An algorithm for Observability determination in Bus-System State Estimation using Matlab Simulation

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ABSTRACT:-

This paper 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. The observability characterization of an electric power system from a topological point of view with respect to a given measurement acquisition system is equivalent to the existence of a certain spanning tree. The notation of observability, is a measure of how well internal states of a system can be reconstructed using a given set of measurements. In this work we derive necessary and sufficient conditions for observability in a power system. It is also show that standard measurement sets of at least one voltage measurement, and paired active and reactive power measurements may lead to unobservability for certain measurements configuration. Using a non linear transformation and properties of graph theory, a set of sufficient conditions are derived for observability. These conditions are shown to be dependent on the topological properties as well as the type of available measurements. The results is validated using an IEEE-3 Bus system. This method can be utilized off-line as a planning tool during the initial stages of measurements system design as well as on-line prior to state estimation. We use observability algorithm and state estimation algorithm, also use the Mat lab to obtain the various graphs of bus systems. The main objective of this paper is to measure the Observability analysis of bus system by using Mat lab simulation.

Index Terms- Power system state estimation, Observability analysis, Pseudo-measurement, Mathematical technique, Critical measurement

NOMENCLATURE

Ar	Reduced node to branch incidence matrix
G	Gain matrix
H	Jacobian matrix
P	Real power
Q	Reactive power
M	Measurement to branch incidence matrix
V	Voltage magnitude at buses
δ	Voltage angle at buses
W	Weighting matrix
X	State vector
Y	Admittance matrix
Z	Measurement vector
RTU	Remote terminal unit
SCADA	Supervisory control and data acquisition

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:

1. The analog measurements that include bus voltage magnitude. Real and reactive power injections and real and reactive power flows.

2. The logic measurement which consist of status of switches and breakers.

3. Pseudomeasurments (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.

A vector of line flow and bus injection power measurements is nonlinear function of bus voltage magnitudes and angles. The nonlinear function may be linearized 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. 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 pseudomeasurement are added to the measurement set. 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. The information about power system is collected from the remote terminal units (RTU) which encodes measurement transducer outputs and opened/closed status information into digital signals that are transmitted to the operation centre over communication channels. However the control centre in turn transmits control information in terms of raise/lower commands to generators and open/close commands to circuit breakers and switches. The information coming into the control centre is divided into two parts as breaker/switch status indication and analog measurements. Network topology means the interconnection of various components of power like generators, loads, transmission lines etc, through circuit breakers/switches. Network topology plays an important role in estimating the state of power system. Since the switches and breakers in any substation can cause the network topology to change, a program is provided that reads the telemetred breaker/switch status indication and restructures the electrical model of the power system. This program which reconfigures the electrical model is known as network topology program. This program has complete information of each substation and how the transmission lines are connected to the substation. The commonly available measurements for state estimation are power flows, voltage magnitudes, and power injections. For state estimation the measurements are collected using supervisory control and data acquisition (SCADA). SCADA measurements are not free from errors. The errors can be in the form of noise in measurements, bad measurements, and wrong circuit connection information (more often called topology information).

State estimation involves following major functions:

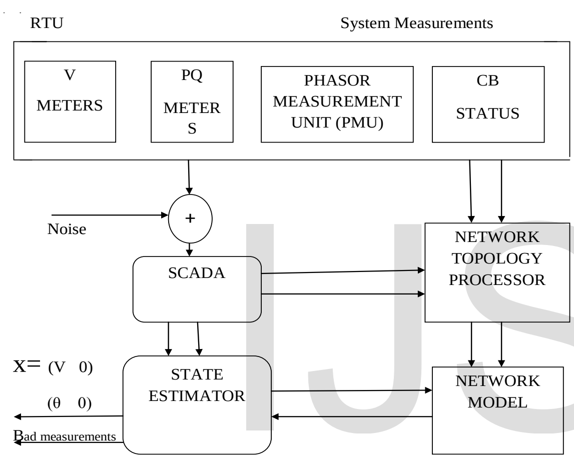
1. Topology processing: this function involves obtaining the model of the system based on status of the circuit breaker, tap positions of transformers, parameters of transmission lines, etc.

2. Observability analysis: this function involves checking if the available SCADA measurements are sufficient to find the state of the system. If the SCADA measurements

are not sufficient, pseudo measurements can be used based on fore casted data or previous state data to make the system observable?

3. State estimation: this function obtains the best estimate of the system state using the SCADA measurements and the topology information.

4. Bad data processing: this function checks for the possible bad measurements. If any bad measurements are detected; they are removed from the measurement set, and the state estimation is repeated again. Block diagram of state estimation is shown below:



In the state estimation model we use the measurement set. As for computing the estimate, the method that has received wide acceptance is the iterative method.

