Observability Analysis Of Large Bus - System Using Matlab Simulation

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Abstract

This methodology provides a numerical approach to observability analysis. The approach enables observability analysis and restoration (pseudo-measurement selection) in a simple way with iteration, via triangular factorization of the jacobian matrix of the weight least square state estimator. An algorithm for precious measurement of topological observability in large bus – system state estimation has been proposed. The algorithm is based on observation that the search for a spanning tree of full rank. We use observability algorithm and state estimation algorithm. We use the Mat lab to obtain the various graphs of bus systems. By using simulation method of bus system we analyze the observability.

Keywords – Power system state estimation, Observability analysis, Pseudo – measurement.

1. Introduction

State estimation is an essential element of modern computer assisted power system control package. It is the process of determining the Bus voltage magnitude and Bus voltage angle at each bus from a set of measurement. The measurement set consist of, the analog measurements that include bus voltage magnitude real and reactive power injections and real and reactive power flows. Pseudo - measurements (manipulated data, such as MW generation load demand based on historical data).

A fundamental question with regard the measurements on the system is whether these are sufficient in number and location to enable proper estimation of the system state vector i.e., vector of voltage and voltage, angles. If this is possible the network is said to be observable [1]

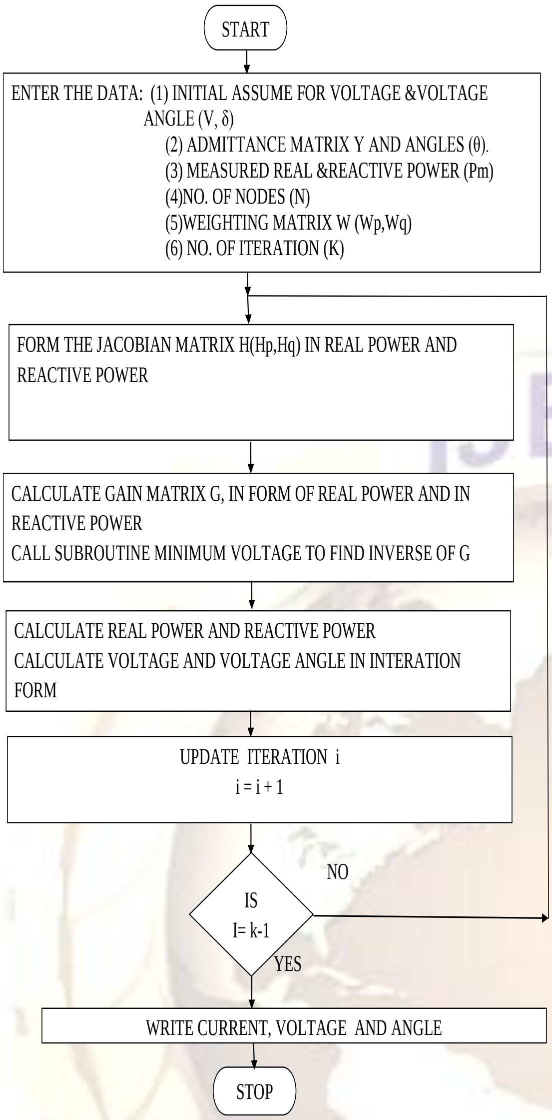
A vector of line flow and bus injection power measurements is nonlinear function of bus voltage magnitudes and angles. The nonlinear function may be about nominal operating point: all bus voltage magnitudes are unity and all bus voltage angles are zero. The determination of network observability is equivalent to deciding whether the matrix [H] that relates measurements to bus voltage magnitudes and angles in the linear zed model is full rank [1]. If this condition is satisfied the network is said to be observable

Question regarding network observability arise both in off line studies and in the on line implementation. Prior to on line implementation, off line meter placement studies are performed to assure that the metering system will provide a reliable state estimate even under such contingencies as telemetry failure and line outages. The design goal is to assure. Network observability under such contingencies. In the on line situation such contingencies will arise possibly rendering the network unobservable. An observability test should be executed prior to performing the state estimation. If network is observable, state estimation may proceed otherwise the estimation is applied either to the observable subsystems of the original system or appropriate pseudo - measurement are added to the measurement set.

