IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

# ESTIMATION OF VOLTAGE SIGNAL ANALYSIS USING EXTENDED KALMAN FILTER AND UNSCENTED KALMAN FILTER

[1]G.Muthupandi,[2]G.Sivakumar,[3]M.Deepak Pious, [4]M.Naveen Kumar

[1]Assistant Professor,[2]Assistant Professor,[3]UG Student, [4]UG Student
Department of Computer Science and Engineering,
PSN College of Engineering and Technology, Tirunelveli,Tamilnadu, India

*Abstract:*The fundamental electrical signal are required for the wide variety of power systems application. The input signal must be taken from the power source, when the error signal is occurred in the system it is very difficult to access the power application. In the proposed method white noise is added to the input voltage signal waveform to get the unbalanced voltage signal from the source in simulation environment. Then the unbalance signal is given to an Unscented Kalman filter to estimate and remove the noise signal present in the input voltage signal waveform. The unscented Kalman filter is used to remove the voltage disturbance from the input power signal. In this paper we estimate the voltage signals by using Embedded system with the help of Extended Kalman Filter and Unscented Kalman Filter.

***Index Terms* - Error signals, white noise, Kalman Filter, Extended Kalman Filter, Unscented Kalman filter, Embedded Systems.**

## I. INTRODUCTION

Voltage dips and swells are the most common types of power quality disturbances. They represent a major concern for the industry because they lead to important economically losses and/or distorted quality of industrial products. The Voltage sags are caused by abrupt increases in loads such as short circuits or faults, motors starting, or electric heaters turning on, or they are caused by abrupt increases in source impedance, typically caused by a loose connection. Voltage swells are almost always caused by an abrupt reduction in load on a circuit with a poor or damaged voltage regulator, although they can also be caused by a damaged or loose neutral connection.

### 1.1 Kalman filters:-

The Kalman filter is essentially a set of mathematical equations that implement a predictor-corrector type estimator that is optimal in the sense that it minimizes the estimated error covariance. It can do so even when the precise nature of the modeled system is unknown. It is a state estimator which produce an optimal estimate.System state cannot be measured directly, need to estimate "optimally" from measurements, The Kalman gain is the optimal weighting matrix for combining new sensed data with a prior estimate to obtain a new estimate. Kalman filter are used to remove the error signal from the voltage signal. The error occurred in the frequency of the voltage signal can be remove by the kalman filter, the State space form for a grid representation and related Kalman filter theory with goal to fit the measured voltage of the grid.

### 1.2 Extended Kalman filter:

The extended Kalman filter (EKF) is the nonlinear version of the kalman filter which linearizes about an estimate of the current mean and covariance. The state evolution and measurement equation are non-linear, the process noise w is drawn from $N(0,Q)$, with covariance matrix Q. and the measurement noise v is drawn from $N(0,R)$, with covariance matrix R.The Iterated Extended Kalman Filter (IEKF) repeats the linearization of $H_k$ as soon as a better estimate for the state is available

## II. STATE SPACE ESTIMATION

The three-phase voltage signal of utility grid is measured and utilized for the purpose of grid localization. In the presence of unbalance, the discrete three-phase voltage signal corrupted by additive noise is expressed as follow

$$v_a(t) = v_a \cos(\omega t + \varphi_a) + e_a(t)$$
$$v_b(t) = v_b \cos(\omega t + \varphi_b) + e_b(t)$$
$$v_c(t) = v_c \cos(\omega t + \varphi_c) + e_c(t)$$

Where t is the time instant t=0, 1, 2,……..,n. and $\varphi_a, \varphi_b, \varphi_c$ is the amplitude and phase angle of the three phase voltage source. The value of voltage signal of each phase is different, the difference between the two phase angle is 120 degree. $\omega$ is the angular frequency of the grid ,the grid frequency may vary from 50 to 60 Hz, the error signal of the three phase voltage source

The three phase voltage signal with error is represented as

$$V(t) = V_a(t) + V_b(t) + V_c(t) + e(t)$$
$$e(t) = [e_a(t), e_b(t), e_c(t)]^T$$

## III. PROPOSED ALGORITHM

### 3.1 Extended Kalman Filter

The voltage signal of the three phase Va,Vb,Vc and the error signal is denoted as e(t) with respect to the time sequence, transform the signal to $\alpha\beta$ stationary reference frame

$$[V_\alpha(t), V_\beta(t)]^T = T[V_a(t), V_b(t), V_c(t)]^T$$

Where T is the Clark transformation

$$\begin{bmatrix} V_\alpha(t) \\ V_\beta(t) \end{bmatrix} = V_p \begin{bmatrix} \cos\theta_p(t) \\ \sin\theta_p(t) \end{bmatrix} + V_n \begin{bmatrix} \cos\theta_n(t) \\ -\sin\theta_n(t) \end{bmatrix} + \begin{bmatrix} e_\alpha(t) \\ e_\beta(t) \end{bmatrix}$$

