



Colombian
Independent
System
Operator

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GESTIÓN INTELIGENTE
PARA UN MUNDO MEJOR



Installing a PMU for an Underground Power Plant

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Outlook - PMU for an Underground Power Plant

- Our motivation
 - ❑ Reasons to install a PMU in a generation terminal
 - ❑ Extremely Low Frequency Oscillations (ELFO)
 - ❑ Need to monitor system dynamics
- Challenge description
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 - ❑ Distance from PMU and GPS antenna
- Solution requirements
 - ❑ External synchronization signal
 - ❑ Line to line voltage measurement
 - ❑ Maximum time deviation
 - ❑ Change management
- Summary



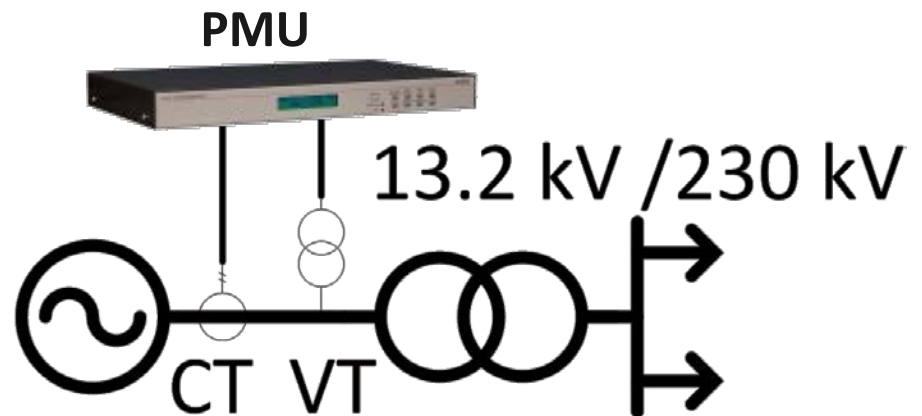
- Motivation
- Challenge
- Requirements
- Summary



Our motivation

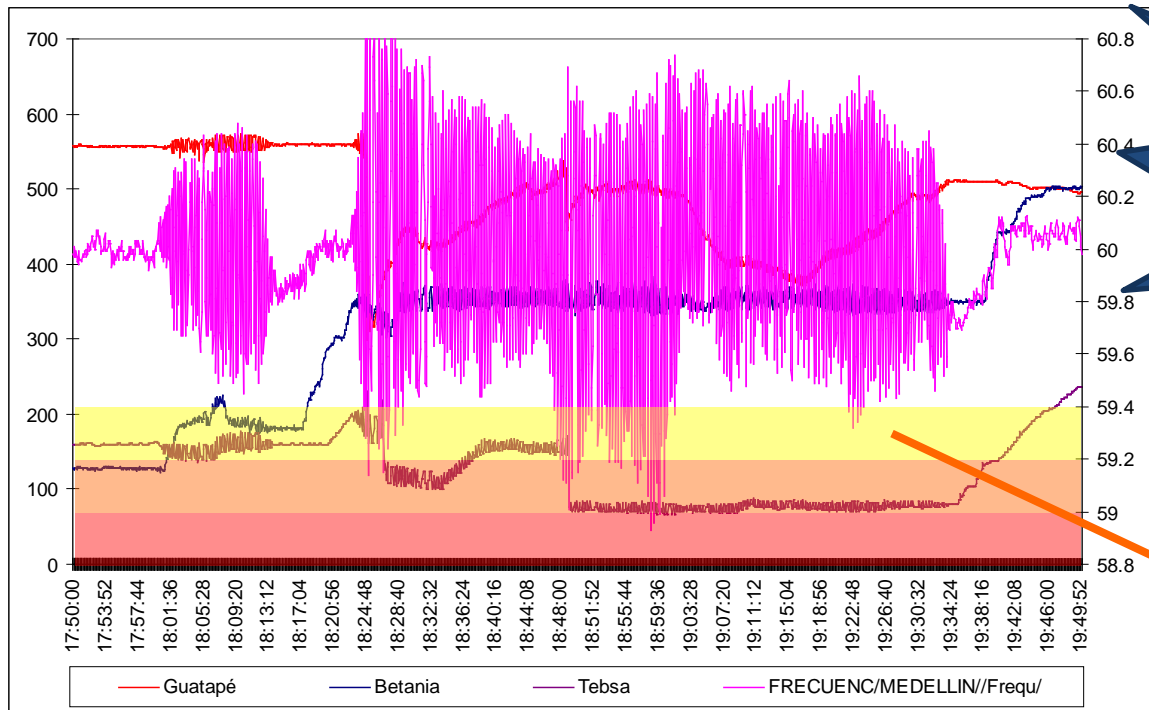
Reasons to install a PMU in a generation terminal