1.1 OBSERVABILITY ANALYSIS

In the modern times Power system control and dispatch centeres 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 centeres includes measurement and transmission of critical data to the control center 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 listed below.

1. It is very difficult or nearly impossible to measure some quantities like voltage angle difference.

2. 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 not 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 to make state estimation problem?

The analysis which leads to the answers to above, a question is called observability analysis. According to definition given by Clement

"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 measurements on network not by measurement weights and network admittance Values" Thus the problem can be thought of one where algorithms have to be developed for

. Testing observability

. Identification of observable islands.

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. Measurement placement for observability analysis.

1.2. TOPOLOGICAL AND NUMERICAL OBSERVABILITY

Monticelli &Felix have defined topological observability as:

Theorem1: If a power system is observable w.r.t. measurement set M, t heir exist a spanning tree of the network graph which is an observable tree.

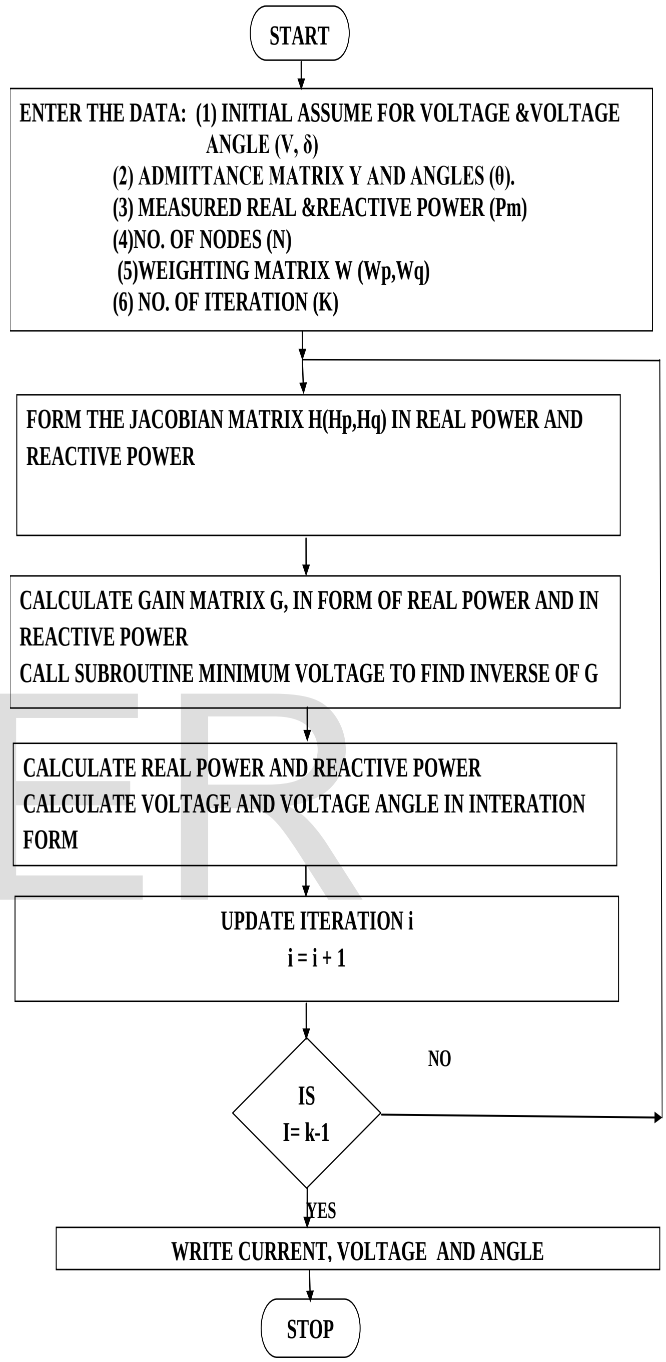
Theorem2: A spanning tree is an observable Spanning tree if and only if it is possible to assign a measurement to each one of the tree branches such that no two branches are associated same measurement.

Theorem3: A spanning tree is that tree which is incident to every bus of the network .

If the coefficient matrix H in iterative solution of the state estimation becomes less than full rank then system is numerically unobservable. Thus numerical observability is machine dependent. While topological observability depends only on topology of the network.

