**OVERVIEW**

**Effective Inertia: The Frequency Alert Indicator**

The operation of the grid is continuing to grow in complexity, due to the growing volume of variable renewable generation. This has led to a massive displacement of system Inertia, with networks now requiring enhanced system visibility and understanding to deliver fast-acting response services. Analytics services now facilitate the measurement and forecasting of Effective System Inertia.

**Effective inertia** measures the combined inertia-like effects of rotating machines, passive load responses, and active generator controls. GE Effective Inertia metering is nonintrusive, with no injection of forced stimulation into the network. **WAMS data and analytics** measures effective inertia in each regional area of the power system in real time, and can combine them to a global value.

Metering real-time effective inertia provides confidence to operators about the margin and the risk on the current position, to make a decision on the appropriate frequency response service. Furthermore, the Effective Inertia Forecast allows forward planning to reduce the cost of services.

GE inertia metering and forecast is agnostic of EMS and PMUs; however, integration within the GE Advanced EMS Network, Generation and WAMS advanced applications maximize overall solution value.

**KEY OUTCOMES**

- Increase network resilience.
- Prevent potential blackout.
- Reduce curtailment fees and penalties.
- Lower frequency response services.
- Increase renewables penetration.

**KEY FEATURES**

- Nonintrusive metering.
- No engineering project to install expensive hardware required for signal injection.
- Regional and global inertia metering.
- Real-time metering.
- EMS and PMU PDC agnostic.
- Forecast from analytics.

- When inertia reduces, then load shed limits may be reached for governor response, resulting in a blackout.
- Frequency change takes time to propagate > Angles diverge > Stability risk.
- Frequency and RoCoF (Rate of Change of Frequency) varies substantially between locations in the first seconds.

**Customer profiles**

- Transmission System Operations (TSO)
- Regional Transmission Organization (RTO, ISO)
- Integrated utilities (generation, transmission, distribution)
Digital Energy

Effective Inertia

High non-synchronous renewables penetration
Avoid major blackouts from frequency drops - Lower frequency service costs

**Effective Inertia Metering**

- The principle is built upon a proven PMU-based method for continuous metering at a regional level.
- The frequency is measured at selected points within the area, preferably close to main sources of real inertia.
- PMUs are located on all transmission circuits crossing the area boundary for summation of net power exchange.

![Continuous inertia measurement (1 week)](image)

**Effective Inertia Forecast**

- Applying machine learning relates inertia to known and predictable values: conventional rotating inertia, load, solar power, wind power.
- Accurate inertia forecasting give the TSO confidence in a secure level of renewables penetration and associated reserve services.

![Inertia forecast chart showing historical forecasts vs. actual metered inertia and 1-day ahead forecast](image)

**Fast Frequency Control: WAMS control to provide fast frequency service**

**KEY FEATURES**

- Fast detection.
- Real-time resource availability.
- Minimize the risk of system separation.
- Targeted and proportional response.
- Harness fast-acting resources in a reliable and safe manner.

**WIDE-AREA MONITORING AND CONTROL SYSTEM**

System split into a number of regions:

- Multiple distributed controllers.
- In each region, PMUs send data to aggregators.
- Aggregated signals broadcast to controllers.
- Resource information sent to a central supervisor.

![Event timeline](image)

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