Monitoreo de Líneas con PMUs y Cargabilidad Dinámica

Jornadas Técnicas de Transmisión C.N.O - 2022

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Electrical Machines & Drives

Contenido

- Introducción
- LAB+I
- Implementación piloto de PMU's
- Implementación WAMS UN
- Dynamic line rating (DLR) in overhead lines (OHL)
- Conclusiones

JORNADAS TÉCNICAS DE TRANSMISIÓN 2022

Confiabilidad, Flexibilidad y Resiliencia

> > > Retos de los Sistemas de Transporte de Energía

Introducción

Las redes inteligentes

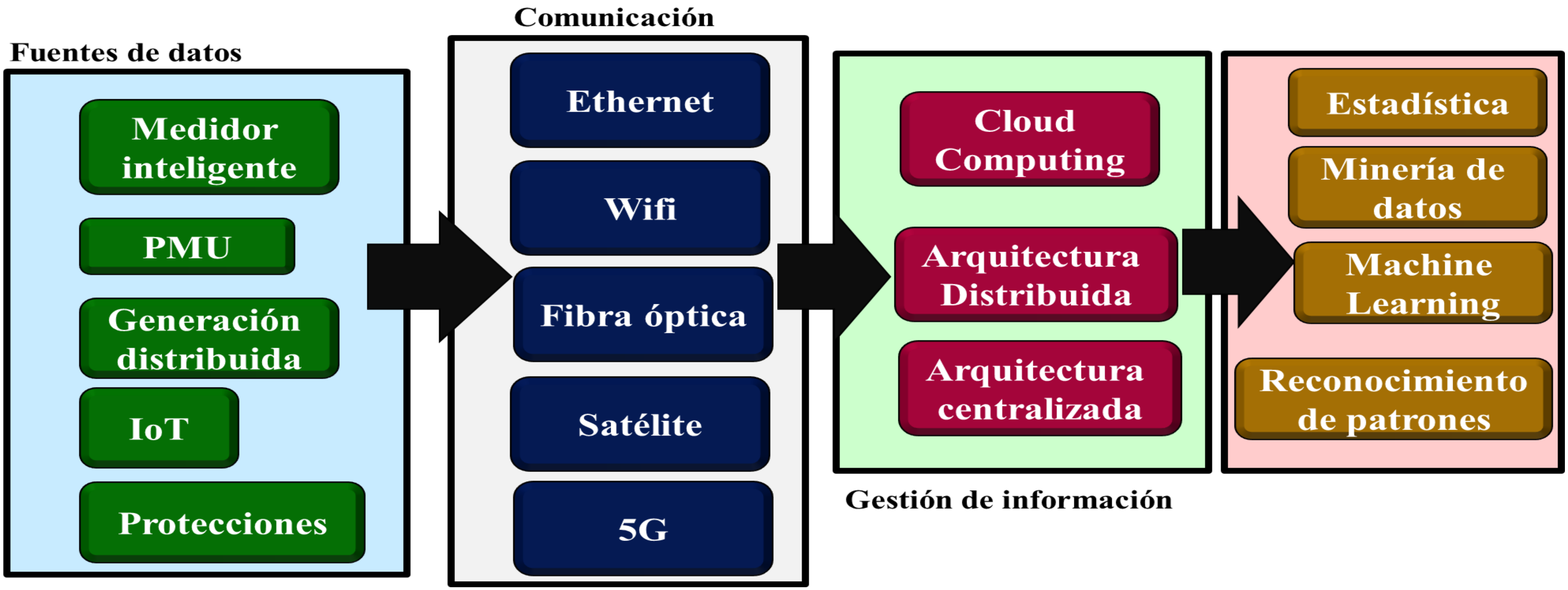
Apropiación de nuevos conceptos

La evolución de los sistemas eléctricos de potencia obliga a la integración de nuevos conceptos dentro del día a día en la operación, gestión y monitoreo de los sistemas.

Cada vez es más común encontrar diferentes fuentes de datos en el sistema que bajo un proceso de análisis permitirá mejorar la toma de decisiones que se hace sobre el sistema.

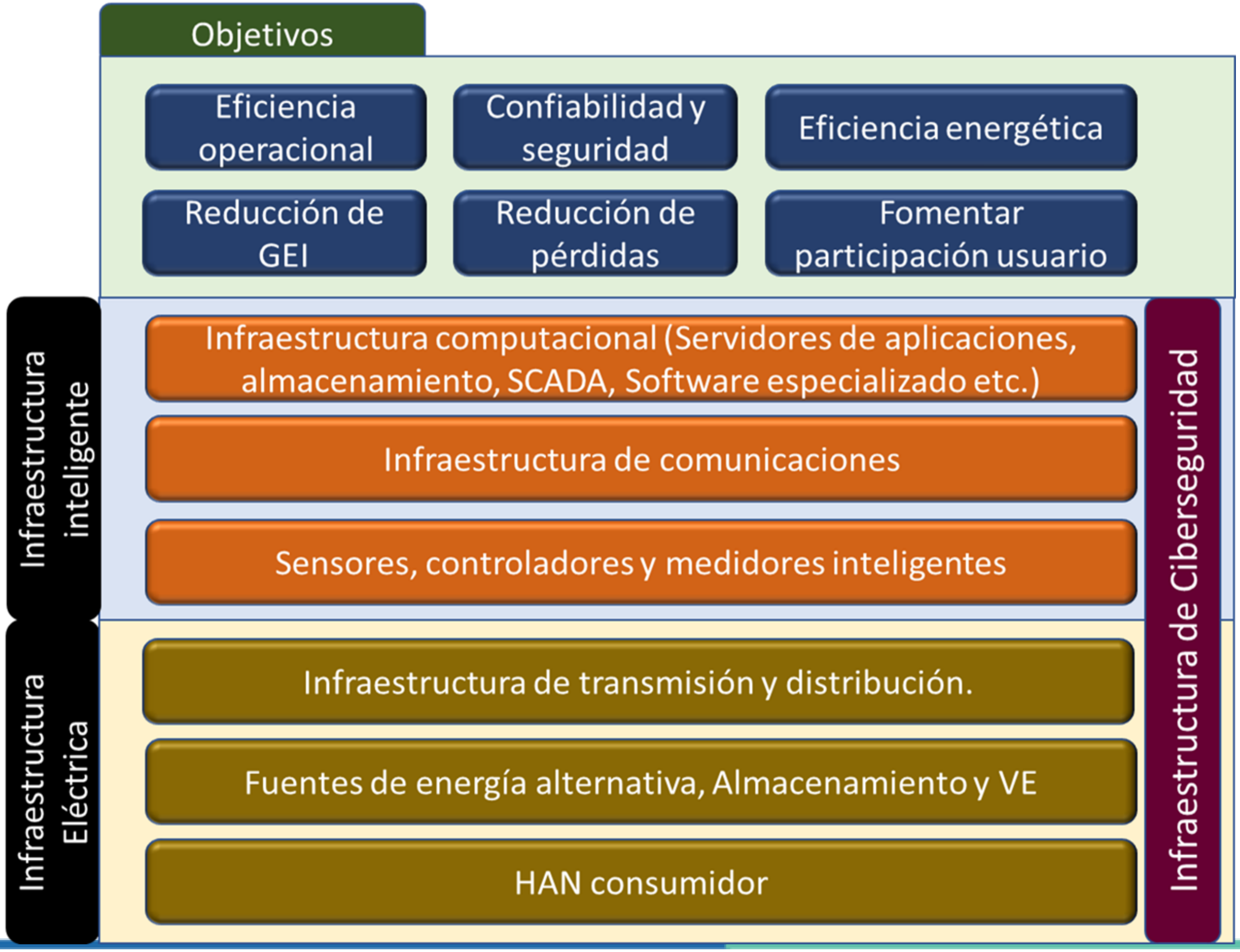
Introducción

Las redes inteligentes



Introducción

Las redes inteligentes



Interacción entre diferentes infraestructuras

Lograr explotar todos los datos requiere de la interacción de diferentes infraestructuras y coordinar todas ellas para que exista un flujo de datos que garantice el correcto funcionamiento de las aplicaciones que se van a implementar.

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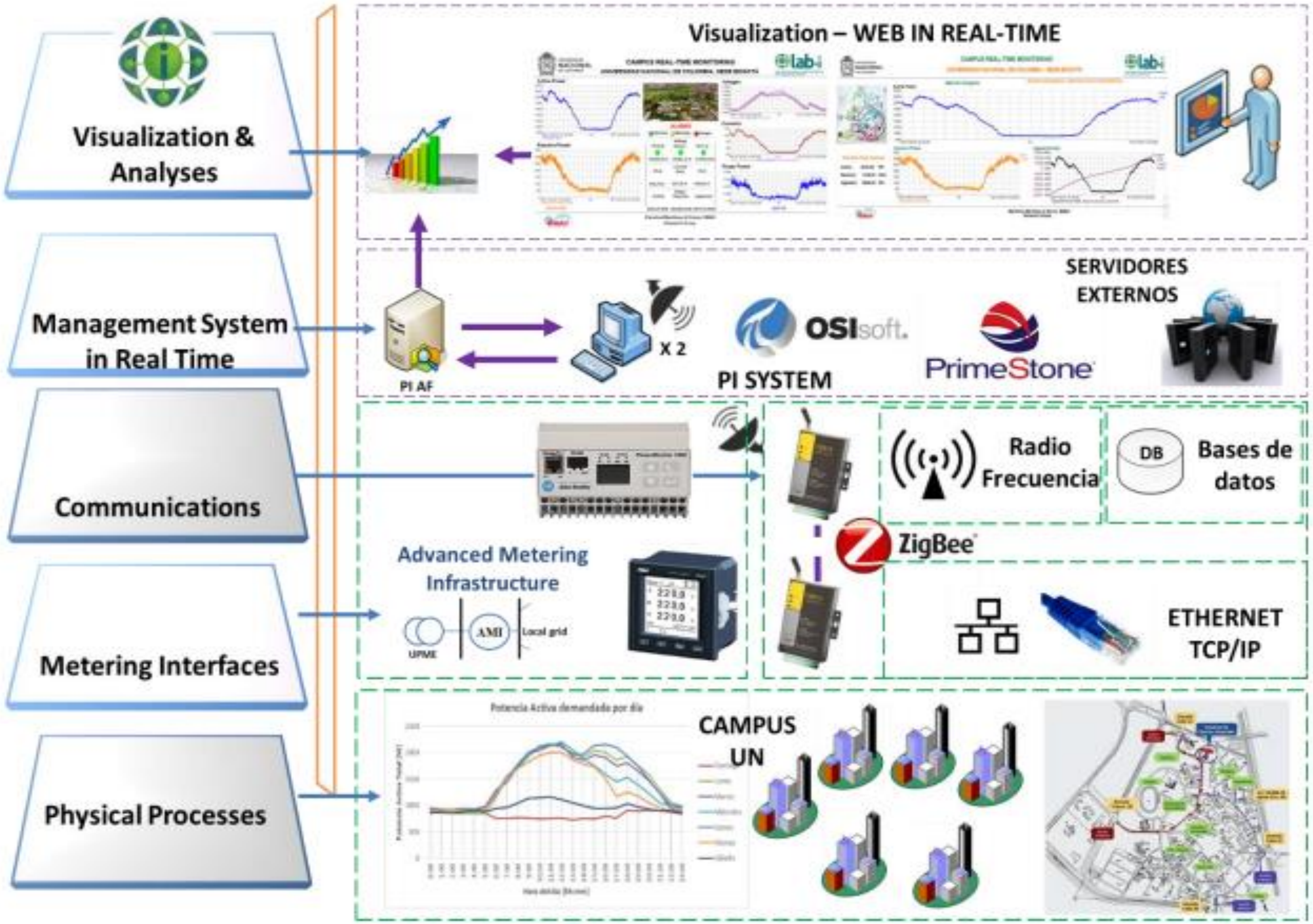
Laboratorio de redes inteligentes LAB+i

El laboratorio de redes inteligentes LAB+i proporciona una arquitectura que permite validar tecnologías de red inteligente desplegadas sobre el campus universitario. Así mismo es posible el despliegue de diferentes aplicaciones enfocadas hacia el monitoreo y control de los sistemas integrados al laboratorio



LAB+i

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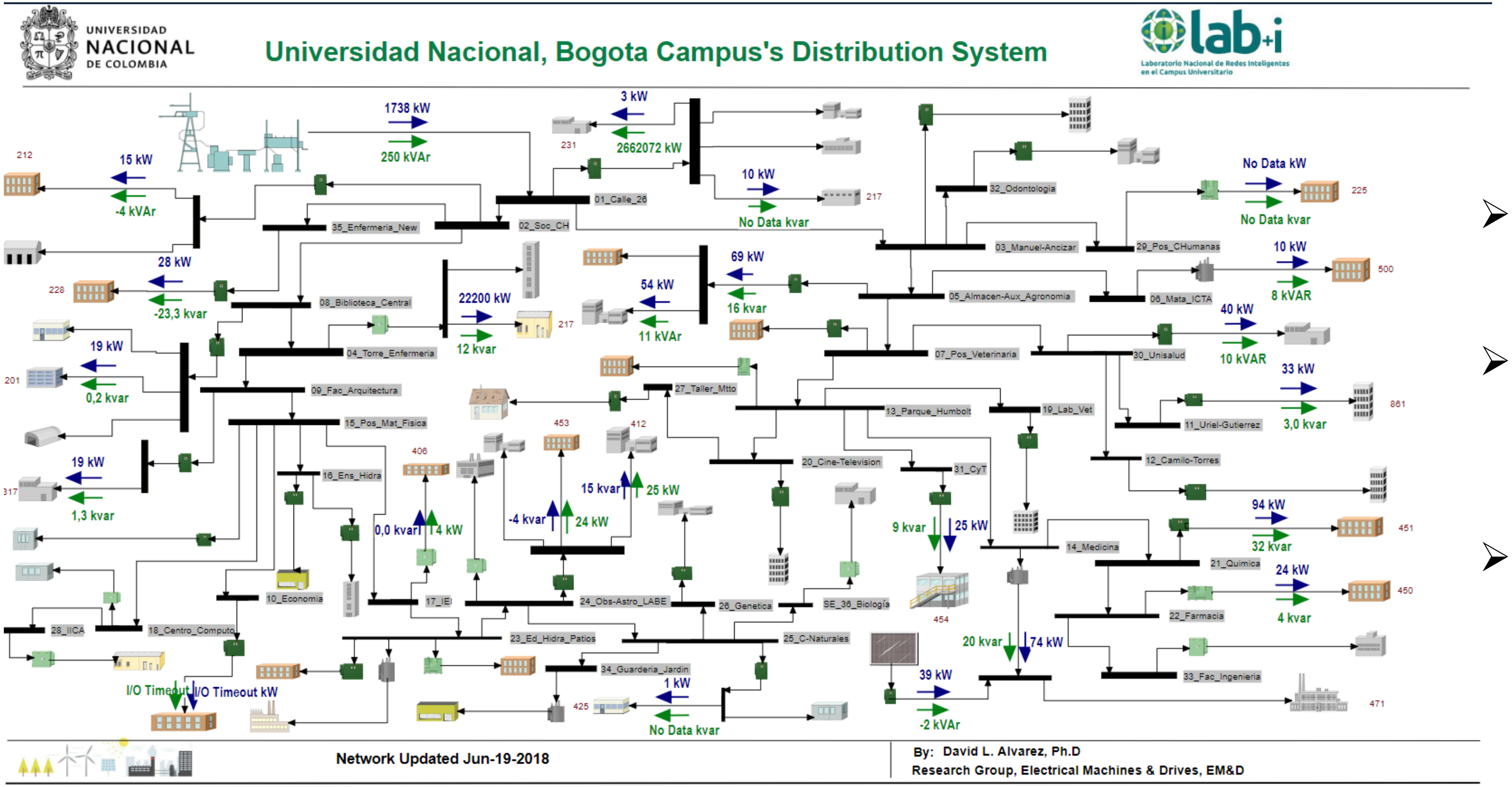

- Monitoreo de subestaciones.
- Comportamiento de los flujos de carga
- Monitoreo de generación fotovoltaica

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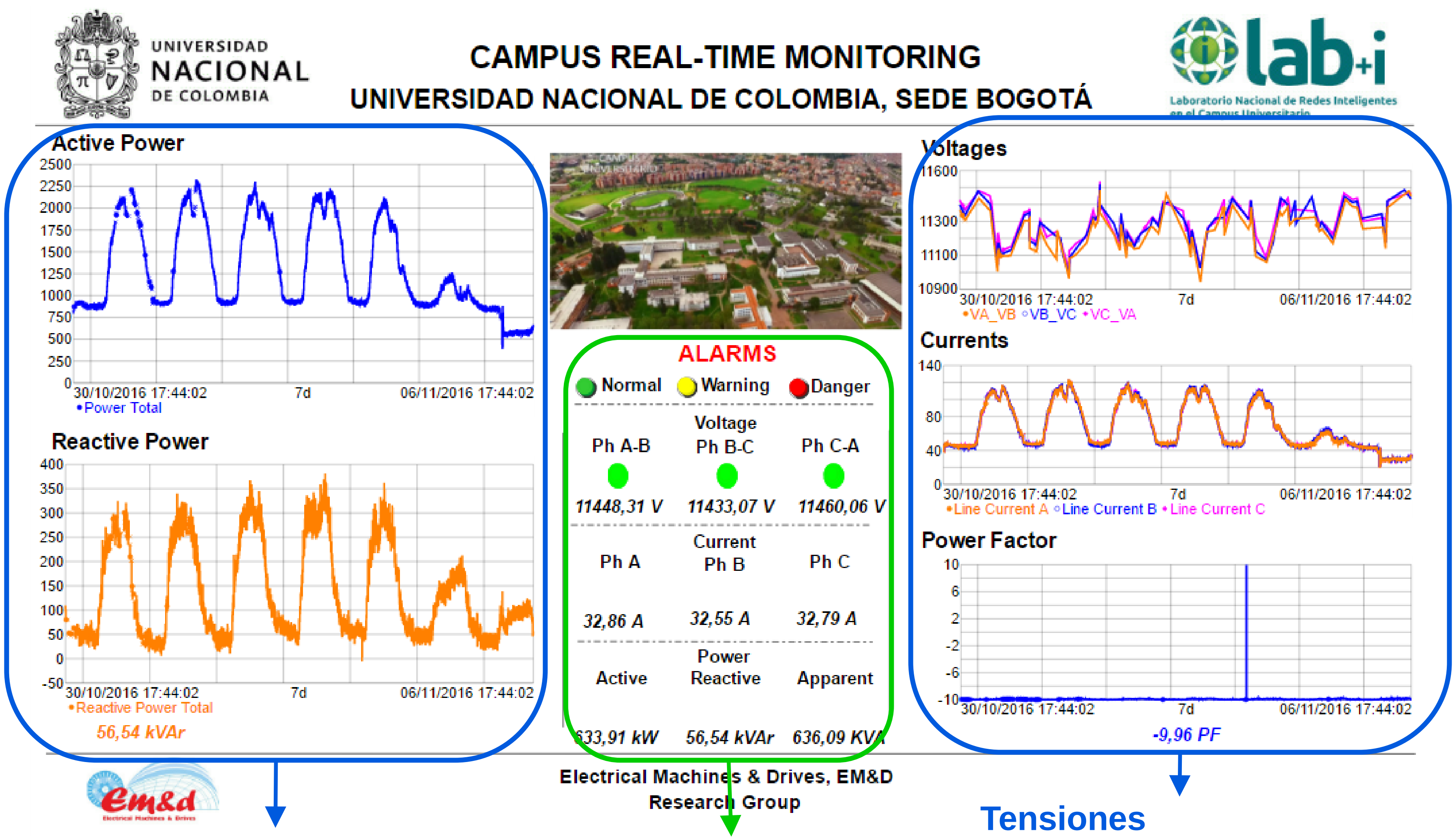
LAB+i



