

# WAMSTER

A decade dedicated to  
synchrophasor technology

STER - Studio Elektronike Rijeka Ltd.

**NASPI Work Group Virtual Meeting and Vendor Show**

*October 05-07, 2021*

STER Ltd. Croatia · [www.ster.hr](http://www.ster.hr) · [www.wamster.net](http://www.wamster.net)

# WAMSTER-RT in HOPS

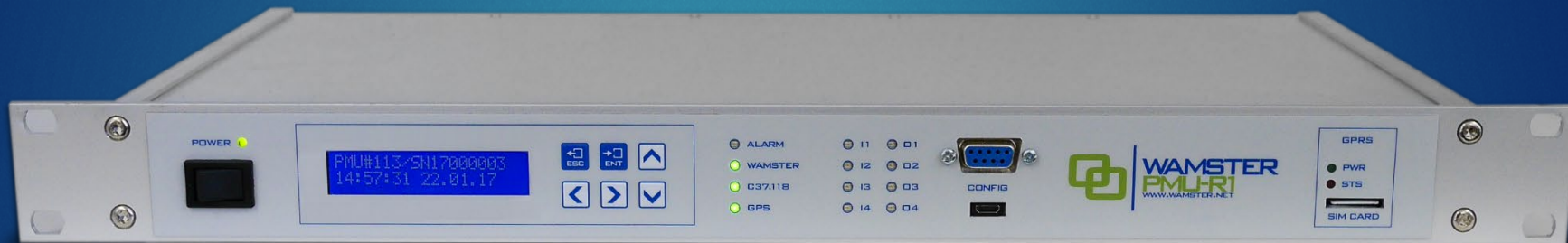
2

- WAMSTER-RT PDCs in HOPS
  - 1 in NDC, 2 in area control centers
- PDC in NDC - WAMS to WAMPAC transition testbed
  - Communication delays and issues
  - Line protection monitoring (basic, differential, impedance)
  - Line monitoring: voltage angle difference, charging currents, high resistance faults, corona losses, synchro-check
  - Fault locator - superior for high resistance SLG faults
  - Oscillation monitoring: detection, Prony tool analysis
  - Performance monitoring: primary frequency control
  - Integration with EMS – Emergency load shedding
  - Equipment deterioration, protection coordination flaws



# STERPMU-R1

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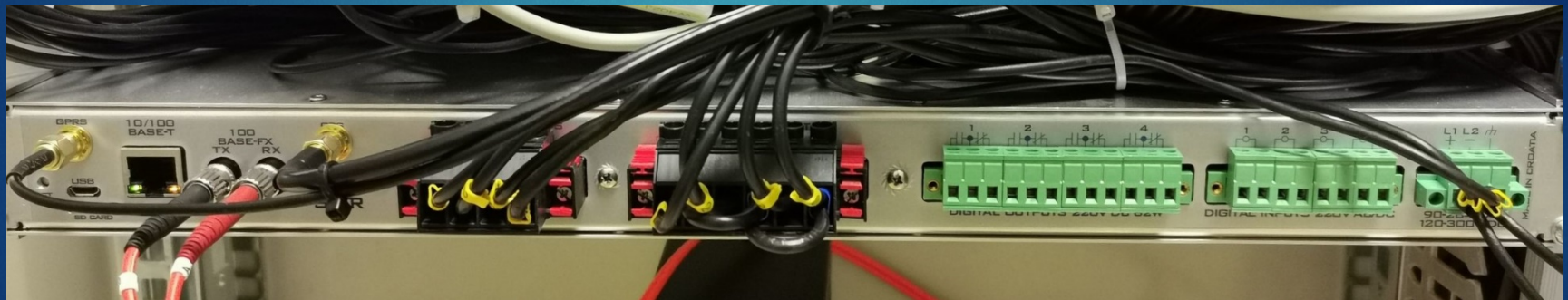


- 1) Installation in 19" rack – 1U size
- 2) current ranges: 2A precision, 32 A high current overload 100 A: > 2 min
- 3) 4 x binary inputs, 4 x relay outputs
- 4) binary outputs controlled by IEEE C37.118 protocol achieved: PMU-PDC-PMU loop reaction time: 40 ms



# STERPMU-R1

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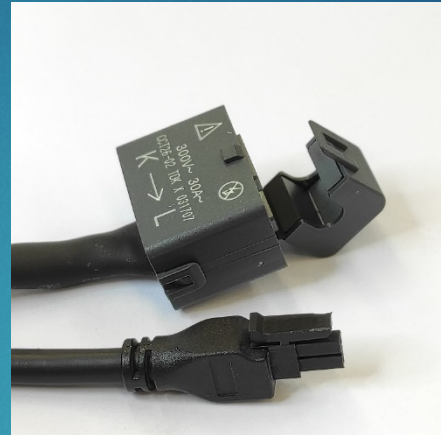


...5) secondary service channel (GPRS)



# STERPMU-Rx

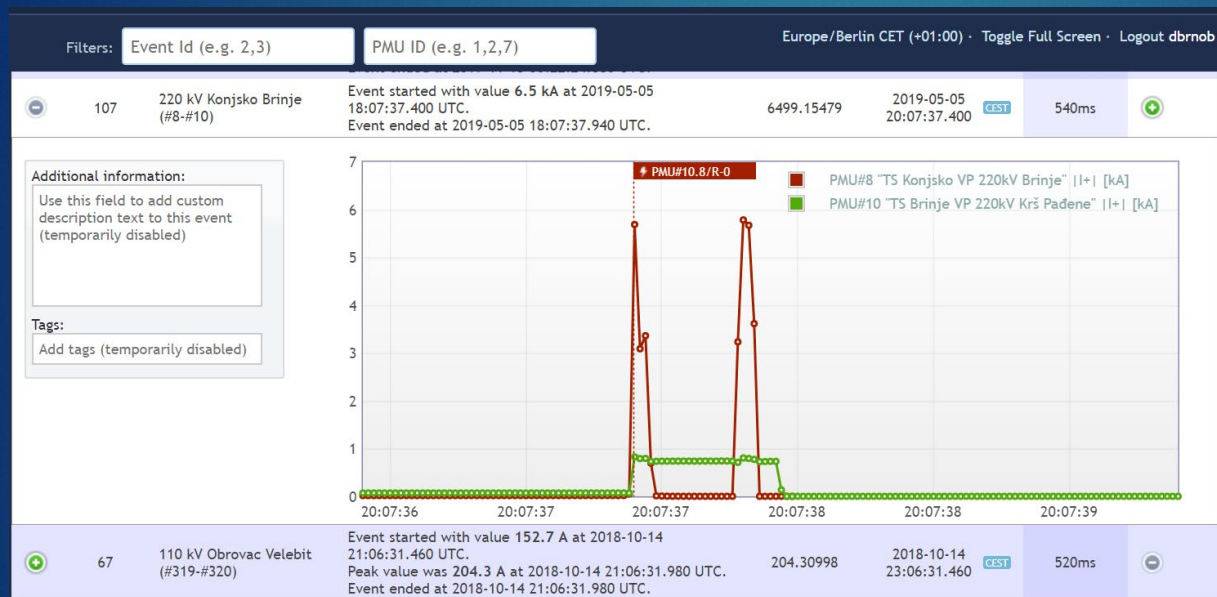
5



- -R1 in reduced footprint
- external clamp-on current sensor
- RES monitoring
- Distribution, generation and older transmission feeders
- 4th U&I channels with DC measurement capability
- excitation, PSS, synchro-check
- extensions for R&D

# Differential current

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## Individual PMU Currents

### Magnitudes

☒ |Isym+| [A]

☐ |Isym-| [A]

☐ |Isym0| [A]

### Angles

## Operate Current (Vector)

### Magnitudes

☒ |Isym+B + Isym+A| [A]

☐ |Isym-B + Isym-A| [A]

