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MICRO PHASOR MEASUREMENT UNITS:

a Review from the Prosumer Point of View

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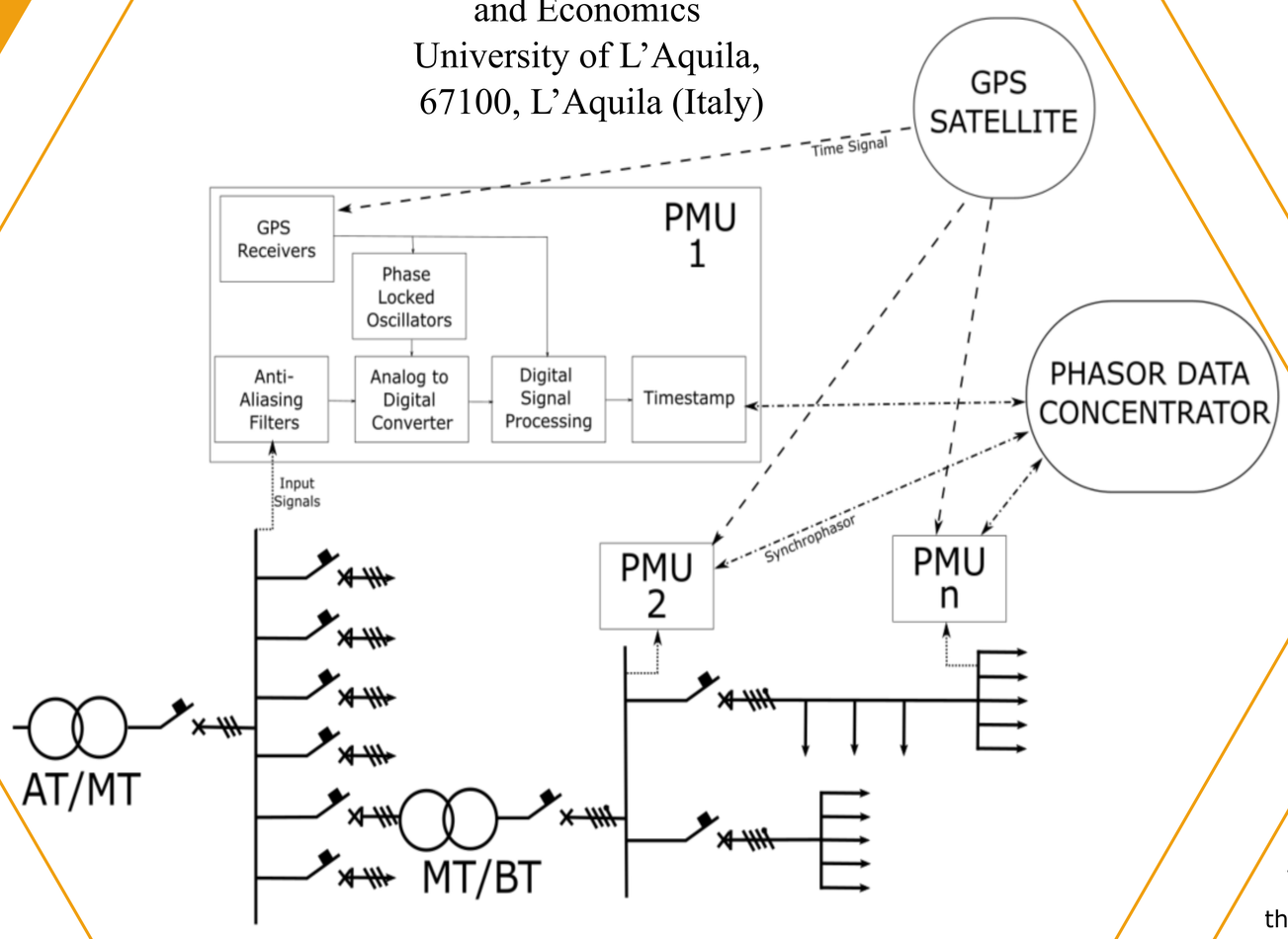

