Systems for supporting power system operation of modern TSO

HOPS
Croatian Transmission System Operator

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Agenda

- About HOPS Croatian Transmission System Operator
- Wide Area Monitoring
  - WAMS infrastructure in HOPS
  - WAMS in the Control Room
  - Real time applications
- Dynamic Thermal Rating
About HOPS – Croatian Transmission System Operator

Croatia is in Central and Southeast Europe, on the coast of the Adriatic Sea

Transmission Lines (km) 7.795
Substations (num) 183
Voltage levels 400 kV, 220 kV, 110 kV
**Synchrophasor applications in HOPS**

- Over 60 PMUs installed in HOPS network
  - Placement function:
    - Measurement redundancy for network applications
    - Tie lines
    - 400 kV internal lines
    - Point of Connection with power plants

- Synchrophasors data exchange with TSO community
  - sending / receiving

- 2 PDCs
  - SynchroShield PDC – develop by HOPS
  - WAMSTER PDC – commercial application

- WAMS connected to the SCADA system
  - IEC 60870-5-104
Synchrophasor applications in HOPS - today

- No ‘killer’ application to cover all possible usages
- Niche cases to cover needs
- The usage of PMU data in HOPS depends on the issue to monitored or solved

Real Time Application
- Phase angle difference monitoring
- Frequency monitoring
- AGC measurements
- Broken conductor detection
- Island detection
- Oscillation detection (pilot)

Planning and Monitoring
- Monitoring of FCR
- Loss calculation
- Transmission line parameter calculation (pilot)

Disturbance Detection and Analysis
- Protection functions:
  - Overcurrent
  - Differential
  - Distance
  - Fault Locator on transmission Lines
WAMS in the control room

- Wide Area Monitoring has been in use worldwide for more than fifteen years within TSOs environments, a lot of experience has been accumulated.

- However, the final goal of integrating WAM system capabilities into TSOs standard operation and monitoring processes has not been fully achieved.

### Technical Integration Issues
- Integration issues related to the communication network
- WAM system data exchange between TSOs with different IT policies
- High availability on the application layer
- Existing SCADA/EMS are often not suited for seamless WAM system integration
- Integration issues related to data management and analysis methods

### Non technical Integration Issues
- Operator acceptance – confidence gap
- Missing clearly defined countermeasures to mitigate unsecure operation
- Usability and capabilities of WAM system based control applications
- Missing regulatory aspects
WAMS in the control room – HOPS approach

Obtain information from synchrophasor measurements to be presented to the operator with associated measure / action

How?

1. Integration with SCADA system:
   - Warnings / alarms
   - Basic views (as much as possible due to the limitations in the possibilities of visualization in the SCADA system)

2. Integration with other existing systems in the operator’s room (OsiSoft, EMS, …)

3. Access to WAM system for detailed analysis and review of information in case of an alarm

4. Development of WEB application for advanced views on the Video wall
Real time applications – PDC view
Real time applications – SCADA view (1)

- Dynamic Contour Coloring by frequency
- Islanding detection
- Data from internal PMUs and PMUs from neighbouring TSOs
Real time applications – SCADA view (2)

- Phase angle difference monitoring
- Frequency deviation monitoring
Real time applications – SCADA view (3)

- Monitoring of unbalanced operation
- Broken conductor monitoring
Real time applications – integration with AGC

- PMU data used as primary measurements for Automatic Generation Control system:
- Integration of synchrophasors (2 s $\rightarrow$ same as AGC cycle)
- Synchrophasor measurements on tie lines
Real time applications – island detection and integration with AGC

- PMU based island detection algorithm

PDC

Island detection flag triggered

AGC system

- AGC going to stop mode
- Generators in AGC stars operate in frequency mode
  Frequency measurement mostly from PMU
Real time applications – broken conductor detection

- Measurements of symmetrical components delivered by PMUs to the control center
- Alarming in the National Dispatch Center if broken conductor detection is detected
Real time applications – fault locator

- Fault location assessment usually calculated in distance protection relays
- HOPS uses a system using:
  - Single PMU method
  - PMUs on both terminals
- Calculation methods confirmed with field survey
Monitoring of Frequency Containment Reserve