- Many theoretical reasons to do it
- ✓ Simulation model validation
- ✓ Capability curve validation
- ✓ Measure cavitation issues
- ✓ Oscillatory stability analysis
- ✓ PSS tuning
- ✓ Primary control adequacy
- ✓ Secondary control adequacy (AGC)



Extremely Low Frequency Oscillations – ELFO

- Almost faced another black-out in 2008, after experiencing one in 2007
- No PMUs installed in Colombia before 2008
- Need to monitor system dynamics



Not a mistake,
it was a 0.06 Hz
mode

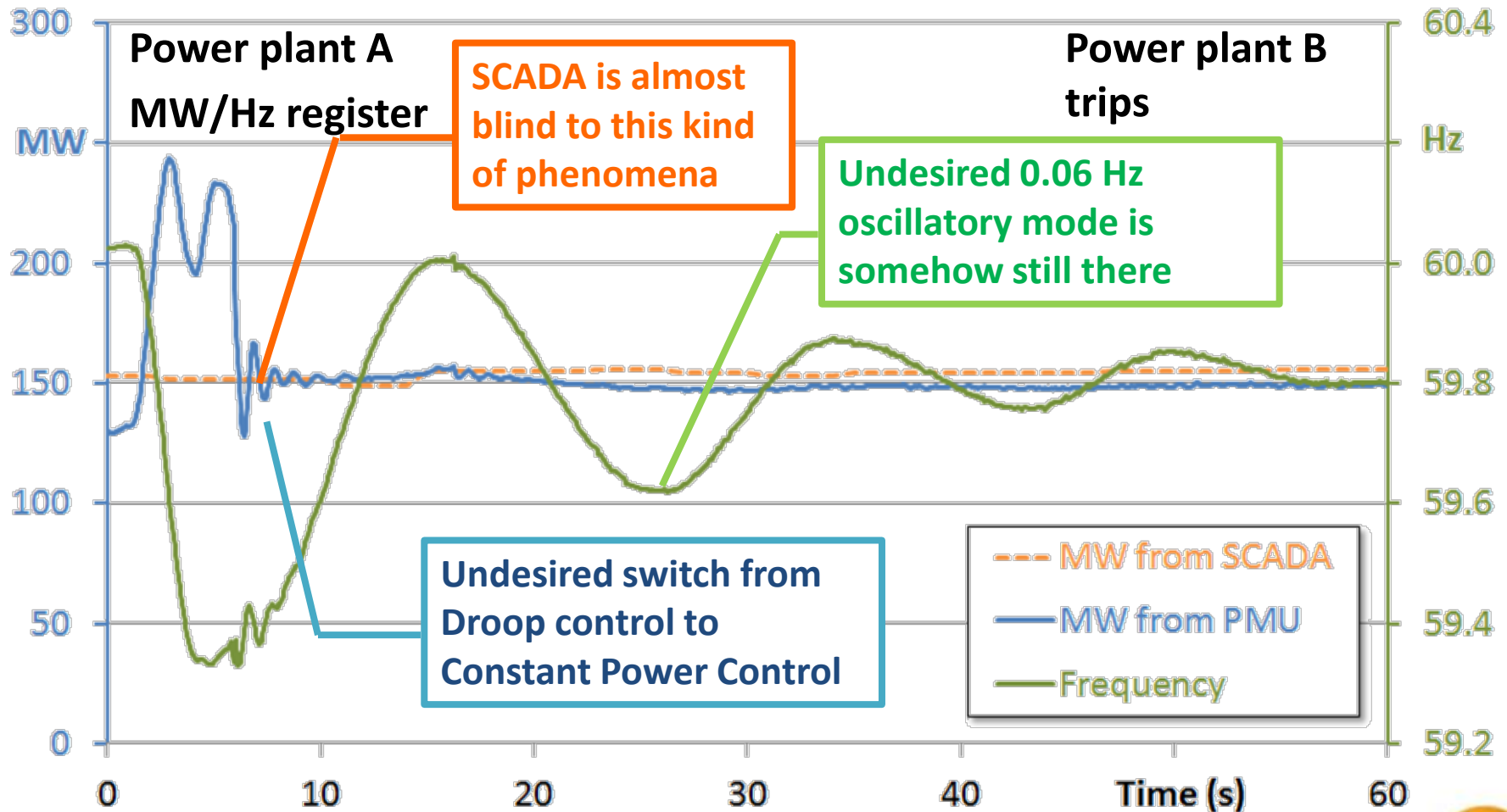
Under Frequency
Load Shedding
scheme was
triggered