☐ |Isym0B + Isym0A| [A]

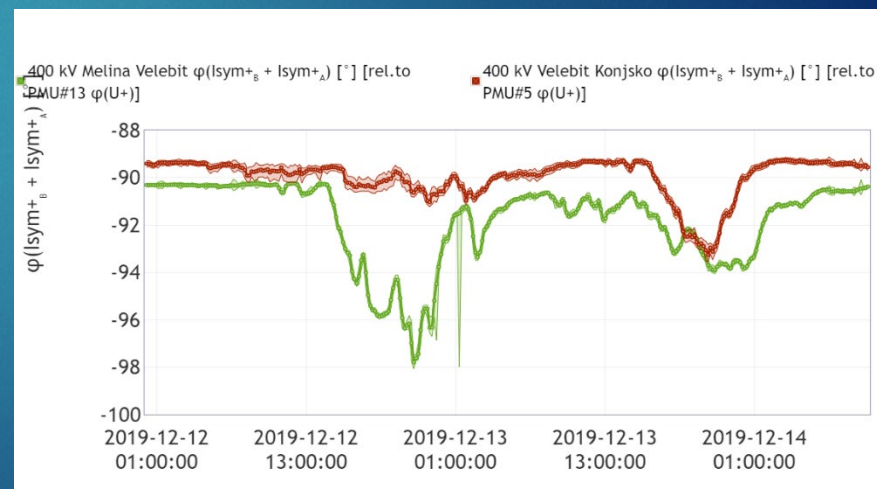
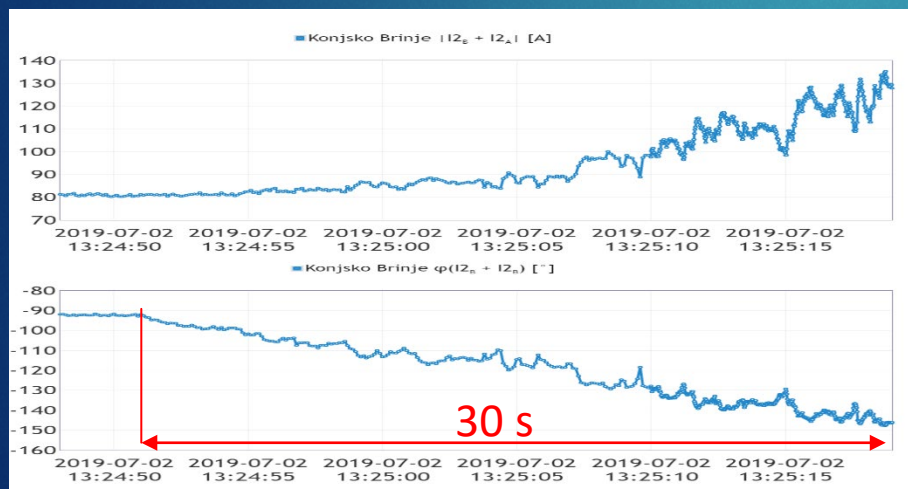
☐ |I1B + I1A| [A]

☐ |I2B + I2A| [A]

☐ |I3B + I3A| [A]

### Angles

## Restrain Current (Scalar)





# Fault locator tooltip window

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(right click to pin tooltip)

Device: PMU#13 "RHE Velebit VP 400kV Melina"

Channel: |I2| [kA]

Time: 2020-12-08 13:44:45.780 CET

Value: 2.7612 kA

PowerLine: 400 kV Melina Velebit; Length = 178.8 km

TS Melina

RHE Velebit

- Differential Fault type:SINGLE PHASE (L2-E)

PMU#3 TS Melina VP 400kV Velebit:

- U/I/Phi Fault type:NONE
- Quadrilateral Fault type:NONE

L1-E: R=-193.9 (-3300.7% Rd); X=-15.1 (-24.7% Xd); phi=-175.6° False  
 L2-E: R=56.2 (956.1% Rd); X=61.9 (101.3% Xd); phi=47.8° False  
 L3-E: R=-63.1 (-1074.1% Rd); X=-364.8 (-597.3% Xd); phi=-99.8° False  
 L1-L2: R=308.2 (5246.4% Rd); X=64.0 (104.7% Xd); phi=11.7° False  
 L2-L3: R=-18.5 (-314.4% Rd); X=185.0 (302.8% Xd); phi=95.7° False  
 L3-L1: R=-464.2 (-7901.1% Rd); X=-40.6 (-66.4% Xd); phi=-175.0° False

\* One-side estimation methods:

- Simple Reactance : L = 181.06 km (-2.26 km to other end)
- Takagi : L = 146.79 km (32.01 km to other end)
- Modified Takagi : L = 138.69 km (40.11 km to other end)
- Ziegler : L = 148.87 km (29.93 km to other end)

\* Two-side estimation methods:

- Pos. Sequence : L = 139.23 km (39.57 km to other end)
- Neg. Sequence : L = 131.86 km (46.94 km to other end)
- Zero Sequence : L = 137.04 km (41.76 km to other end)
- STER Method : L = 136.28 km (42.52 km to other end)

$U_F = 132242.80 < -45.85^\circ \text{ V}$

$Z_{\text{loop}} = 83.55 < 47.76^\circ \Omega$

$R_F = 26.84 < 16.59^\circ \Omega$

PMU#13 RHE Velebit VP 400kV Melina:

- U/I/Phi Fault type:SINGLE PHASE (L2-E)
- Quadrilateral Fault type:SINGLE PHASE (L2-E)

L1-E: R=-168.6 (-2869.0% Rd); X=-53.3 (-87.3% Xd); phi=-162.4° False  
 L2-E: R=31.8 (540.6% Rd); X=18.4 (30.1% Xd); phi=30.0° True  
 L3-E: R=81.9 (1394.5% Rd); X=-74.9 (-122.6% Xd); phi=-42.4° False  
 L1-L2: R=124.3 (2115.2% Rd); X=-3.7 (-6.1% Xd); phi=-1.7° False  
 L2-L3: R=67.4 (1146.5% Rd); X=108.8 (178.1% Xd); phi=58.2° False  
 L3-L1: R=467.8 (7962.9% Rd); X=-56.8 (-93.0% Xd); phi=-6.9° False

\* One-side estimation methods:

- Simple Reactance : L = 53.74 km (125.06 km to other end)
- Takagi : L = 49.13 km (129.67 km to other end)
- Modified Takagi : L = 51.32 km (127.48 km to other end)
- Ziegler : L = 47.34 km (131.46 km to other end)

\* Two-side estimation methods:

- Pos. Sequence : L = 39.80 km (139.00 km to other end)
- Neg. Sequence : L = 47.36 km (131.44 km to other end)
- Zero Sequence : L = 41.76 km (137.04 km to other end)
- STER Method : L = 42.53 km (136.27 km to other end)

