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Accurate Synchrophasor Estimation to Support the Islanding Maneuver of Active Distribution Networks

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Outline

The challenge of using PMUs in active distribution networks

Configuration of the network

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The challenge of using PMUs in active distribution networks

Peculiarities of electrical distribution networks

- lower p.u.l. inductances with non-negligible p.u.l resistance;
- low power flows values;
- high harmonic distortion levels;
- higher dynamics compared to transmission networks

(electromechanical transients).

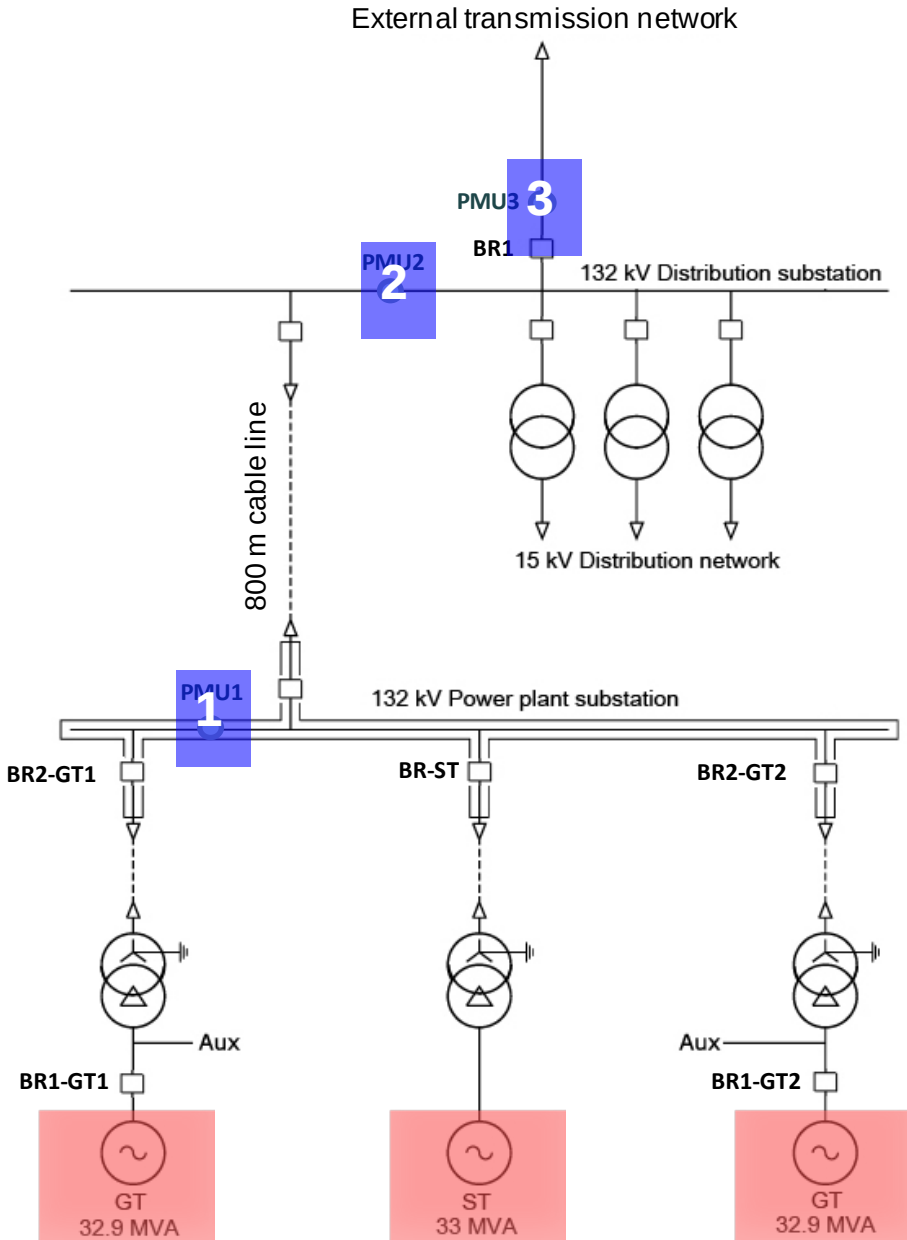
PMU prototype based on the National Instruments cRio platform

Peculiarities of the developed PMU

- TVE, phase and amplitude accuracies in the **order of PPM**;
- **Accuracies not influenced by the harmonic distortion** of the analyzed signals;
- **Accuracies not influenced by large frequency transients** (1 Hz/s).