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Need to monitor system dynamics

- Un-expected control behavior can be pinpointed using PMUs



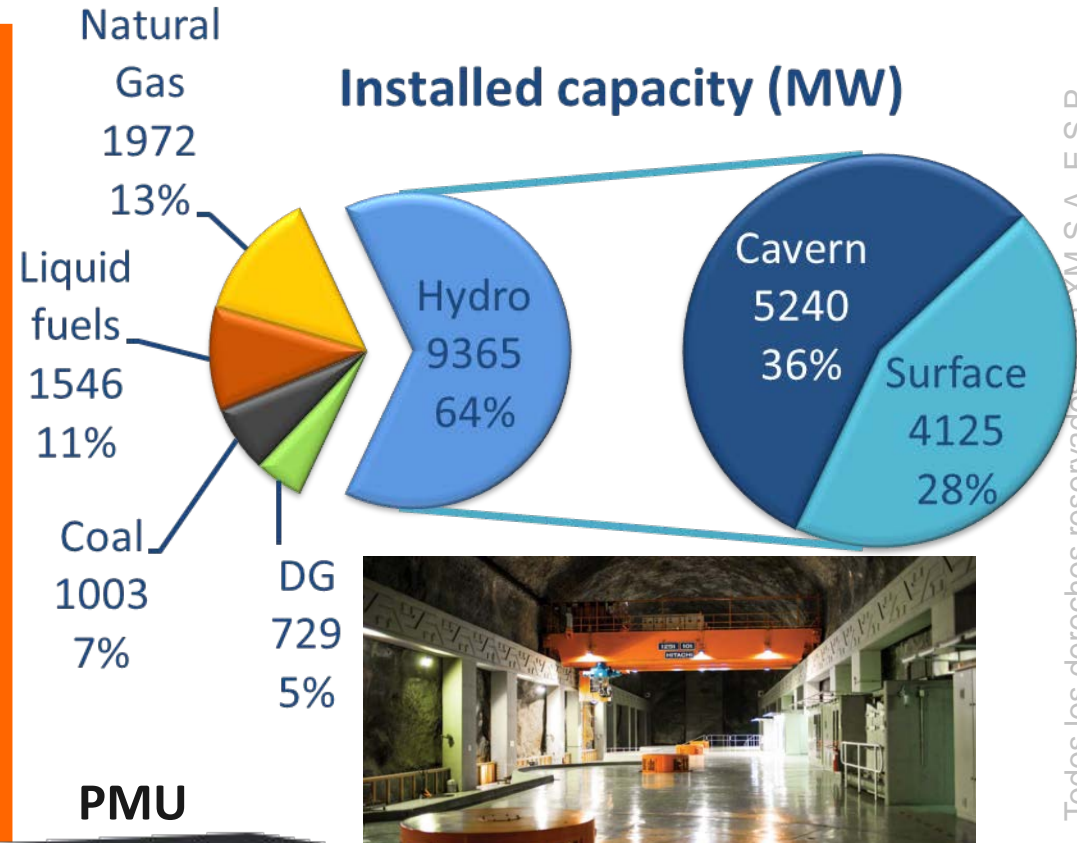
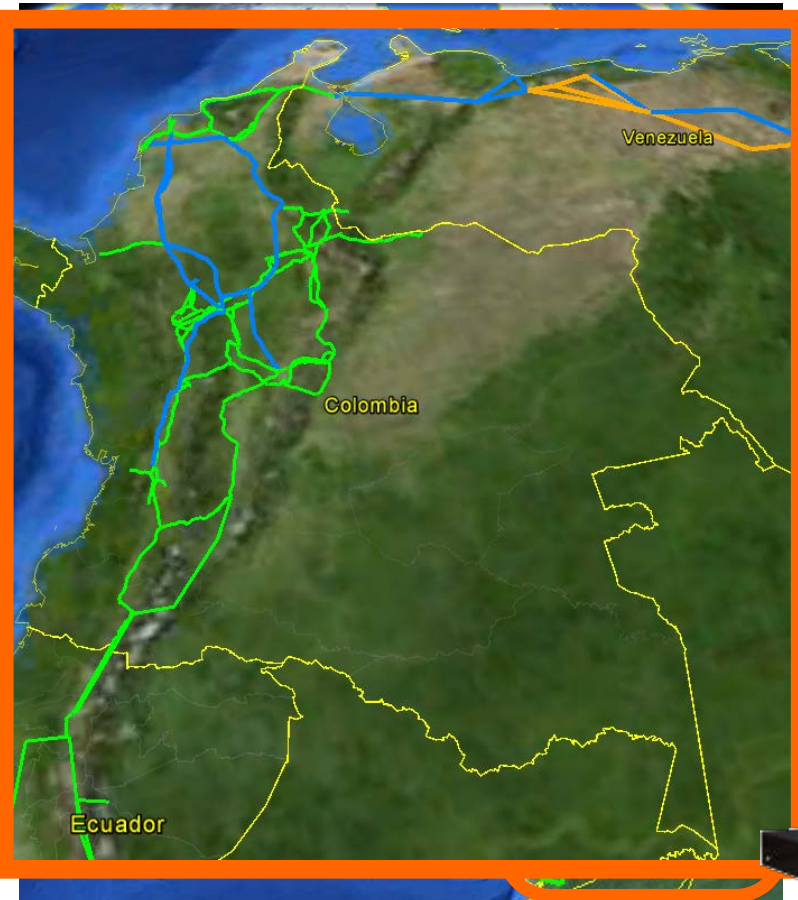
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Challenge description

Generation in Colombia

- Over one third of the generation capacity is installed underground
- PMUs should be also installed underground



Source: Isagen

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Distance from PMU and GPS antenna

- In an underground facility, the maximum recommended distance between the GPS antenna and the PMU can't be met straight forward