$U_F = 132242.80 < -45.85^\circ \text{ V}$

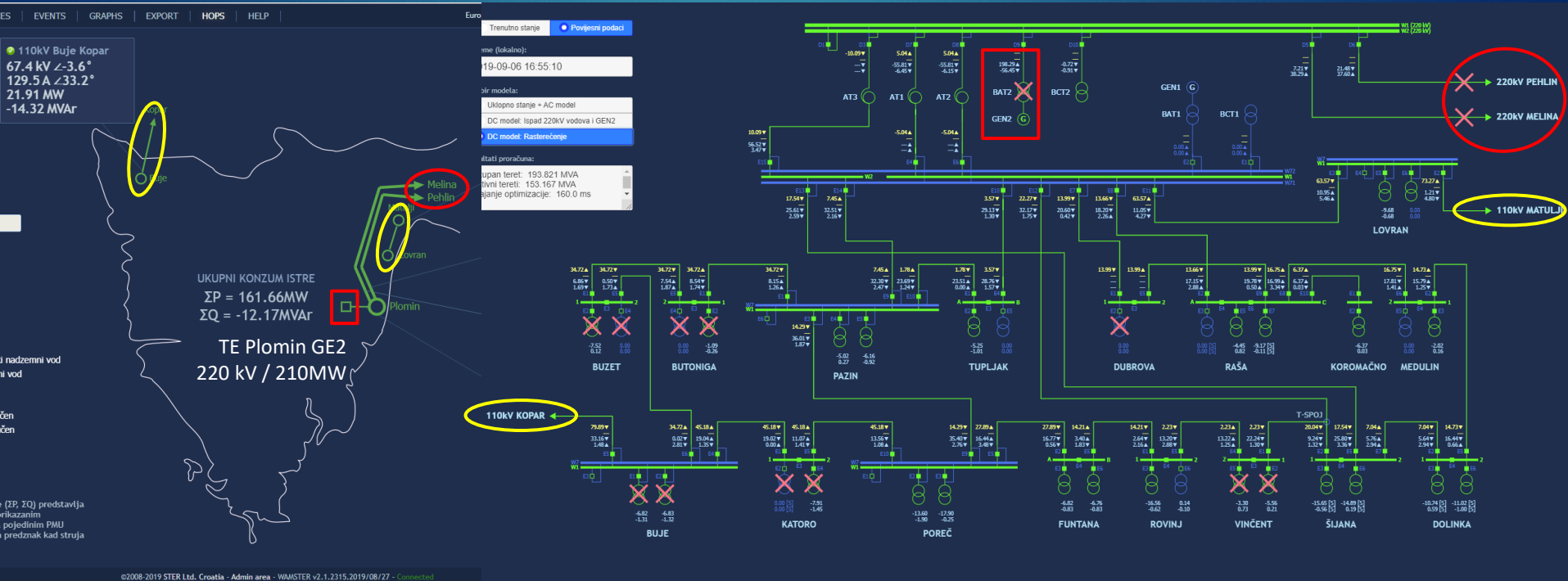
$Z_{\text{loop}} = 36.68 < 30.03^\circ \Omega$

$R_F = 15.43 < 7.09^\circ \Omega$

Event	Distance Error (%)
08.12.2020, 13:44:45:780	136.28 km 0.10%
08.12.2020, 13:21:14:720	136.45 km 0.20%
05.12.2020, 18:20:50:920	136.24 km 0.08%
04.12.2020, 22:23:52:560	136.43 km 0.18%
<b>OHL Team</b>	<b>136.1 km</b>