From the above equation Positive and negative sequence are used for further implementation the zero sequence is removed from the sequence

$$[V_\alpha(t), V_\beta(t)]^T = T[V_a(t), V_b(t), V_c(t)]^T$$

Then the covariance of noise vector is

$$e_{\alpha\beta}(t) = [e_\alpha(t), e_\beta(t)]^T$$
$$V_\alpha(t) = V_\alpha \cos(n\omega + \varphi\alpha) + e_\alpha(n)$$
$$V_\beta(t) = V_\beta \cos(n\omega + \varphi\alpha) + e_\beta(n)$$

Sinusoidal signal

$$x_1(n) = v_\alpha \cos(n\omega + \varphi_\alpha)$$
$$x_2(n) = v_\alpha \sin(n\omega + \varphi_\alpha)$$
$$x_3(n) = v_\beta \cos(n\omega + \varphi_\beta)$$
$$x_4(n) = v_\beta \sin(n\omega + \varphi_\beta)$$
$$x_5(n) = \omega$$

The state equation can be modeled as

$$x_1(n+1) = x_1(n)\cos(x_5(n) - x_2(n)\sin(x_5(n))$$
$$x_2(n+1) = x_1(n)\sin(x_5(n) + x_2(n)\cos(x_5(n))$$
$$x_3(n+1) = x_3(n)\cos(x_5(n) - x_4(n)\sin(x_5(n))$$
$$x_4(n+1) = x_3(n)\sin(x_5(n) + x_4(n)\cos(x_5(n))$$
$$x_5(n+1) = (1-e)x_5(n) + e_\omega(n)$$

Then the voltage signal from the $\alpha\beta$ stationary is

$$v_\alpha(n) = x_1(n) + e_\alpha(n)$$
$$v_\beta(n) = x_3(n) + e_\beta(n)$$

Then the EKF equation can be written as follow

$$\hat{x}(n/n) = f(\hat{x}(n-1/n-1)) + K(n)(y(n) - Pf(\hat{x}(n-1/n-1)))$$
$$K(n) = M(n)P^T(Q_{\alpha\beta} + PM(n)P^T)^{-1}$$
$$M(n+1) = F(n)(M(n) - K(n)PM(n)F^T(n) + qA$$

Where K is the Kalman gain and K (n) - weighting matrix and m (n+1) - prediction Mean square error matrix

### 3.2 Unscented Kalman Filter

The voltage signal of the three phase Va,Vb,Vc and the error signal is denoted as e(t) with respect to the time sequence, transform the signal to $\alpha\beta$ stationary reference frame

$$[V_\alpha(t), V_\beta(t)]^T = T[V_a(t), V_b(t), V_c(t)]^T$$

Where T is the Clark transformation

$$\begin{bmatrix} V_\alpha(t) \\ V_\beta(t) \end{bmatrix} = V_p \begin{bmatrix} \cos\theta_p(t) \\ \sin\theta_p(t) \end{bmatrix} + V_n \begin{bmatrix} \cos\theta_n(t) \\ -\sin\theta_n(t) \end{bmatrix} + \begin{bmatrix} e_\alpha(t) \\ e_\beta(t) \end{bmatrix}$$

From the above equation Positive and negative sequence are used for further implementation the zero sequence is removed from the sequence
Then the covariance of noise vector is

$$e_{\alpha\beta}(t) = [e_\alpha(t), e_\beta(t)]^T$$

Assume that the state transition and measurement equations for an *M*-state discrete-time nonlinear system have additive process and measurement noise terms with zero mean and covariances *Q* and *R*, respectively:

$$x[k+1]=f(x[k],u_s[k])+w[k]$$

$$y[k]=h(x[k],u_m[k])+v[k]$$

$$w[k]\sim(0,A[k])$$

$$v[k]\sim(0,B[k])$$

The initial values of A and B in the Process Noise and Measurement Noise properties of the unscented Kalman filter object.