2. WLS STATE ESTIMATION PROCESS

A. FLOW CHART OF STATE ESTIMATION ALGORITHM:

The state estimation computes the static state of the system (voltage magnitude and phase angle) by monitoring available measurements. The state estimation has to be modelled in such a way so as to ensure that the system is monitored reliably not only in day- to - day operations, but also under the most likely condition of system stress. The role of power system state estimation in the operation of power system and how state estimation, contingency evaluation and generator corrective action take place in a modern operation control centre. For the state estimation algorithm we follow the flow chart below given:



FLOW CHART OF STATE ESTIMATION

B. Observability Analysis

In the modern times Power system control and dispatch centres are equipped with supervisory (control and data acquisition) systems. It is possible to consider the operation of such a control system in two steps: 1.Raw information is processed in real time by a digital computer into a more useful form. 2. Control decisions are made from the processed information either by digital computer or by a human operator.

The function of these centres includes measurement and transmission of critical data to the control centre by telemetry and monitoring for alarm, and display system for the benefit of operating personnel.

The quantities that are normally measured and monitored in power system network are the injected power or power flows over the lines. From these some of the quantities of interest have to be calculated for several reasons is that It is very difficult or nearly impossible to measure some quantities like voltage angle difference and Metering and communication equipment is costly and hence the number of meters should be reduced a much as possible.

3. A lost measurement can be simulated by calculating it.

Following questions may arise regarding power system state estimation

1. Are there sufficient real time measurements to make state estimation possible?
2. If riot which part or parts of the original system whose states can still be estimated (known as observable islands) with the available measurements?
3. How to estimate the states of these observable islands?
4. How to select additional pseudo - measurements to be included in the measurement et to make state estimation possible?

The analysis which lead to the answers to above. Questions are called observability analysis. According to definition given by Clement [2] "...Network observability is a Yes/No type of property; the network is either observable or not. This property is determined solely by the location of rneaurements on network not by measurement weights and network admittance Values."

3. PROPOSED APPROACH

The most widely used approach in power system observability analysis is based on a linear zed decoupled version of the standard weighted least square (WLS) Estimator which tries to find the best estimate of the state of power system network by minimizing the weighted sum of measurement error squared.

Crainiac. Hoisberger, Mukhedkar [3] suggested a criterion for observability analysis based on measurement to branch incidence matrix M and reduced node to branch incidence matrix Ar. According to them "if the matrix $W = MA^t_r$ is considered its Gramian det (w^t w) is nonzero for observable network and zero for unobservable network".

In this methodology we have to test the value of Gramian of W matrix a technique based on triangular factorization of matrices is presented. Technique is simple and does not involve combinatory type complexities as exist in techniques based on Graph theory [1, 5] and very appropriate for on line observability analysis. Here this method has been tested on selected examples. Further a 3 Bus Power system is considered to demonstrate the observability analysis and state estimation together. The algorithm used for state estimation is fast decoupled version of WLS. Method [4]. To improve the accuracy of state estimation recalculation of state dependent Jacobian matrix H and refacterization of gain matrix (H^TWH) is done in every operations instead of taking it as a constant matri

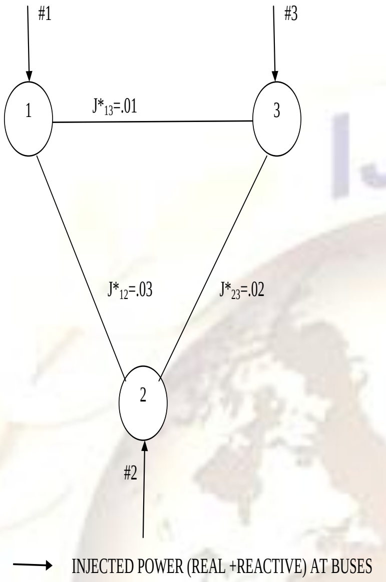
4. TEST AND RESULTS

To verify the efficiency of the proposed approach the algorithm presented in the previous section was implemented under the matrix laboratory (MATLAB) and obtained graphs.

4.1 Tests with the 3- bus system

Figure 2 shows the 3- bus system with injected power (real + reactive) at buses

$V_1 = 1.05 + j0$



Both observability algorithm and state estimation algorithm is applied to above network. This example is taken from reference (4).

INPUT DATA FOR STATE ESTIMATION:-

Number of nodes N = 3

Vector of initial bus voltage:

1.05
V =
1.00
1.00

Vector of initial bus angle:

0
DELTA =
0
0

Admittance Matrix: 133.3 33.3 100
Y = 33.3 83.3 50
100 50 150

Admittance (Angles in radians): -1.5707963 1.5707963 1.5707963
THETA = 1.5707963 -1.5707963 1.5707963
1.5707963 1.5707963 -1.5707963

Weighting Matrix: 3 0 0
$W_p = W_q =$ 0 5 0
0 0 2

Measured real power: .12
$P_m =$ .21
-.30 MW (100 MVA BASE)

