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Power System State Estimation using Weighted Least Square Method

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Abstract: State estimation is an essential part of every energy control management system. Accurate estimation of state or operating state is essential for security control and monitoring of power systems. Power system state estimation is a procedure to estimate true state from the inexact state of a power system. The conventional state estimator provides estimates of the power system states, i.e., bus voltages and angles which is obtained. State estimation is a computational technique for electrical power system. It empowers the calculation of the power flows of the electrical power system which are not observed or not directly measured. State estimation is a computer program that detects, isolate and eliminate the incorrect or bad measurement data and estimates the accurate state. The magnitudes of bus voltage and phase angle are the states variables for an electrical power system. This paper outlines Weighted Least Square (WLS) estimation techniques and simulated estimation for standard IEEE systems.

Keywords: State estimation, State Variable, Weighted Least Square estimation.

Introduction

State estimation statically examines a measurement to estimate the accurate electrical power system state variable [1]. Power system state estimate must be undertaken to validate the accuracy of the measurements in case of faulty data [2]. Least square estimate is a statistical technique that has been employed in order to minimize or maximize the statistical property of the estimation [3]. The evaluating criteria is based on shrinking the sum of the square between estimated and measured values of a state variable [4].

This unreliability arises from metering errors, error from remote communication. Errors in measurements are caused by faulty measuring instruments in transmission lines and inaccurate equipment calibration. The functionality of state estimator is presented in figure 1. This paper approach weighted least square method (WLS) to determine estimated state variable. Rest of the paper is organized as follows. The concept of Conventional state estimation in power system is discussed in Section 2, Whereas Section 3 described mathematical formulation of the WLS techniques. The experimental results of simulated estimated state of standard IEEE test bus and associated error using WLS techniques are presented in section 4.

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1 Conventional State Estimation in Power System

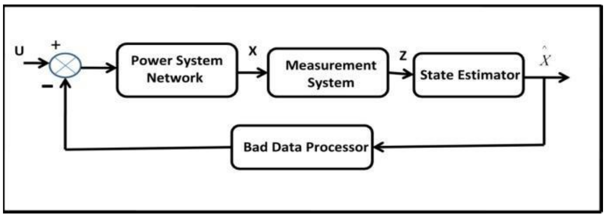

Figure 1 State Estimator

State estimation technique can be expressed as a transformation between raw input measurements and output estimated states. State estimation is primarily used to filter and eliminate incorrect measurements and to estimate the system's true state. The other important parameters like power flows are determined or calculated which are not directly measured or not available. The state estimation procedure is performed for an electrical power network by taken into account the set of measurement like voltage measurement, current measurement, power flows, power injections, transformers tap setting. The estimated state variables are used for contingency analysis, penalty factor calculation voltage stability assessment, optimal power flow and load forecasting, on-line system security assessment [4]. Power system network is monitor by many sensors such as phasor measurement units, current transformers, relay and potential transformer. The flowchart of state estimation is as follow.

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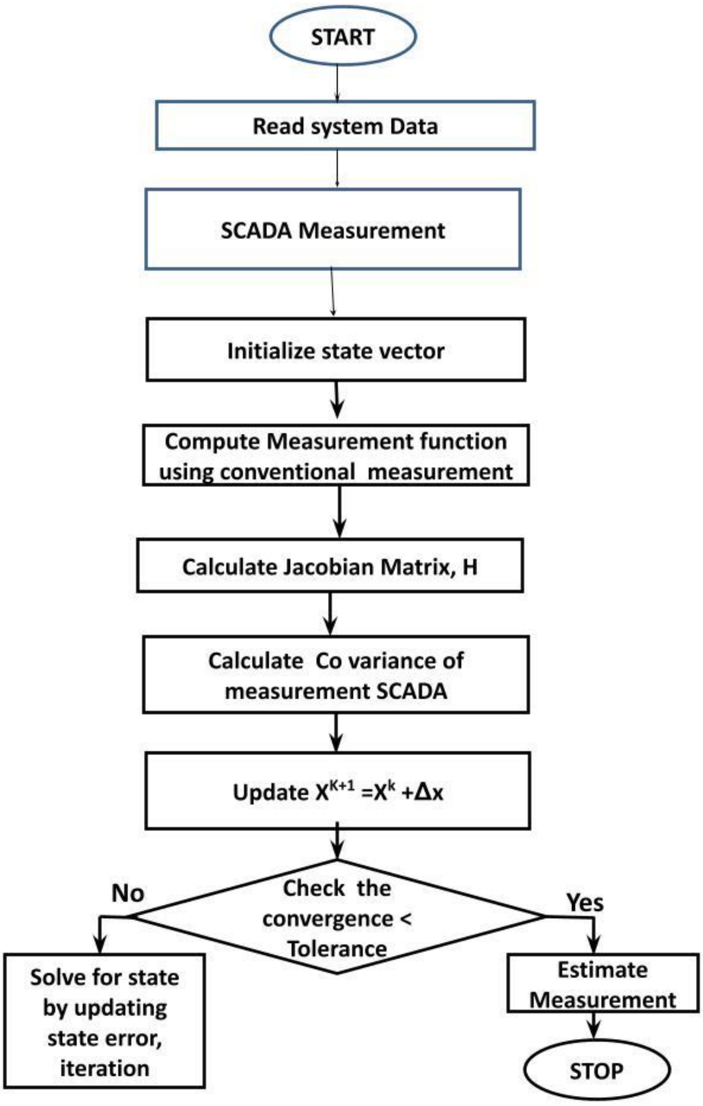

Fig. 2 Weighted Least square state estimation flow chart

State Estimation Algorithm using Weighted Least Square

State estimation is a mathematical computational procedure to estimate real time measurements

Mathematical formulation of the WLS technique is presented here.

