Power Grid Fault Detection in Noisy Environment using PMU

Xiaoyu Guo and Anirban Ganguli

SYRACUSE UNIVERSITY ENGINEERING & COMPUTER SCIENCE

INTRODUCTION

Typical uses of the Kalman filter include smoothing noisy data and providing steady state estimates of parameters of interest [1-3]. During the fault in power grids a short window optimal least square error solution can reduce the nonsinusoidal effect of the waveform and identify the sudden change in voltages and currents [4]. In this work, during the fault in power grid, we use the phasor measurement unit (PMU) data to compare the outputs of a Kalman filter and a short window noise reduction filter [3], both developed for sinusoidal process. By setting a threshold adaptive to the noise variance, proposed method can detect a fault in noisy environment by comparison of the two outputs [4].

In this work we present the time delay detection trade-off findings for the algorithm robustness for varied noise variance and filter window lengths.

BACKGROUND

Kalman filter [2] estimator block diagram is shown in Fig.1.

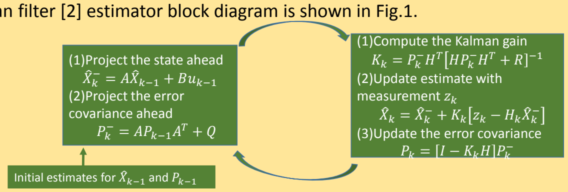

Figure 1: Kalman filter approximation algorithm

Kalman filters efficiently suppress the white noise in a known steady state process, but the sudden change detection is not quick, as shown in Figure2.

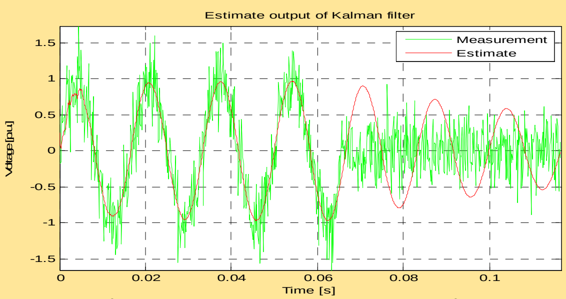

Figure 2: Kalman filter cleaned the sinusoid noise until 65 ms when a fault in a 60Hz power system occurred. Kalman filter takes time for the adjustment (red line), while the real time measurement of a noisy signal is suddenly changed (green line).

Short window filter for the sinusoid measurement optimization takes the multiple consecutive measurements of a noise spoiled sinusoid and outputs an optimized approximation as shown in equations 1-3.

$$(1)\begin{bmatrix} y_{-1} \\ y_0 \\ y_1 \end{bmatrix} = \begin{bmatrix} cos\theta & -sin\theta \\ 1 & 0 \\ cos\theta & sin\theta \end{bmatrix}\begin{bmatrix} Y_c \\ Y_s \end{bmatrix} \qquad (2)\hat{Y}_c = \frac{[y_1 cos\theta + y_0 + y_{-1} cos\theta]}{1+2cos^2\theta} \qquad (3)\hat{Y}_s = \frac{[y_1 - y_{-1}]}{2sin\theta}$$

The examples of sinusoid approximation based on a 3-sample window filter output is shown in Fig. 3 and 9-sample window output in Fig. 4.

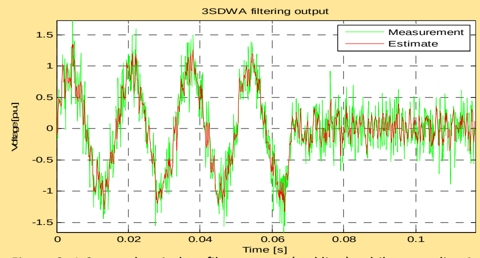

Figure 3: A 3-sample window filter output (red line), while green line is the noisy measurement

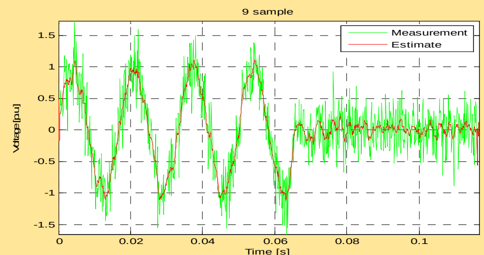

Figure 4: A 9-sample window filter output (red line), while green line is the noisy measurement

METHOD & SIMULATIONS

By setting a threshold adaptive to the noise variance, proposed method can detect a fault in noisy environment by comparison of the two outputs, as shown in Fig. 5.

