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Sliding Innovation Filter For Microgrid Application

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ABSTRACT

Currently, microgrids are frequently used and various control algorithms have been applied to improve their performance in both grid-connected and islanded modes. However, research has shown that incorporating a filtering technique into the controller can lead to even better performance. As a result, a simple controller with a filter can perform just as well as a complex controller that operates alone. This study focuses on the performance of a microgrid using a new filter called the sliding innovation filter, which is known for its robustness and stability. The filter is an excellent option for estimating performance under various conditions, such as load and injected powers. To demonstrate the filter's advantages, modeling uncertainties are introduced into the system while the filter is estimating states. The filter's performance is evaluated using a MATLAB© simulation environment.

Keywords: Micorgrid, SIF, SVSF, performance.

1. INTRODUCTION

Distributed generation system (DGS) refers to the current trend in the power grid toward using smaller generators to meet peak demand [1-3]. The distributed generator (DG), which may be any number of technologies such renewable energy sources with sophisticated inverter circuits [1-3], is a crucial part of the DGS. As a result of their reliable operation, inverters have become more commonplace [4].

Estimation techniques are essential for monitoring and assessing plant health using sensor data in fault and diagnostic applications. These approaches examine sensor data to reveal hidden states, system characteristics, and system health, enabling system evolution study and monitoring. Filters cater for sensor reading restrictions and uncertainties to enhance system state assessment accuracy and reliability [5-14]. Filters minimize sensor data noise, enhancing estimated information and issue and diagnostic discoveries [15-25].

The Kalman filter (KF) estimates a system's state using poor or noisy data. It calculates a system state using system dynamics, observed data, and noise statistics. Navigation, tracking, and control benefit from the KF's real-time handling of ambiguous and noisy data [26-41]. The EKF and UKF give approximate solutions for nonlinear systems [42-69]. The KF assumes linearity, Gaussian noise, and entire system dynamics, which limits it. SMOs, SVSFs, and SIFs come under the second family of filtering estimating techniques that use stability functions such Lyapunov functions [70-114]. These filters provide consistency and durability to make the estimate process robust and stable, even with disruptions and uncertainties. They give steadiness in specific situations. Combining filters from both classes improves estimate efficiency and reduces limitations [115-125]. Moreover, several studies have proposed new filtering techniques for various applications, such as robotic manipulators, pneumatic systems, battery condition monitoring, and photovoltaic/thermal systems, among others [126-139] and Kalman filters are widely used for state estimation in various fields, as seen in recent research studies such as adaptive extended/unscented Kalman filters for lithium-ion battery state-of-charge estimation, vehicle running states-fused estimation strategy, and multi-area distributed state estimation in smart grids [140-163].

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2. METHODOLOGY

As previously explained, the filter requires a state-space form for estimating the state variables. Hence, the subsequent state-space forms and equations in the $d-q$ frame is defined as [106]:

$$\dot{x} = Ax + Bu \tag{1}$$

$$\text{Where } A = \begin{bmatrix} -R_f/L_f & \omega & -1/L_f & 0 \\ -\omega & -R_f/L_f & 0 & -1/L_f \\ \left(R_f^2/L_f - \omega^2 L_f\right) & -2R_f\omega & R_f/L_f & -\omega \\ 2R_f\omega & \left(R_f^2/L_f - \omega^2 L_f\right) & \omega & R_f/L_f \end{bmatrix} \tag{2}$$

$$B = \begin{bmatrix} 1/L_f & 0 & -R_f/L_f & -\omega \\ 0 & 1/L_f & \omega & -R_f/L_f \end{bmatrix}^T \tag{3}$$

$$\begin{bmatrix} P_{est} \\ Q_{est} \end{bmatrix} = \frac{3}{2}\begin{bmatrix} I_{DG-d}V_{DG-d} + I_{DG-q}V_{DG-q} \\ I_{DG-d}V_{DG-q} - I_{DG-q}V_{DG-d} \end{bmatrix} = \frac{3}{2}\begin{bmatrix} x_1x_3 + x_2x_4 \\ x_1x_4 - x_2x_3 \end{bmatrix} \tag{4}$$