Configuration of the network

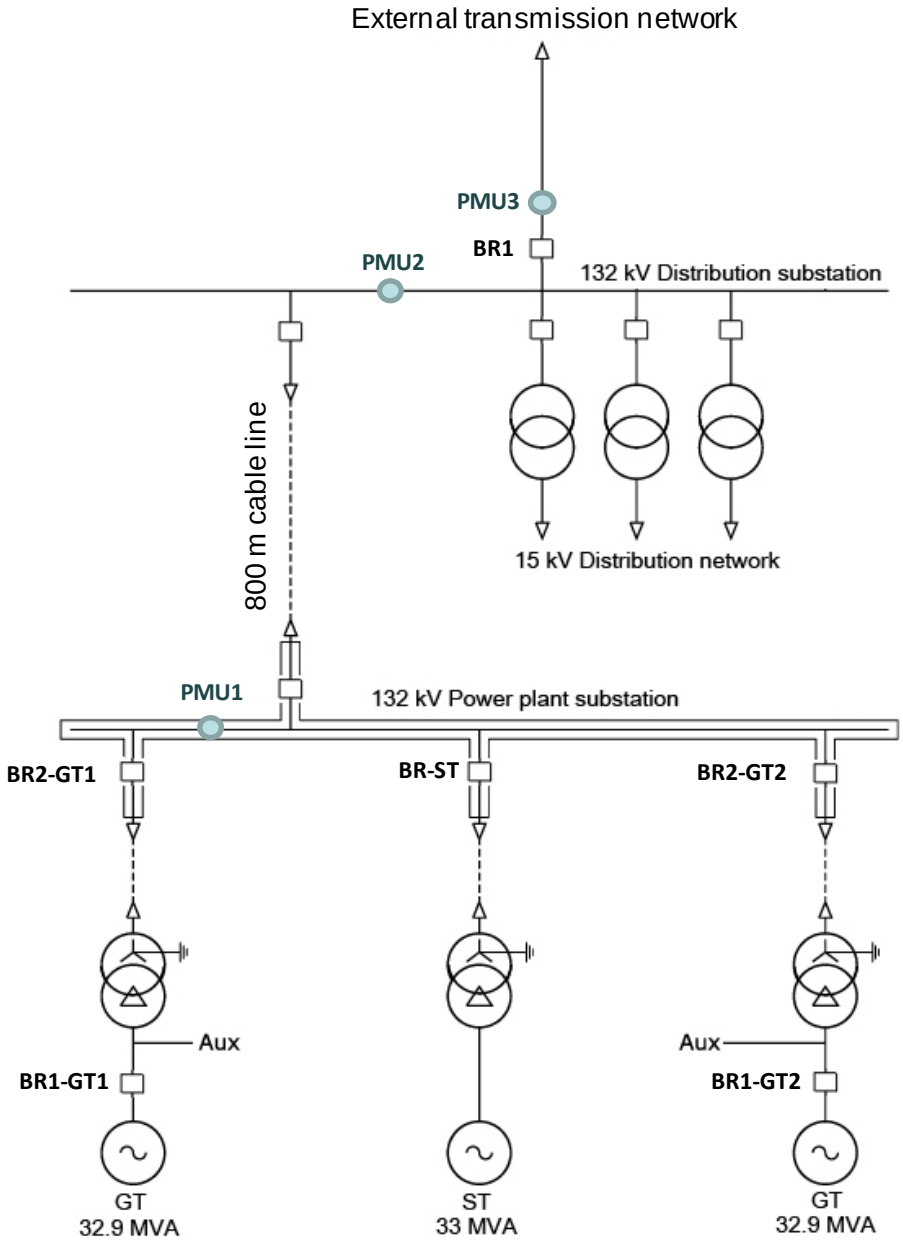
- 80 MW power plant (PP): **two aeroderivative gas turbine** (GT) units and a **steam turbine unit** (ST) in **combined cycle**;
- PP substation is linked, by means of a cable line, to a local 132 kV substation that **supply 15 feeders of the local medium voltage (15 kV) distribution network**. The substation also provides the **connection with the external transmission network** throughout circuit breaker BR1.
- Three PMUs were installed in correspondence of the PP and before/after BR1



Configuration of the network

PP is equipped with a **power management system** that, after network **disconnection** (remote ctrl of breaker BR1), performs the following operations

- communicates the **load droop anticipator command** to the ST control system in case of islanding maneuvers;
- **disconnects MV feeders** to guarantee the **load balance**;
- **selects the operation control** mode of the two gas turbines for the **frequency regulation** of the network in **islanded conditions**;
- **controls PP units to allow a reliable reconnection maneuver**.