# Emergency load shedding Istrian peninsula

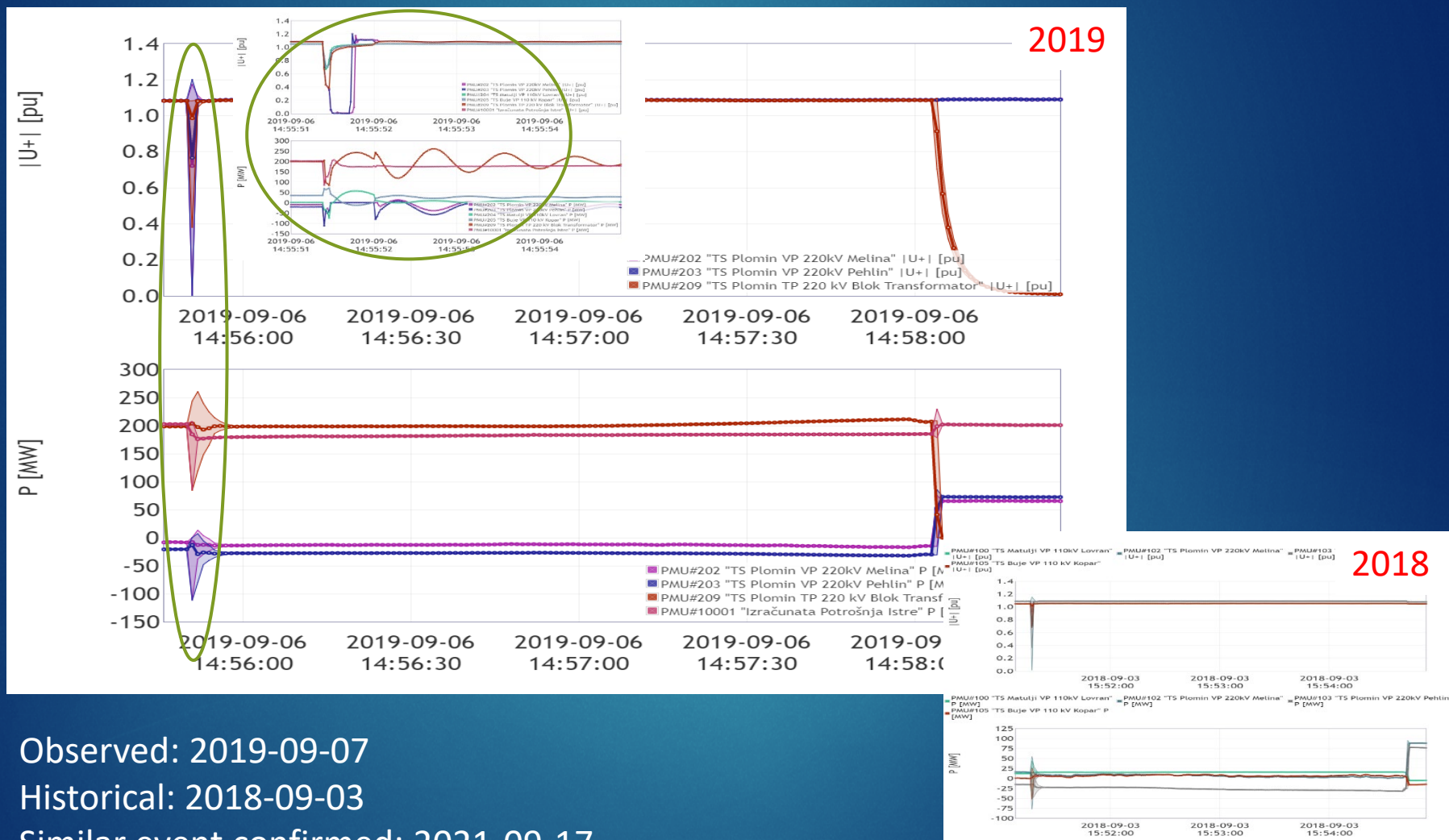
8





# Trip 2.5 min after reclosure

9

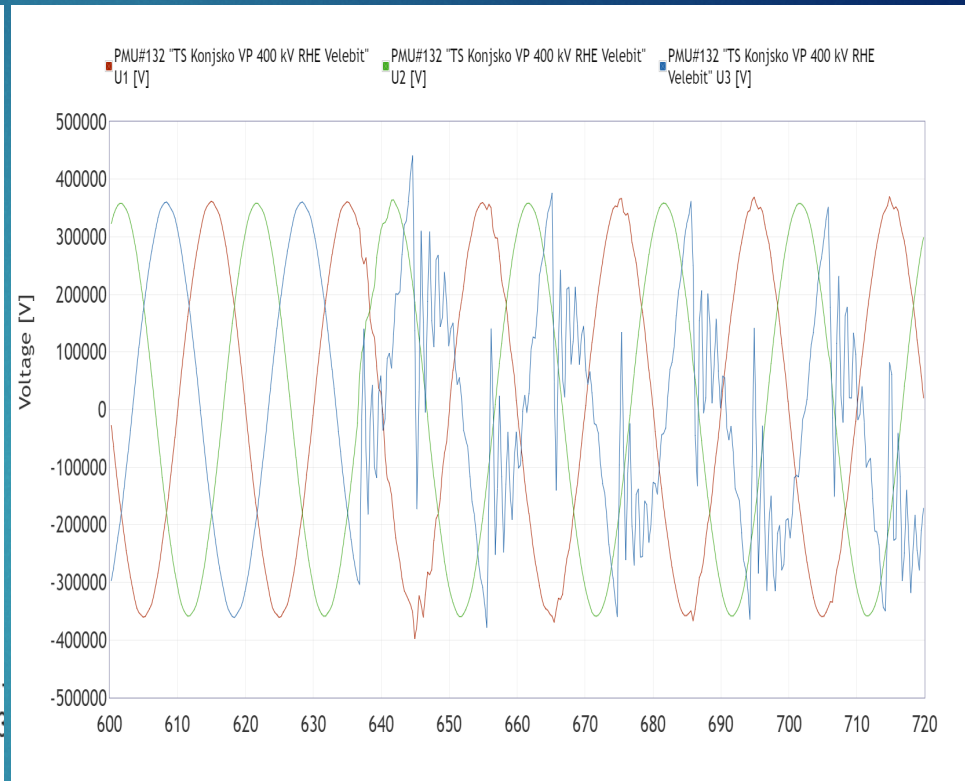
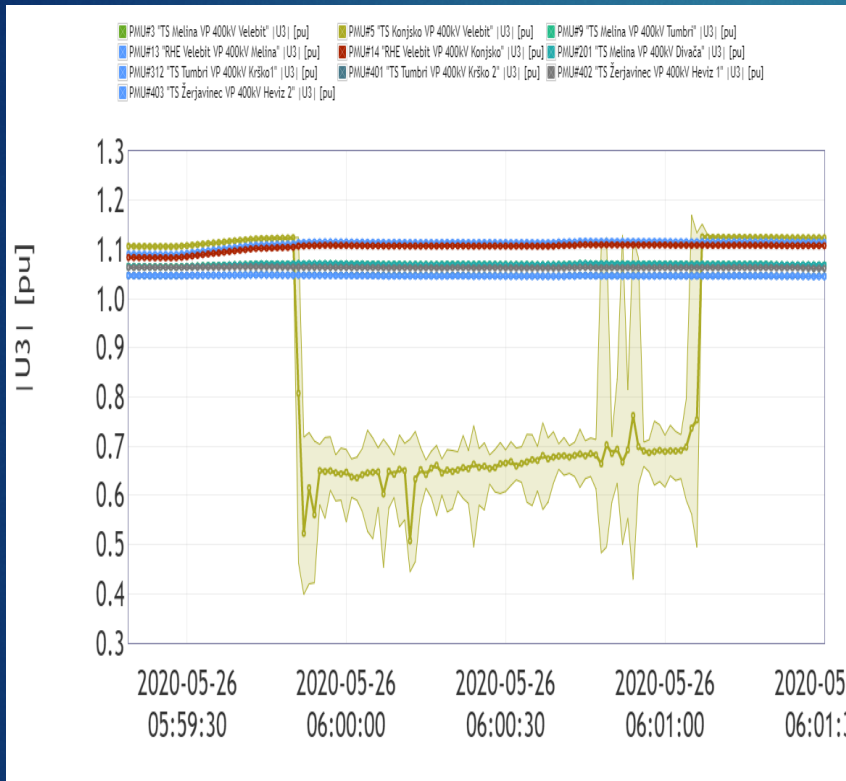


Observed: 2019-09-07

Historical: 2018-09-03

Similar event confirmed: 2021-09-17

# 400 kV PT pre-failure warning<sup>10</sup>

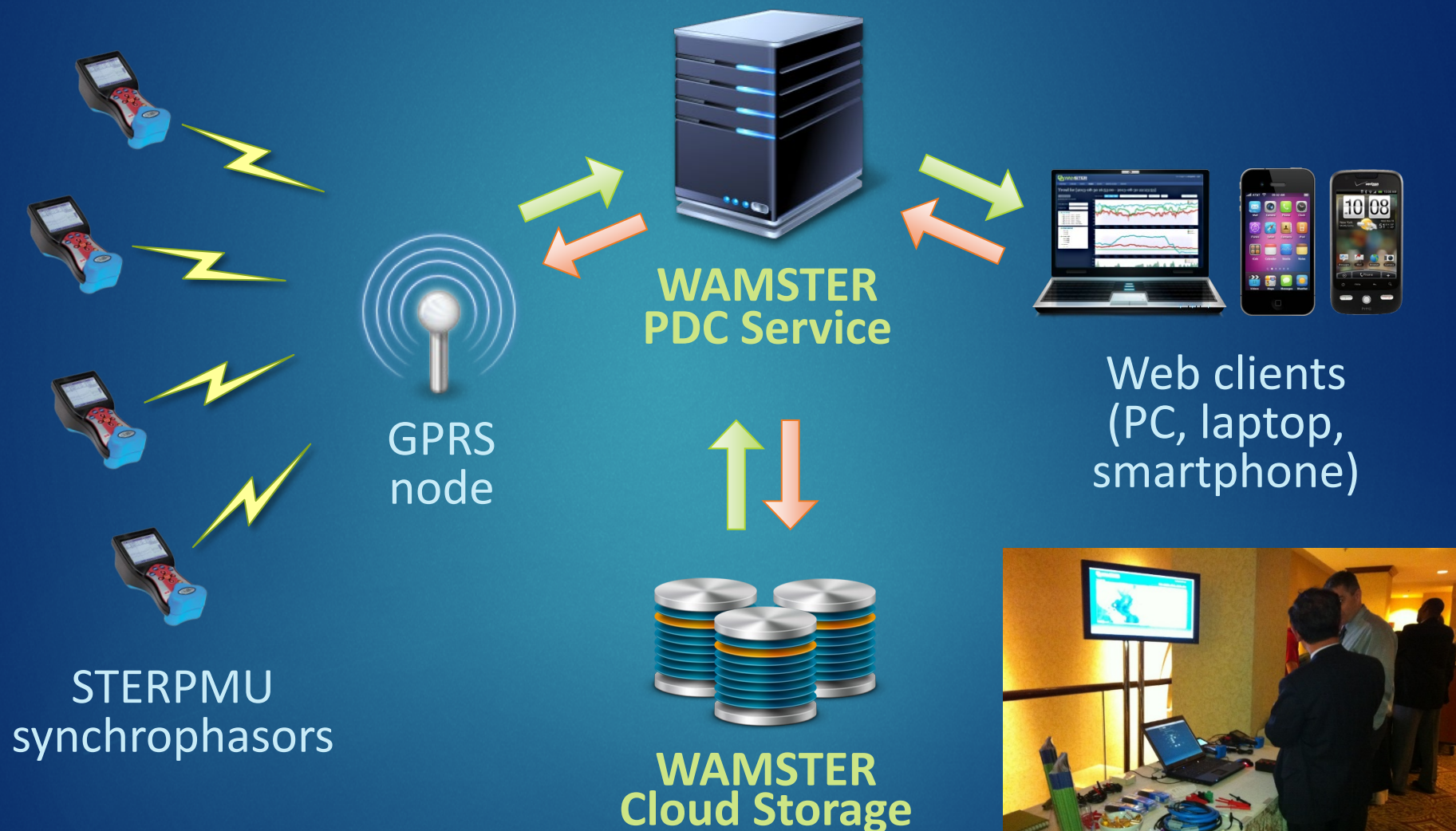


HOPS was informed about the problem in Feb. 2020.

A tripping on 15/09/2020 caused by PT deterioration was not declared as false by EMS.

400 kV PT was replaced on 18/09/2020







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## Synchrophasor Wide Area Monitoring over a **mobile network**.

