timing redundancy. Ensures precise PMU synchronization grid-wide.

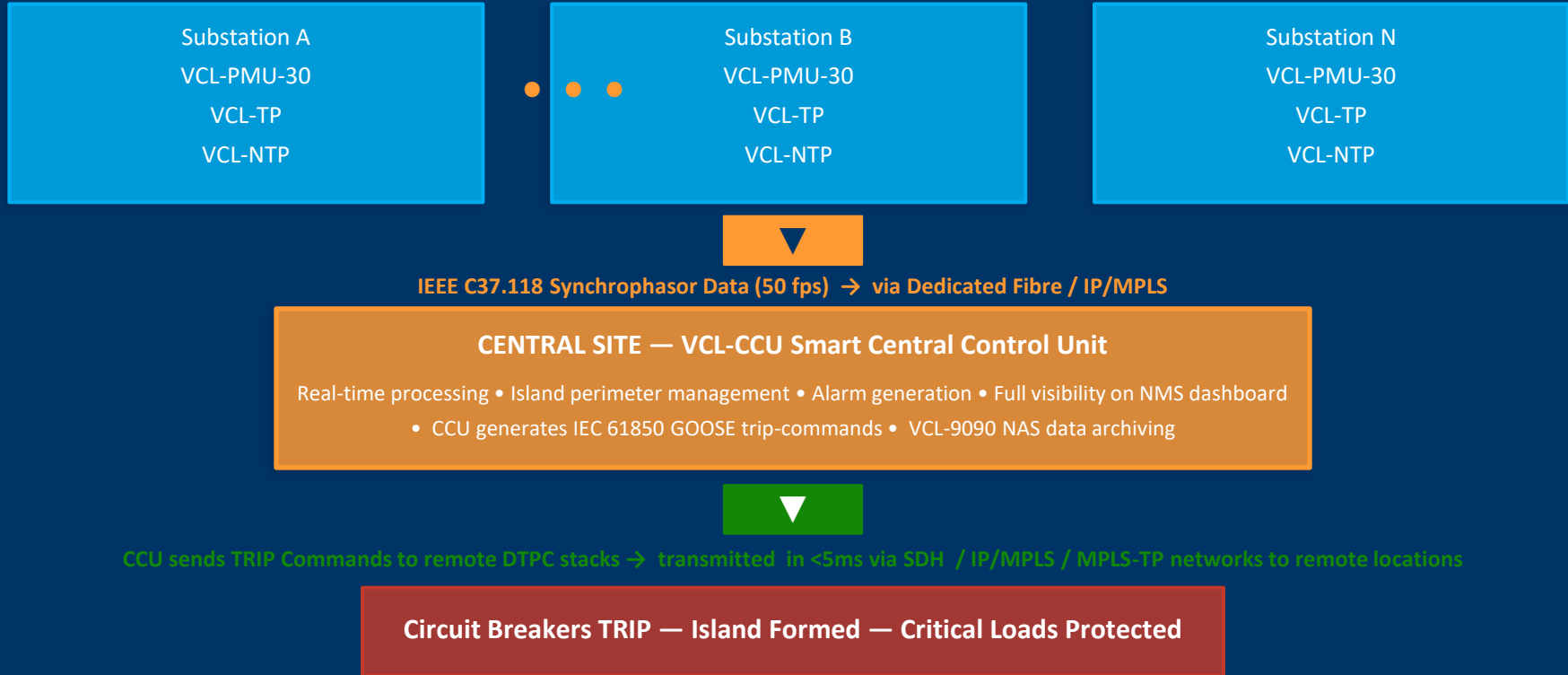
## VCL-9090 NAS

*Industrial NAS Storage*

Industrial-grade Network Attached Storage. 120TB base, expandable to 480TB. MFA authentication. Real-time ransomware detection. Stores ~1GB/day/PMU for long-term archiving and root-cause analysis.