1.3 FLOW CHART OF WLS STATE ESTIMATION PROCESS ALGORITHM:

The state estimation computes the static state of the system (voltage magnitude and phase angle) by monitoring the available measurement. The state estimation has to be modeled in such a way so ensure that system is monitored reliably not only in day to day operation but also under the most likely condition of system stress. State estimation is vital part of power system operation as it is ofen the starting point for many applications. But in its implementation an important challenge is the increasing size and complexity of the power system. Thismethod has been fundamental for other algorith ms and the majority of the state estimators will use Weighted least squares. An important point to be noted here is that the state estimation is run repeatedly and is better that the state vector always has the state of the system in the previous state as the initial value rather than using a flat start for every run. Predication is very useful tool as it gives the operator a rough estimate of the one state estimation step in the future. For state estimation flow chart is shown below:



FLOW CHART OF STATE ESTIMATION

ALGORITHM:

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2. TEST AND RESULTS:

To verify the efficiency of the proposed approach the algorithmpresented in previous section was implemented under the Matrixlaboratory (MATLAB).

2.1 Test with the 3-bus system:

Below figure shows the 3- bus system With injected (real and reactive) power.

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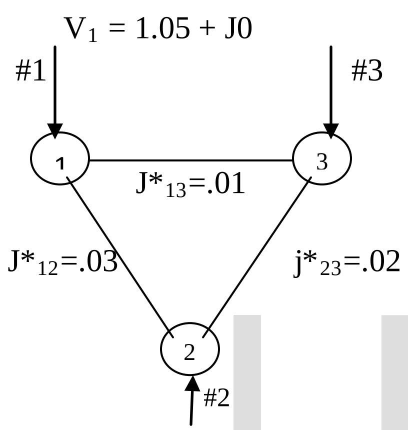


3- Bus system

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

INPUT DATA FOR STATE ESTIMATION:

Number of nodes N = 3

Vector of initial bus voltage

$$V = \begin{matrix} 1.05 \\ 1.00 \\ 1.00 \end{matrix}$$

Vector of initial bus angle

$$Delta = \begin{matrix} 0 \\ 0 \\ 0 \end{matrix}$$

Admittance Matrix:

$$Y = \begin{matrix} 13.3 & 33.3 & 100 \\ 100 & 83.3 & 50 \\ 100 & 50 & 150 \end{matrix}$$

Admittance (angles in radians):

$$THETA = \begin{matrix} -1.5707963 & 1.5707963 & 1.5707963 \\ 1.5707963 & -1.5707963 & 1.5707963 \\ 1.5707963 & 1.5707963 & -1.5707963 \end{matrix}$$

Weighting Matrix

$$W_p = W_q = \begin{matrix} 3 & 0 & 0 \\ 0 & 5 & 0 \\ 0 & 0 & 2 \end{matrix}$$

Measured real power:

$$P_m = \begin{matrix} .12 \\ .21 \\ -.30 \end{matrix}$$

MW (100 MVA BASE)

Measured reactive power:

$$Q_m = \begin{matrix} -.24 \\ -.24 \\ .50 \end{matrix}$$

MVAR (100 MVA BASE)

INPUT DATA FOR OBSERVABILITY

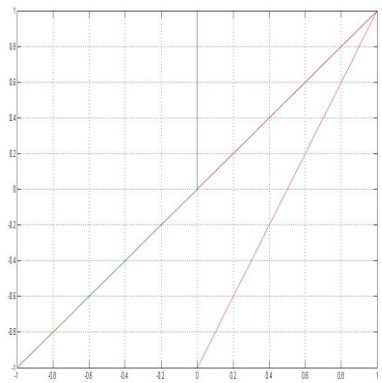
Reduced node to branch incidence matrix

$$A_r = \begin{matrix} 1 & 1 & 0 \\ 0 & -1 & 1 \end{matrix}$$

Measurement to branch incidence matrix

$$M = \begin{matrix} 0 & -1 & 1 \\ -1 & 0 & -1 \end{matrix}$$

If we remove measurements (1) and (2) network is not observable.



Observable graph of bus system

With all three measurements available at nodes The network is found to be observable and state Estimation results are shown in table A.

Now removing one measurement at node (1) the \network is still observable and state estimation Result in table B. After removing measurement (1), the matrix A_r and M are:

$$A_r = \begin{matrix} 1 & 1 & 0 \\ 0 & -1 & 1 \end{matrix}$$

$$M = \begin{matrix} 0 & -1 & 1 \\ -1 & 0 & -1 \end{matrix}$$

If we remove measurement (1) &(2) the network is Unobservable.