Potencias Activa y Reactiva

Gestión de alarmas

Tensiones
Corrientes
Factor de Potencia

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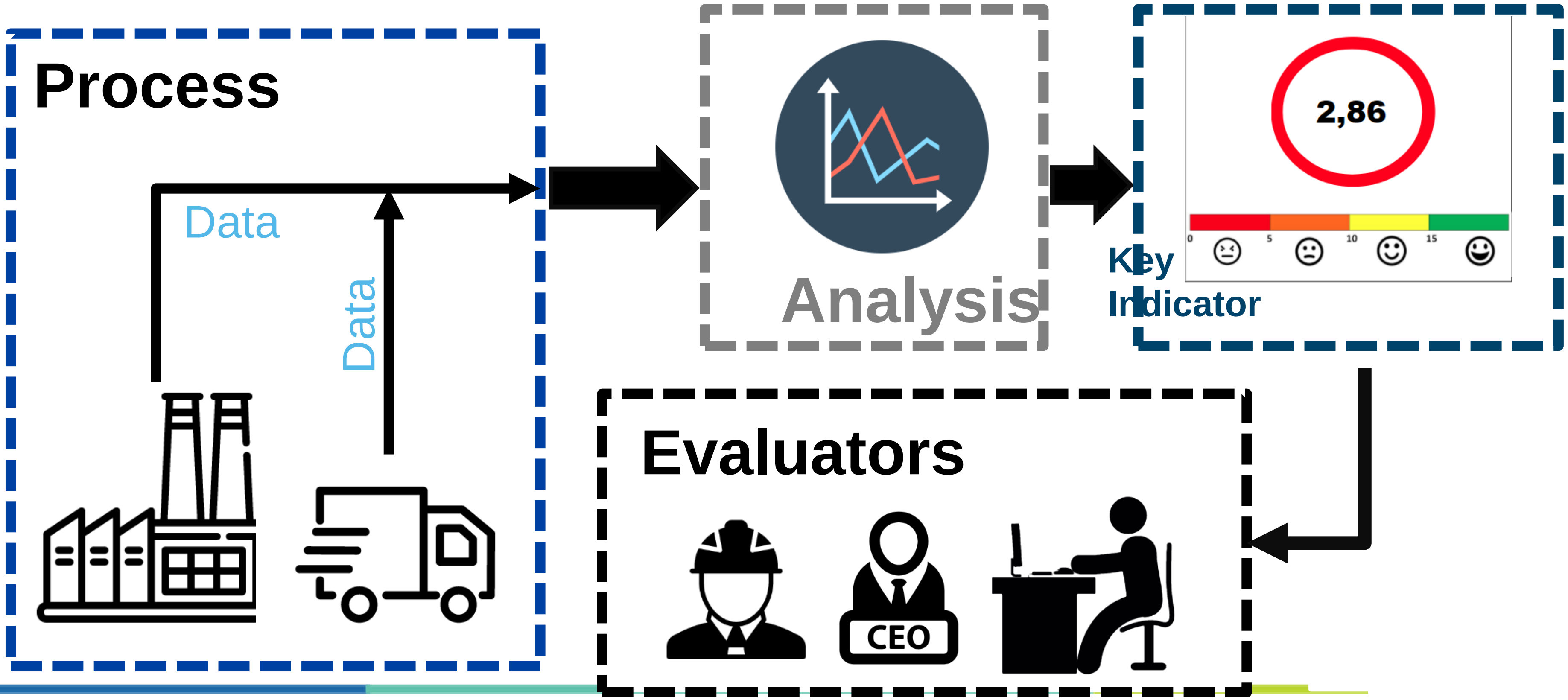
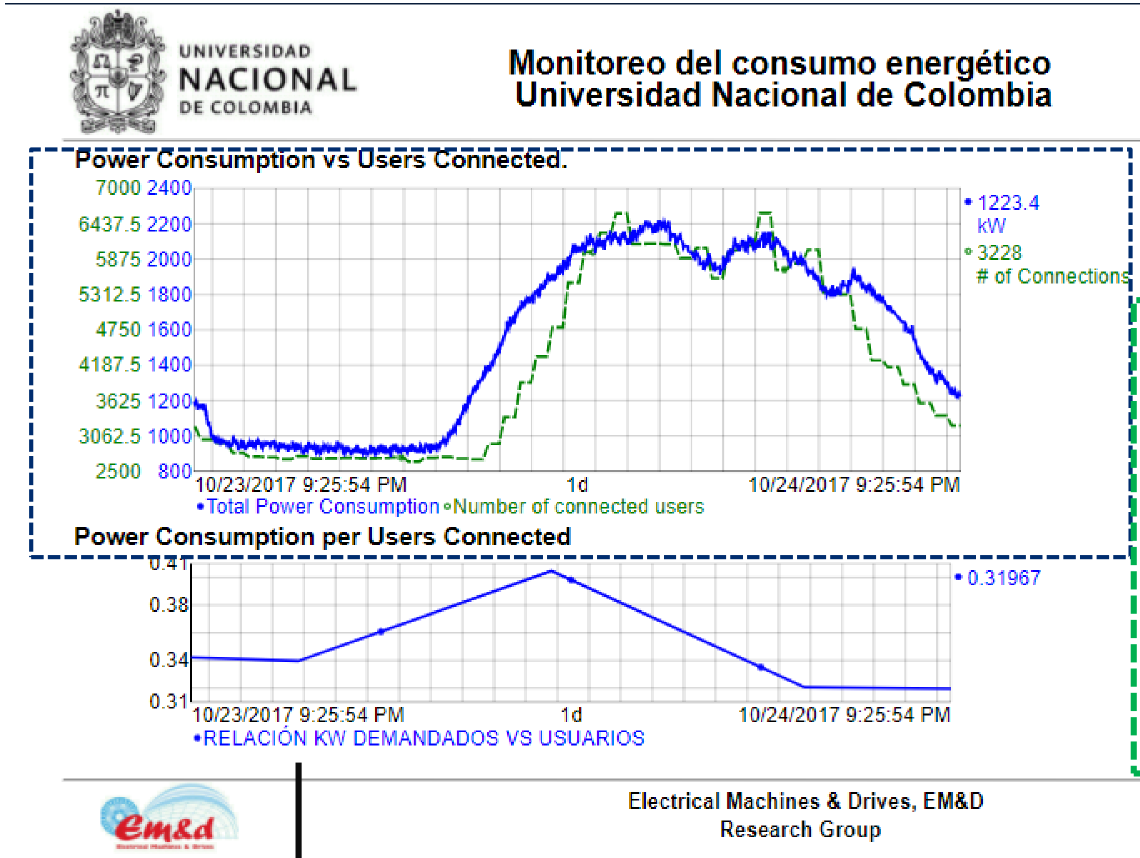
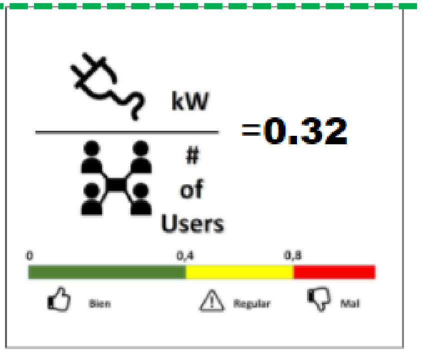
LAB+i

A partir de los datos recolectados fue posible implementar indicadores KPI (Key performance Indicator) para gestionar el sistema de mejor manera



LAB+i





KPI:

kW per Number of Internet Connections

Real-time display of KPI behavior.

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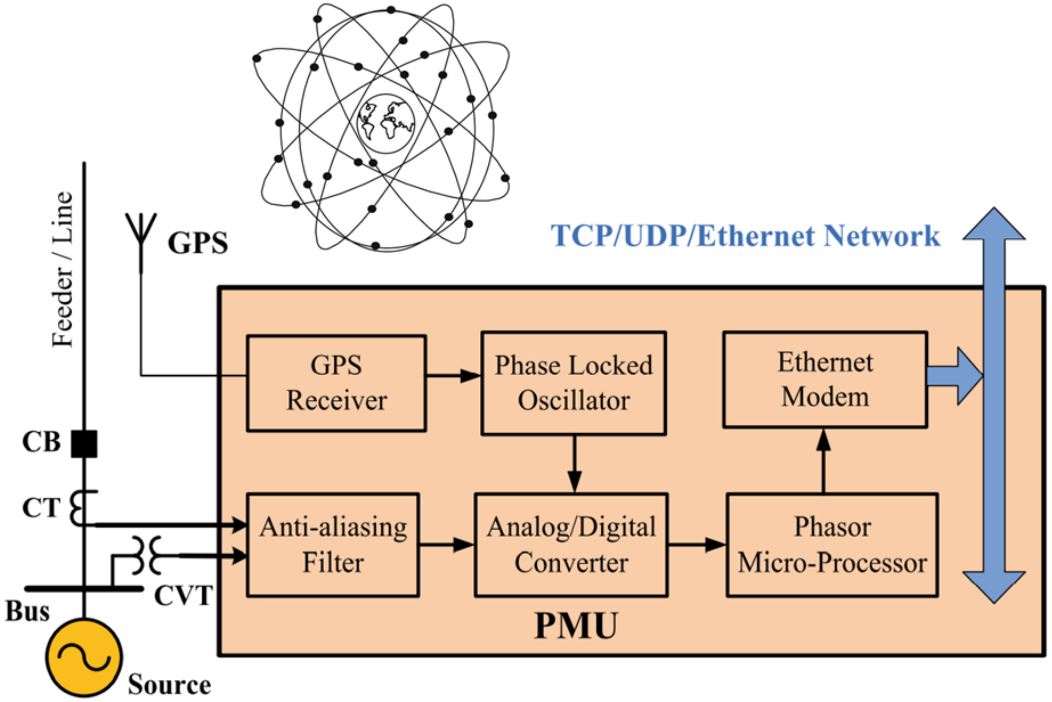
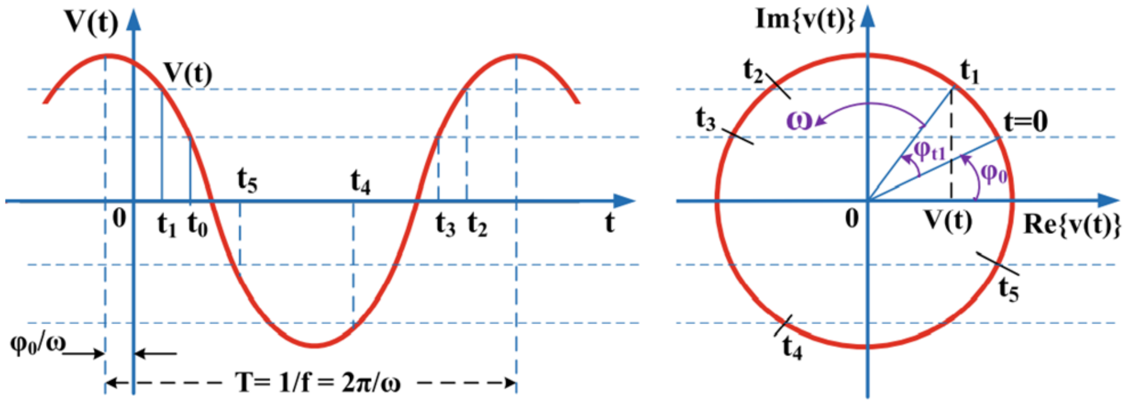
Implementación piloto de PMU’s

Implementación piloto de PMU's

Unidades de medición fasorial





$$x(t) = X_m \cos(\omega t + \phi)$$

1. Phadke, A. G., & Bi, T. (2018). Phasor measurement units, WAMS, and their applications in protection and control of power systems. Journal of Modern Power Systems and Clean Energy, 6(4), 619–629. https://doi.org/10.1007/s40565-018-0423-3

Implementación piloto de PMU's

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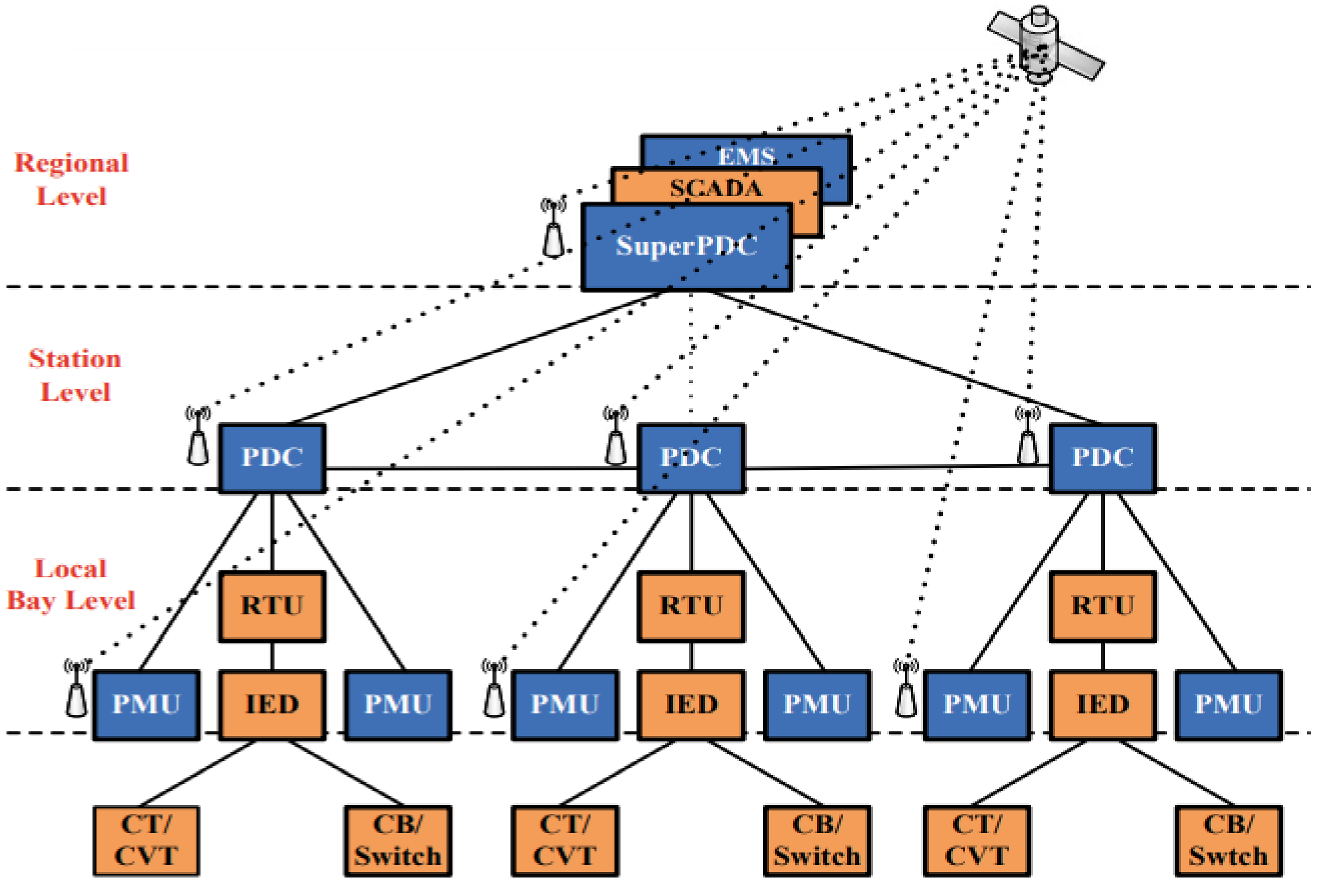
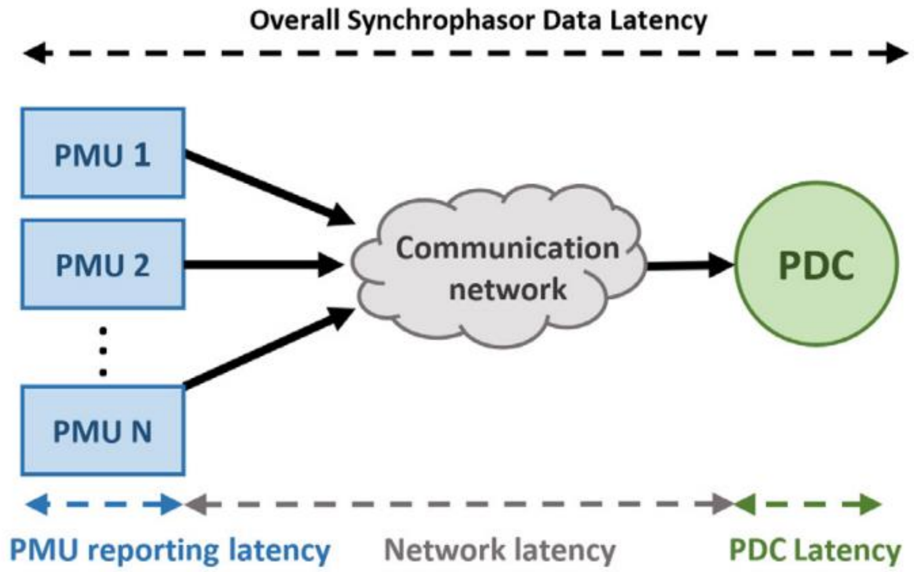
Unidades de medición fasorial





Arghandeh, R., Brady, K., (2018). Synchrophasor Monitoring for Distribution Systems: Technical Foundations and Applications. *North American SynchroPhasor Initiative (NASPI), January*, 1–62. https://doi.org/10.13140/RG.2.2.35267.04649

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Implementación piloto de PMU's