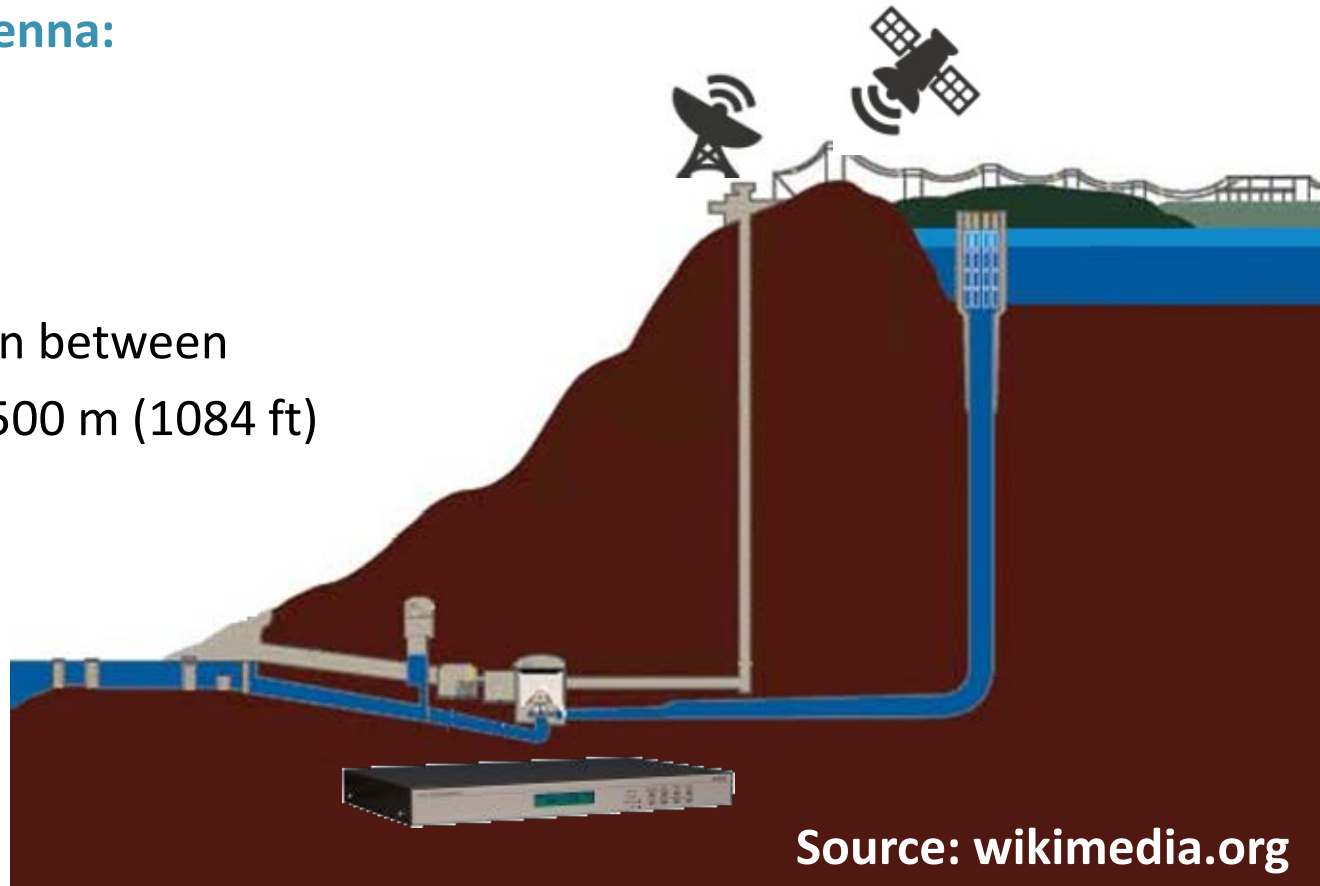
GPS antenna:

Surface



In between
500 m (1084 ft)

PMU:
Cavern



Source: [wikimedia.org](https://commons.wikimedia.org/wiki/File:GPS_antenna_in_cavern.jpg)