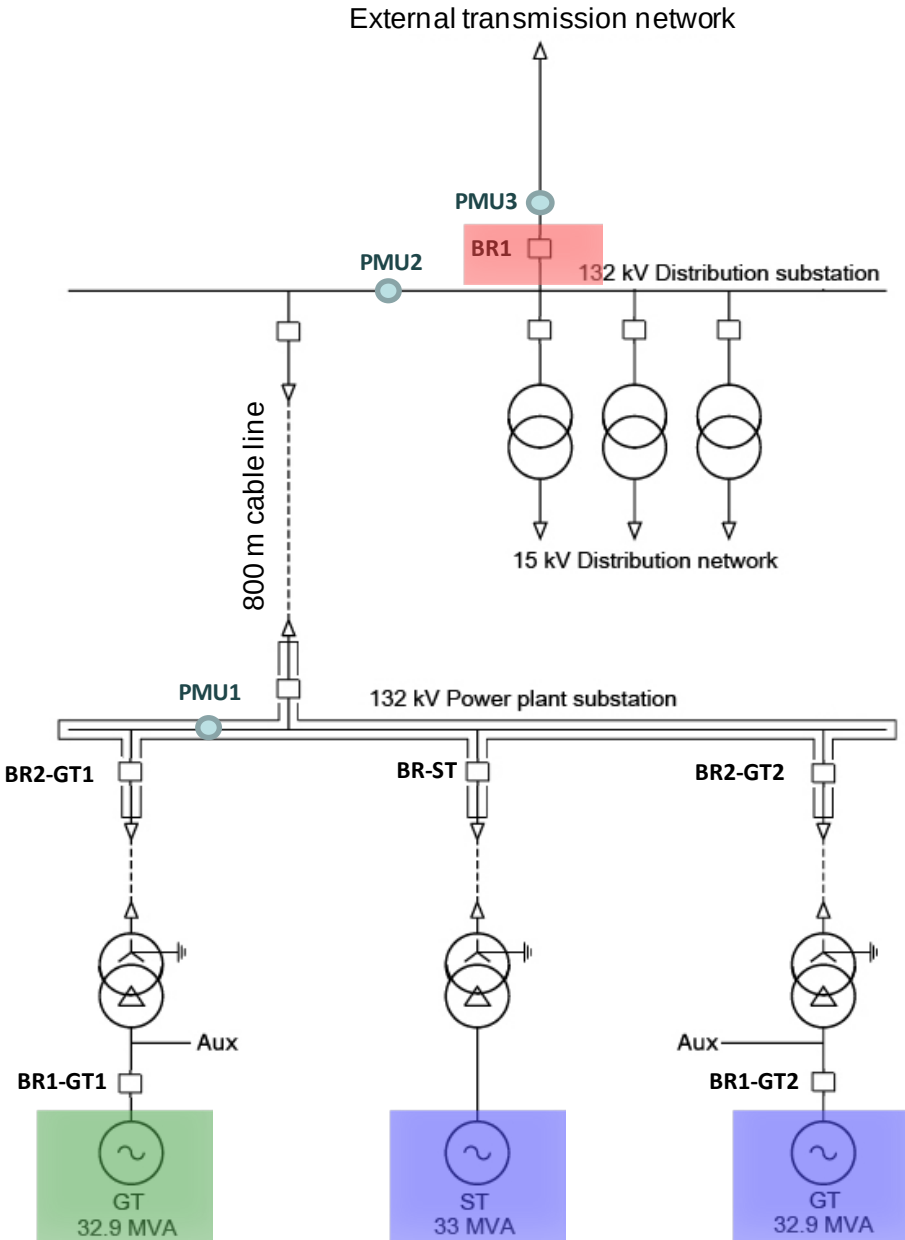
Goals of the PMU monitoring system

- Support the system operators during the islanding maneuver and reconnection to the external network;
- Monitor possible network instabilities subsequent to the islanding maneuver;
- Provide help to the PMS action with the synchro-check relay in order to support the reconnection maneuver.

