Fast Taylor-Fourier Transform for Monitoring Modern Power Grids With Real-Time Dynamic Harmonic Estimation

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***Abstract*—This paper proposes the FTFT for the real-time monitoring of modern power grids through dynamic harmonic estimations. The FTFT results from the DTTFT implemented with the FFT, instead of its filter bank implementation. In FTFT, the harmonic Taylor-Fourier coefficients are obtained in batch, and from these complex coefficients, estimates of frequency, amplitude, and RoCoF are obtained. The FTFT is embedded in two low-cost platforms, one consisting of a digital signal processor (DSP) coded using C programming language, and a development PMU (D-PMU); where a computationally efficient calculation of the FTFT is coded in both platforms. Both platforms process instantaneous voltage and current signals, rendering phasor and harmonic estimates as if they were extracted by the impulse response of a set of FIR filters and their first and second differentiators of the DTTFT. The phasor and harmonic estimations are accomplished using a sliding window that updates sample by sample, instantaneously providing amplitude, phase, frequency, and RoCoF estimations at the fundamental and harmonic frequencies with a high reporting rate. Experimental results confirm the proposition's performance, precision, and effectiveness under steady-state conditions, sudden changes, and harmonic analysis.**

***Index Terms*—Phasor estimation, frequency, rate-of-change-of-frequency, phasor measurement unit, fast taylor-fourier transform.**

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I. Introduction

THE provision of accurate phasor estimates in real-time is a paramount task that phasor measurement units (PMUs) need to deal with [1]. The reliability of such estimates depends on the phasor estimation algorithms embedded into PMUs. These algorithms must guarantee phasor estimates for voltage and current channels, and they also must compute frequency and rate of change of frequency (RoCoF) [1]. At present, the use of reliable phasor estimates is imperative at any control center, since they support the decision-making process and feed the situational awareness of transmission and distribution system operators via wide-area monitoring systems (WAMS) [2]. For instance, remedial action schemes make use of frequency and RoCoF measures to establish load-shedding automatic stages by either over or under frequency [3]; the state estimation in [4] benefits from the use of synchronized phasors; in [5] and [6], undamped oscillations are respectively detected and controlled at early stages by PMU data-based strategies; system disturbances are detected and located by phasor-driven strategies in [7]. Likewise, the coherency and model reduction in power systems exploit the PMU measurements in [8]. In this context and with the power system's digitalization, the phasor estimates together with frequency and RoCoF estimations for future energy systems robust cyber-phisicaly wise face several challenges [9], such as dealing with a massive amount of data generated by sensing devices.

A. State-of-The-Art

In the literature, one of the major challenges is the capacity to observe and monitor changes in frequency and its derivative (RoCoF) under high variability conditions triggered by the renewable energy intermittency that brings sudden changes across the system [10], [11]. If these changes are not monitored, the demand and generation balance may be hard to achieve by the operators in a short time [3]. To tackle this issue and provide accurate synchrophasor measurements under these conditions, the PMU needs to track the dynamic change of variables and ensure high accuracy and low latency [12].

Another fundamental issue is related to the ability to provide a high reporting rate [13], since the massive penetration of