- ✓ Portable phasor measurement units.
- ✓ No dedicated networking infrastructure needed.
- ✓ No dedicated server equipment needed.
- ✓ Negligible deployment costs.
- ✓ **Online since 2010.**

[→ View online demo now](#)



### Wamster Features at a Glance

 <b>Portable PMU devices</b> Lightweight, handheld PMUs with rechargeable	 <b>GPRS/Ethernet IEEE C37.118 link</b> STER PMU devices can use a custom, optimized	 <b>Deployment in 15 minutes</b> All the equipment necessary to deploy a STER PMU
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## WAMSTER web PDC service



# STERPMU

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## 2010 Portable phasor measurement unit

- 4 voltage + 4 current inputs
- 3 voltage ranges: 150/300/1000V phase
- External clamp-on current sensors (1..3000A)
- Battery backup (>4h)
- GPS, GPRS modules in set



## 2012

- 32GB flash memory, Harmonics, Continuous Waveform Recorder (CPOW)

## 2019

- GNSS, LTE, 200+ GB flash memory
- Ethernet connectivity for IEEE C37.118

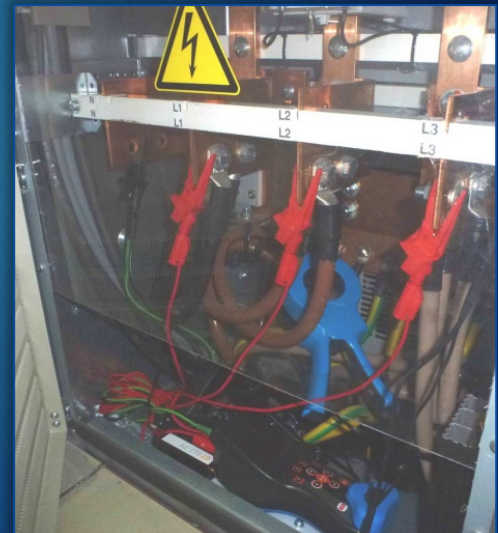
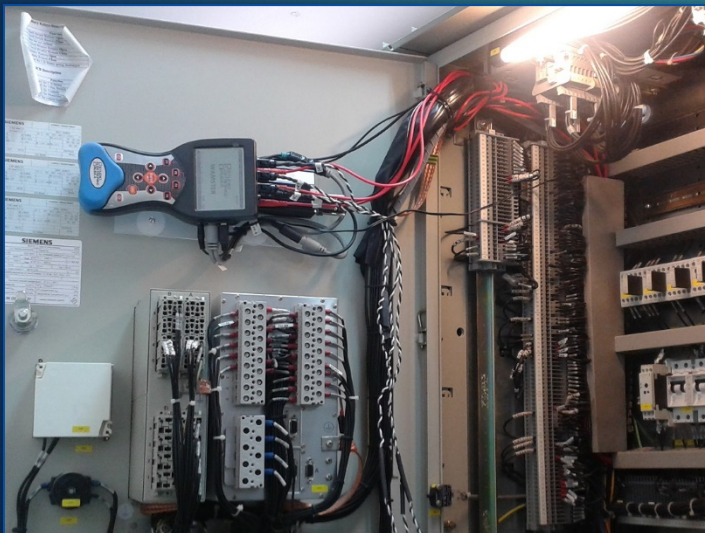
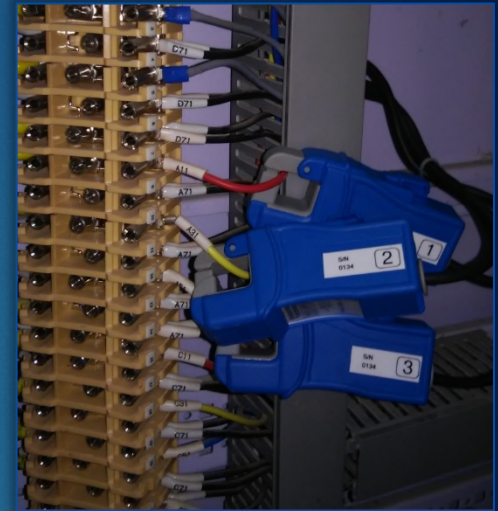




# STERPMU

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- Baseplate with magnetic fixture
- No ventilation, any orientation
- 20 minutes to PMU data on web
- 60 minutes for installation



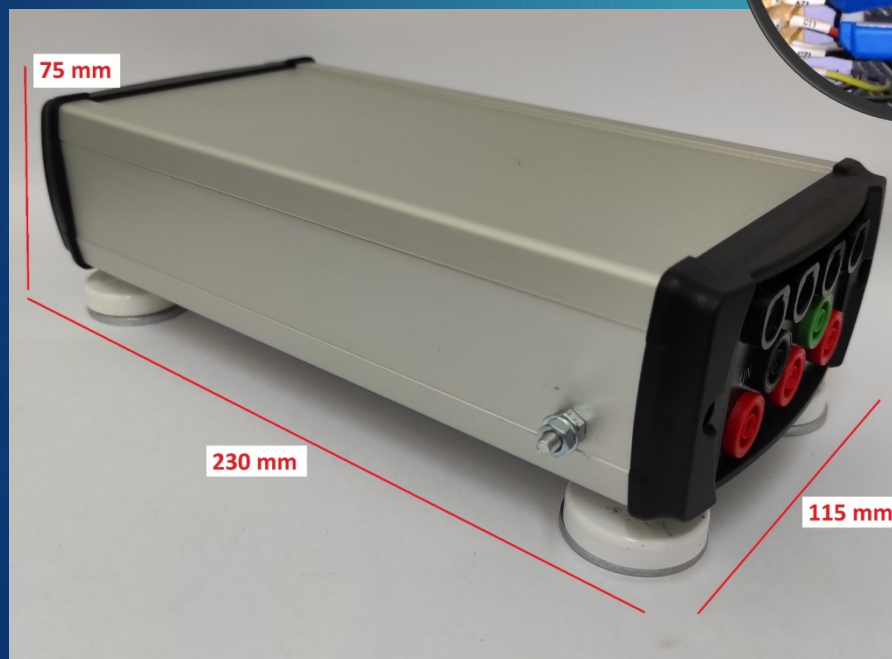


# STERPMU-Rp

15

- Integrated design
- Reduced footprint
- LTE, GNSS

- 100BASE-TX RJ45
- IEEE C37.118





# Projects 2010-2021

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- **CARWAMS, Croatia** 2010-11, 9 PMUs for University of Rijeka
- **Zagreb 110kV, Croatia** 2011-12, 6 PMUs, HEP (Croatian TSO, now HOPS)
- **Hydro North, Croatia** 2012, 4 PMUs for HEP (Croatian TSO)
- **UMEME 24/7, Kenya** 2012-13, 6 PMUs, Energynautics Germany
- **NIAF Abuja, Nigeria** 2013, Bridging SCADA demo, KU Leuven
- **RES assessment, Seychelles** 2014, 3 PMUs, Energynautics
- **Dynamic React. Compensation, UAE** 2014, 20 PMUs, TRANSCO
- **INARNR Rijeka, Croatia** 2015-19, 6 PMUs, troubleshooting, oil refinery
- **Barbados, Caribbean** Assessment of frequency and voltage, Energynautics
- **Wind turbine R&D project, India** 2015-16, 3 PMUs, PDC, POSOCO
- **200 MVA Phase shifter validation, Croatia** 2016, 6 PMUs, HOPS
- **Dynamic modelling, Oman** 2016-17, 20 PMUs, TRACTABEL & OETC
- **PFC monitoring pilot, Croatia** 2019, 2 PMUs, HOPS
- **Modular Offshore Grid, Belgium** 2019-20, 3 PMUs, Elia grid
- **ALEGRO islanding test, Belgium** 20, 3 PMUs, Elia grid
- **Crete-Peloponnese interconnector, Greece** 2020-21, 4 PMUs, IPTO
- **Polar cruiser sea trial, Croatia** 2021, 3 PMUs, PDC, Quark Expeditions



# WAMSTER POSOCO Installation

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KALADUNGAR  
JAISALMER, RAJASTHAN