The event and the outcome

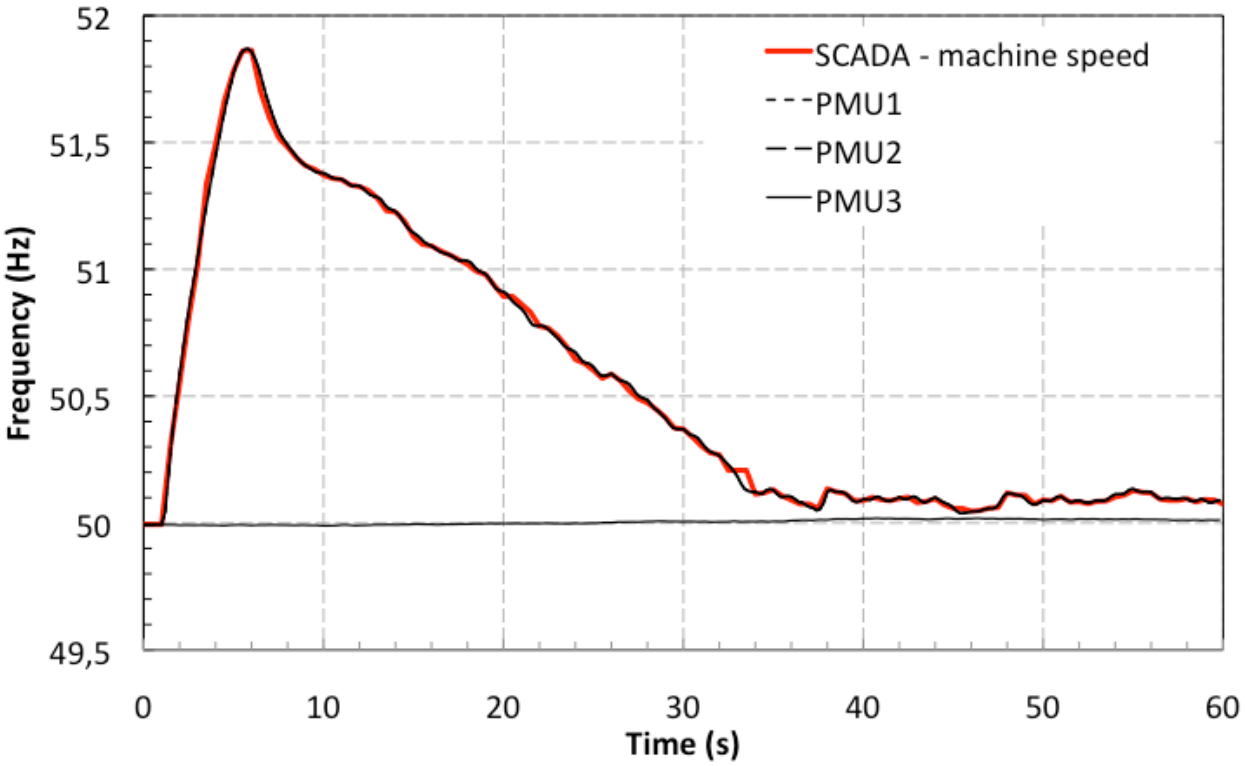
Islanding maneuver description:

- GT1 unit was in operation at an output level equal to 29.4 MW, with a **positive export to the external network equal to 1.9 MW**; GT2 and ST units were in standby.
- Intentional opening of circuit breaker BR1.



