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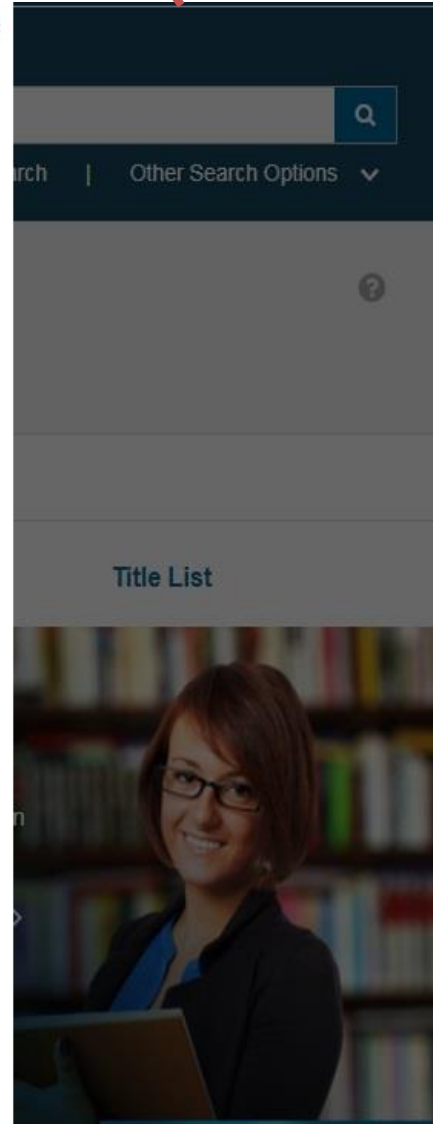
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H[∞] non-fragile robust controller and its application to the paper basis weight control

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Robust Detection and Analysis of Power System Oscillations Using the Teager-Kaiser Energy Operator

3 Author(s) Innocent Kamwa ; Ashok Kumar Pradhan ; Geza Joos [View All Authors](#)

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Abstract: Critical to real-time oscillations monitoring is early detection which becomes a serious threat to grid stability. The next urgent issue is to determine the frequency and damping of the problematic modes when the signal is embedded in noise and the system contains closely spaced natural modes. The present paper addresses the detection issue using the Teager-Kaiser energy operator (TKEO) which has shown to be a fast predictor of the instability onset time when applied to the output signals of an orthogonal filter bank. In the system stability context, linear filter decomposition (LFD) is preferred rather than empirical mode decomposition (EMD), well known for its tendency to generate modes with no physical meaning. A narrowband LFD with a less than 0.2-Hz bandwidth is achieved in the range 0.05 to 3 Hz through a cosine-modulated filter bank design. The effectiveness of the scheme in accurately detecting and tracking the frequency and damping of oscillatory modes is demonstrated using Monte Carlo simulations of three closely spaced modes and a detailed analysis of an actual event recorded by Hydro-Québec's WAMS in 2006.

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2. Tao Jiang, Haoyu Yuan, Hongjie Jia, Ning Zhou, Fangxing Li, "Stochastic subspace identification-based approach for tracking inter-area oscillatory modes in bulk power system utilising synchrophasor measurements", *Generation Transmission & Distribution IET*, vol. 9, no. 15, pp. 2409-2418, 2015.

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3. Saeid Hasheminejad, Seyed Ghodrattollah Seifossadat, Morteza Razaz, Mahmood Joorabian, "Traveling-wave-based protection of parallel transmission lines using Teager energy operator and fuzzy systems", *Generation Transmission & Distribution IET*, vol. 10, no. 4, pp. 1067-1074, 2016.

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4. Tao Jiang, Linquan Bai, Fangxing Li, Hongjie Jia, Qinran Hu, Xiaolong Jin, "Synchrophasor measurement-based correlation approach for dominant mode identification in bulk power systems", *Generation Transmission & Distribution IET*, vol. 10, no. 11, pp. 2710-2719, 2016.