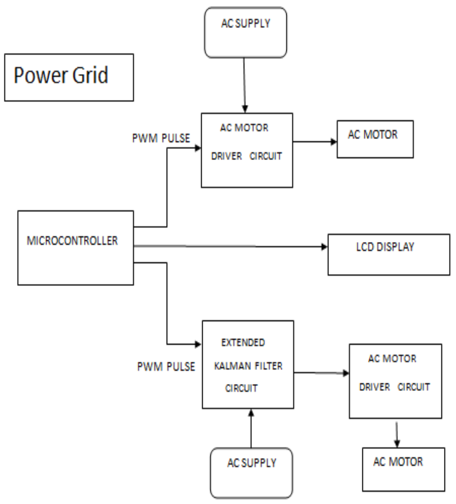
Initialize the filter object with initial values of the state, `x[0]`, and state estimation error covariance, *P*.

$$\hat{x}[0|-1]=E(x[0])$$

$$P[0|-1]=E(x[0]-\hat{x}[0|-1])(x[0]-\hat{x}[0|-1])^T$$

Here $\hat{x}$ is the state estimate and $\hat{x}[k_a|k_b]$ denotes the state estimate at time step $k_a$ using measurements at time steps $0, 1, \ldots, k_b$. So $\hat{x}[0|-1]$ is the best guess of the state value before you make any measurements. You specify this value when you construct the filter.

## IV. BLOCK DIAGRAM



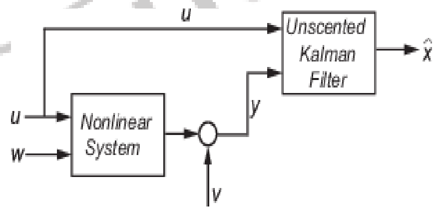




Fig 1. Block diagram of Extended Kalman FilterFig 2. Block diagram of Unscented Kalman Filter

The power source is from the power grid the DSP microcontroller is used to filter the error occurred by the system the result must be show by the help of the ac motor, when any error is occurred for example voltage sag and swell then the Extended Kalman filter program dumped in the microcontroller will remove the error and produced the error free signal

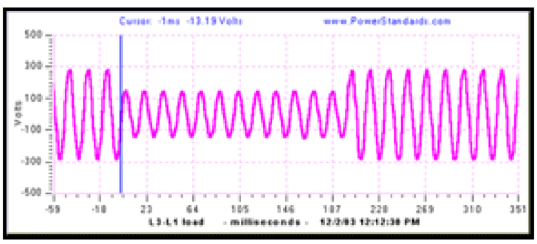


Fig 3. Voltage sag

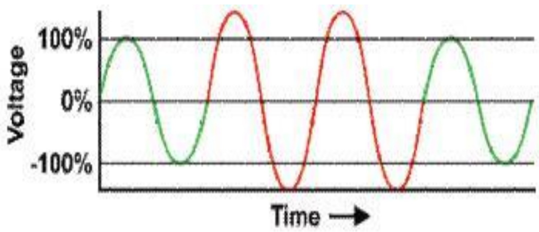



Fig 4.voltage swell

## V. SIMULATION AND RESULTS

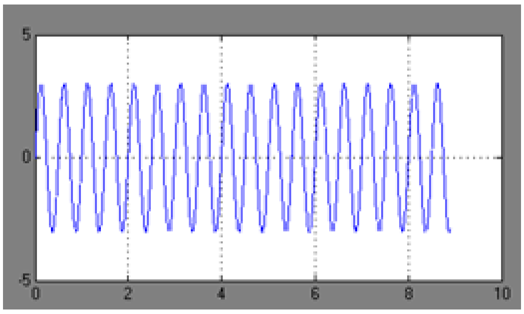



Fig 5. Original Signal(input sine wave)