The event and the outcome

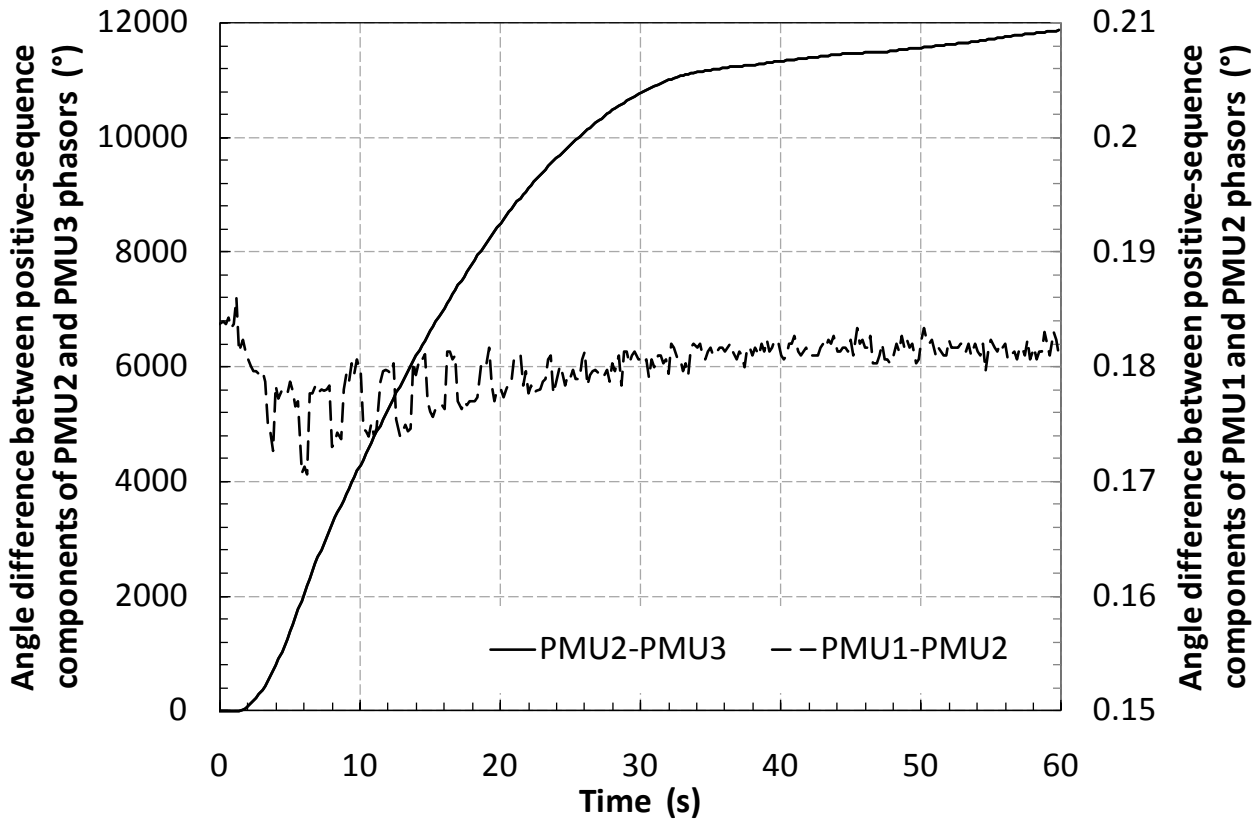
PMU measured frequency transient



- The islanding maneuver in presence of a positive PP power export to the external network, has resulted in a decrease of the PP power production and a consequent large frequency transient.
- Frequency transient characterized by a **rate of rise in the order of 1Hz/s**.
- Good match between the **SCADA machine speed and the PMU measured frequency**.

