P+M Phasor Measurement Unit for Electrical Distribution Networks

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RESEARCH SCENARIO

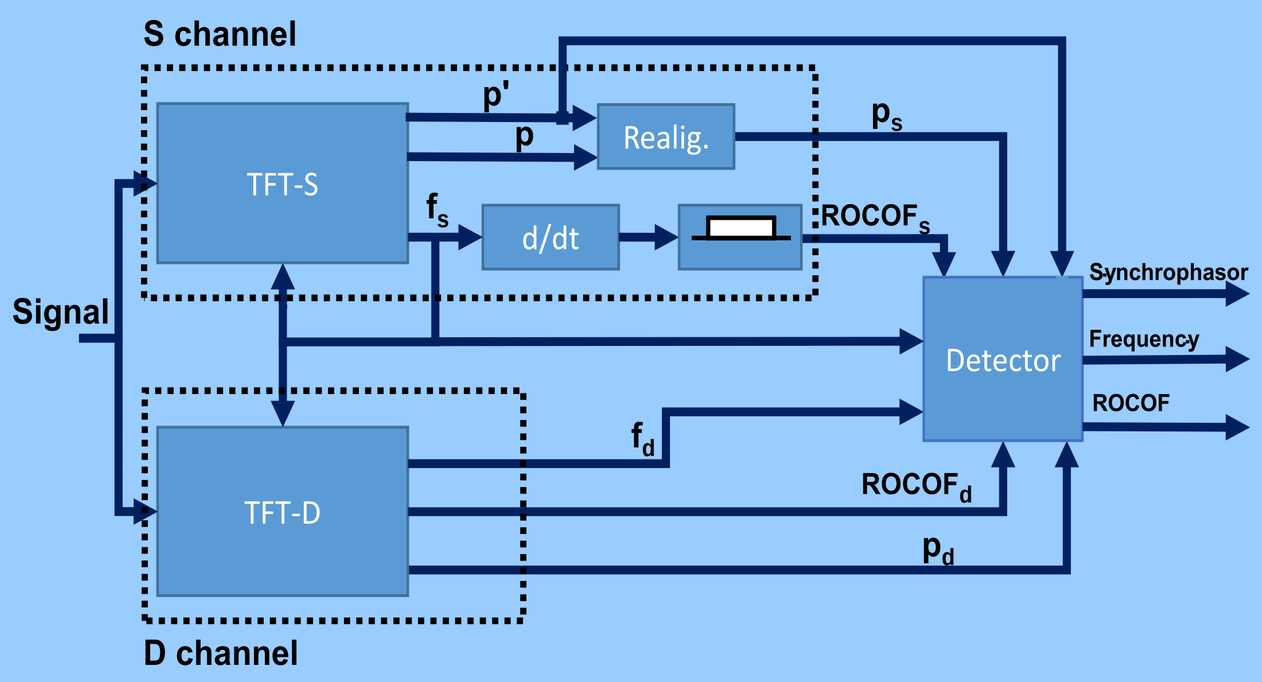
The IEEE Standard C37.118.1-2011 defines two performance classes, P and M, for Phasor Measurement Units (PMUs), respectively for protection and monitoring oriented applications.
The goal of this research activity is to define an algorithm that allows the requirements of both classes to be met simultaneously, thus avoiding an a priori selection of either the fast response time of class P or the accuracy of the class M.

THE PROPOSED P+M PMU DESIGN

The PMU architecture is composed by two channels. Each channel is designed to achieve good performance for different conditions: the S channel is well tuned for steady state conditions, whereas the D channel is specifically designed for fast dynamic situations. To obtain an accurate measurement for steady state signals and a faster response during dynamic changes of phasors and frequency, like amplitude or phase steps, strong modulations, and frequency ramps, a fast changing detector is designed to choose the appropriate output from the two channels.