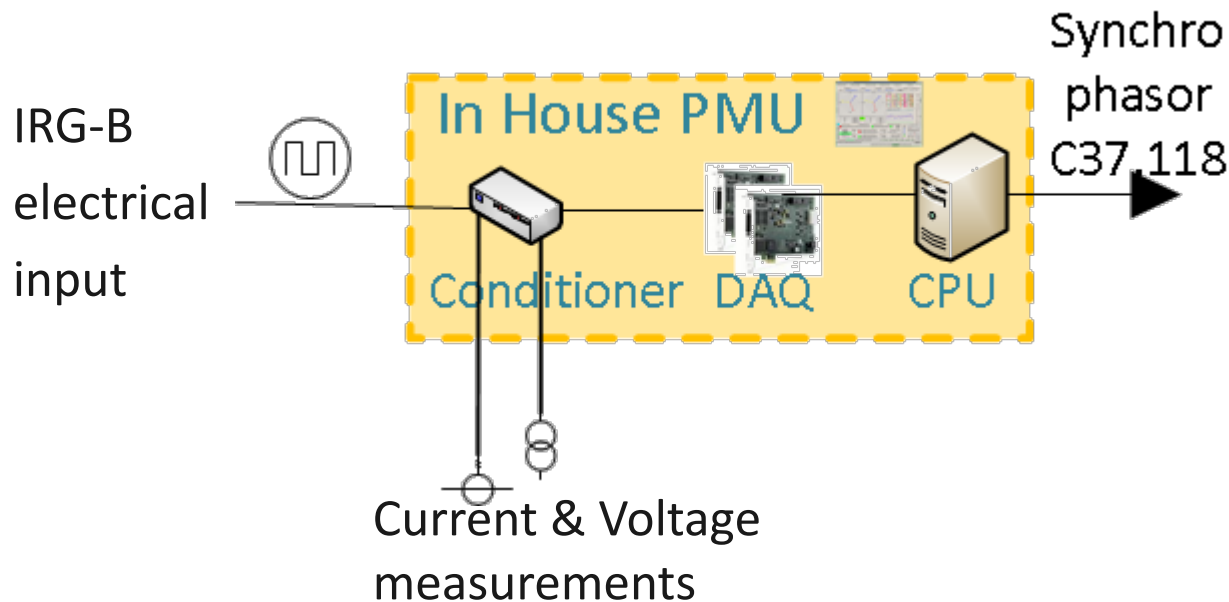
- ✓ Motivation
- ✓ Challenge
- ✓ Requirements
- Summary



Solution requirements

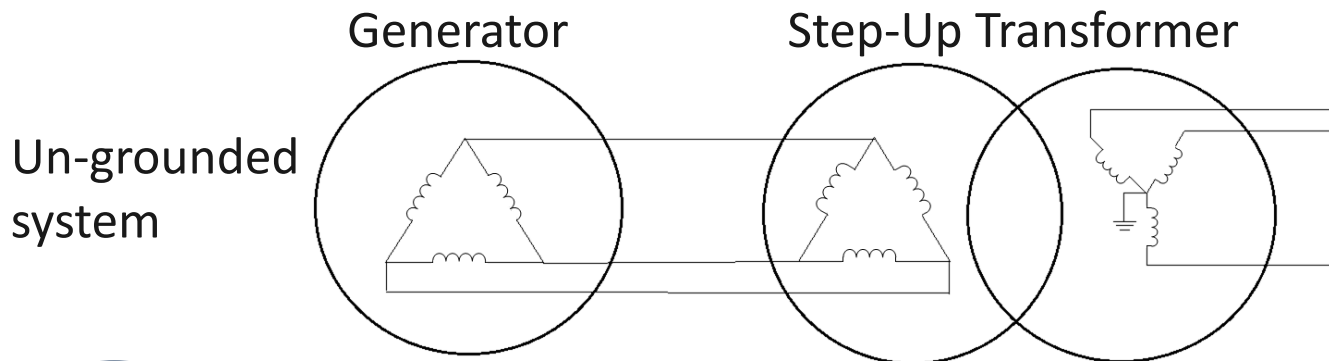
Req. 1: External synchronization signal

- An external synchronization signal is required (IRIG-B, PTP or others)
- We implemented an “in-house” PMU as an adaptable device to be used as a proof of concept
- Software-based processing algorithms (LabView)