The event and the outcome

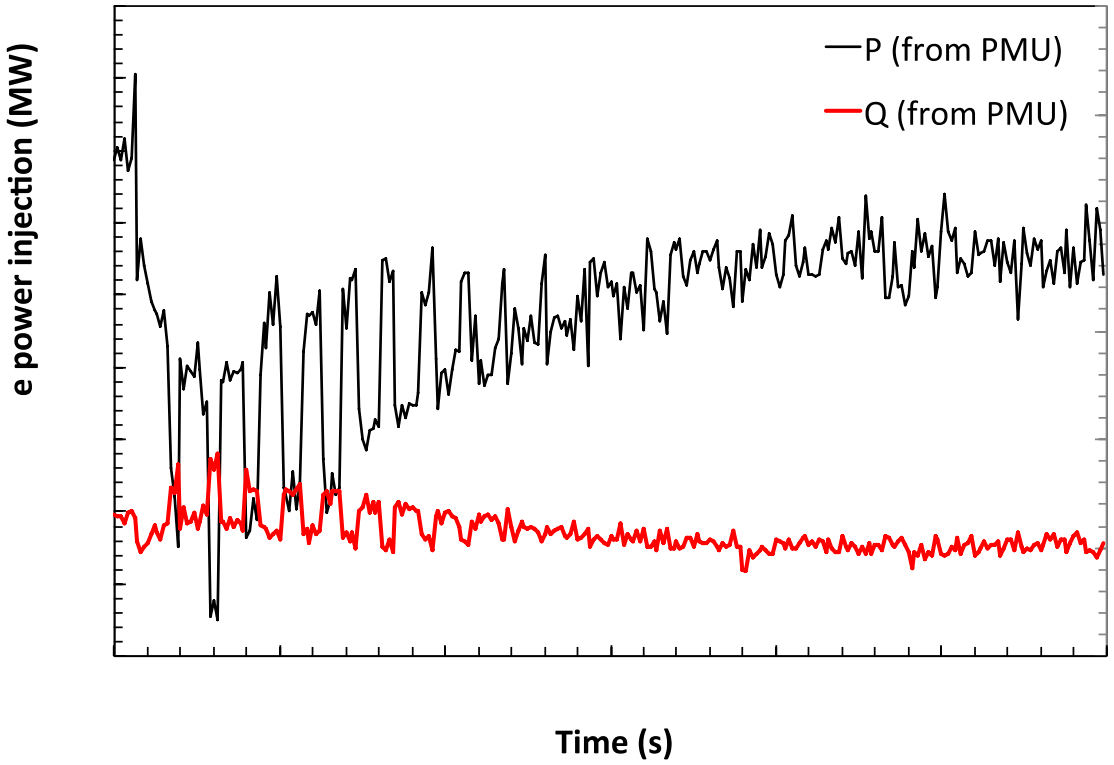
Voltage phasors angle differences



- Clear **identification of the separation between the two networks** (continuous line PMU2-PMU3).
- Identification of an **oscillation (0.3 Hz) between the PP and the rest of the network**.
- Measurement of the post-islanding reduction of the phasors angle deviation between PMU1-PMU2 associated to the reduced power flow between the PP and the rest of the network.