The equation expressing the measurement function and state variable vector are as follows:

$$Z = Z_{true} + e \qquad (1)$$

$$[Z] = [n(x)[x]] + [e] \qquad (2)$$

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$$Z = \begin{bmatrix} n_1(x1, x2, ...xn) \\ n_2(x1, x2, ...xn) \\ . \\ n_3(x1, x2, ...xn) \\ . \\ . \\ . \\ . \\ N_n(x1, x2, ...xn) \\ \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \\ . \\ . \\ . \\ . \\ . \\ . \\ . \\ e_n \end{bmatrix} \quad (3)$$

Where, e is measurement error, n is number of state variable, z represents set of measurement, n(x) is non-linear function.

Error is carried between true measurement Z and measurement value of measured quantities is given

$$[e] = [z] - [N(x)] \quad (4)$$

True value of state can not be evaluated so estimation of states variables required

$$e = \left[\hat{z}\right] - [N] * \left[\hat{x}\right] \quad (5)$$

A technique is required for determine the estimates to determine the error. Weighted least square technique objective function of state estimator is to minimize the error between true value and measured value.

$$f = \sum_{i=11}^{n} w_i * e_i^{\ 2} \quad (6)$$

$$\frac{\partial(z - Hx)}{\partial x} = [w]\left[z - P\hat{x}\right] \quad (7)$$

$$\Delta\hat{x} = (g^T W g)^{-1} g^T W Z \quad (8)$$

The iterative approach is used to solve for the state

$$x^{k+1} = x^k + \Delta\hat{x} \quad (9)$$

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State estimation assists to evaluate estimated values of the measurements in spite of inaccurate measurements..

Simulation Result

The simulation results using MATLAB based on weighted least square approach is presented. Table 1, shows the result of estimated states of standard IEEE 14 bus respectively.

Table 1. State Estimation output of IEEE 14 bus system

BUS number	Estimated voltage	Estimated Angle
1	**1.0068**	**0.0000**
2	**0.9899**	**-5.5265**
3	**0.9518**	**-14.2039**
4	**0.9579**	**-11.4146**
5	**0.9615**	**-9.7583**
6	**1.0185**	**-16.0798**
7	**0.9919**	**-14.7510**
8	**1.0287**	**-14.7500**
9	**0.9763**	**-16.5125**
10	**0.9758**	**-16.7476**
11	**0.9932**	**-16.5397**
12	**1.0009**	**-13.1877**
13	**0.9940**	**-17.0583**
14	**0.9647**	**-17.8967**

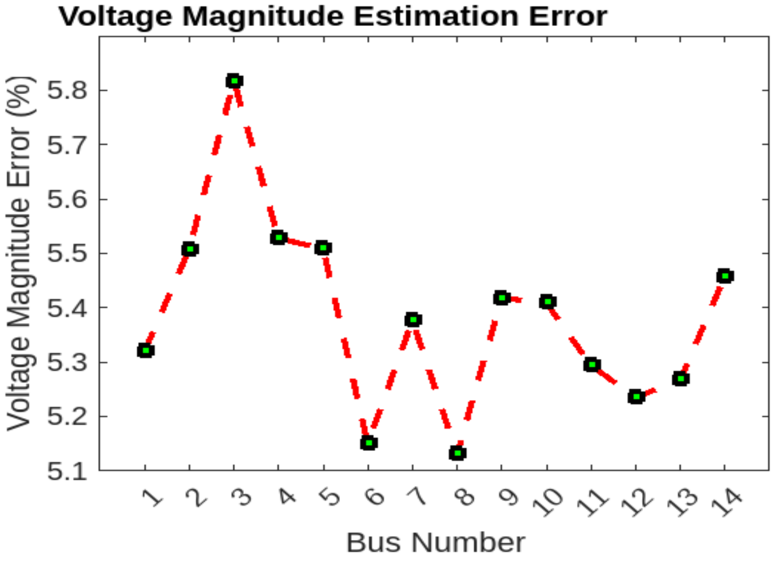

Fig. 3. **Voltage magnitude estimation error 14 bus.**

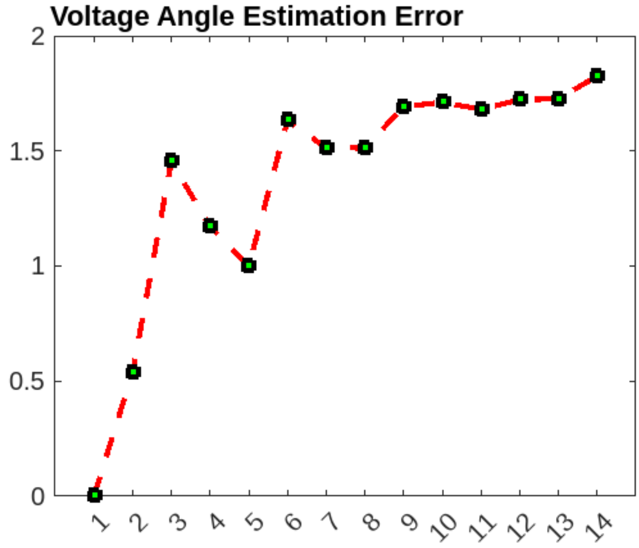

Fig. 4. **Voltage angle estimation error 14 Bus.**

Simulation Result

Weighted Least Square (WLS) method with the help of actual data and data measured are implemented. The algorithm and codes are developed and tested in MATLAB for standard IEEE 14 bus systems with a set of measurements. Estimation error is estimated using true values and estimated valued achieved using the Weighted Least Squares (WLS) algorithm are presented in figure 3 and figure 4.

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