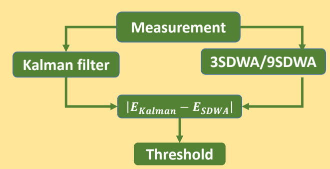

Figure 5: Proposed algorithm block diagram

Simulation results: In the following simulations the fault happened in 4th cycle, i.e. at 65 ms in a 60 Hz noisy signal. For the demonstration purposes the exaggerated noise has varied from 0.7 pu to 1.2 pu. A 3-sample window filter and a 9-sample window filter results are compared. The results of the noisy voltage signal sudden change detection are tabulated in Table 1.

Noise content	0.7 pu		1.0 pu		1.2 pu	
	Threshold	Delay time (ms)	Threshold	Delay time (ms)	Threshold	Delay time (ms)
3-sample window	1.4 pu	3.90	2.18 pu	5.46	2.30pu	23.56
9-sample window	1.0 pu	3.65	1.0pu	4.30	1.30pu	5.34

The noise suppression rate increase with the length of the window. The optimal filter window length depends on the application requirements. In presented simulations, the 9-sample filter length has achieved faster fault detection with lower adaptive threshold. The examples of a difference of the two filter outputs are shown in Figs. 5 and 6.

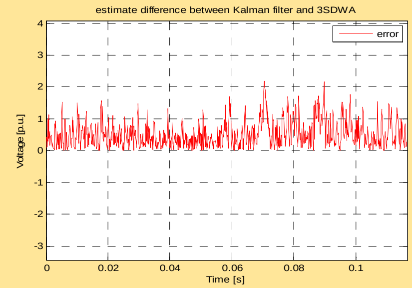

Figure.5: Difference output of a Kalman filter and 3-sample window filter, with an appropriate threshold detected to be about 2.18 pu. The input sinusoidal signal was spoiled by 1.0 pu noise content. The minimum detection delay was 5.46ms.

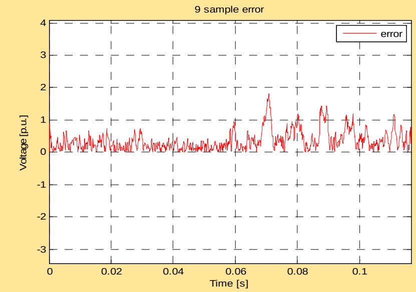

Figure.6: Difference output of a Kalman filter and 9-sample window filter, with an appropriate threshold detected to be about 1.0 pu. The input sinusoidal signal was spoiled by 1.0 pu noise content. The minimum detection delay was 4.30ms.

CONCLUSION

In this work a grid fault to ground is analyzed. In the simulations it is assumed that the fault and measurement happen at the same location. The noise suppression is effective and allows accurate and quick fault to ground detection. In future work, line-to-line fault detection in noisy environment should be analyzed. Further research should cover the line parameters under changing the phase angle when a fault occurs.

REFERENCES

[1] Julio Barros, Enrique Pérez, Ramón I. Diego, Matilde de Apráiz, “Application of Kalman Filtering in Power Systems: Harmonic Distortion and Voltage Events”, Nova Science Publishers Inc., 2011 pp. 43

[2] R. E. Kalman, “A new approach to linear filtering and prediction problems,” J. Basic Eng., vol. 82, no. 1, pp. 35–45, Mar. 1960.

[3] Stanley Horowitz & Arun Phadke, “Power System Relaying”, John Wiley & Sons Ltd, 2014

[4] Tomislav Bujanovic, "ELE 791 Power Systems Protection [Lecture]" Department of Electrical Engineering and Computer Science, Syracuse University, May 2014

Acknowledgement: We express our warm thanks to Dr. Tomislav Bujanovic for his support and guidance.