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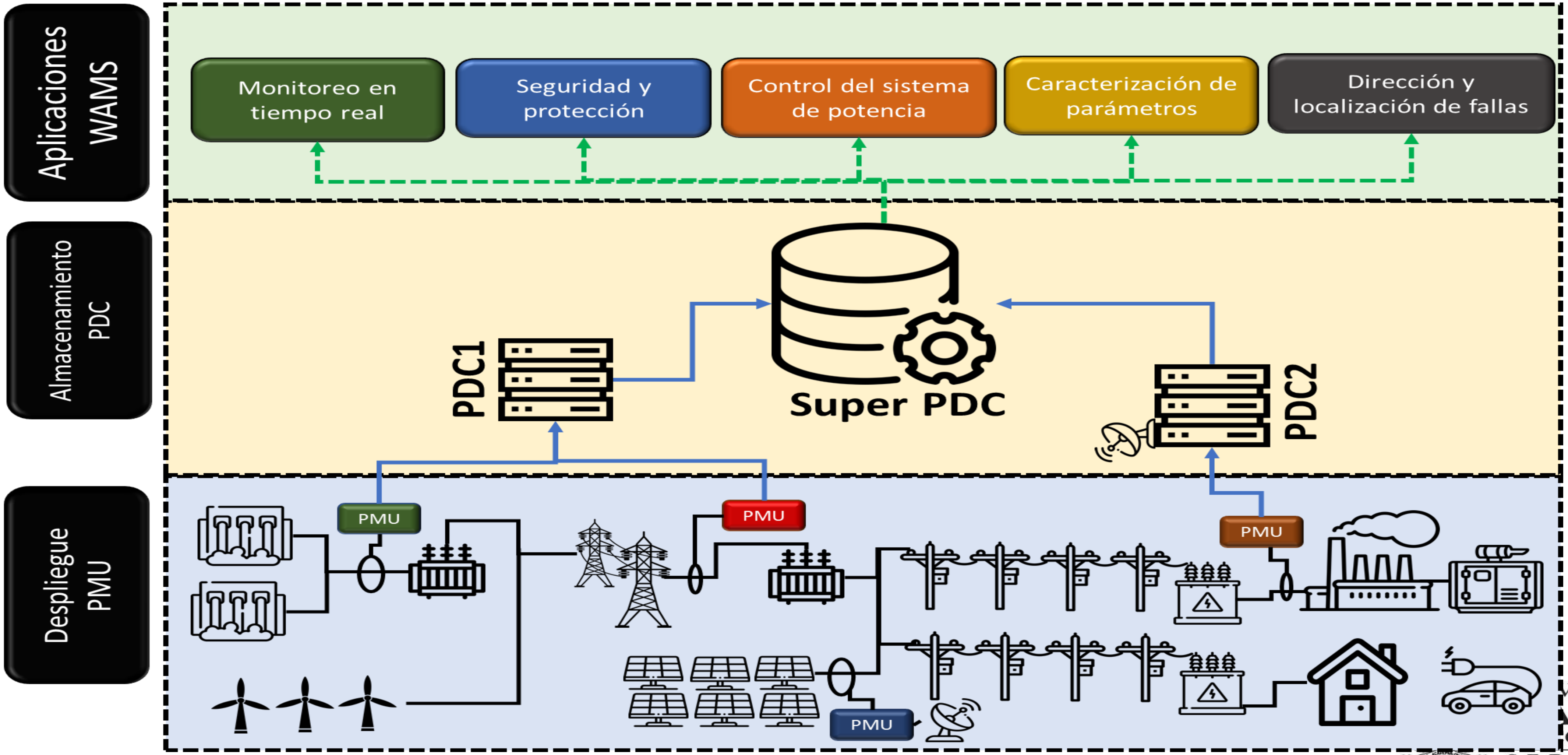
Sistemas de monitoreo de área extendida



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Sistemas de monitoreo de área extendida

Parámetros	SCADA	WAMS
Resolución	1 muestra entre 1 minuto a 5 minutos	60-240 muestras en 1 segundo
Medida	Mide solo la magnitud de las variables	Mide magnitud y ángulos de fase
Tiempo de sincronización	Estampa de tiempo del servidor	Sincronización por GPS
Tiempo de reacción	Entre 1 minuto y 5 minutos	Entre 160 y 15 milisegundos
Foco	Diseñado para monitoreo y control de forma local	Diseñado para monitoreo y control en áreas amplias y tiempos de respuesta bajos

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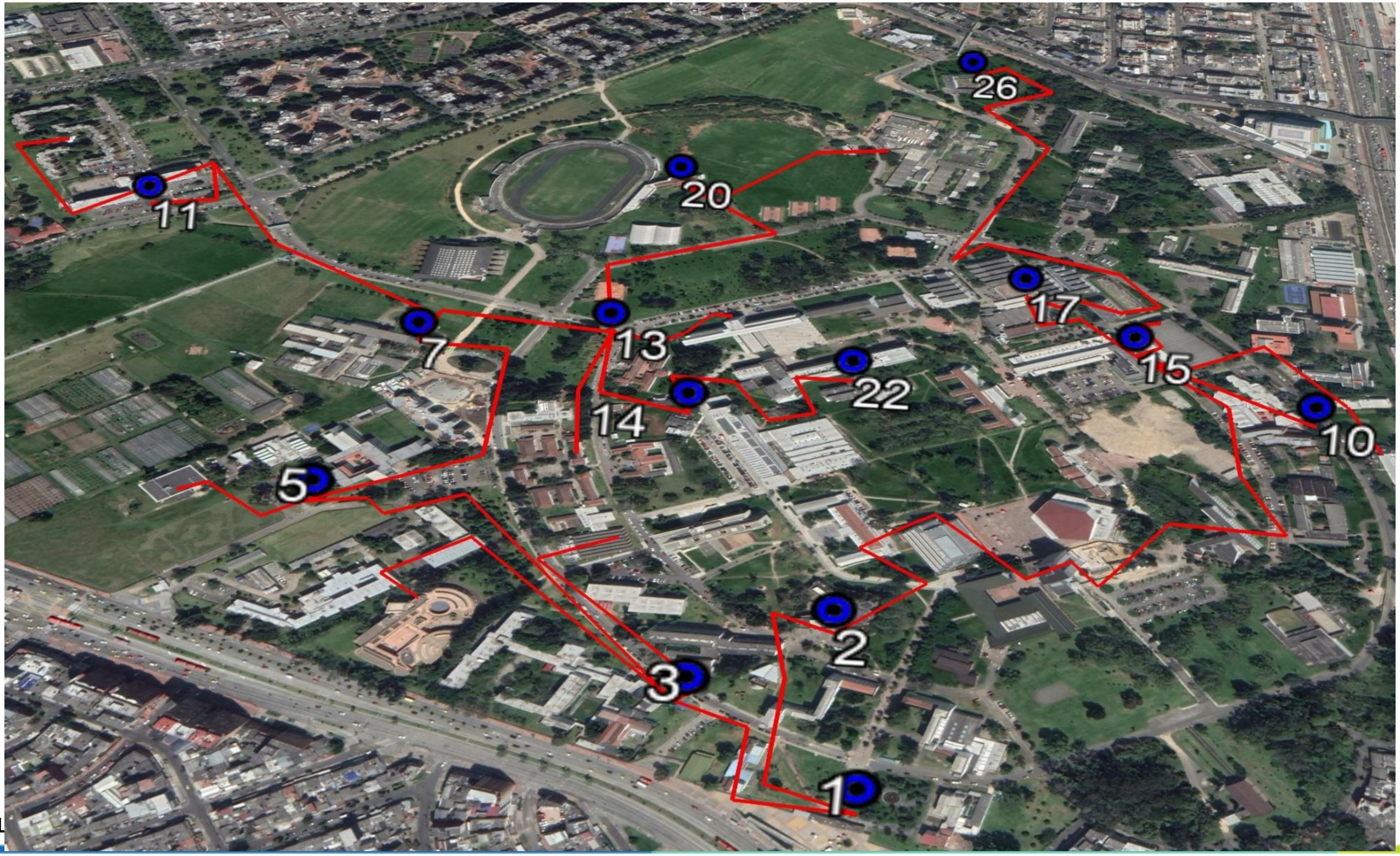
Aplicaciones según los niveles de SP

Aplicaciones WAMS

- **Generación**
  - Monitoreo del estado del generador
  - Estabilidad transitoria del Angulo
  - Protección en isla
  - Control y protección
- **Transmisión**
  - Estimación de estados
  - Flujo de carga
  - Flujo de potencia optimo
  - Protección y control
- **Distribución**
  - Automatización de subestaciones
  - Automatización de alimentadores
  - Automatización en el lado del consumo
  - Protección y control

Implementación piloto de PMU's

Posición optima sincro fasores



Nodos PMU

- SE-1 Calle 26
- SE-2 Sociología
- SE-3 Manuel Ancizar
- SE-5 Almacén agronomía
- SE-7 Posgrados veterinaria
- SE-8 Biblioteca central
- SE-10 Economía
- SE-13 Parque Humboldt
- B-14 Medicina
- SE-15 Posgrados de física
- SE-17 Labs de resistencia
- SE-20 Cine y televisión
- SE-26 Genética

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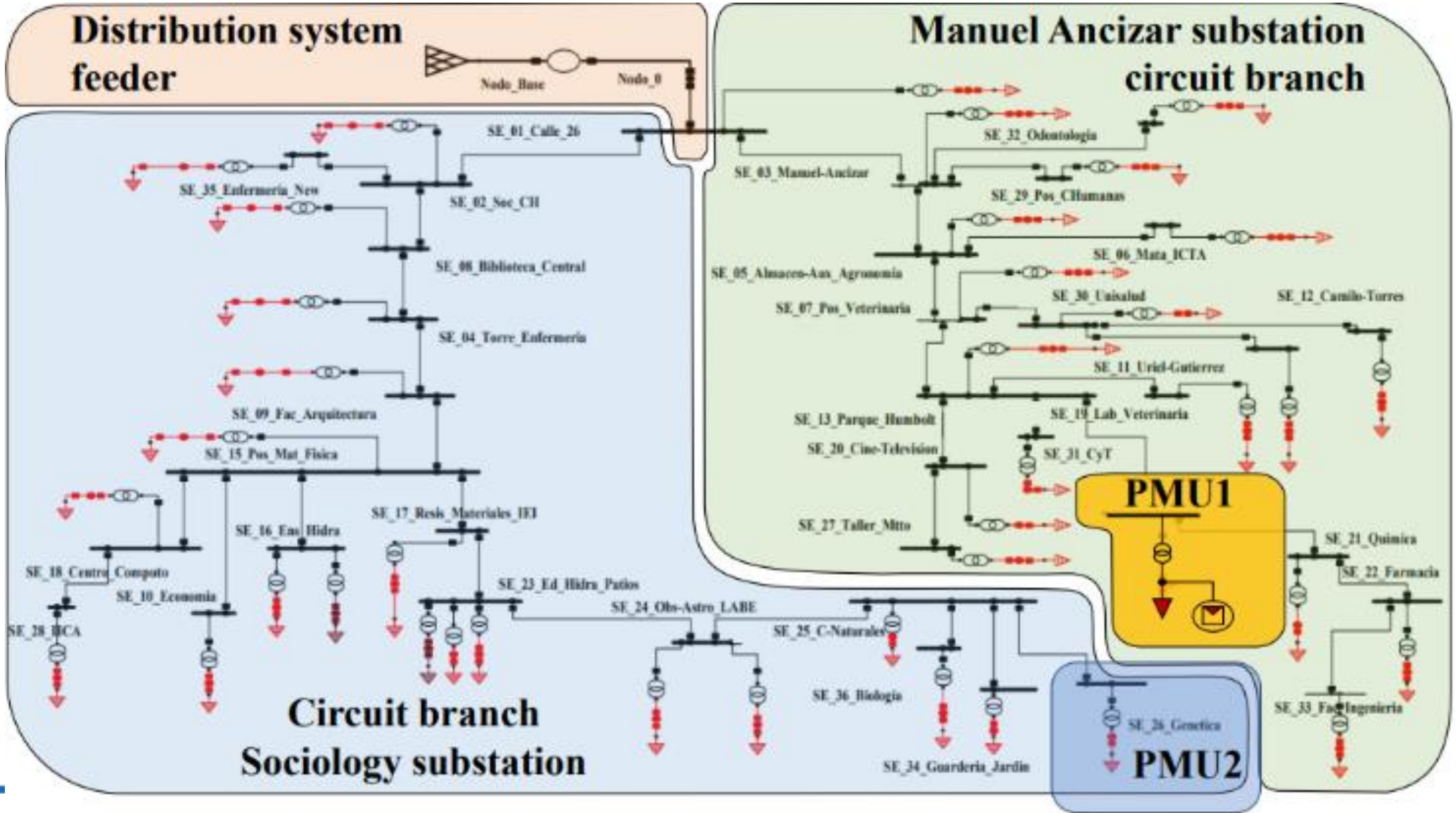
Ubicación de pmu en el campus



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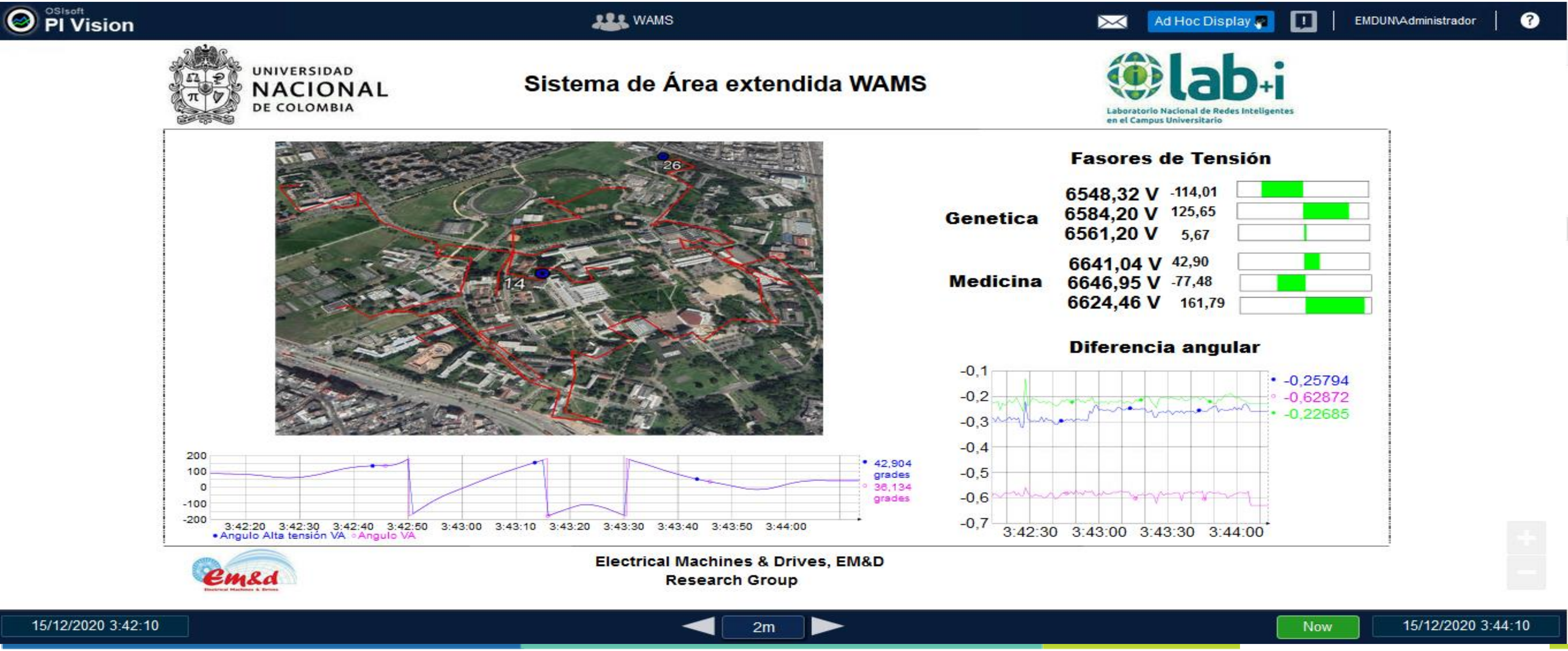
Monitoreo de la diferencia angular



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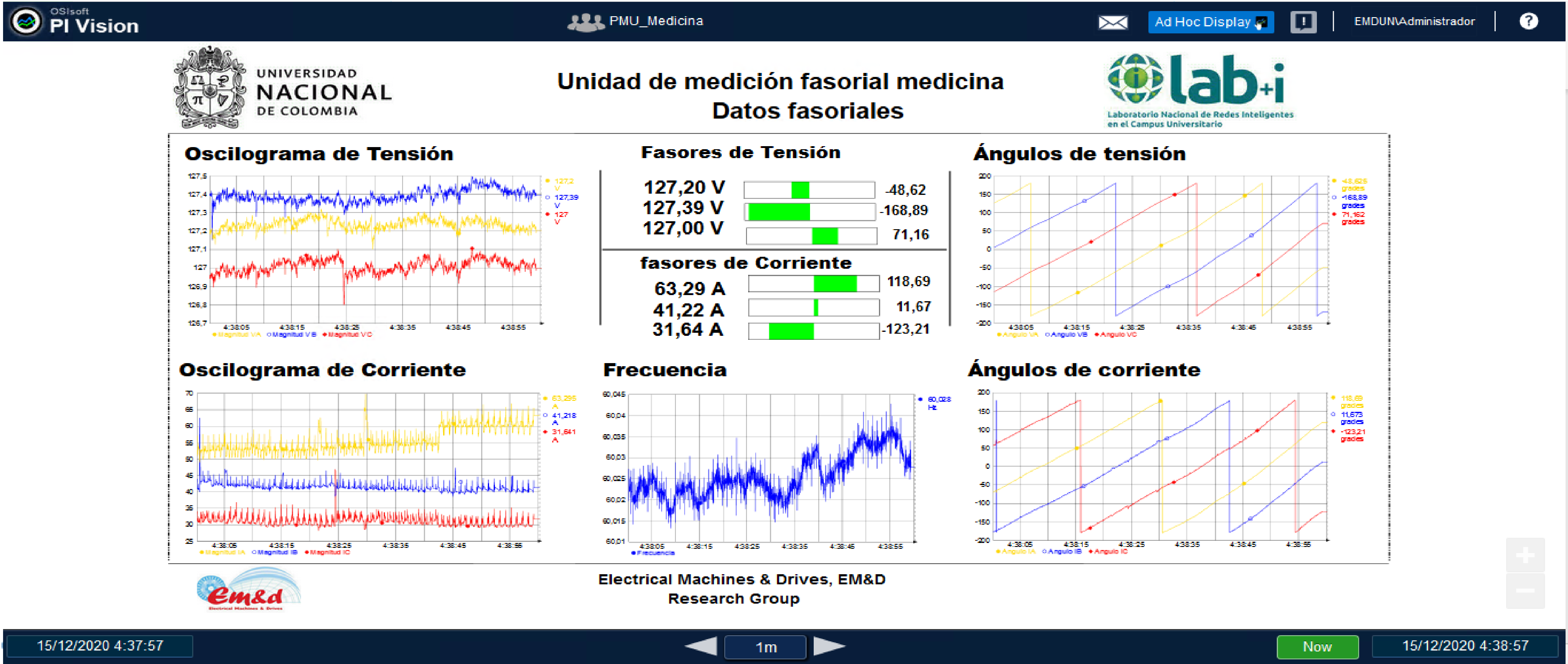
Monitoreo de la diferencia angular