The event and the outcome

Phasor-based estimated power injections into the cable link

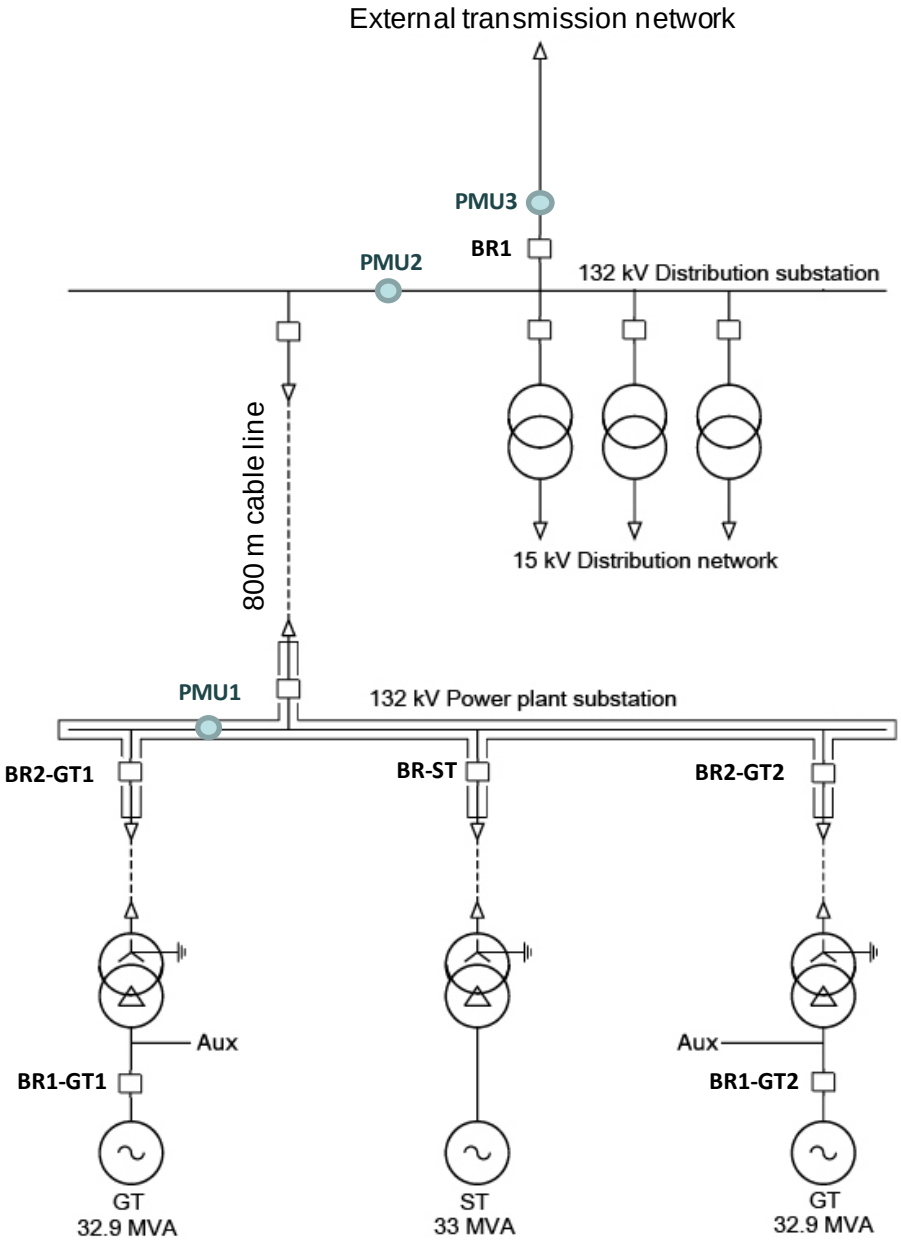


- Estimation of the power flows between the PP and the primary substation and related amplitude of the active power flow oscillation.

The event and the outcome

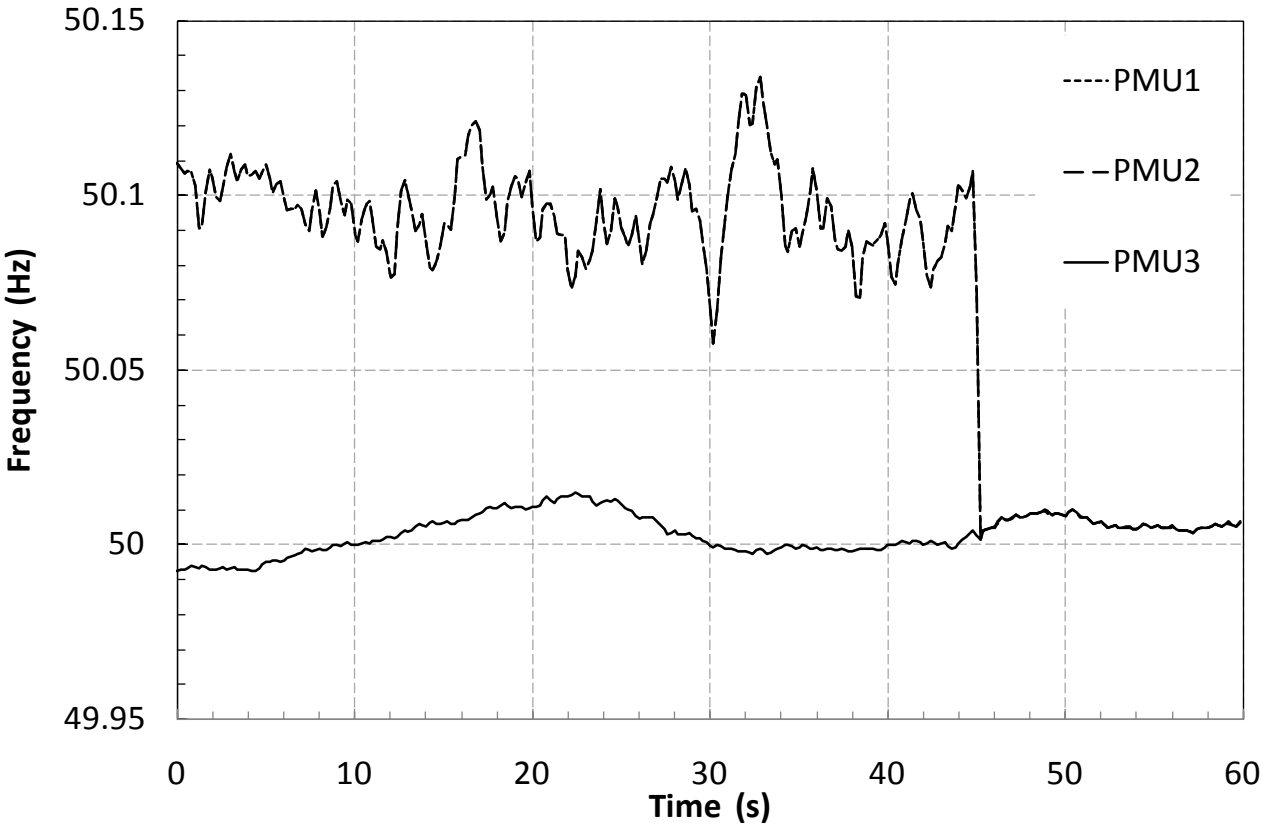
Reconnection maneuver description:

- **A feedback of the PMU measurements was given to the PP operator**.
- The synchro-check relay and the synchronizing PMS action permitted the smooth reconnection maneuver.