- Frequency containment reserve (FCR) - necessary for constant containment of frequency deviations (fluctuations) from nominal value
- Monitoring of activation of primary regulation with PMUs installed on the Ppoint of connection with power plants
- PMU data sent to the visualization tool OsiSoft PI
Weather system in HOPS

Weather predictions:
- Based on GFS model – input grid (27.5 x 27.5km)
- 4 calculations per day (00, 06, 12 and 18 UTC) – each takes around 7 hours
- Output grid 2x2km for Croatia and surrounding countries
- All relevant weather parameters predicted for 72 hours in advance

Weather measurements:
- 2 types of weather stations
- 55 weather stations installed in power stations
- 15 weather stations installed on power lines

Used for system loses prediction, renewables prediction, DLR
Weather system in HOPS

Weather forecast values:
- Pressure,
- Wind speed at height (10, 30, 50, 80, 100 meters),
- Wind gust,
- Wind direction at height (10, 30, 50, 80, 100 meters),
- Ambient temperature and humidity,
- Dewpoint,
- Rain rate,
- Solar radiation,
- Cloudiness,
- Composite radar reflection,
- Hourly rain,
- Hourly snow

Measured values from Weather stations:
- Pressure,
- Wind speed,
- Wind gust,
- Wind direction,
- Ambient temperature and humidity,
- Dewpoint,
- Rain rate,
- Solar radiation,
- UV index,
- Rain,
- Indoor temperature
Weather system in HOPS

55 locations in PS
15 locations on line
Weather system in HOPS

System design

Web GUI application

Internet

GFS 0.25° DATA

Firewall

Weather station - Power station

MySQL DB

Application server

PostgreSQL

DMZ server

Firewall

Weather station - Powerline

User 1

User 2

User N

Weather system in HOPS

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User 1

User 2

User N
DLR systems in HOPS

**SUMO DTR – SINCRO.GRID project**
- Implemented in 2020. by PCI founded project SINCRO.GRID
- Based on weather data and terrain profile
- Tower data (type and height) and line data (conductor parameters) needed
- DLR limit calculated each minute and used in SCADA / EMS calculations
- DLR limit forecast for 3 hours in advance
- 220kV lines equipped with DLR – important for renewables production at the south of the country

**OTLM and LineVision - FARCROSS project**
- Implemented in 2021. by Horizon 2020 founded project FARCROSS
- Proof of concept – Equipment installed on one tower on 220kV line HE Senj – Melina
DLR system in HOPS – SINCRO.GRID project

HE Senj - Melina

VE Krš Pađene - Brinje

Konjsko – VE Krš Pađene

HE Zakučac - Konjsko
DLR system in HOPS – SUMO DTR

DTR - SCADA view

DTR - ODIN view
OTLM sensor

- Powered by line current >65A
- Measures conductor temperature and sag angle
- DLR limit calculated if sensor installed together with weather station
- Data is sent over LTE to OTLM server
**DLR system in HOPS - LineVision**

**LineVision sensor**
- Powered by solar panels
- Measures distance with LIDAR between sensor and line
- DLR limit and conductor temperature calculated in LineVision Centre
- Data is sent over LTE to LineVision Centre
- Result data downloaded by API
DLR system in HOPS – DLR different technology comparison

Conductor temperature OTLM vs SUMO vs LineVision - Decembre 2021.

- **OTLM temperatura vodiča**
- **SUMO DTR temperatura vodiča**
- **LineVision temperatura vodiča**
DLR system in HOPS – DLR vs static limit in 2021.

Line 220 kV HE Senj - Melina

- DTR limit DV 220 kV HE Senj - Melina (A)
- Technical limit (A)
- Line loading (A)
DLR system in HOPS – DLR benefits

Line 220 kV HE Senj - Melina
- 7863 h
- 95% >780 A
- 5% <780 A
- 391 h

Line 220 kV Konjsko - VE Pađene
- 7812 h
- 93% >780 A
- 7% <780 A
- 560 h

Line 220 kV Konjsko - HE Zakučac
- 7991 h
- 97% >780 A
- 3% <780 A
- 251 h

Line 220 kV VE Pađene - Brinje
- 7597 h
- 90% >780 A
- 10% <780 A
- 834 h
Questions? Comments?

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