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5. Huaishuo Xiao, Jianchun Wei, Hongshun Liu, Qingquan Li, Yalin Shi, Tongqiao Zhang, "Identification method for power system low-frequency oscillations based on improved VMD and Teager-Kaiser energy operator", *Generation Transmission & Distribution IET*, vol. 11, no. 16, pp. 4096-4103, 2017.

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Abstract: Critical to real-time oscillations monitoring is early detection when otherwise dormant natural modes become a serious threat to grid stability. The next urgent issue is to determine the frequency and damping of the problematic modes when the signal is embedded in noise and the system contains closely spaced natural modes. The present paper addresses the detection issue using the Teager-Kaiser energy operator (TKEO) which has shown to be a fast predictor of the instability onset time when applied to the output signals of an orthogonal filter bank. In the system stability context, linear filter decomposition (LFD) is preferred rather than empirical mode decomposition (EMD), well known for its tendency to generate artificial modes with no physical meaning. A narrowband LFD with a less than 0.2-Hz bandwidth is achieved in the range 0.05 to 3 Hz through a cosine-modulated filter bank design. The effectiveness of the scheme in accurately detecting and tracking the frequency and damping of oscillatory modes is demonstrated using Monte Carlo simulations of three closely spaced modes and a detailed analysis of an actual event recorded by Hydro-Québec's WAMS in 2006.

Published in: IEEE Transactions on Power Systems (Volume: 26 , Issue: 1 , Feb. 2011)

Page(s): 323 - 333 **INSPEC Accession Number:** 11769649

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SECTION I. Introduction

Oscillation monitoring [1]–[2][3][4][5] is a topic of increasing recent attention, owing to a heightened interest in the prevention of widespread blackouts, which can result from uncontrolled power swings across large geographical areas. Basically, the entity responsible for this task should first determine from power system response signals when/if there is an oscillation issue and then quantify the underlying threat by means of an accurate assessment of the frequency and damping of the oscillation. Since the early days of modal analysis of power system responses recorded by WAMS [6] or simulated using power system studies software [7], the two issues of detecting and quantifying oscillations have been generally mixed together with few exceptions [8]–[9][10], but detailed analysis obviously makes little sense when there is no significant oscillation activity in the electromechanical frequency range (typically 0.1–3 Hz).

In this paper, a Teager-Kaiser energy operator (TKEO) [11]–[12][13][14] based criterion is proposed as a predictor of power oscillation problems. To the best of our knowledge, this is the first time that the TKEO concept has been used in this context. Since the concept is known to perform poorly on multi-component signals [13], a multi-band pre-filter is first applied to the raw input. This allows us to decompose the waveform into a set of largely orthogonal monochromatic components which are then subjected to time-frequency analysis using the energy separation algorithm (ESA). One of the benefits of the linear filter bank is that, when the prototype is designed with a very narrow bandwidth, e.g., 0.2 Hz, any analysis method applied to the output will provide noise-resilient frequency and damping estimates.

Recent authors have investigated closely related ideas using the EMD as filter bank [15] and discrete Hilbert transform (DHT) as the basis for instantaneous frequency and amplitude estimation [16], [17].

Modal Identification From Power System Measurements
IEEE Transactions on Power Systems
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Inductive Pulsed Power Supply Consisting of Superconducting Pulsed Power Transformers With Marx Generator Methodology

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Abstract—We have been developing an inductive pulsed power supply (PS) consisting of several superconducting pulsed power transformers with Marx generator methodology. Each of these pulsed power transformers consists of a copper secondary winding and a high-temperature superconducting primary winding. In order to obtain a high-voltage impulse, the Marx generator should be charged via the parallel connection of capacitors and discharged

When energy transfer is required, a rapid current collapse in the primary winding is excited, and a large level of current is induced in the secondary winding. In this case, another problem occurs, i.e., the load voltage on the secondary side moves to the primary side with multiplied voltage by the winding ratio of the transformer, and as a result, it becomes difficult to open the



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