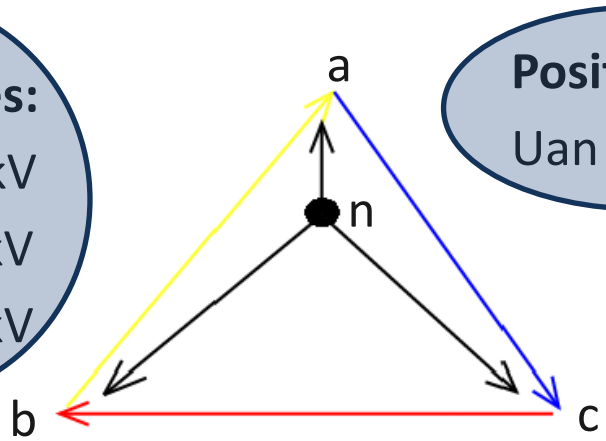


Req. 2: Line to line voltage measurement

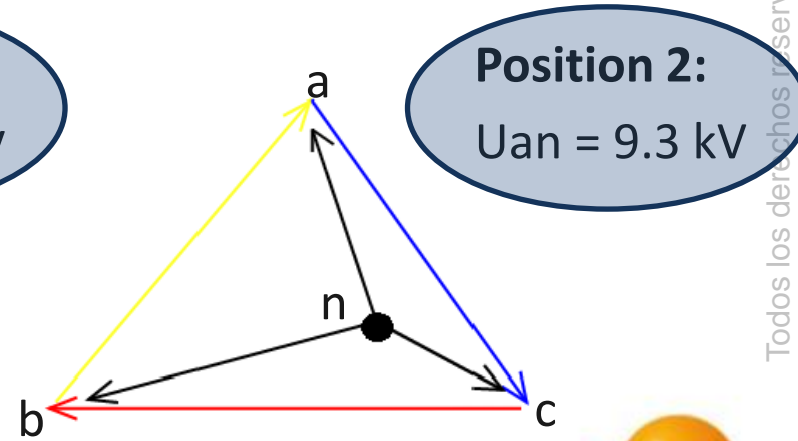
- Even with balanced line voltages, phase voltages had an erratic behavior
- Line voltage measurement avoids this phenomena
- This required a modification in the software of our “in-house” PMU



Line voltages:
 $U_{ab} = 13.2 \text{ kV}$
 $U_{bc} = 13.2 \text{ kV}$
 $U_{cd} = 13.2 \text{ kV}$