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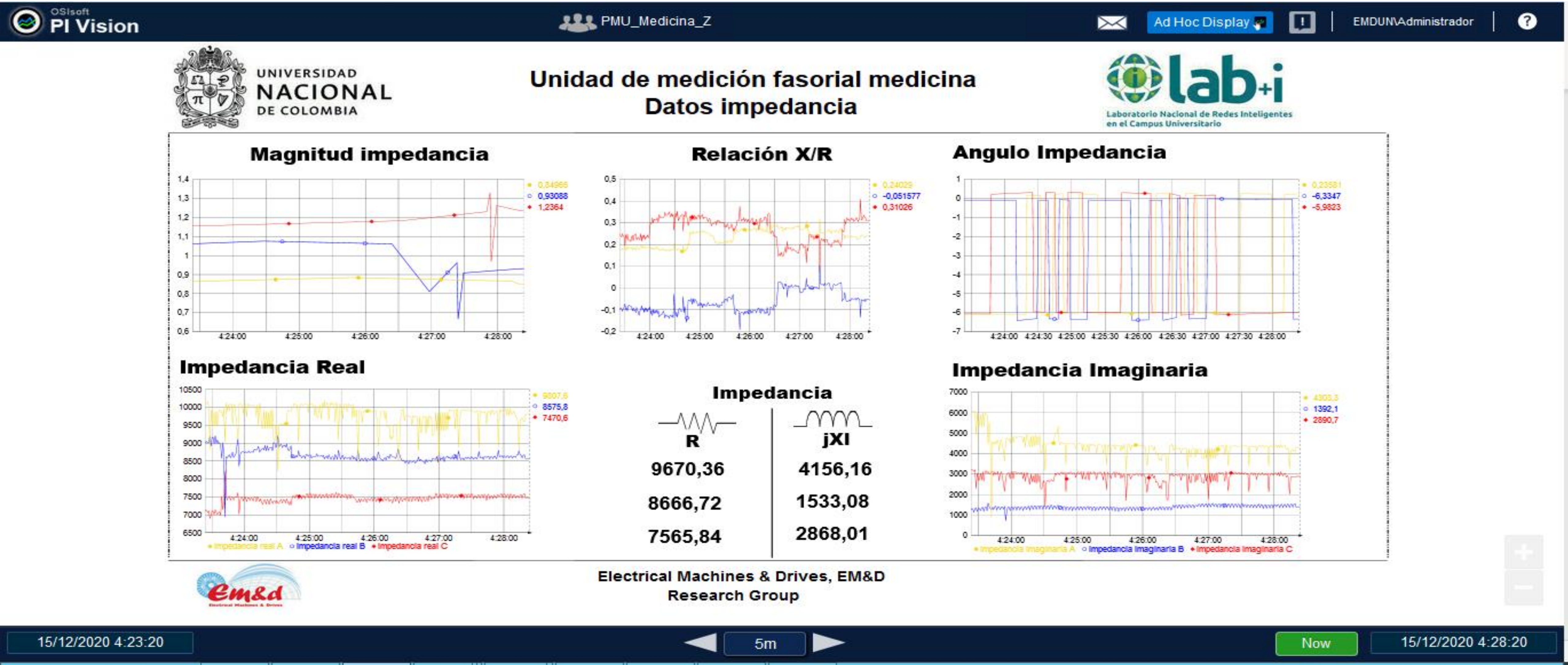
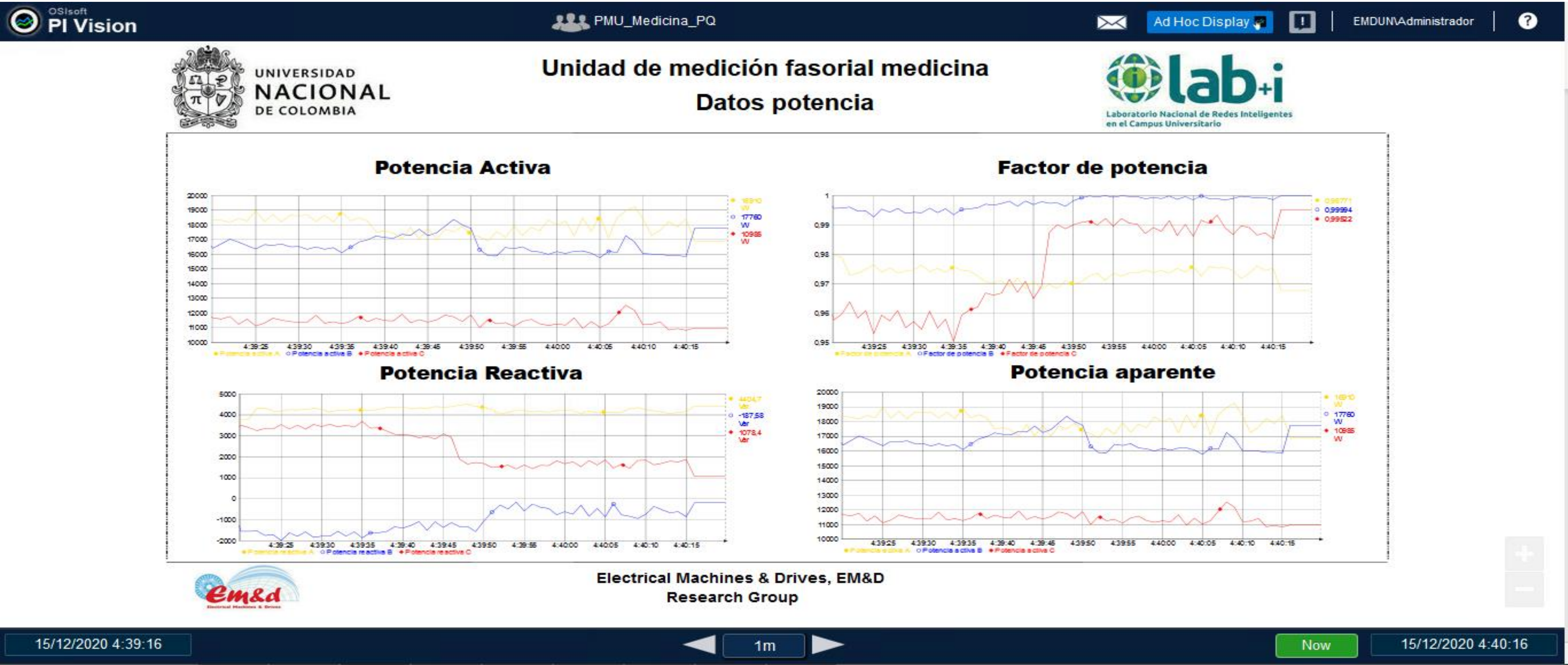
Monitoreo de impedancia



Implementación piloto de PMU's

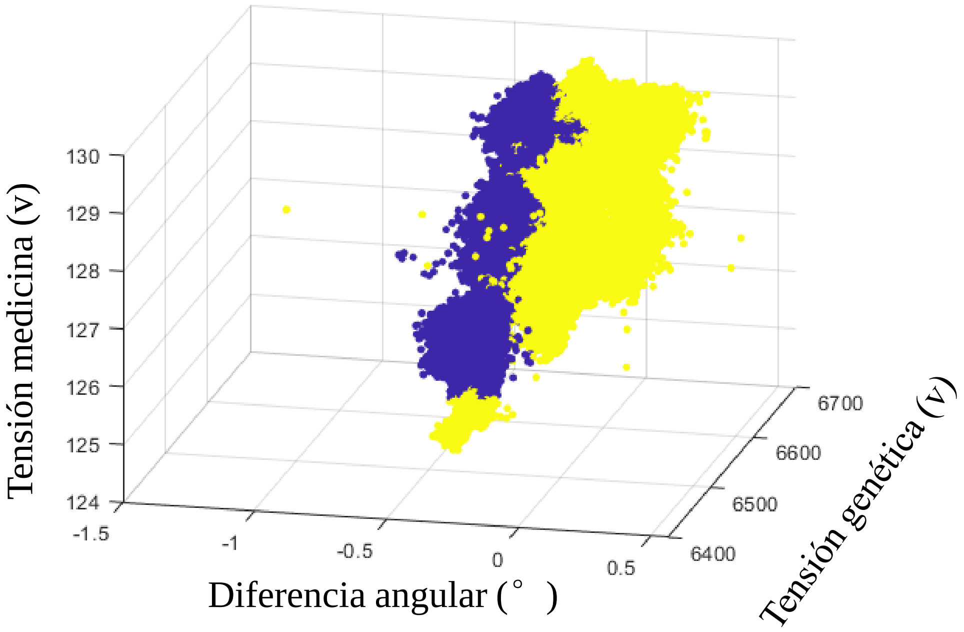
Monitoreo de potencia



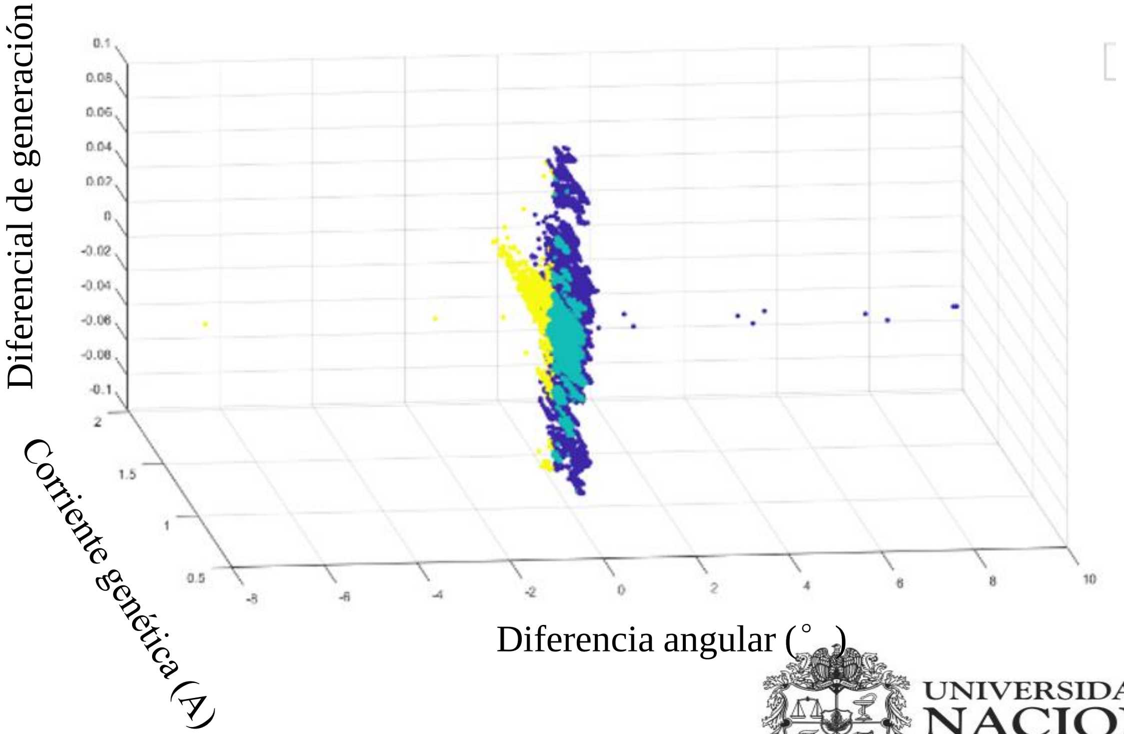
Implementación piloto de PMU's

Agrupación de datos en PMU

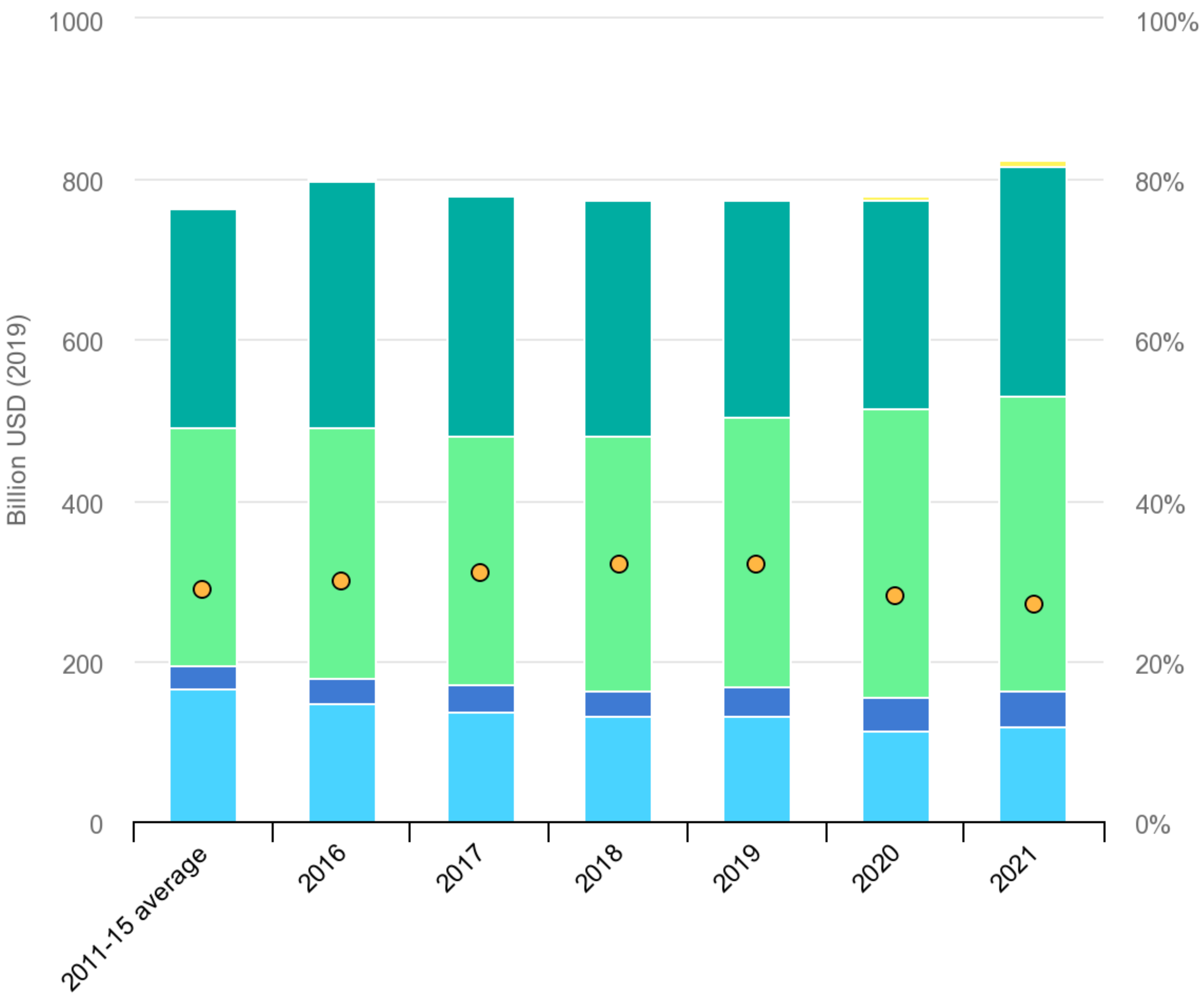
Agrupación de eventos de diferencia angular con respecto a la generación y los voltajes de los dos nodos



Agrupación de eventos de diferencia angular con respecto a la derivada de la generación de energía solar y las corrientes del nodo de genética

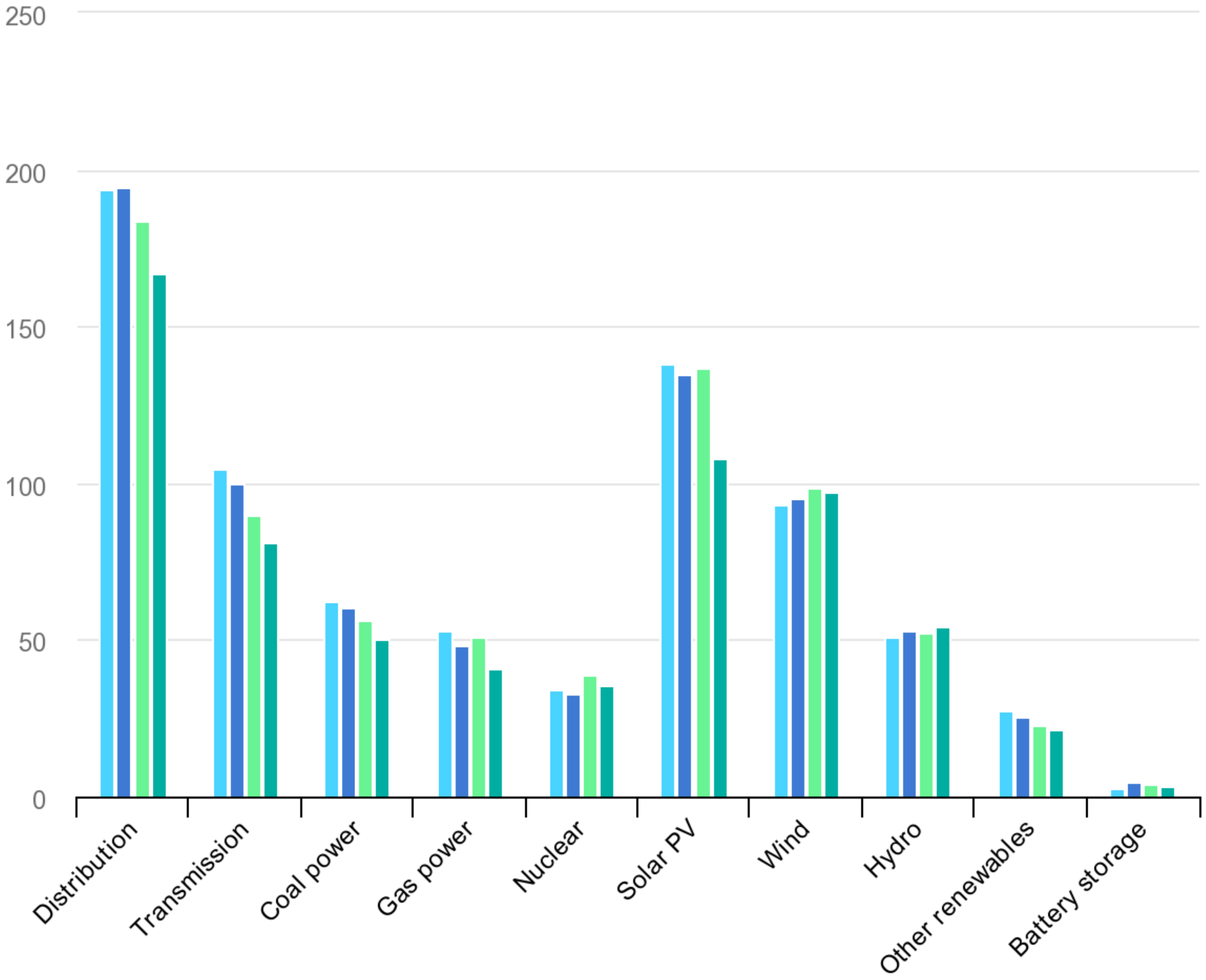


Dynamic line rating (DLR) in overhead lines (OHL)



IEA, Global investment in the power sector by technology 2011-2021, IEA, Paris|

IEA, *Global investment in the power sector by technology, 2011-2021*, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-investment-in-the-power-sector-by-technology-2011-2021