0.69 / 33 kV

33 / 132 kV

PMU#75

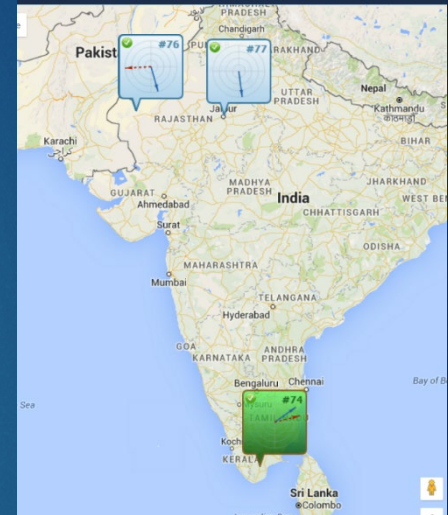
PMU#76

GPRS



NIWE, test station  
KAYATHAR, TAMIL  
NADU

PMU#74



Web  
access

IEEE  
C37.118

POSOCO  
NEW DELHI

WAMSTER

POSOCO  
PDC

PMU data

- Synchrophasors
- Waveforms
- Harmonics



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- 

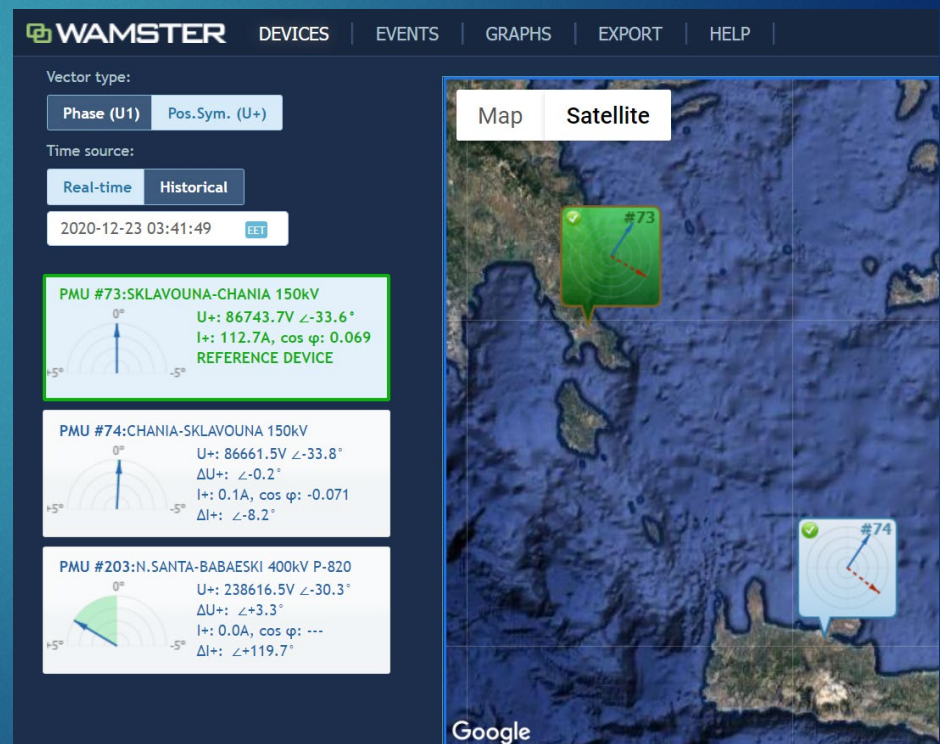




# Crete –Peloponnese interconnection

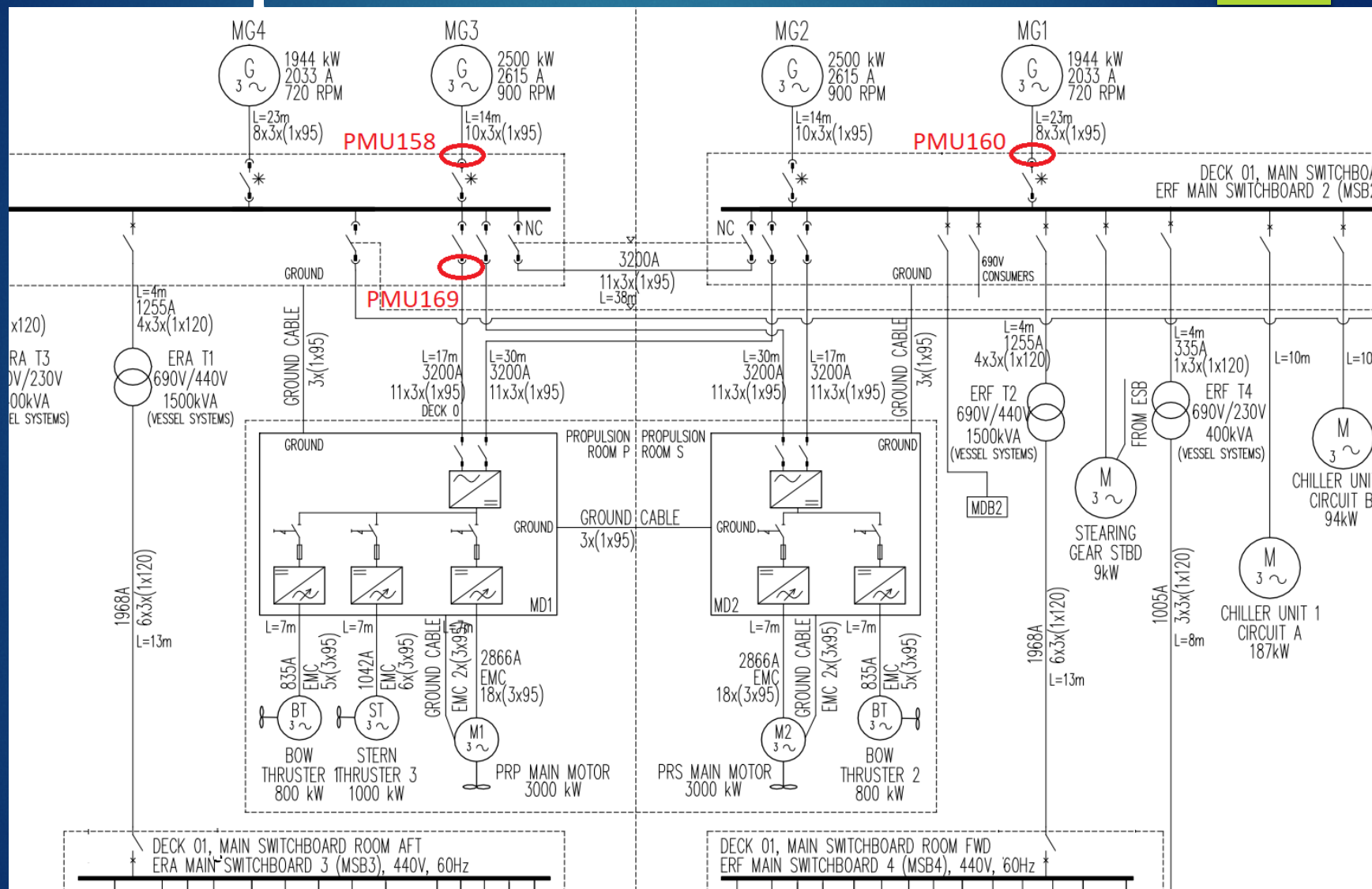
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- Phase 1: 150kV AC,  $2 \times 200\text{MVA}$  ( $\sim 2 \times 140\text{MW}$ )
- Lines energized on 22/12/2020 (A) and 18/05/2021 (B)