# SYSTEM DATA FLOW ARCHITECTURE

*How PMU Data Flows from Substations to the Central Site and Back as Trip Commands*



# RENEWABLES, LOW INERTIA & ROCOF — THE NEW GRID CHALLENGE



Why Modern Grids With High Renewables are Uniquely Vulnerable — and Why UFRs Are Becoming Obsolete

## The Low-Inertia Problem

- Traditional synchronous generators (coal, gas, hydro) have massive rotating mass that provides GRID INERTIA — natural resistance to frequency change.
- Solar PV and wind turbines connect through power electronics inverters. They provide ZERO physical inertia to the grid.
- As renewable penetration rises, grid inertia falls. When generation is lost, frequency drops MUCH faster.
- Spain 2025: 78% renewables at the time of blackout. Frequency collapsed in <5 seconds.
- South Australia 2016: Low inertia caused RoCoF so fast that UFR thresholds were triggered too late to prevent total blackout.
- India is rapidly adding solar (100 GW+) and wind capacity. India's grid faces the same low-inertia risk unless wide-area PMU + ROCOF protection is deployed NOW.

## ROCOF: VCL's Early Warning System

VCL-PMU-30 continuously calculates Rate of Change of Frequency ( $df/dt$ ) at every site. When ROCOF indicates that frequency WILL breach 47.9 Hz — even before it does — VCL-CCU initiates the islanding sequence, gaining critical extra milliseconds.

## Synthetic Inertia Compensation

- VCL-CCU's fast load-shedding (via DTPC) mimics the stabilizing effect of grid inertia by rapidly balancing load and generation
- PMU phase-angle monitoring detects the early signatures of inter-area oscillations (like those seen at 12:03 and 12:19 in Spain 2025) before they cascade
- Dynamic perimeter adjustment prevents over-shedding or under-shedding — maintaining island stability without operator intervention

# WHY CHOOSE VALIANT'S GRID ISLANDING SOLUTION



Seven Compelling Reasons to Deploy VCL PMU + Teleprotection + CCU

01

## Proven Field Components

VCL Teleprotection, PMU and Synchronization equipment has been successfully deployed across various countries.

02

## IN 100% Made in India

All components — VCL-PMU-30, DTPC, CCU, NTP, NAS — designed and manufactured in Bharat. Supports Atmanirbhar Bharat and Make in India mission.

03

## Superior Technical Depth

Phase angle + ROCOF + frequency + load monitoring. No other solution combines all these parameters with centralized AI decision-making.

04

## Cyber-Attack Resistant

Multi-parameter anomaly detection catches grid manipulation attacks that completely bypass frequency-only UFR protection.

05

## Dynamic Perimeter Control

Only solution that dynamically adjusts island size in real-time based on actual load vs. generation balance — per IEEE C37.118 and IEC 61850.

06

## Complete Data & Analytics

50 fps PMU data archived on VCL-9090 NAS (up to 480TB). Years of data for root cause analysis, audit compliance, and pattern-based predictive maintenance.

07

## Full-Stack Solution

Single-vendor, end-to-end: PMUs, Teleprotection, CCU, NMS, NTP, NAS. One point of accountability. Seamless integration. Factory-tested system.

# Contact: Valiant Communications Limited

Website: [www.valiantcom.com](http://www.valiantcom.com)



U.K.

**Valiant Communications (UK) Ltd**  
Central House Rear Office,  
124 High Street, Hampton Hill,  
Middlesex TW12 1NS, U.K.

E-mail: [gb@valiantcom.com](mailto:gb@valiantcom.com)



U.S.A.

**Valcomm Technologies Inc.**  
4000 Ponce de Leon Blvd.,  
Suite 470, Coral Gables,  
FL 33146, U. S. A

E-mail: [us@valiantcom.com](mailto:us@valiantcom.com)



INDIA

**Valiant Communications Limited**  
71/1, Shivaji Marg,  
New Delhi – 110015  
INDIA

E-mail: [mail@valiantcom.com](mailto:mail@valiantcom.com)