IEA, Global investment in the power sector by technology 2017-2020, IEA, Paris

IEA, Global investment in the power sector by technology, 2017-2020, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-investment-in-the-power-sector-by-technology-2017-2020

Table 2-2 | Asset life estimation [2]

Plant type	System voltage (kV)	Mean and range of asset life estimates (years)	Standard deviation (years)	Reason for asset life variances
Circuit breakers				
Air	110-199 200-275 ≥345	**41** (30 to 50) **41** (30 to 50) **40** (30 to 50)	6 6 6	Rating requirements, fault duty changes, maintenance costs, spares obsolescence, mechanical wear, safety, seal problems
Oil	110-199 200-275 ≥345	**42** (30 to 50) **41** (30 to 50) **38** (30 to 45)	6 6 5	Rating requirements, fault duty changes, maintenance costs, spares obsolescence, mechanical wear, safety, seal problems
Gas	110-199 200-275 ≥345	**43** (30 to 50) **42** (30 to 50) **42** (30 to 50)	6 6 6	Rating requirements, fault duty changes, maintenance costs, spares obsolescence, mechanical wear, safety, seal problems, seen as "less robust", environmental concern re SF6
Bay assets				
Earth switches and disconnectors	≥110	**42** (30 to 50)	8	Rating requirements, maintenance costs, corrosion, mechanical wear
CTs-Oil	≥110	**39** (30 to 50)	7	Design weaknesses, seals
CVT's	≥110	**39** (30 to 50)	7	Moisture ingress, PCB contamination of oil
Transformers	≥110	**42** (32 to 55)	8	Design, loading, insulating paper and oil degradation, system faults, spares, rating requirements, high temperature, moisture levels
Indoor GIS	≥110	**42** (30 to 50)	8	Rating requirements, fault duty changes, maintenance costs, spares obsolescence, mechanical wear, safety, seal problems, environmental concern re SF6
Electro-mechanical protection	–	**32** (20 to 45)	9	Wear, contact erosion, reliability, verdigris, temperature extremes, skilled labour, spares, functionality, system design changes
ACSR-OHL				
"Normal" environment	≥110	**54** (40 to 80)	14	Climate, environment, corrosion, conductor grease levels, creep, mechanical fatigue, insulator failures, wind, precipitation, ice loading, pollution levels, material quality, high temperatures due to loading, joint, design
"Heavily polluted"	≥110	**46** (30 to 70)	15	
Towers				
Steel lattice	≥110	**63** (35 to 100)	21	Climate, environment, corrosion, maintenance, poor galvanizing, ground conditions, concrete spalling, grillage corrosion, steel/concrete junction

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IEC White Paper Asset Management:2015 Strategic asset management of power networks

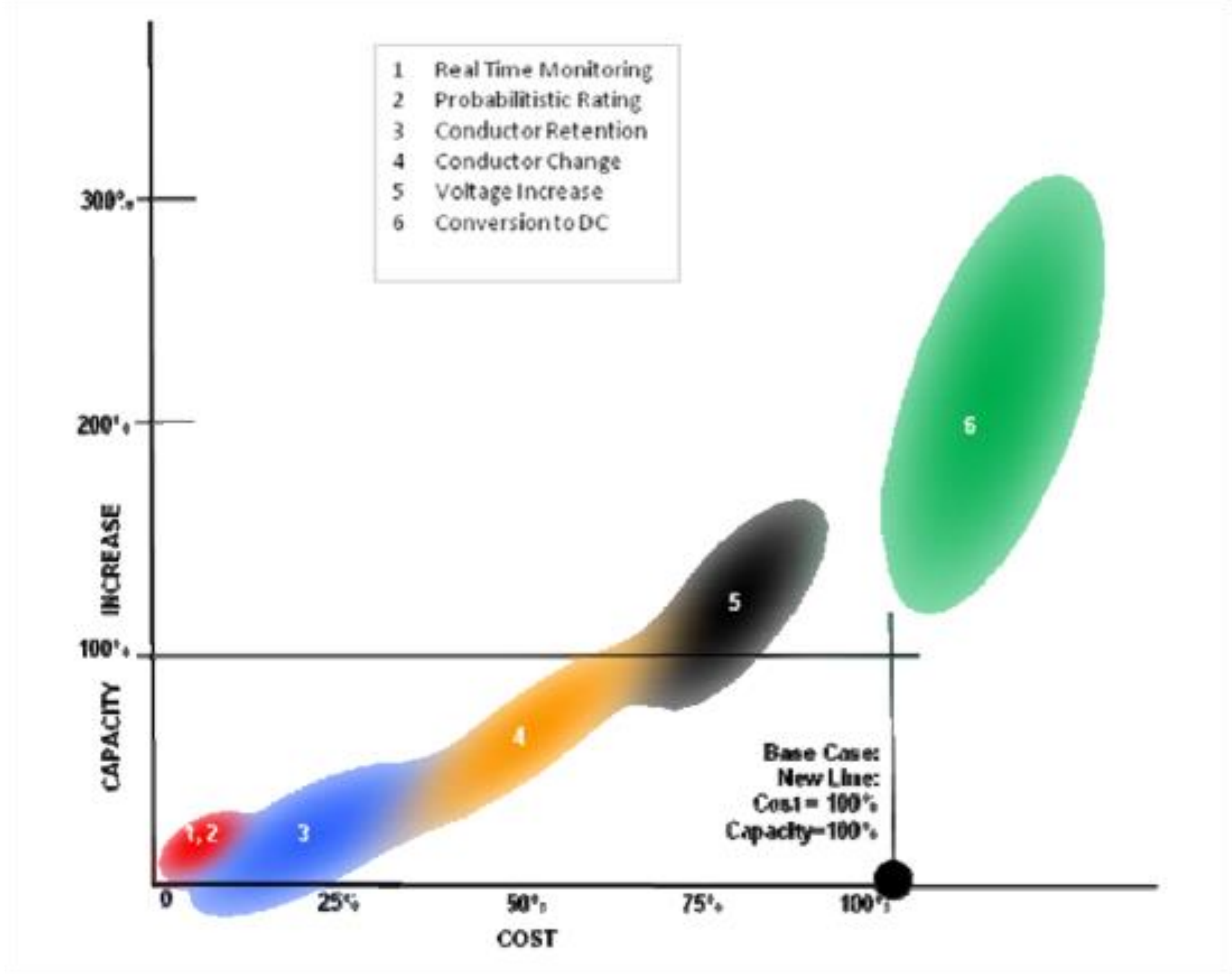
Table 2-1 | Estimated years to replace aged assets from 5 electricity network businesses

	OHL wire	Tower	Cable	Transformer	Switchgear
Utility A	47	399	112	110	80
Utility B	68	178	278	93	45
Utility C	758	179	63	124	172
Utility D	276	327	n/a	59	41
Utility E	96	174	42	49	47

A perfect storm created by aging assets, retiring experts, increasingly engaged stakeholders and rapidly changing technology has triggered the need for increased sophistication and rigor in asset management.

CIGRE TB 787 - 2019

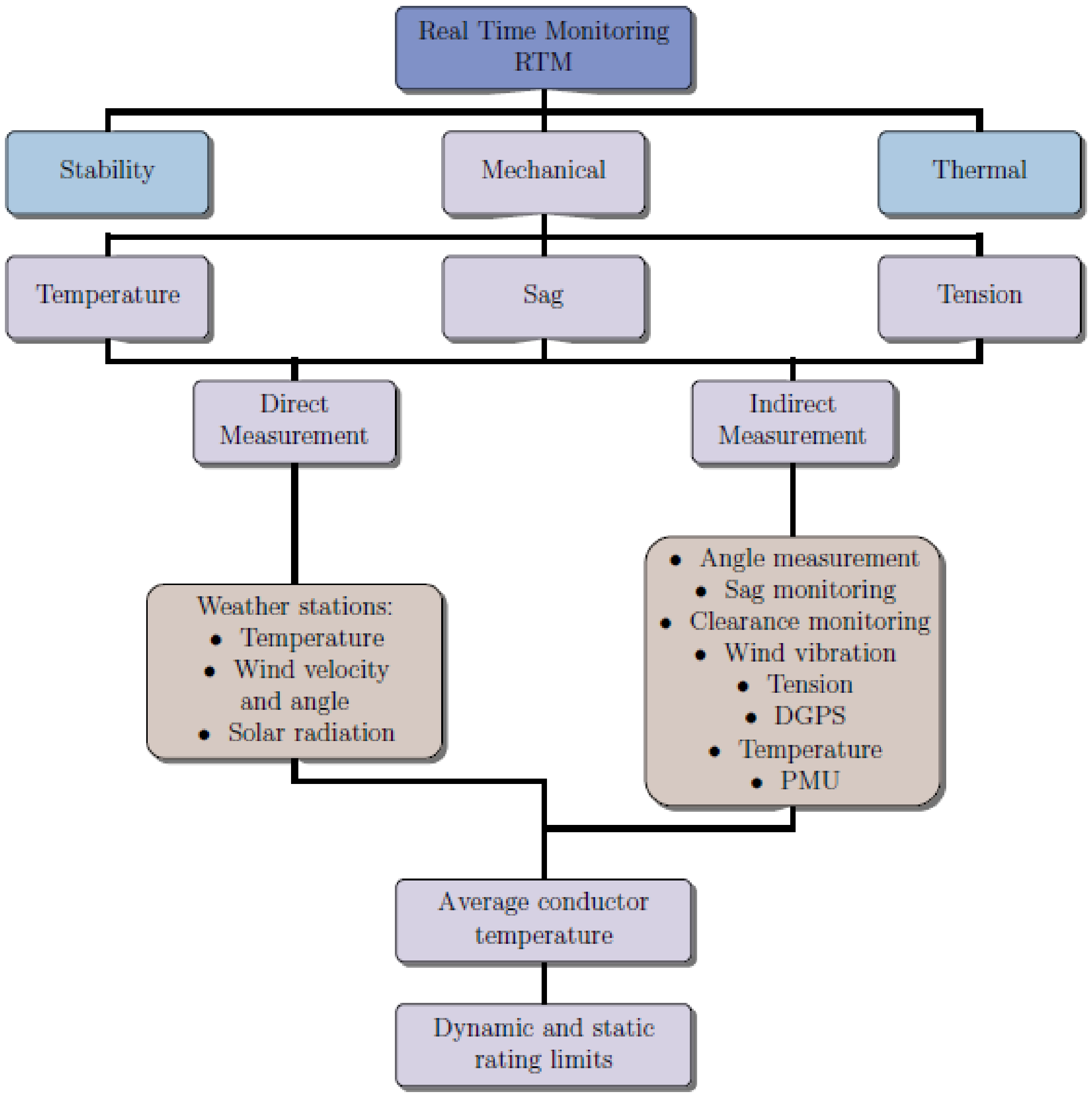
ISO series 55000 standards: Implementation and information guidelines for utilities

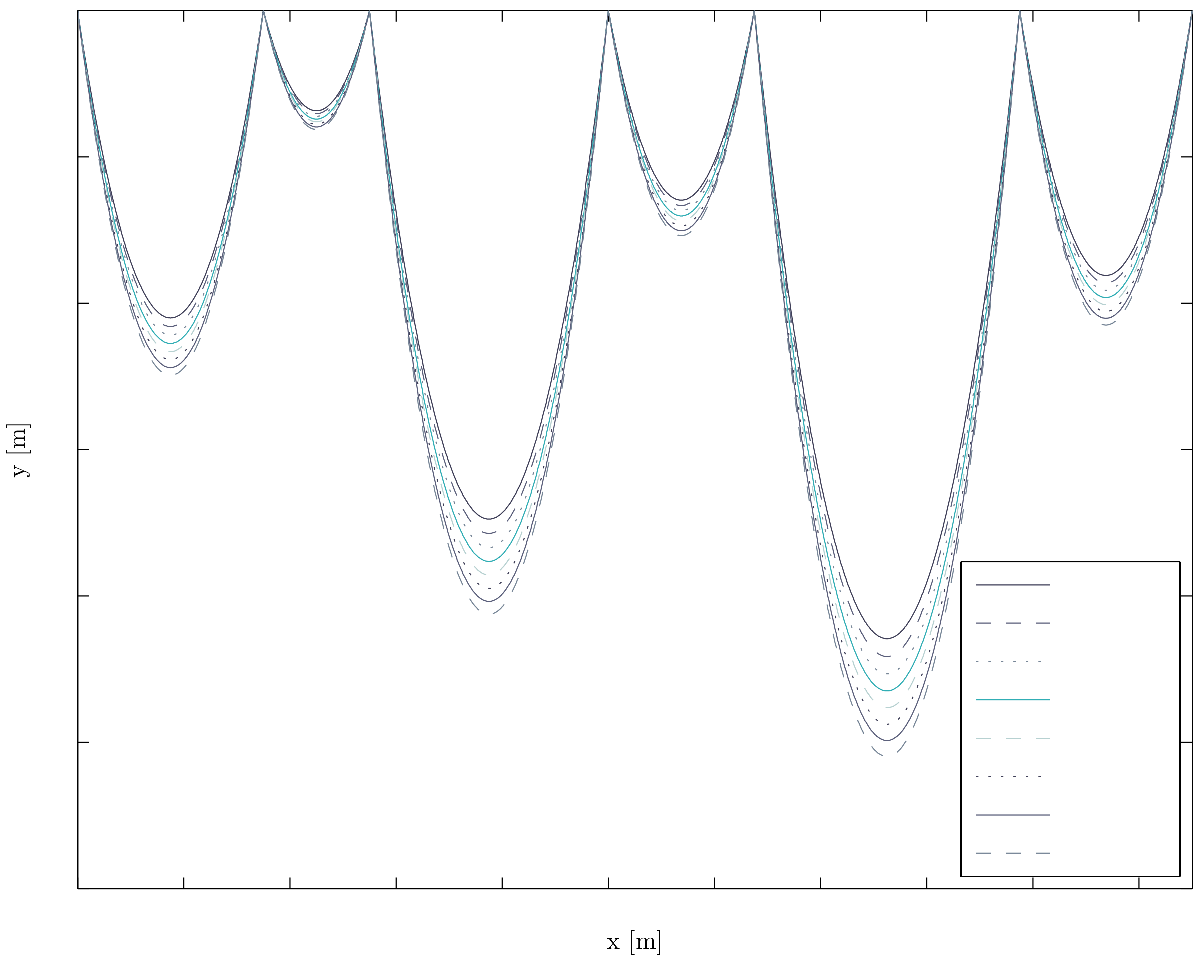


CIGRE TB 425 - 2010

Increasing Capacity of Overhead Transmission Lines: Needs and Solutions

Dynamic line rating (DLR) in overhead lines (OHL)





OHL located in Iceland and operated by LandsNet

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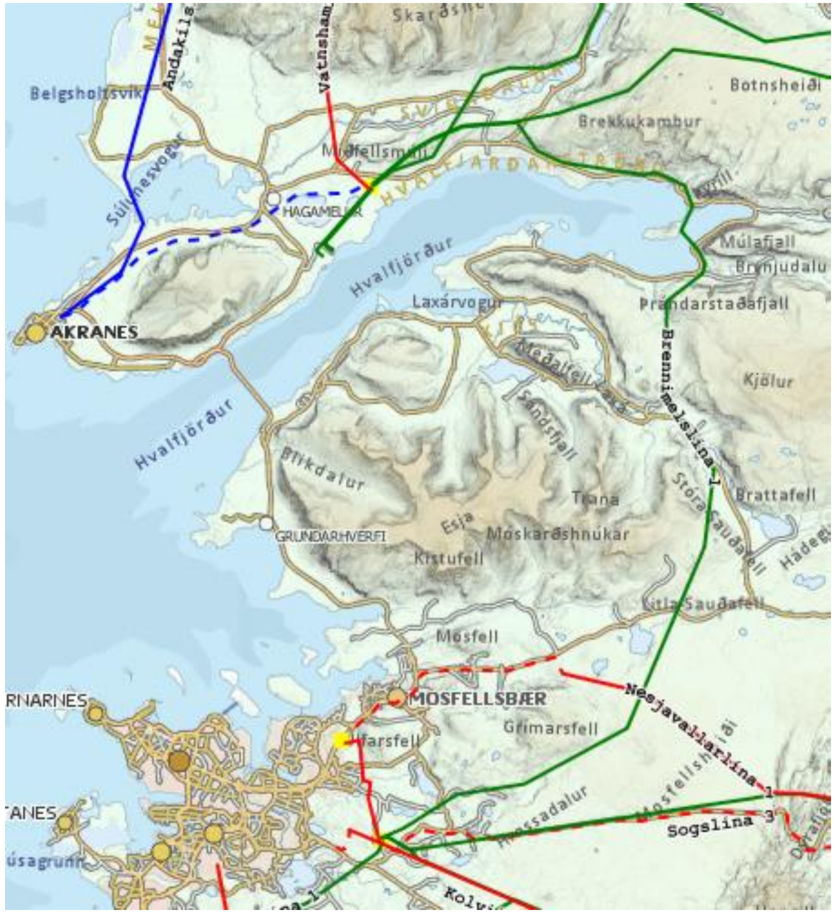