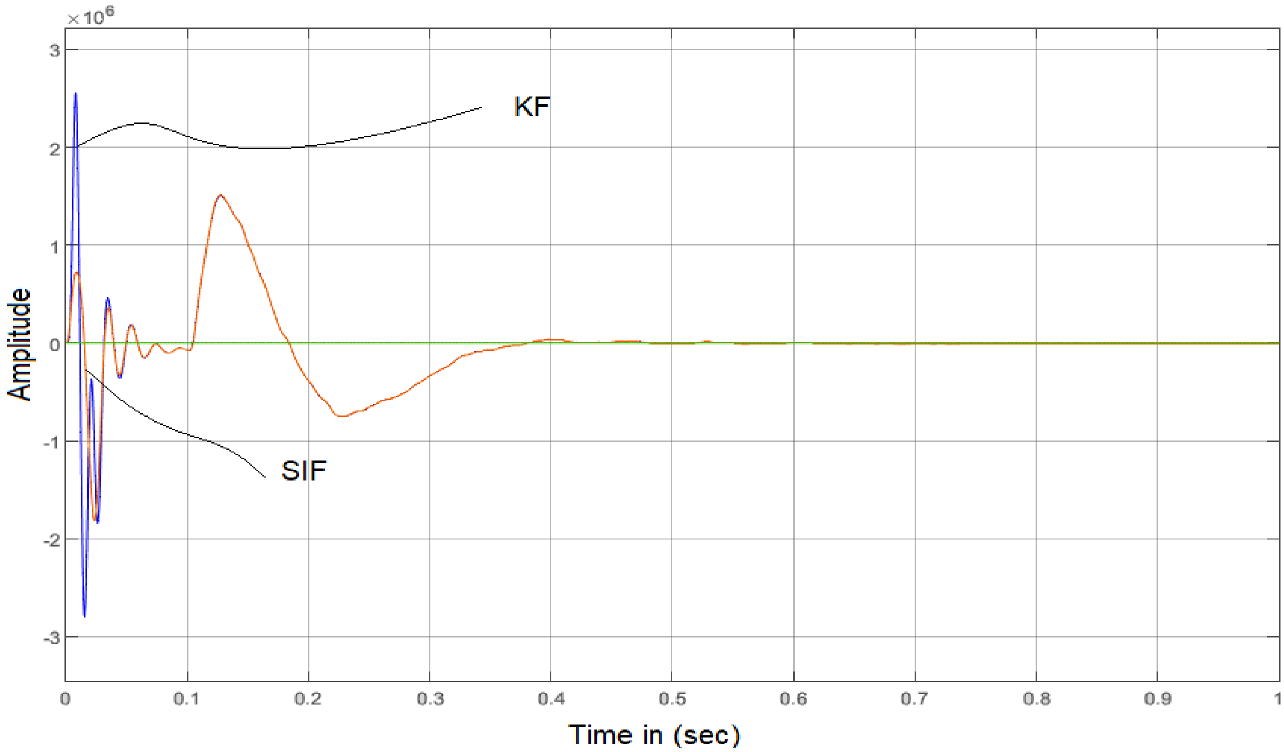
The estimated power in (4) is linked to the estimation of I_{DG} based on the measured V_{DG}. These matrices are integrated with the formulation of the SIF to estimate the power.