Channel S:
- Taylor Fourier Transform (TFT-WLS) of the first order.
- Kaiser window of length = 5.8 nominal cycles and β = 3.7.
- The frequency is used to adjust the model of the TFT, with a frequency feedback.
- Il ROCOF (Rate Of Change Of Frequency) is obtained from the derivative of the frequency.

Channel D:
- TFT-WLS of second order.
- Kaiser window of length = 3.8 nominal cycles and β = 5.55.
- The outputs are synchrophasors, frequency and ROCOF.



Detector:
- The output of the PMU switches from the S channel to the D channel when a fast change is detected.
- The transient detector allows the choice of the best synchrophasor, frequency, and ROCOF estimation for each operating condition.

TESTS AND RESULTS

The simulation results of the compliance tests for the proposed algorithm according to the standard IEEE C37.118.1-2011

Test	Range	TVE Limit (%)	Max TVE of the estimated phasors (%)
Signal frequency range for P class	± 2 Hz	1	0.22
Signal frequency range for M class	± 5 Hz	1	0.22

Tests	Range	|FE| Limit (mHz)	Max |FE| of the estimated frequency (mHz)
Signal frequency range for P class	± 2 Hz	5	0.4
Signal frequency range for M class	± 5 Hz	5	0.4

Tests	Range	|RFE| Limit (Hz/s)	Max |RFE| of the estimated ROCOF (Hz/s)
Signal frequency range for P class	± 2 Hz	0.01	0.0045
Signal frequency range for M class	± 5 Hz	0.01	0.0084

In the tables, the results of synchrophasor in terms of Total Vector Error (TVE), frequency and ROCOF measurements for the steady state condition of off-nominal frequency are reported.

Tests	Range and Parameters	TVE Limit (%)	Max TVE of the estimated phasors (%)
AM+PM (P-class)	Max fm = 2 Hz; ka=kx=0.1	3	0.009
PM (P-class)	Max fm = 2 Hz; ka= 0.1	3	0.059
AM+PM (M-class)	Max fm = 5 Hz; ka=kx=0.1	3	0.022
PM (M-class)	Max fm = 5 Hz; ka= 0.1	3	0.665

Tests	Range and Parameters	|FE| Limit (Hz)	Max |FE| of the estimated frequency (Hz)
AM+PM (P-class)	Max fm = 2 Hz; ka=kx=0.1	0.06	0.010
PM (P-class)	Max fm = 2 Hz; ka= 0.1	0.06	0.019
AM+PM (M-class)	Max fm = 5 Hz; ka=kx=0.1	0.3	0.031
PM (M-class)	Max fm = 5 Hz; ka= 0.1	0.3	0.088

Tests	Range and Parameters	|RFE| Limit (Hz/s)	Max |RFE| of the estimated ROCOF (Hz/s)
AM+PM (P-class)	Max fm = 2 Hz; ka=kx=0.1	3	0.49
PM (P-class)	Max fm = 2 Hz; ka= 0.1	3	1.03
AM+PM (M-class)	Max fm = 5 Hz; ka=kx=0.1	30	2.61
PM (M-class)	Max fm = 5 Hz; ka= 0.1	30	1.03

In the tables, the results of synchrophasor in terms of Total Vector Error (TVE), frequency and ROCOF measurements for in presence of the dynamic condition of modulated signals.

Conclusions

- An original PMU design has been proposed to measure synchrophasors, frequency, and ROCOF in power systems, with the aim to comply with the requirements imposed for both P and M classes by the Standard.
- The PMU is able to operate on a single phase basis. This allows the straightforward use of the proposed PMU in power distribution systems with unbalanced conditions.
- The proposed PMU is suitable for both protection and monitoring purposes in power systems.

Paolo Castello, Junqi Liu, Carlo Muscas, Paolo Attilio Pegoraro, Ferdinanda Ponci, Antonello Monti, "A Fast and Accurate PMU Algorithm for P+M Class Measurement of Synchrophasor and Frequency," in Instrumentation and Measurement, IEEE Transactions on, vol.63, no.12, pp.2837-2845, Dec. 2014