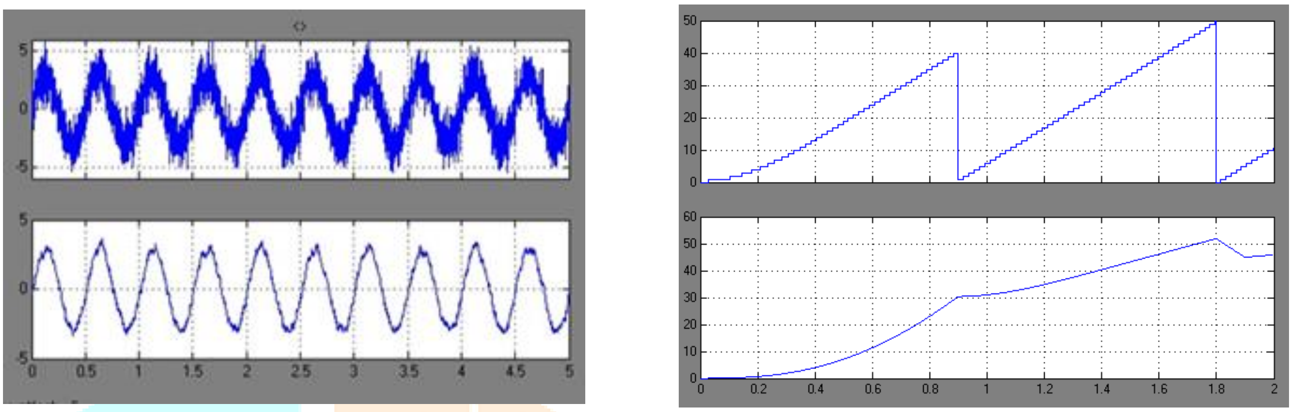
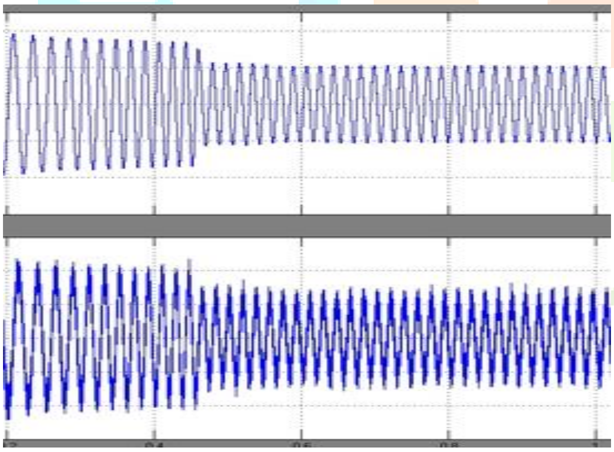


Fig 6. The first signal represent the voltage signal with noise in the frequency where as the second signal represent the error free signal, the noise remove by the kalman filter



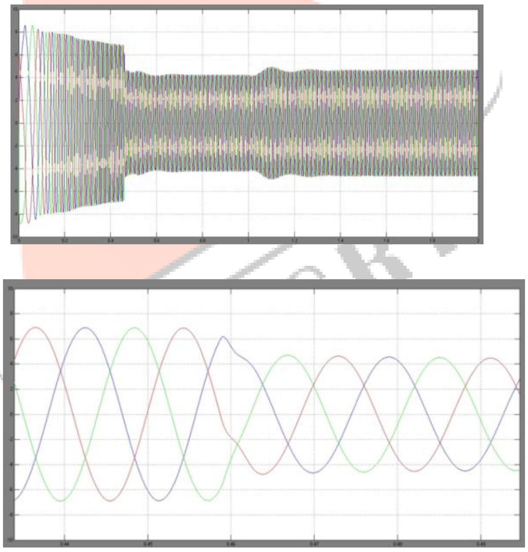
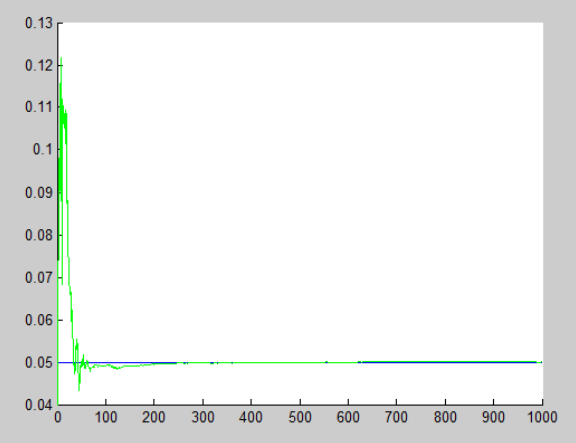


Fig 7: Original signal and error signal

Fig 8: Sag occurred during process

Original signal and the frequency deviation occurred in the signal and the kalman filter is used to remove the error from the signal