3. RESULTS AND DISCUSSION

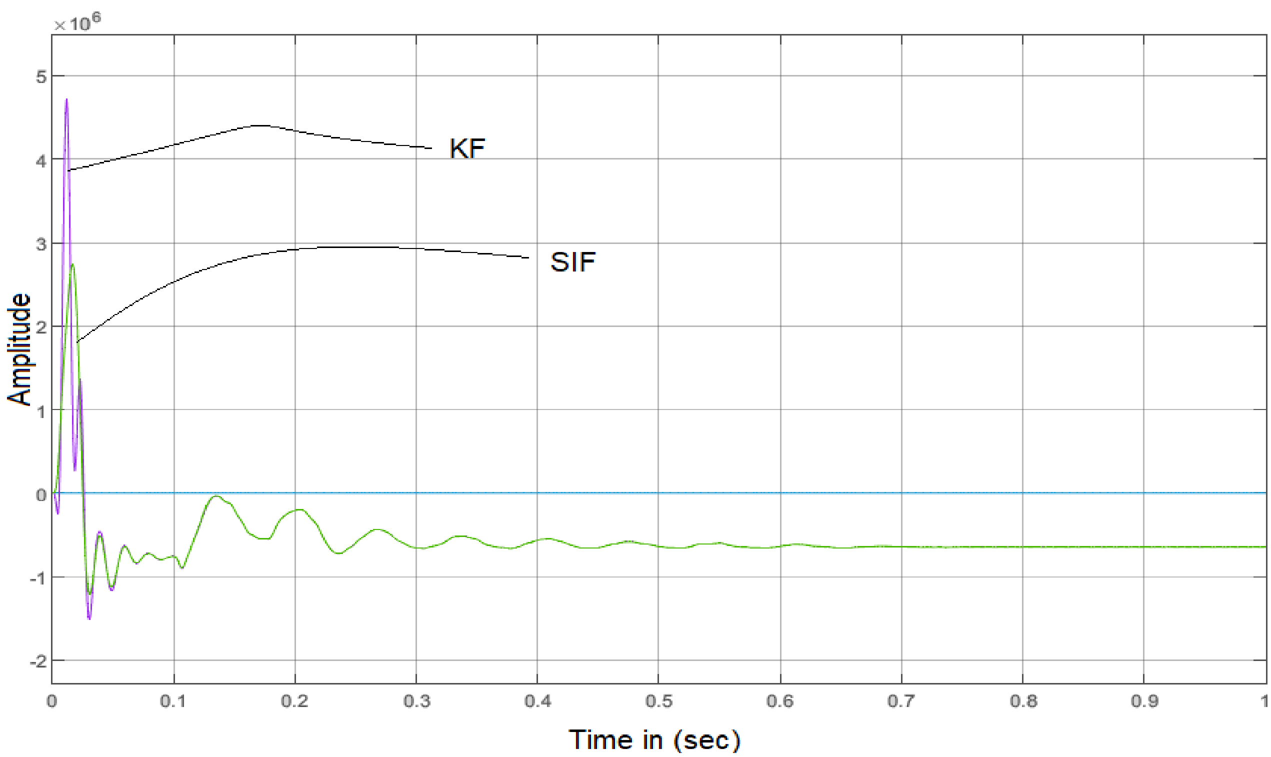
We follow [106] and compare SIF's performance to that of KF and VF methods for online, recursive power reference estimation with no prior offline training. In Table 1, we can see how well SIF performs at predicting active and reactive power, with some variances from the reference. In terms of steady-state performance, SIF outperforms the VF approach by a wide margin since it shows the least variation around its mean. It has a performance between equivalent to superior performance compared to SVSF and KF. Reactive power estimate in steady state also confirms this result, with SIF's output being most in line with the power reference. Notably, SIF is the simplest of the approaches since it needs less calculations and less adjusting than the others. This ease of use is mirrored in the fact that only one parameter is required to fine-tune the performance of the filter in SIF, as opposed to two in SVSF and four in KF. Overall, SIF's stellar performance substantiates its potential as a tool for active power, and reactive power. Moreover, Fig. 1 shows the performance of SIF compared to KF.

Table 1: Comparative analysis for the estimation techniques

PARAMETERS	SIF	SVSF [106]	KF [106]	VF [106]
Number of mathematical operations in only one iteration	21	24	42	28
			Active Power	
Average maximum $\%E_{steady\ state}$	0.18	0.2	0.22	0.5
Average maximum ripples (%)	0.38	0.4	0.44	1.04
Transient time to reach PSS (s)	0.25	0.25	0.25	0.25
Overshoot or undershoot (%)	0	0	0	0
			Reactive Power	
Average maximum $\%E_{steady\ state}$	0.59	0.6	0.6	1.26
Average maximum ripples (%)	0.09	0.1	0.2	0.6
Transient time to reach PSS (s)	0.6	0.6	0.6	0.6
Overshoot (%)	0	0	0	0



(a)



(b)

Fig. 1. Power Estimation, (a) P and (b) Q

4. CONCLUSION

This paper introduces a novel use of recursive Sliding Innovation Filter (SIF) for estimating active and reactive power of PS components and NS currents based on voltage measurements only. SIF outperforms SVSF and KF due to its simplicity and ability to filter out high-frequency harmonics. The research emphasizes the need for efficient control algorithms that can handle different microgrid modes while maintaining optimal performance. Overall, this study contributes to advancing microgrid control algorithms through innovative filtering techniques like SIF, opening avenues for future research in this area.

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