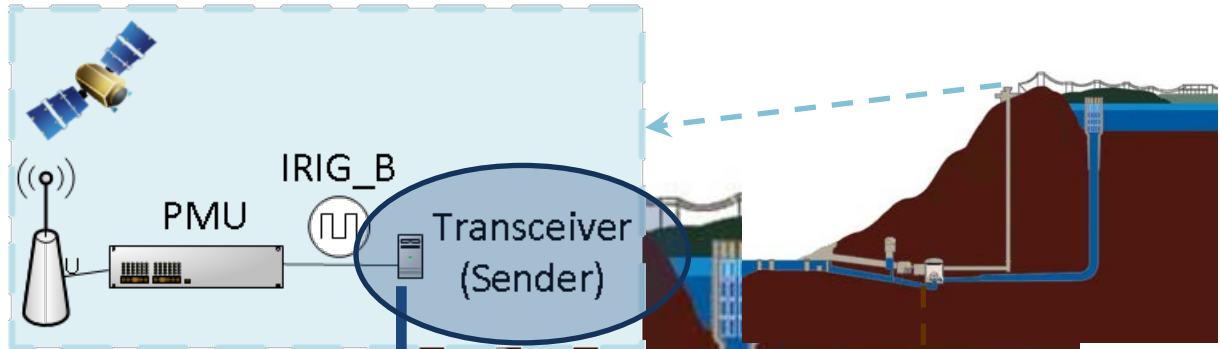
Position 2:
 $U_{an} = 9.3 \text{ kV}$



Req. 3: Maximum time deviation

- Strict requirements on time deviation and waveform quality for IRIG-B signal transmission
- Transceivers are the mayor source of time deviation

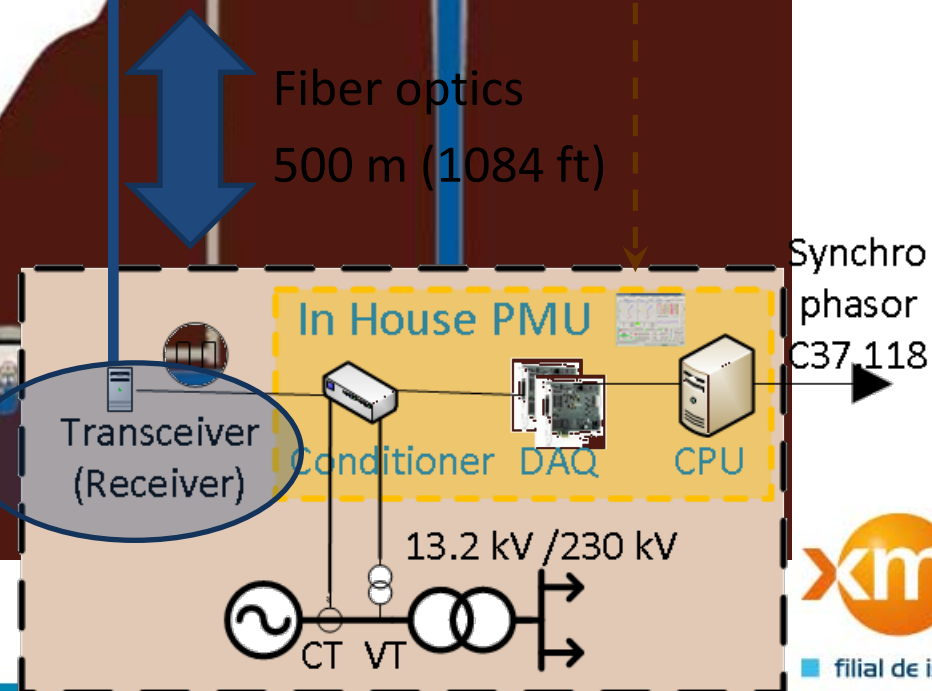
Surface



Solution	Maximum time deviation*	Minimum Angle uncertainty
Initial	15	0.6°
Operational	100	0.004°



* Per transceiver



Req. 4: Technological Change management

- Teamwork between Generation-Company (Gen-Co), hardware Vendor and the ISO is crucial



Gen-Co – EMGESA

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Colombian ISO – XM

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Colombian “EPRI” – CIDET

Neil Ortiz, neil.ortiz@cidet.org.co



- ✓ Motivation
- ✓ Challenge
- ✓ Requirements
- ✓ Summary



Summary

Summary - PMU for an Underground Power Plant

- **An external synchronization signal is required**
 - ❑ IRIG-B
 - ❑ PTP or Others
- **Line voltage measurement avoids the erratic behavior of phase voltages when a PMU is installed in an un-grounded system.**
 - ❑ It should be considered as a functional requirement for commercial PMUs
- **Strict requirements on time deviation for the synchronization signal**
- **Teamwork between the Generation-Company (Gen-Co), the hardware Vendor and the ISO is crucial.**
- **A proof of concept is always a good choice when testing out-of-the-shelf solutions**





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