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

P1 = 1103055

Error = 8%

TABLE-A

KK	D2	D3	V2	V3
1	-.00149	-.00154	1.05127	1.047
2	-.001352	.001455	1.05114	1.047
3	-.001352	.001455	1.05114	1.047
4	-.001352	.001455	1.05114	1.047
5	-.001352	.001455	1.05114	1.047
6	-.001352	.001455	1.05114	1.047
7	-.001352	.001455	1.05114	1.047

TABLE-B

KK	D2	D3	V2	V3
1	-.001645	.001485	1.0511	1.0470
2	-.001497	.001319	1.0510	1.0471
3	-.001497	.001319	1.0510	1.0471
4	-.001497	.001319	1.0510	1.0471
5	-.001497	.001319	1.0510	1.0471
6	-.001497	.001319	1.0510	1.0471
7	-.001497	.001319	1.0510	1.0471

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 :

PI = 0900124PU

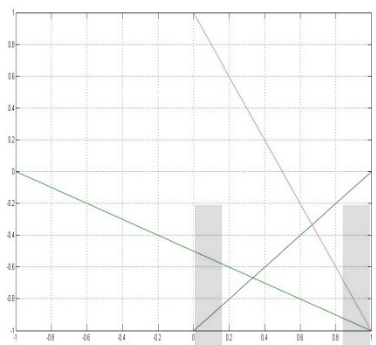
Error = 24%

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

OBSERVABILITY ANALYSIS PROGRAM

```
Ar = [ 1 1 0;
       0 -1 1];
M = [0 -1 1;
    -1 0 -1];

W=M*Ar';

G=W'*W;
z=size(G);
p=z(1);
% x1=size(Ar);
x1=size(Ar);
N=x1(1);%% row

x2=size(M);
M1=x2(1); %%row
L1=x2(2); % column

DET=1.00;

for j=1:N
R(j)=j;
end

for i=1:N-1
for k=i+1:N
if((abs(G(R(k),i)))>(abs(G(R(i),i))))
T= R(i);
R(k)= T;
else
continue;
end
k1=q1(1);
k2 =q2(1);
k11=q1(2);
if((G(R(i),i))==0)
  disp('Network is observable')
  break;
  else
  DET=DET*G(R(i),i);
  end
  u1(i) = G(R(i),i);

  if((G(R(i),i))==0)

  break;
 else
 DET=DET*G(R(i),i);
 end

for k1=i+1,n;
 PL=G(R(K1),i/G(R(i),i);
for L=i+1,N
G(R(k1),L)=G(R(k1),L)-PL*G(R)
end
end
end
DET=DET*G(R(N));
 if (G(R(i),i)=0)

If (abs(DET)==0)
disp('Network is unobservable')
 else
disp('Network is observable')
end
end

q1= size (Ar);
q2= size (M);
```

```
k22=q2(2);

k=min(k1, k2);
for i=1:k
for j=1:k
Ar1(i,j)=Ar(i,j);

M1(i,j)=M(i,j);
end
end
 plot(Ar1,M1)
 axis([-1 1 -1 1])

 grid on .
```



Unobservable graph of 3-Bus System

3. CONCLUSION

In this paper technique based on numerical Technique is used to detect topological obs ervability. The algorithm is tested toSelected bus system. In the state estimation Algorithm it is seen that when all three mea Surements are used error is 8%. After reducing One measurements network is still observer But error increases 24%. Thus one redundant Measurement increases the accuracy but Metering cost also increases. There should be a optimal meter placement criteria.

REFERENCES:

(1) Fred C. Schweppes and Wildes "Power static state estimation part-1: Exact Model", IEEE Trans on power apparatus and system, Vol PAS-89,PP 120 -125 Jan 1970.

(2) G.R. Krumpholz, K. A. Clements and P.W. Davis "Power System Observability : A Practical algo. using network topology", IEEE Trans on power apparatus and system VOL PAS-99,PP1534-1542 July/Aug 1980.

(3) A. Monticelli, F.F. Wu, "Network observability: identification of observability islands and Measurement Placement", IEEE Transactions on power apparatus and system, VOL.pas-10NO.5 PP.1035-1040, 1985

(4) E. D. Crainic, X. D. Do., P.J. Lagace,D.Mukhedk "Power System observability: On line Measureme Nt set contingency Analysis," Proceedings of IFAC Power systems Modeling and control appli. Belgium,pp. 491-499,1988.

(5) K. A. Clements "Observability method and opti mal meter placement",Int. J.Elec. Power and Energy, vol. 12, pp. 89-93,Apr. 1990.

(6) A. Monticelli, "State Estimation in Electric Power system: A generalized approach", Kluwer Acade mic Publishers Boston/Dordrench/London, 1999.

(7) Korres, "Reduced model for numerical observa bility analysis in generalized state estimation", IEEE generation, Transmission and distribution ISSN 1350-2360, 99-108 Jan 2005.

(8) Vanfretti, " A Framework of power system bas ed on Synchronized phasor measurement data IEEE transaction on power system ,26-30, 1-6 July 2009.

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