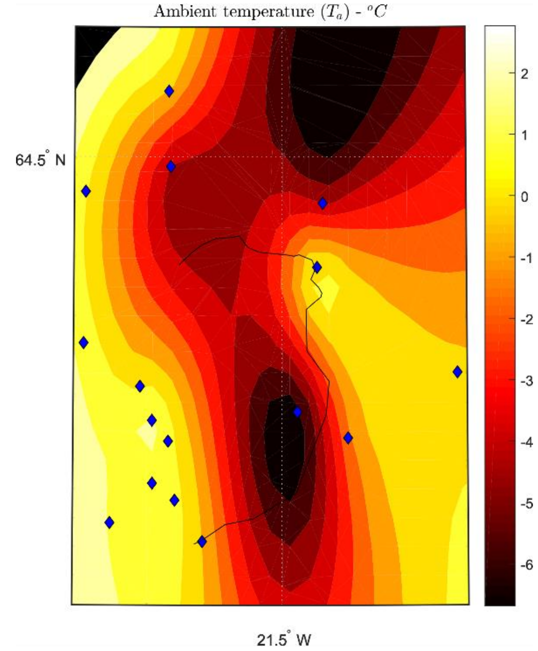

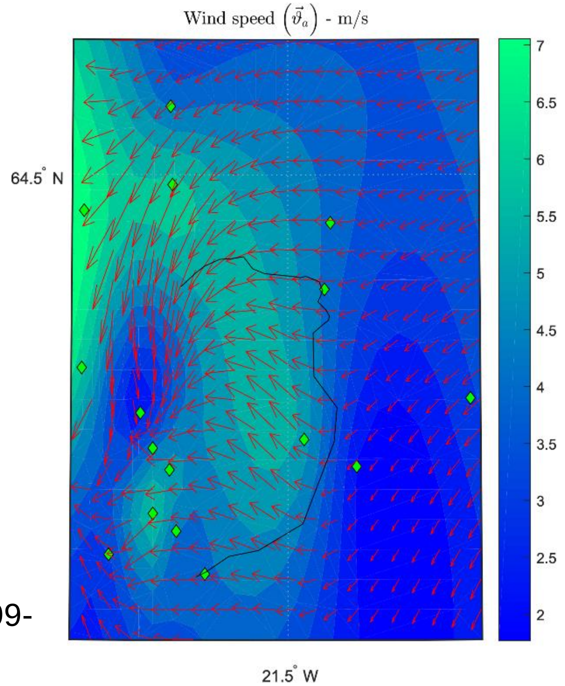

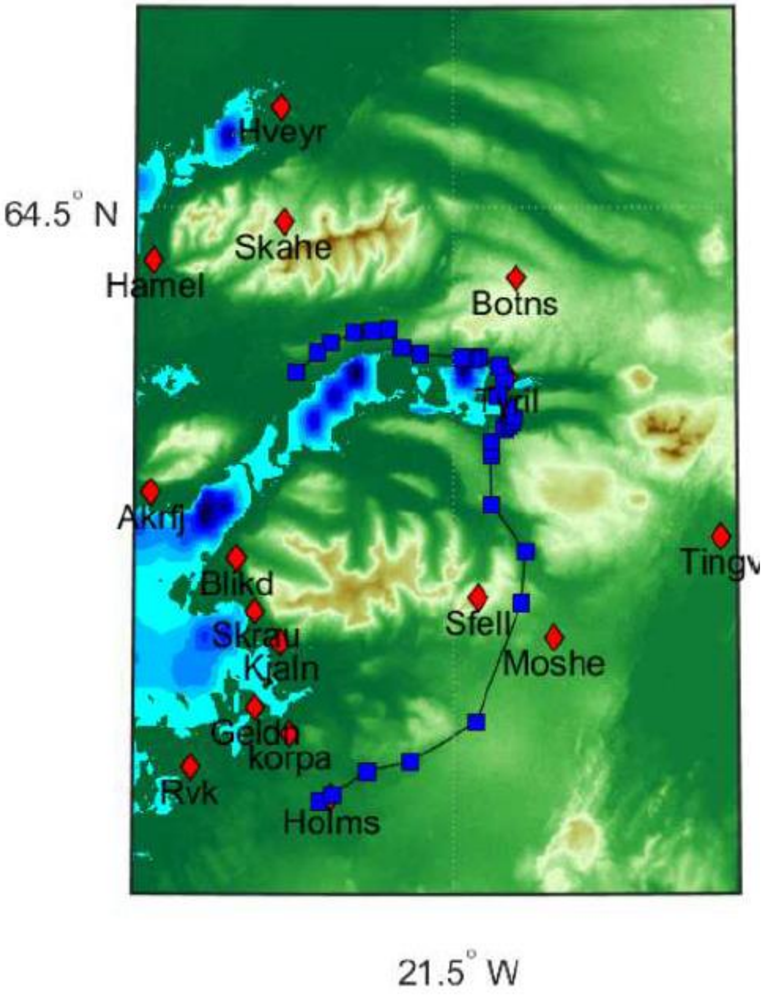

David L. Alvarez, et al. An approach to dynamic line rating state estimation at thermal steady state using direct and indirect measurements, Electric Power Systems Research, 2018, Pages 599-611, ISSN 0378-7796. https://doi.org/10.1016/j.epsr.2017.11.015.

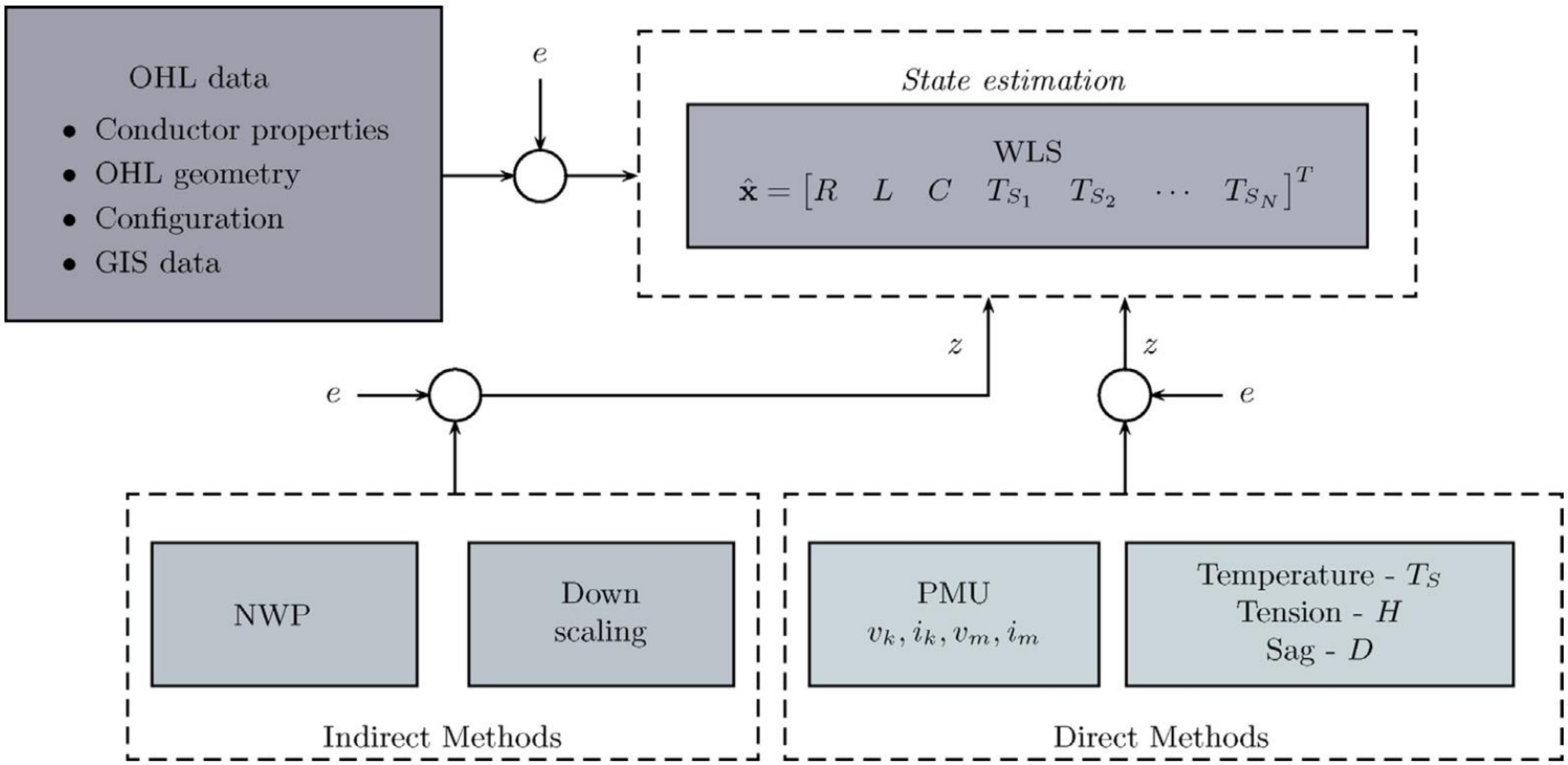

Fig. 1. Dynamic line rating estimation using WLS, an overview using direct and indirect measurements.

David L. Alvarez, et al. An approach to dynamic line rating state estimation at thermal steady state using direct and indirect measurements, Electric Power Systems Research, 2018, Pages 599-611, ISSN 0378-7796. https://doi.org/10.1016/j.epsr.2017.11.015.

An Approach to Dynamic Line Rating Estimation at Steady State Using Direct and Indirect Measurements

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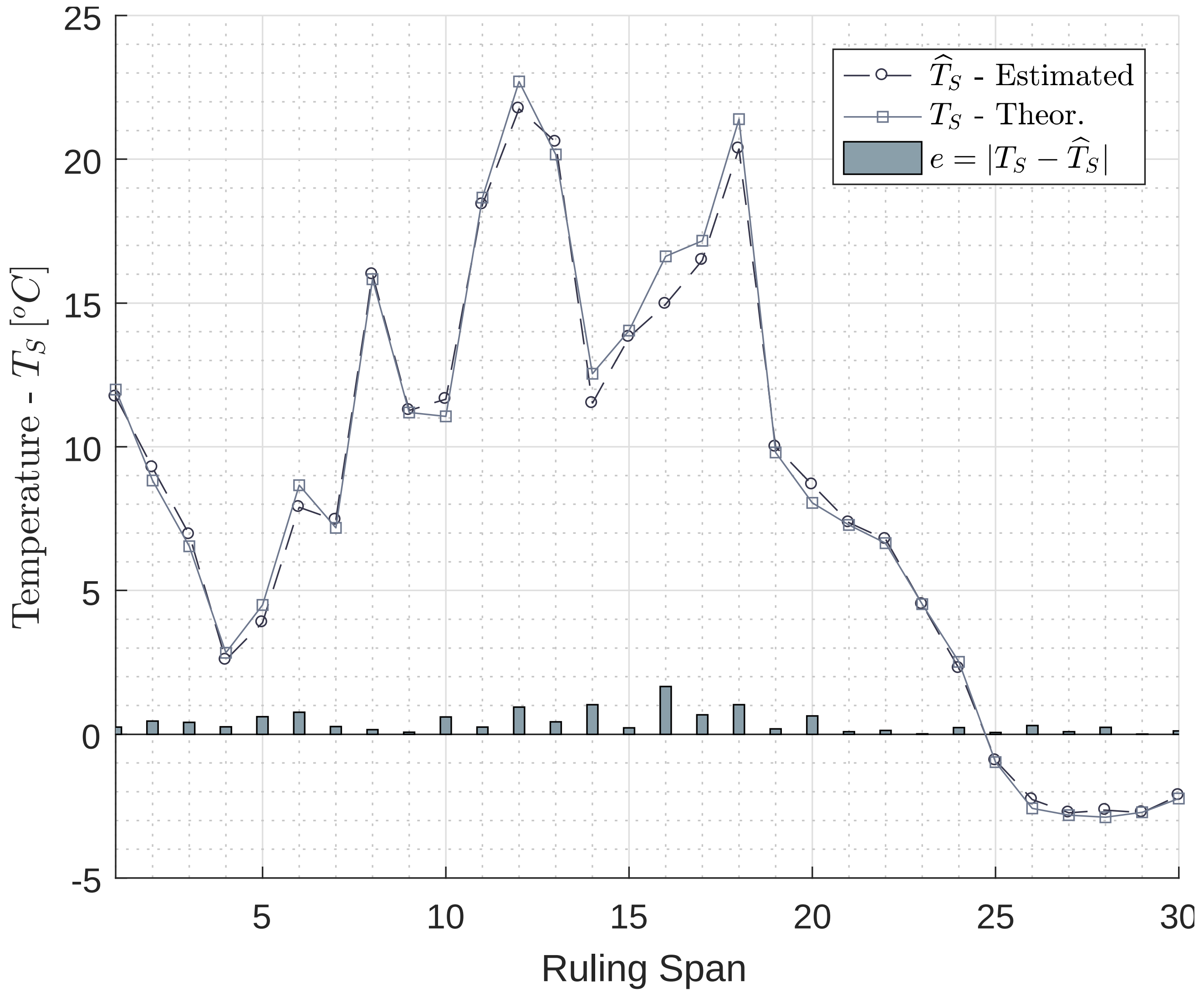
	$z_{\text{Theor.}}$	$z_{measured}$ $z_{\text{Theor.}} + e$	Ruling Span	Span	Units
v_k	$-125.78 + j26.667$	$-125.60 + j26.63$	–	–	[kV]
i_k	$-518.32 + j486.70$	$-517.26 + j486.07$	–	–	[A]
v_m	$-111.32 + j37.853$	$-111.39 + j37.95$	–	–	[kV]
i_m	$513.00 - j506.26$	$511.86 - j505.74$	–	–	[A]
T_S	16.8	16.7	17	1	[°C]
H_1	25.356	25.353	1	1	[kN]
H_{15}	15.698	15.696	15	1	[kN]
D_{11}	10.38	10.39	11	1	[m]



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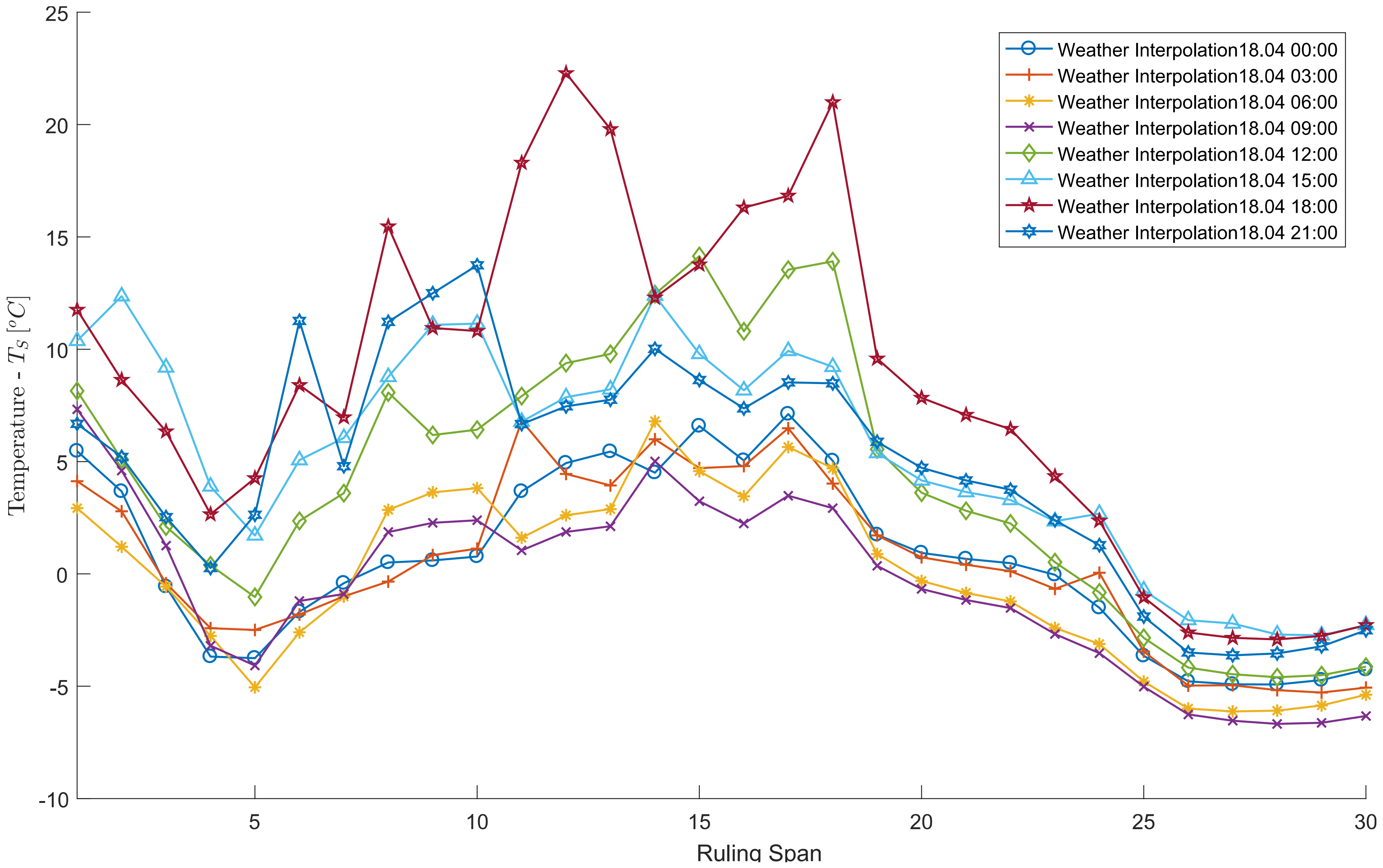

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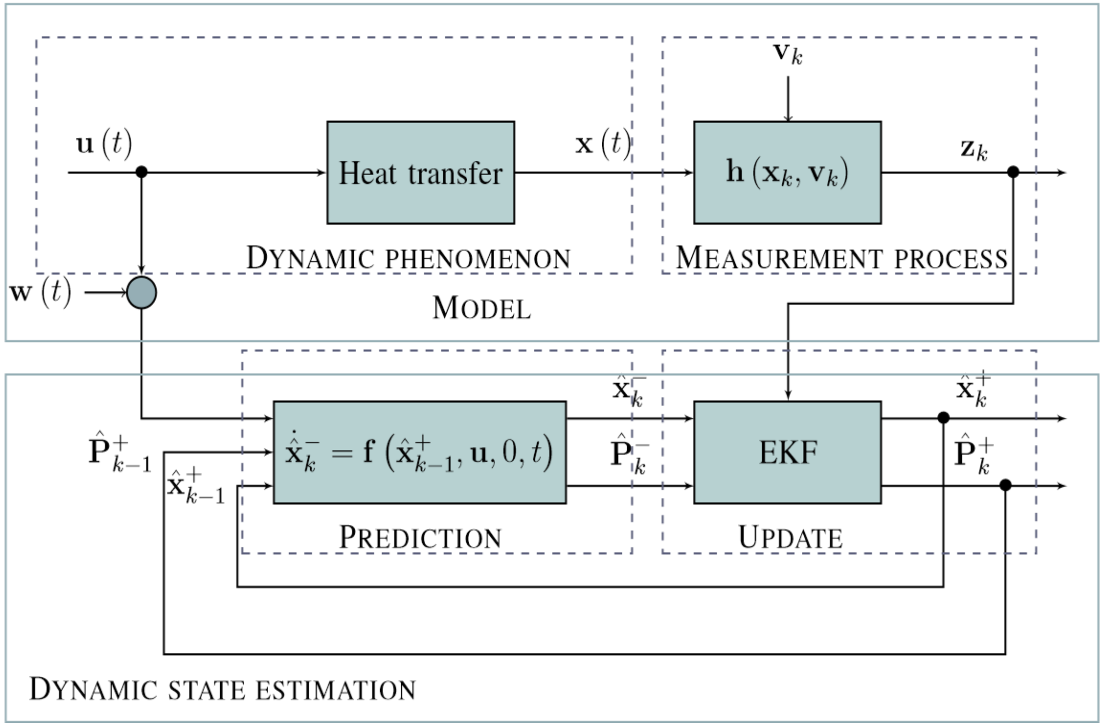
Alvarez, D.L., da Silva, F.F., Bak, C.L., Mombello, E.E., Rosero, J.A. and Ólason, D.L. (2018), Methodology to assess phasor measurement unit in the estimation of dynamic line rating. IET Gener. Transm. Distrib., 12: 3820-3828. https://doi.org/10.1049/iet-gtd.2017.0661