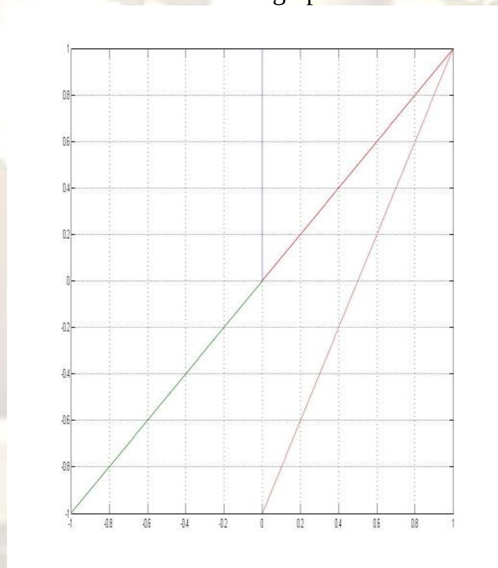
Measured reactive power: -. 24
$Q_m =$ - . 24
. 50 MVAR (100 MVA BASE)

INPUT DATA FOR OBSERVABILITY ANALYSIS:-

Reduced node ho branch incidence matrix A_r = 1 1 0
0 - 1 1

Measurement to branch incidence matrix M= 1 1 0
0 -1 1
-1 0 -1

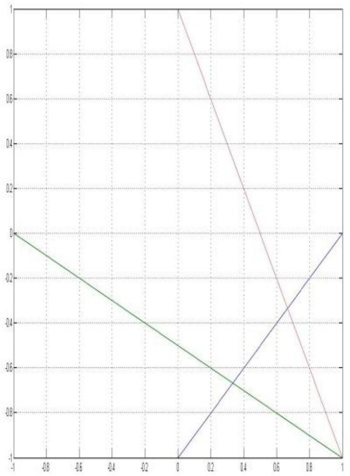
With all three measurements available at nodes the network is found to he observable and state estimation results are shown in table 4.1 .Now we use mat lab to obtain the graph.



Now removing one measurement at node (1) the network is at still observable and state estimation result are shown in table 4.1 .After removing measurement (1), the matrix Ar and M are:

Ar = 1 1 0
0 -1 1
M = 0 -1 1
-1 0 -1

If we remove measurement (1) & (2) also the network is not observable. Now graph we obtain



Calculating the injected power P at node (1) that all three measurements are available on the basis of estimated result:

Pl = 1103055 pu

Error = 8 %

TABLE 4.1

KK	D2	D3	V2	V3
1	-.001492	.001548	1.051273	1.047196
2	-.001352	.001455	1.051145	1.047266
3	-.001352	.001455	1.051146	1.047266
4	-.001352	.001455	1.051146	1.047266
5	-.001352	.001455	1.051146	1.047266
6	-.001352	.001455	1.051146	1.047266
7	-.001352	.001455	1.051146	1.047266
8	-.001352.	001455	1.051146	1.047266
9	-.001352	.001455	1.051146	1.047266
10	-.001352	.001455	1.051146	1.047266

TABLE 4.2

KK	D2	D3	V2	V3
1	-.001645	.001485	1.051100	1.047033
2	-.001497	.001319	1.051032	1.047158
3	-.001497	001319	1.051033	1.047159
4	-.001497	.001319	1.051033	1.047159
5	-.001497	.001319	1.051033	1.047159
6	-.001497	.001319	1.051033	1.047159
7	-.001497	.001319	1.051033	1.047159
8	-.001497	.001319	1.051033	1.047159
9	-.001497	.001319	1.051033	1.047159
10	-.001497	.001319	1.051033	1.047159

Where: KK = NO. OF ITERATIONS
D2 = VOLTAGE ANGLE AT BUS 2 (RADIANS)
D3 = VOLTAGE ANGLE AT BUS 3 (RADIANS)
V2 = VOLTAGE MAGNITUDE AT BUS 2 (pu)
V3 = VOLTAGE MAGNITUDE AT BUS 3 (pu)

The value of injected power at node [1] when only two measurements are available:

P1=0900124 pu

Error = 24%

(Errors are calculated with respect to measured real power at node [1])

From the Result it is clear that redundant measurement improves the accuracy of state estimation hut metering cost also increases.

5. CONCLUSION

In this paper a technique based on numerical techniques is used to detect topological observability. The algorithm is tested to selected examples. In the state estimation algorithm it is seen that when all three measurements are used error is 8%. After reducing one measurement network is still observable but error increases to 24%• Thus one redundant measurement increases the accuracy but metering cost also increases. There should be an optimal meter placement criterion.

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