# On a polar class cruiser

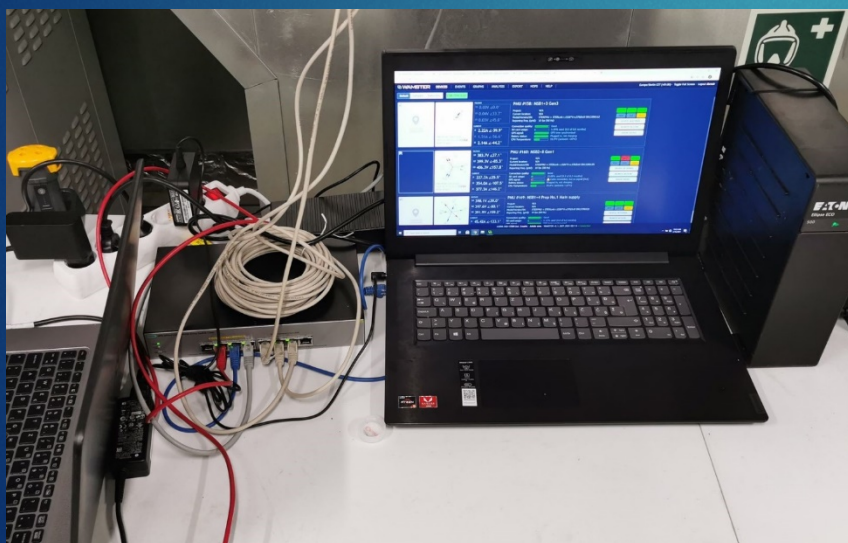
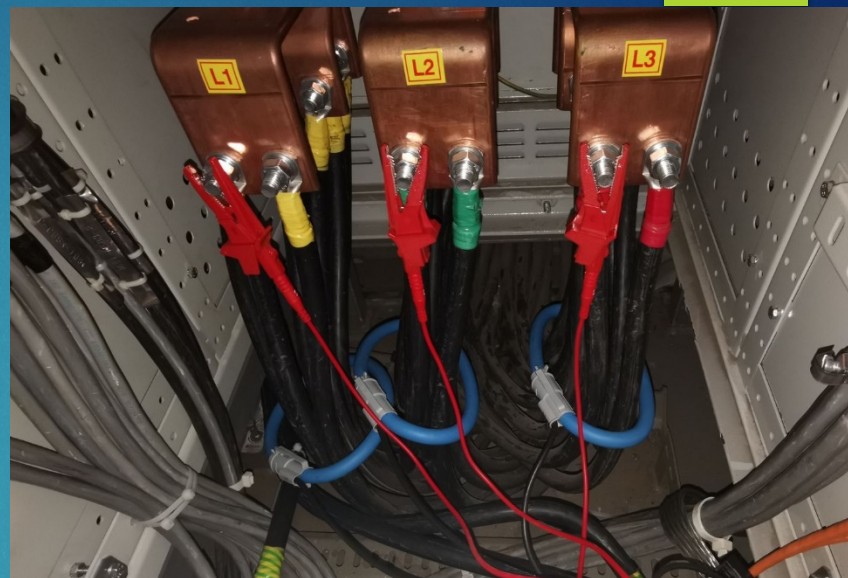
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# On a polar class cruiser

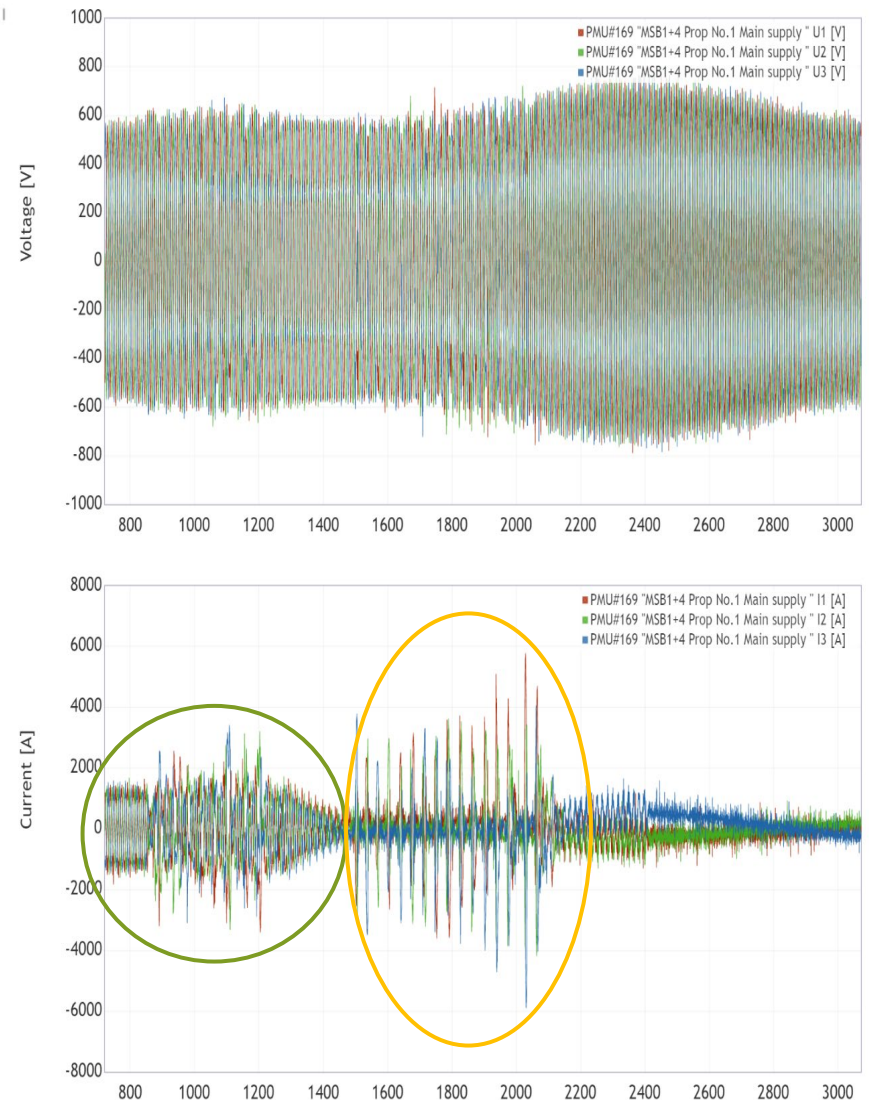
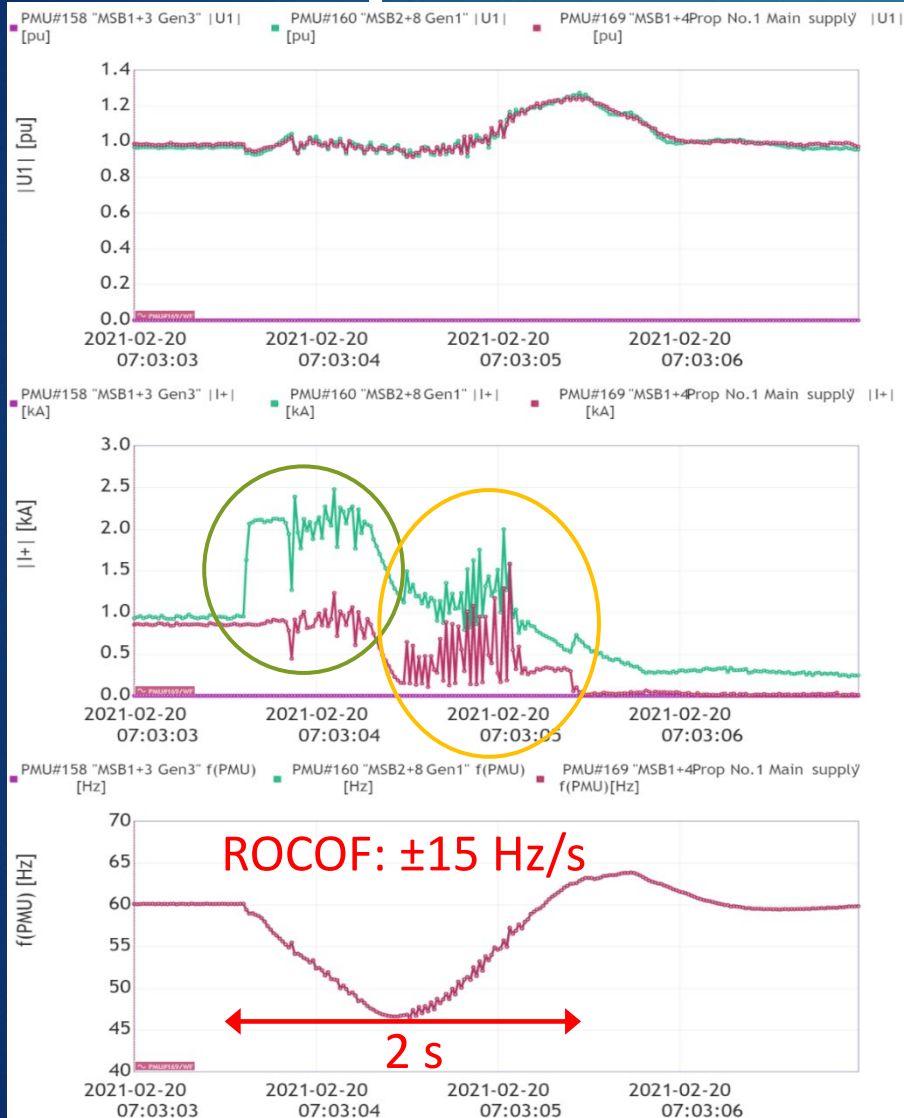
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# On a polar class cruiser