Hybrid Extended Kalman Filter - EKF



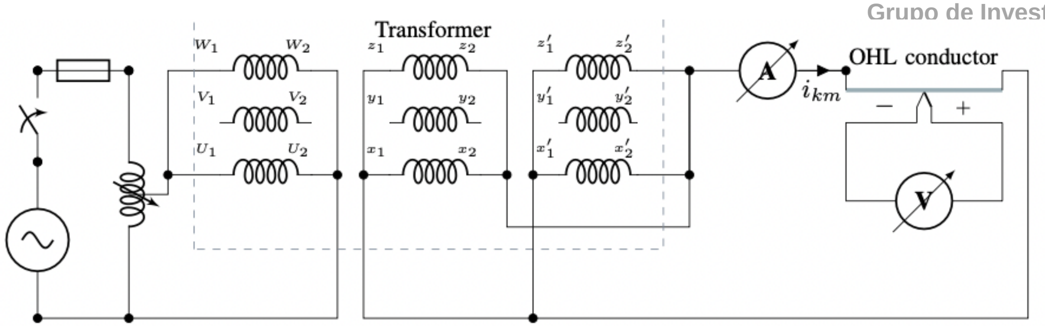
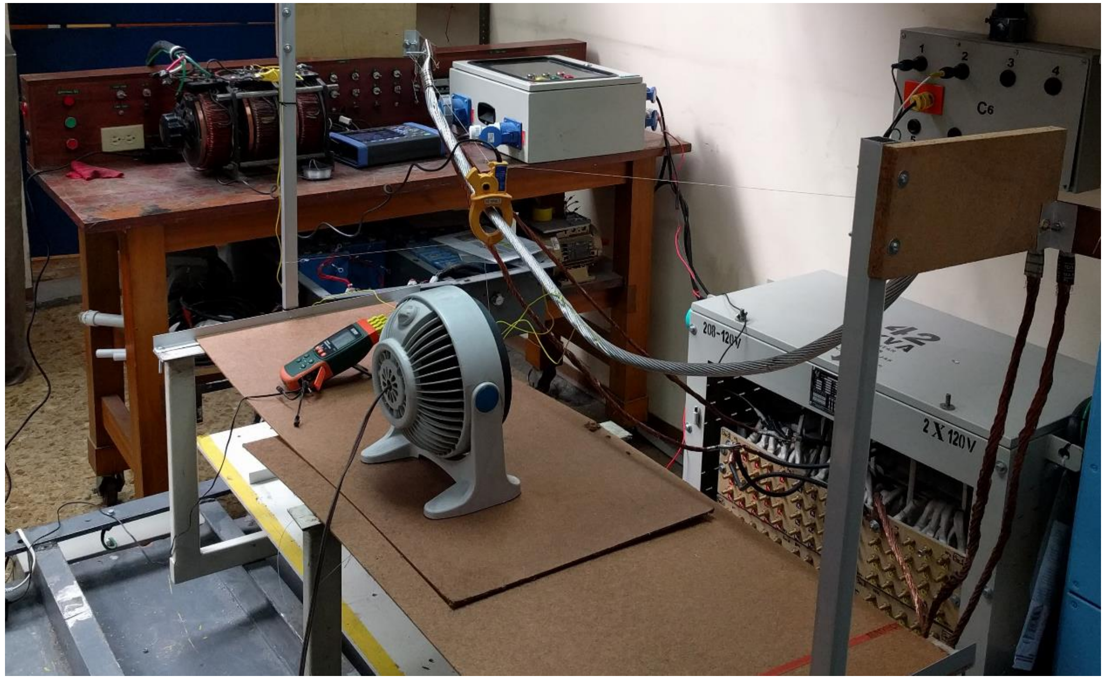
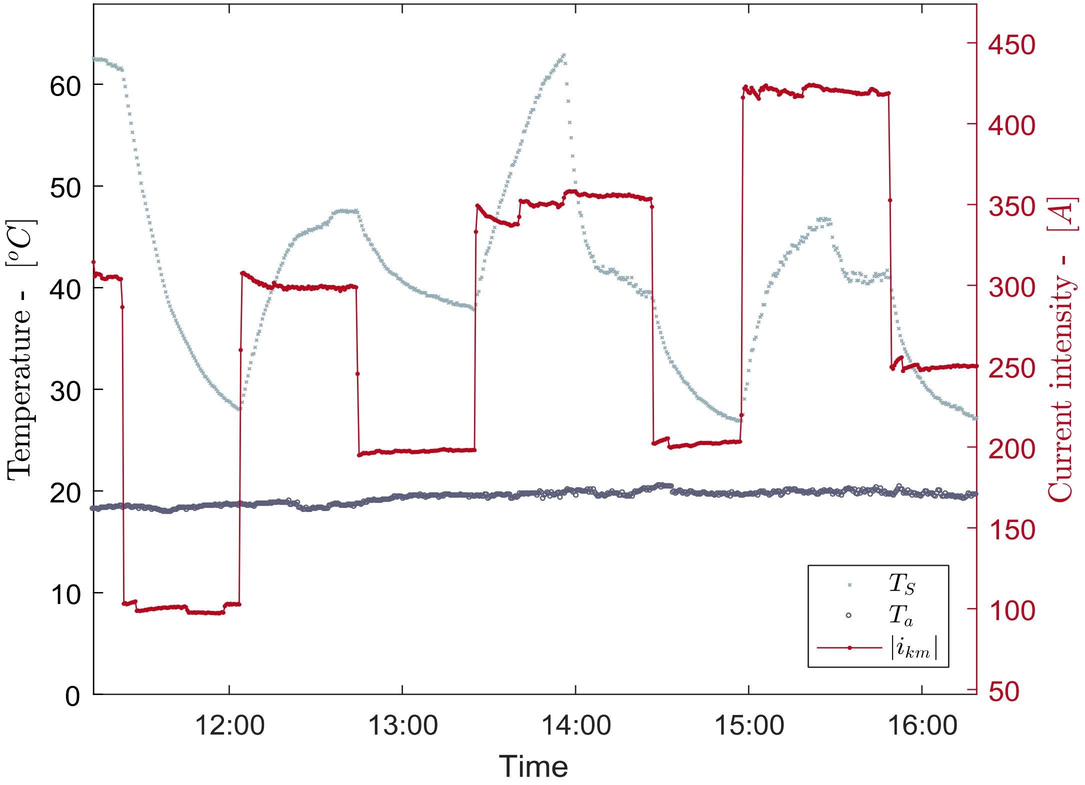


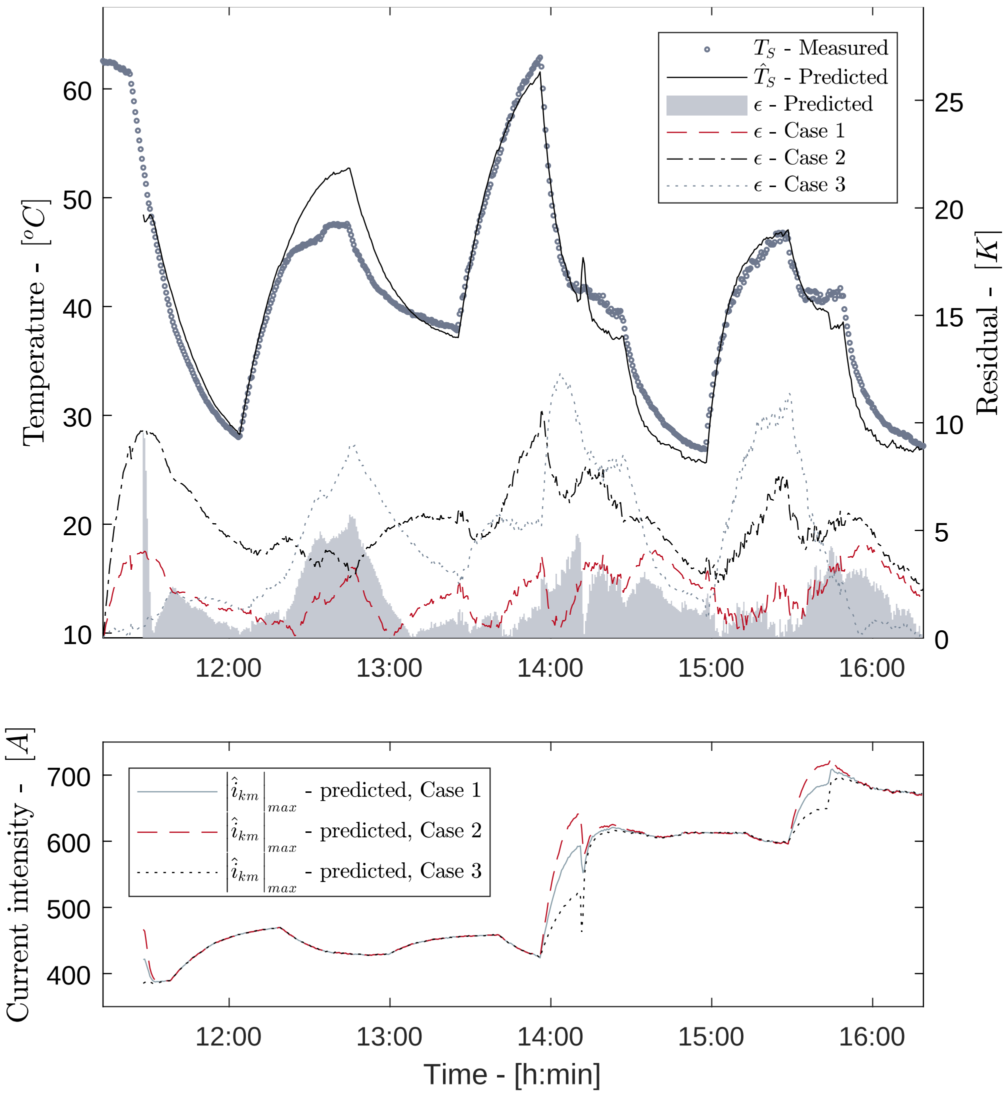
Figure 9. Circuit diagram of the experimental test



D. L. Alvarez, F. F. da Silva, E. E. Mombello, C. L. Bak and J. A. Rosero, "Conductor Temperature Estimation and Prediction at Thermal Transient State in Dynamic Line Rating Application," in *IEEE Transactions on Power Delivery*, vol. 33, no. 5, pp. 2236-2245, Oct. 2018, doi: 10.1109/TPWRD.2018.2831080.

Hybrid Extended Kalman Filter - EKF





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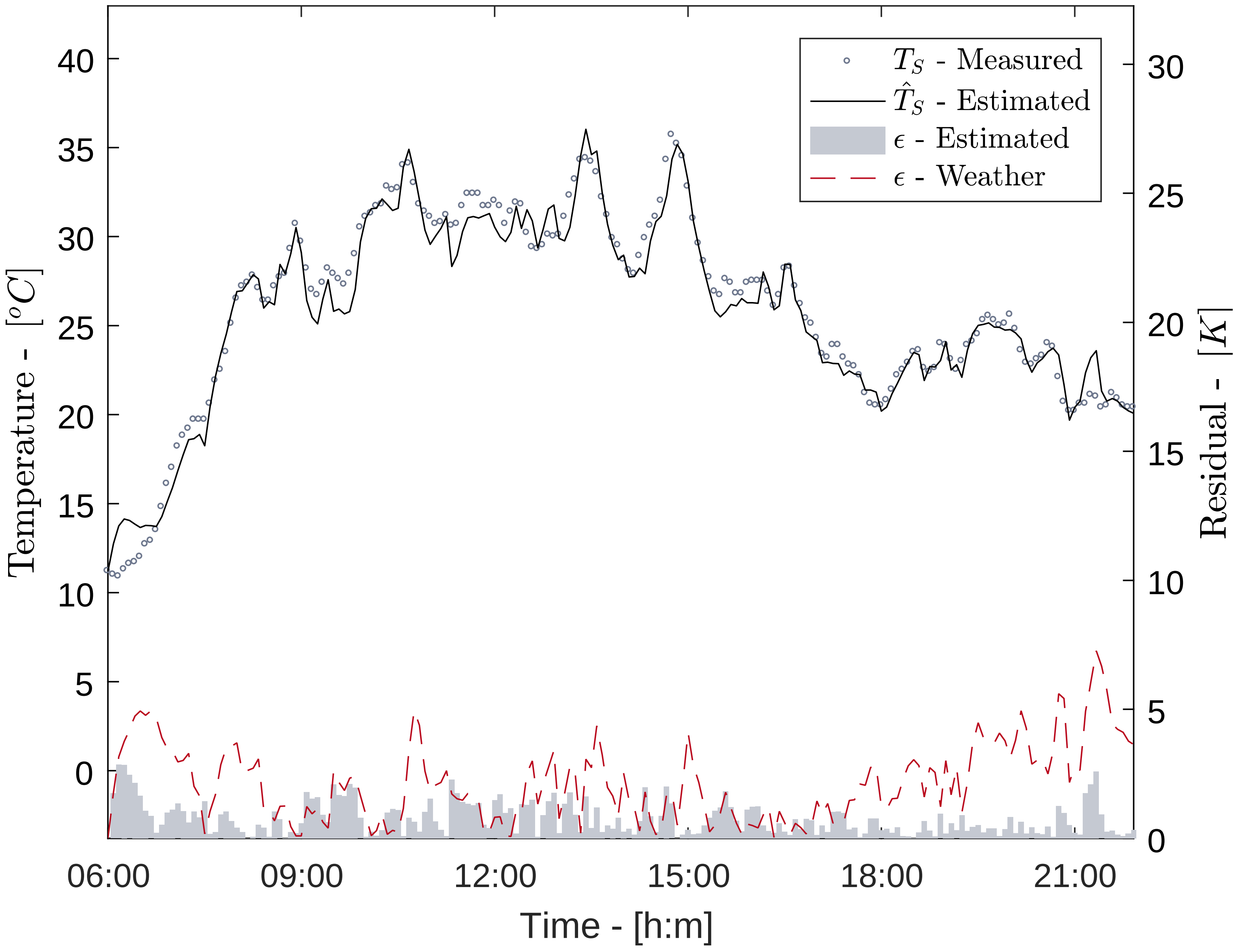


Field Measurements

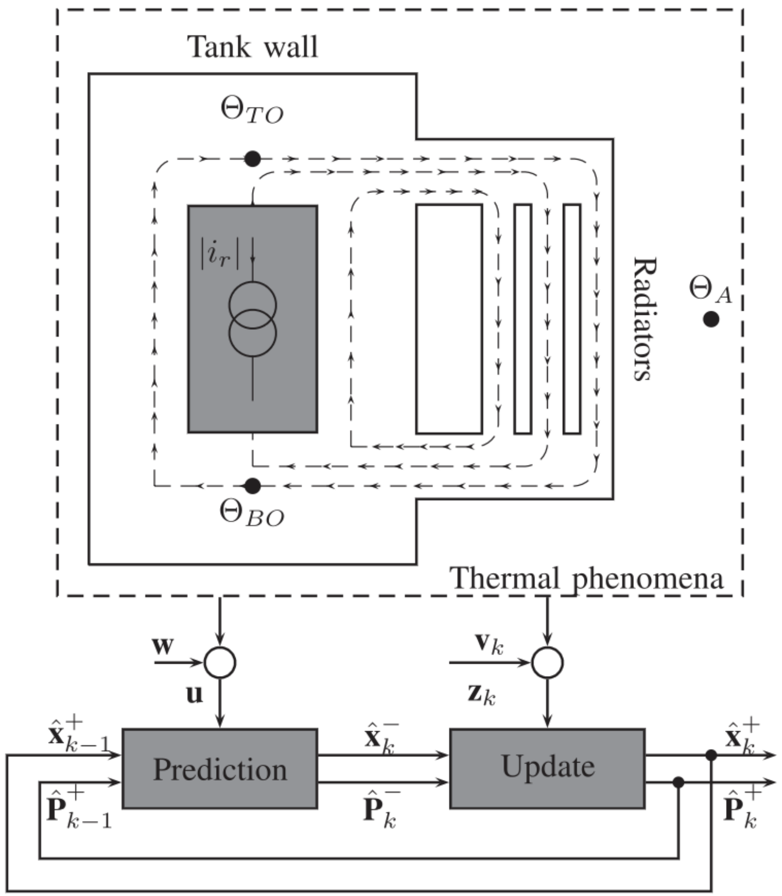
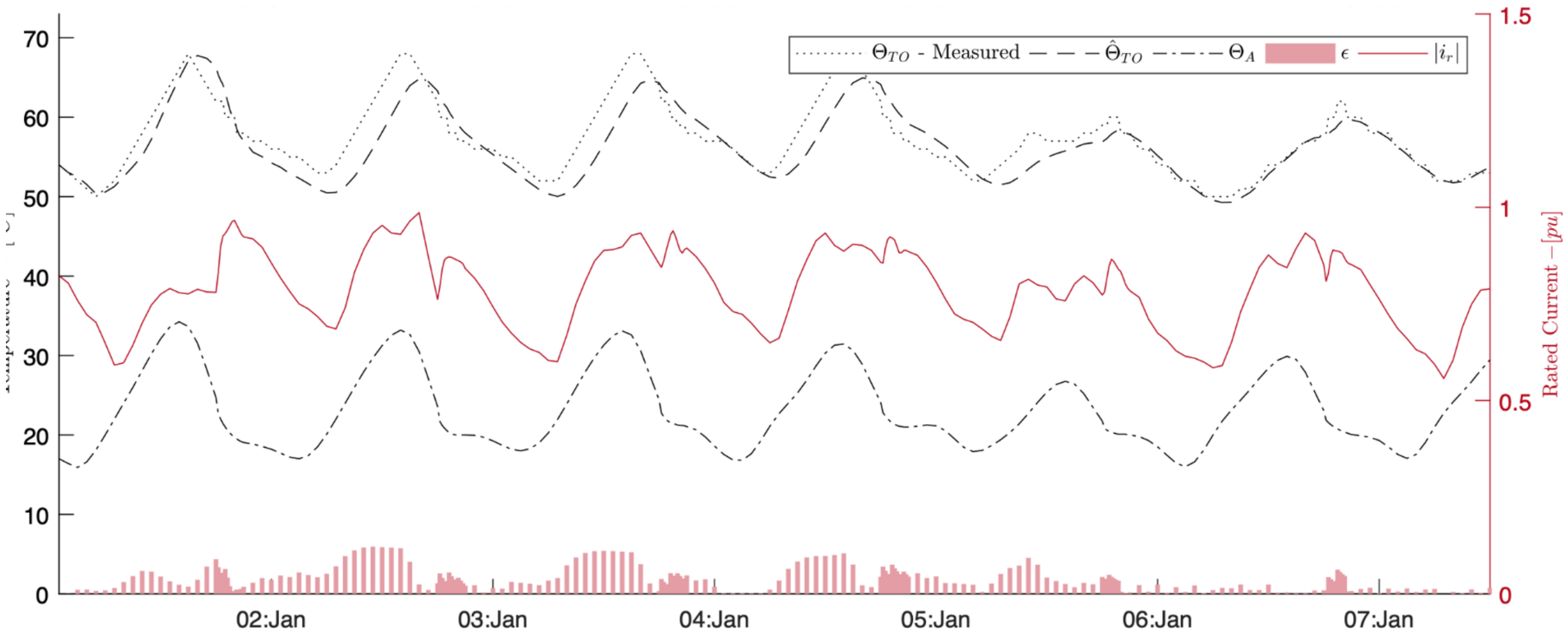
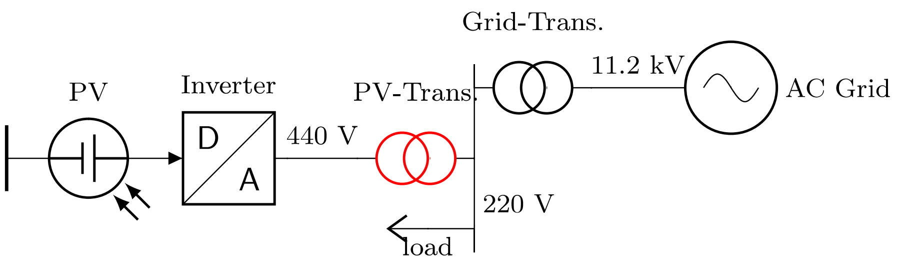
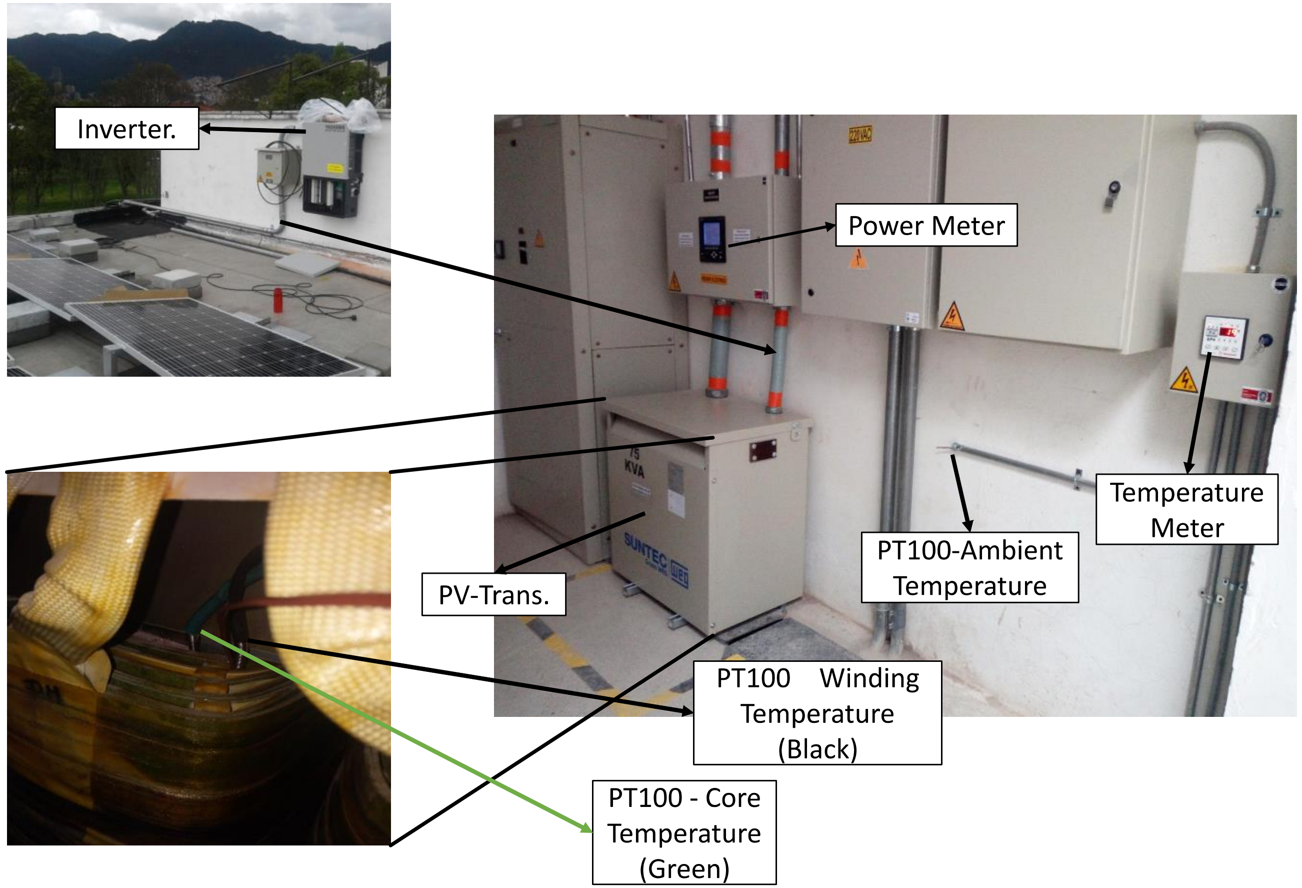