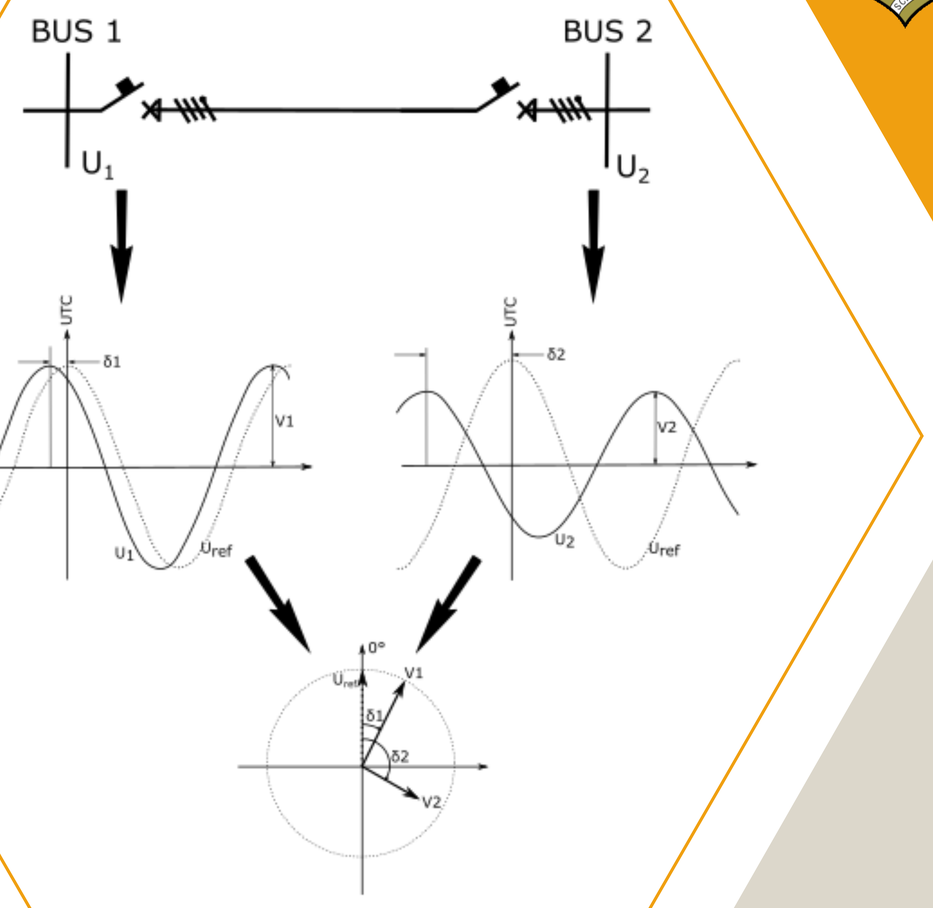

ABSTRACT

Modern grids are increasingly becoming microgrids with interconnected loads and distributed energy resources acting as a single controllable entity with respect to the grid. Management systems for emerging distribution systems need a very new protection paradigm, architecture and philosophy making use of new protection devices and sensors such as digital relays, phasor measurement units (PMUs), smart reclosers and line sensors. This paper examines the application of PMUs in smart distribution grids and from the point of view of prosumers.

1 The role of the PMU in the actual scenario

In modern electrical grids is necessary to collect data quickly, reliably and safely to perform correct actions downstream through the use of PMUs.
A use of PMUs is in the solution of annoying problems on the protection of transmission lines equipped with FACTS or multi-terminal line compensation.
The PMU data helps to predict power system instability in real time to perform better control actions in order to avoid cascading outages.
PMU data is very useful for detecting undamped electromechanical oscillations due to its high sampling rate.
The use of PMUs also allows for the analysis of angular oscillations, allowing for the analysis of their evolution.
The PMUs prove to be valid alternatives to the current load-shedding relays as they allow accurate and timely monitoring of the fundamental frequency and its derivative for the first time.

2 Features of the PMU available on the market

The global market for syncrophasor is valued at 151.3 million US dollars in 2020 and is expected to reach 708.7 million US dollars by the end of 2026, growing at a CAGR of 24.4% during 2021-2026.
PMUs can be distinguished into two main models, as defined in the IEEE standard, namely M-class and P-class. P-class PMUs are optimized for accuracy in a dynamic environment, while M-class PMUs remain accurate over a wider range of frequencies.
Based on the measurement and qualification standards, PMUs are subject to various tests, in particular:
• Measurement bandwidth is evaluated by applying sinewave amplitude and phase modulation to a set of balanced three-phase voltage and current waveforms. The maximum TVE in the measurement bandwidth test range should not exceed 3%. Class P PMUs shall be rated in the range 0.1 Hz to less than 2 Hz up to Fs/10; Class M PMUs are rated at the lower of 5 Hz and Fs/5 (10 Hz).
• The linear ramp in the system frequency is applied as balanced three-phase input signals. For synchrophasor estimation, to be compliant, a class P PMU must maintain 1% TVE over a range of ±2 Hz from the nominal frequency, and a class M PMU must maintain 1% TVE over the range ±5Hz.
• Phase changes in phase angle and magnitude to determine the response time, delay time, and overshoot in the measurement.

3 The PMU in low voltage power systems: the prosumers

PMUs can play an important role in the monitoring, control and protection of distribution systems due to the dynamic load changing due to Distributed Energy Resources:
A. Fault location: PMUs can be very useful for locating and detecting faults in the distribution system due to their high speed and time-synchronized phasor measurements;
B. Islanding detection: The methods for detecting the island in a distributed system with RES can be classified into three categories: active methods which include the active frequency drift method and the phase shift method, passive methods which include over/under voltage, over/under frequency, and communication based methods;
C. Load shedding scheme: New load shedding techniques are based on frequency and rate of frequency change leading to a better understanding and estimation of load to be shed to improve accuracy;
D. Power Quality monitoring; PMU provides relatively accurate results in the minimum positive-sequence voltage magnitude information. One technique for measuring harmonic synchrophasors in a distribution system involves the use of high-precision GPS receivers and general-purpose acquisition hardware for measurement purposes.

4 Advantages in adopting PMU in low voltage

In low voltage distribution systems, the relationships between voltage quantities, angles, and power flows are less approximate than in transmission lines, furthermore, in distribution systems the phase unbalance cannot be neglected, complicating the study of power flows. The use of synchrophasors in distribution grids involves further difficulties related to:
• small angles of difference on the distribution lines of the order of tenths of a degree;
• the presence of noise in the measurements of the distribution circuits, linked both to the randomness of the loads and to the presence of a greater harmonic spectrum caused by the great diffusion of electronic converters;
• the costs of the PMUs if referred to transmission systems are reduced thanks to the size of the system, while in distribution systems due to the proximity of the nodes they increase;
• the adoption of a low-cost, very efficient and reliable monitored data communication system.
The use of microPMUs in distribution systems can be divided into two macro categories: diagnostic applications and control applications. The former are used by grid operators in order to know the current operating conditions and study of anomalous events in the grids, while the latter allow the creation of automated systems for specific actions in almost real-time.

Conclusion

PMU applications still face many challenges in distribution systems, such as the lack of a communication network infrastructure capable of supporting a large number of sensors, but also advanced and persistent cyber threats facing critical infrastructures RES, electric energy storage, active loads such as demand-responsive loads and electric vehicles will introduce new challenges in the operation, planning, protection and control of distribution grids.

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