The event and the outcome

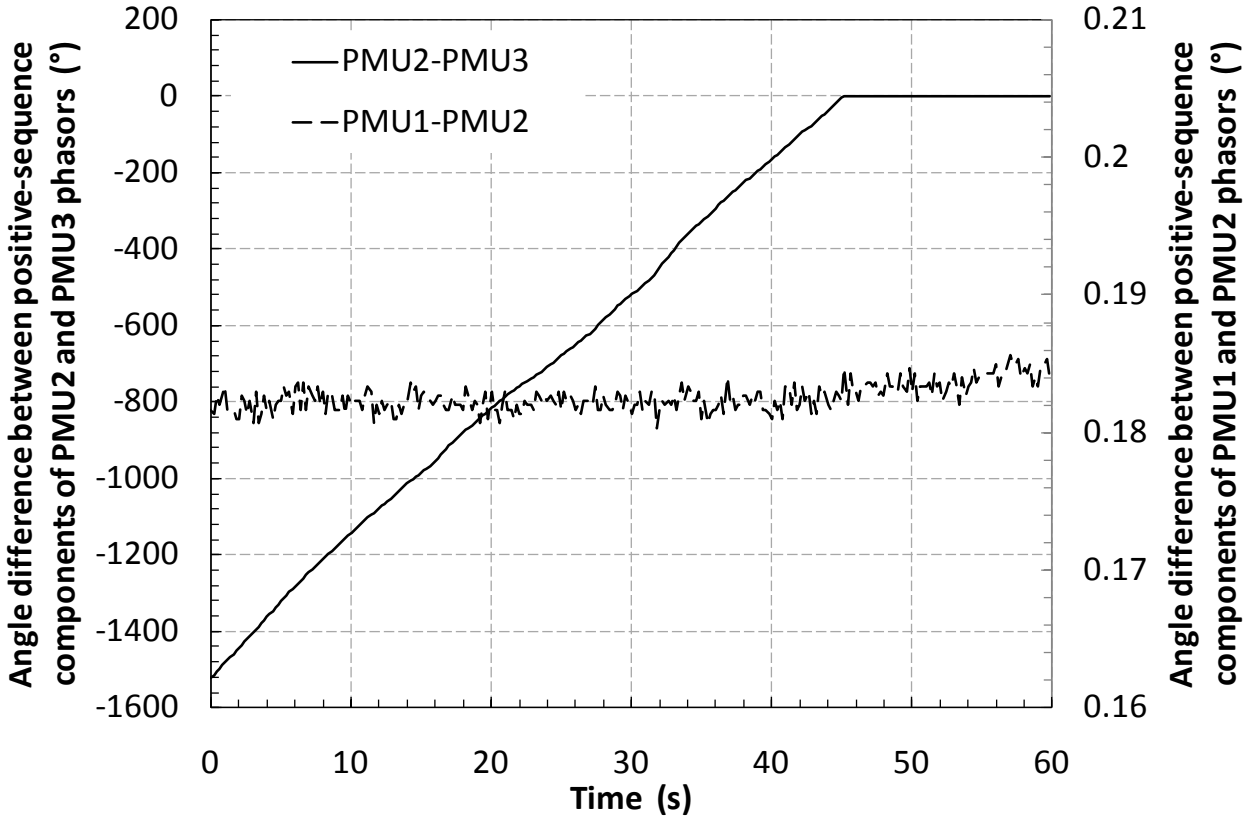
PMU measured frequency transient



- Monitoring of the frequency difference (positive) between the islanded network (PMU1 and PMU2) and the external network (PMU3).

The event and the outcome

Voltage phasors angle differences



- Identification of the correct phase difference between islanded and external network to trigger the reconnection maneuver.

Conclusions

- Requirements of PMU use in active distribution networks could call for more specific indications in the available standards (IEEE C37.118).
- The information provided by PMUs appear to be of great help for the development of improved control and management systems aimed at supporting islanding and reconnection maneuvers more straightforward and reliable.
- The information coming from PMUs may represent a useful support to distribution system operator decisions during critical instances experienced by the system, such as islanding/reconnection operation.