Fig. 5. EKF flowchart to estimate and predict transformer's top-oil temperature.

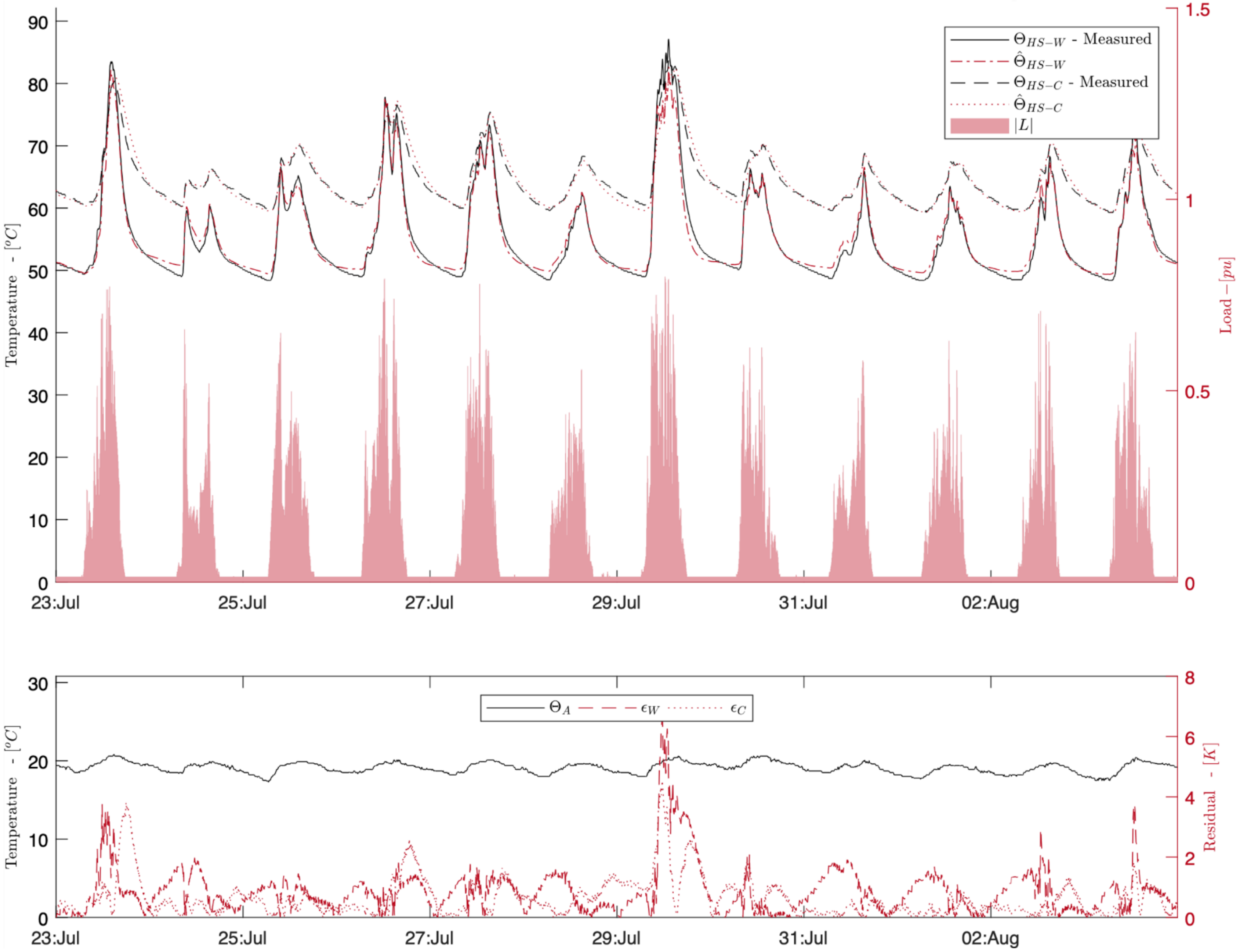


D. L. Alvarez, S. R. Rivera and E. E. Mombello, "Transformer Thermal Capacity Estimation and Prediction Using Dynamic Rating Monitoring," in *IEEE Transactions on Power Delivery*, vol. 34, no. 4, pp. 1695-1705, Aug. 2019, doi: 10.1109/TPWRD.2019.2918243.





Alvarez, D.L., Restrepo, J., da Silva, F.F. *et al.* Load capability estimation of dry-type transformers used in PV-systems by employing field measurements. *Electr Eng* **103,** 1055–1065 (2021). https://doi.org/10.1007/s00202-020-01148-7

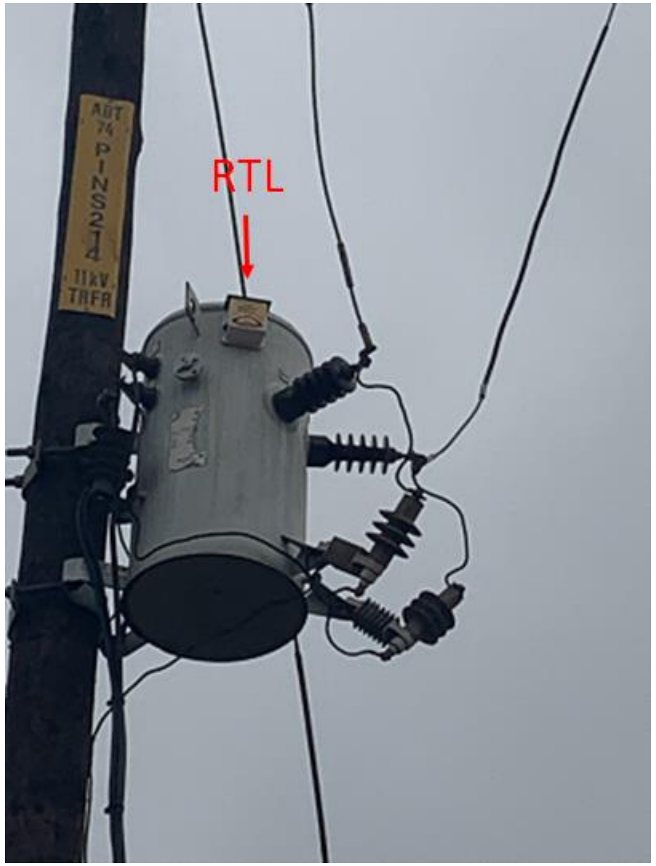


Alvarez, D.L., Restrepo, J., da Silva, F.F. *et al.* Load capability estimation of dry-type transformers used in PV-systems by employing field measurements. *Electr Eng* **103,** 1055–1065 (2021). https://doi.org/10.1007/s00202-020-01148-7

The development of a remote temperature logging system for pole mounted distribution transformers

Electrical Machines & Drives
Grupo de Investigacion

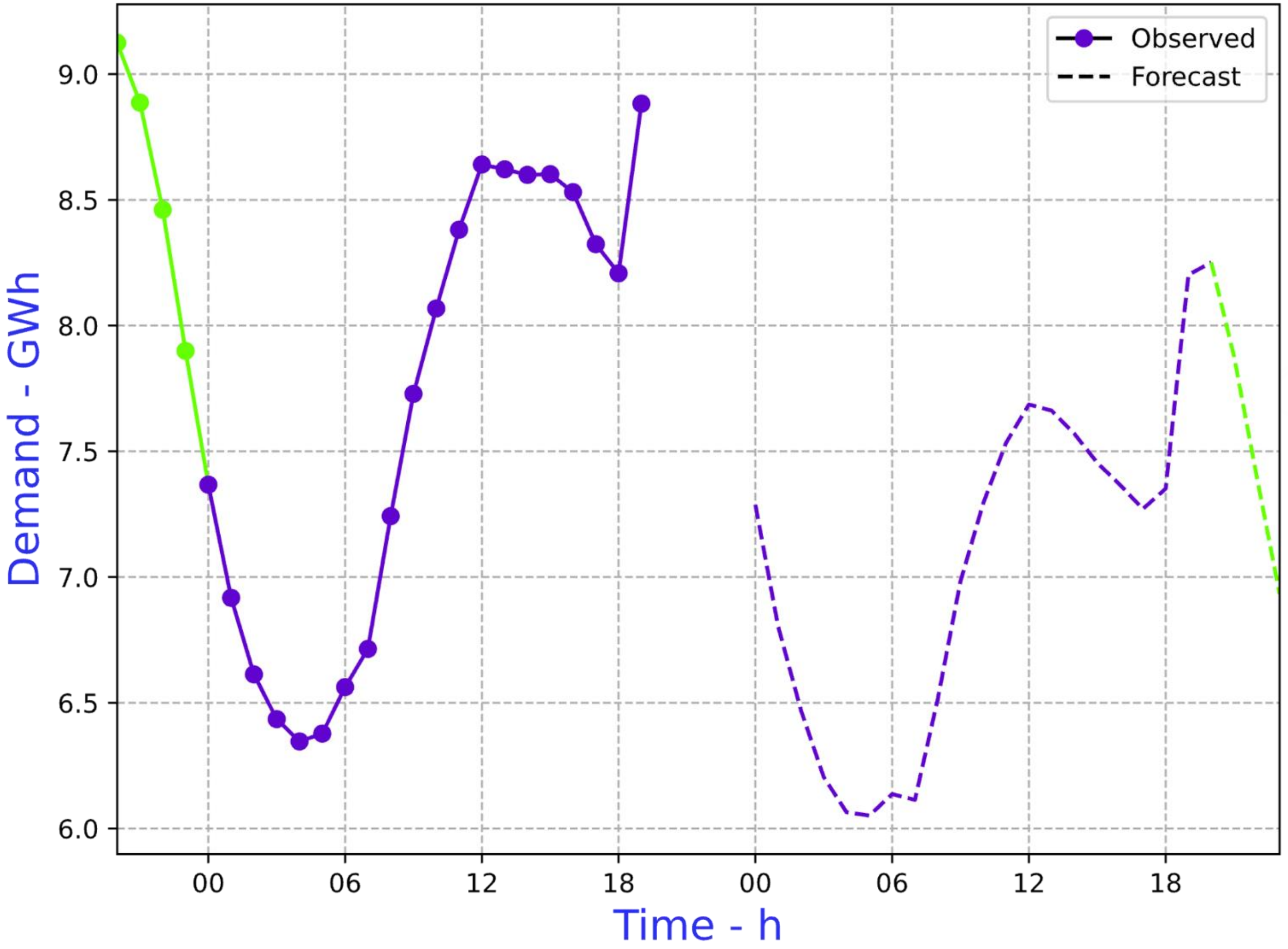
ESKOM's fleet of distribution transformers is greater than 200,000. More than 90% of which are PMT. In the winter months the average PMT failure event is 2200. This costs the company $4.1 Million annually. Additionally, this has a significantly negative impact (>10%) on SAIDI. PMT failure events during the winter period are predominantly due to overloading therefore a remote temperature logging (RTL) system was developed to detect the overload condition.



Using a PMT's tank temperature in the summer months it is now possible to predict if the PMT will be overloaded during the following winter.
Load visibility, Environmental, Safety

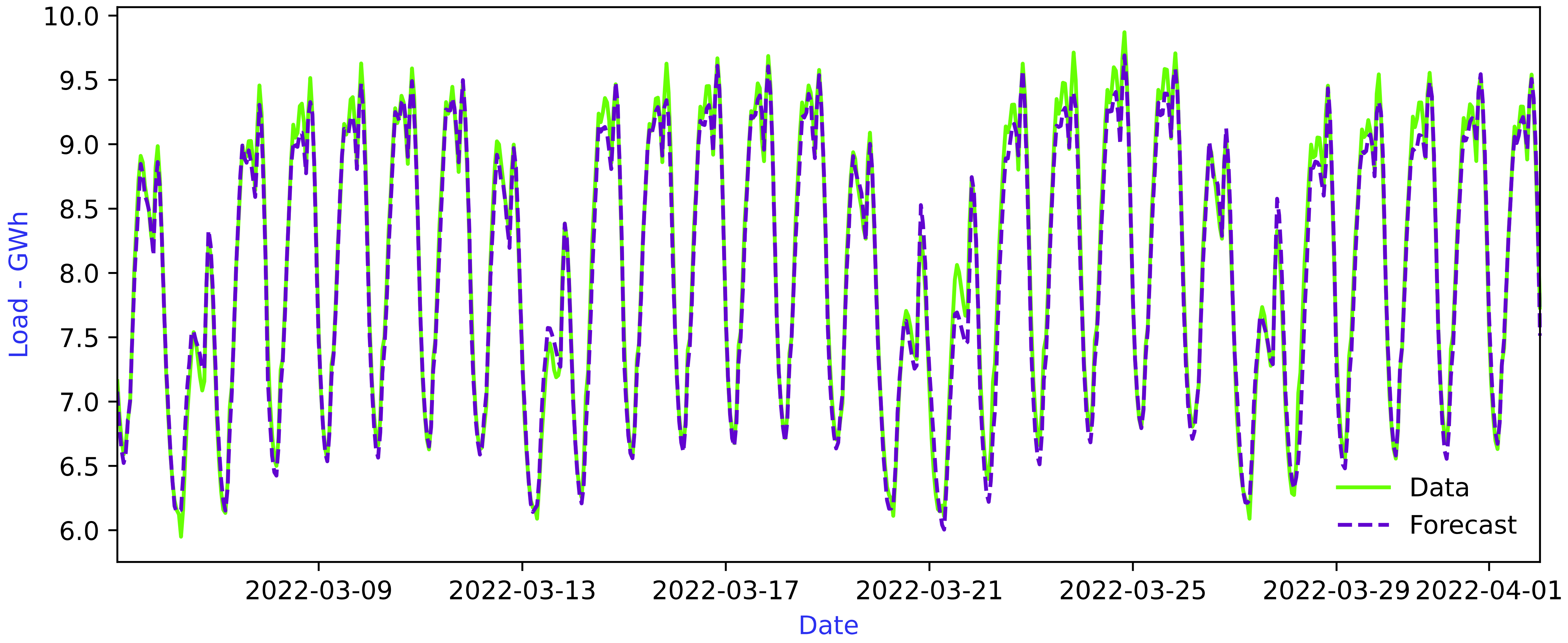
ROI ratio of 39:1 over the 5 year period and making mass RTL deployment a sensible choice.

https://www.cigre.org/article/GB/news/the_latest_news/the-development-of-a-remote-temperature-logging-system-for-pole-mounted-distribution-transformers



https://github.com/EquipoAnaliticaXM/API_XM

Repositorio para compartir herramientas de consulta para extraer información relevante del Mercado de Energía Mayorista colombiano usando la API XM.


10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
Load - GWh
2022-03-09
2022-03-13
2022-03-17
2022-03-21
2022-03-25
2022-03-29
2022-04-01
Date
Data
Forecast

Electrical Machines & Drives
Grupo de Investigacion

Gracias por su atención
¿Preguntas?

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