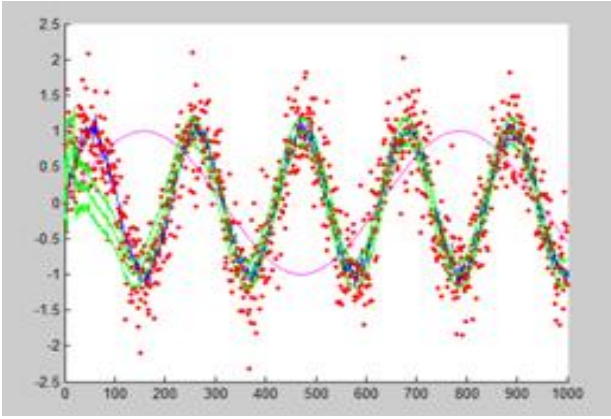




**Fig.9.** Green line denote the error signal when sag is present, Red dot denote frequency deviation and blue line is an error free signal when process noise is 0.5 and measurement noise is 0.4

## VI. Conclusion

The proposed system is used to analyze the voltage signal by using Extended Kalman filter. It is used to measure a power grid representation and estimate the sinusoidal waveform phase and to minimize the error occurred in the power signal a linear space form representing the amplitude and phase. It is used to calculate the Kalman gain value for the different error percentage value. It will remove the error from the power source and kept your system without any error. The proposed algorithm is simulated in MATLAB/SIMULINK environment, the filter is tested and is evaluated for different frequency range. For hardware implementation the proposed algorithm is designed using PIC microcontroller and the result is observed using digital oscilloscope.

## VII. FUTURE WORK

The future work of this project is used to implement the voltage signal analysis by using the modified Extended Kalman filter and Unscented Kalman filter. The ARM processor is used for the hardware modeling and the result is taken for both the AC signal and the DC signal.

## References

[1]. Estimation of voltage signal analysis using Extended Kalman Filter by Muthupandi.G, Elango.S, Manikandan.V, **Published in:** 2014 International Conference on Communication and Signal Processing,**Electronic ISBN:**978-1-4799-3358-7,**Print ISBN:**978-1-4799-3357-0,**CD:**978-1-4799-3356-3

[2]. Monitoring and Optimization for Power Grids: A Signal Processing Perspective Georgios B. Giannakis⋆, *Fellow, IEEE, VassilisKekatos, Member, IEEE, NikolaosGatsis, Member, IEEE,* Seung-Jun Kim, *Senior Member, IEEE, Hao Zhu, Member, IEEE,*and Bruce F. Wollenberg, *Fellow, IEEE*

[3]. Kalman Filter Implementation on an Accelerometer sensor data for three state estimation of a dynamic system by ToshakSinghal, AkshatHarit, and D N Vishwakarma, International Journal of Research in Engineering and Technology (IJRET) Vol. 1, No. 6, 2012 ISSN 2277 – 4378

[4]. M.Kusljevic, J.Tomic, and .Jovanovic,"Frequency estimation of three-phase system using weighted-least-square algorithm and adaptive FIR filtering", IEEE Trans, Meas., vol.59,pp.322-329,Feb.2010.

[5]. Guoqiang Mao, Sam Drake and Brian D.O. Anderson. "Design of Extended kalman filter for UAV Location", IEEE Trans, Meas., vol.12,pp.226-231,Aug.2008.

[6]. "Monitoring and Optimization for Power Grids: A Signal Processing Perspective" Georgios B. Giannakis⋆, *Fellow, IEEE,* VassilisKekatos, *Member, IEEE,* NikolaosGatsis, *Member, IEEE,* Seung-Jun Kim, *Senior Member, IEEE,* Hao Zhu, *Member, IEEE,*and Bruce F. Wollenberg, *Fellow, IEEE*

[7] "State Estimation and Error Analysis of a Single State Dynamic System with Sensor Data Using Kalman Filter" by ToshakSinghal, AkshatHarit, and D. N. Vishwakarma in *International Journal of Information and Electronics Engineering, Vol. 3, No. 4, July 2013*

[8] A. V. Timbus, M. Liserre, R. Teodorescu, and F. Blaabjerg, "Synchronization methods for three phase distributed power generation systems. an overview and evaluation," in *Proc. IEEE Power Electronics Specialists Conference (PESC'05)*, Jun. 2005, pp. 2474 – 2481.

[9]. R. A. Flores, I. Y. H. Gu, and M. H. J. Bollen, "Positive and negative sequence estimation for unbalanced voltage dips," in *Proc. IEEE Power Eng. Soc. General Meeting*, Jul. 2003, pp. 2498–2502.

[10]. F. D. Freijedo, J. Doval-Gandoy, O. Lopez, and E. Acha, "A generic open-loop algorithm for three-phase grid voltage/current synchronization with particular reference to phase, frequency, and amplitude estimation," *IEEE Trans. Power Electron.*, vol. 24, pp. 94 – 107, Jan. 2009.