22



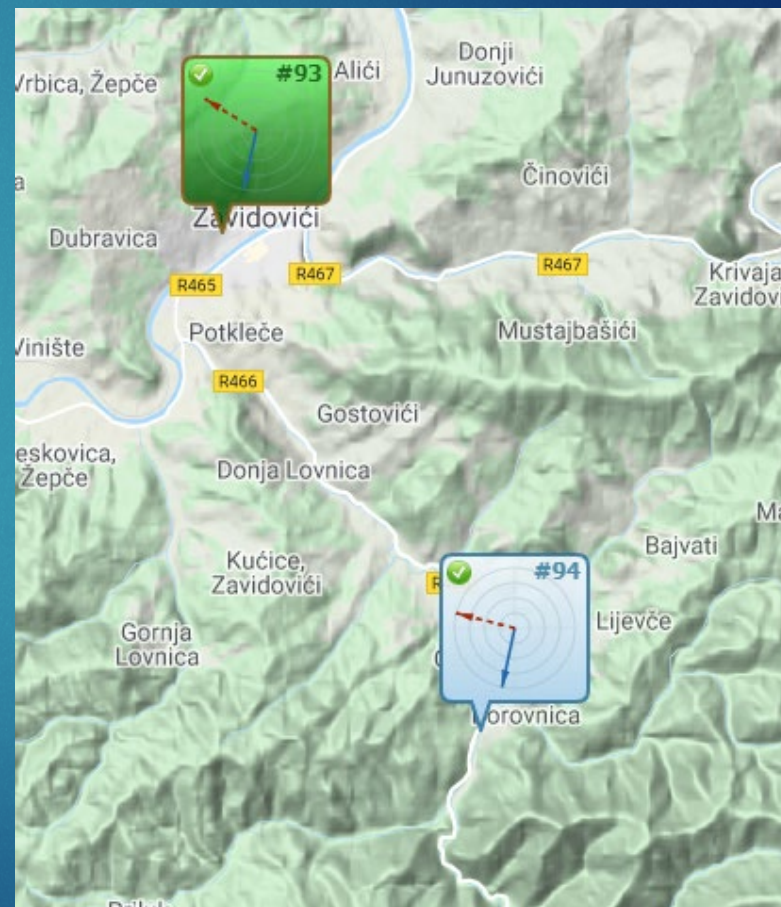


# PDC-less pilot projects

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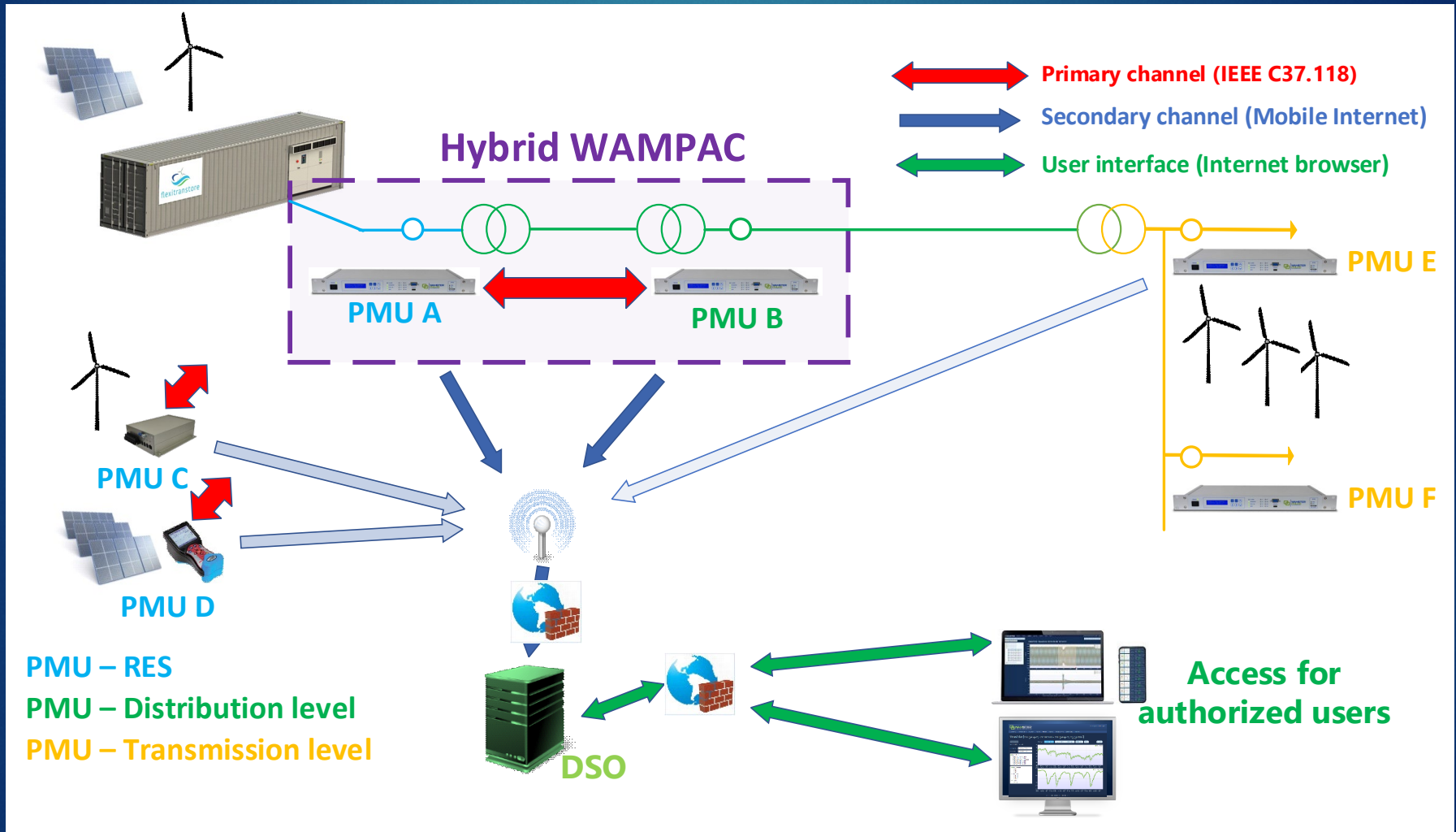
DI Slavonija / 2017  
Cogeneration (HR)

MHE Zavidovići / 2019  
Small hydro plant (BIH)



# Islanding detection

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# Contact:

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Thank you!  
Questions?