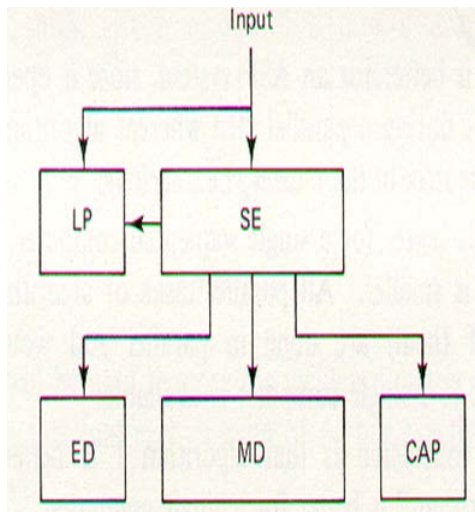


EMS-LECTURE 5: State Estimation

1.1 Introduction:

State estimator is an important tool for online monitoring, analysis and control of power systems. State estimation is used in all Energy Management Systems (EMS) to identify the present operating state of a system.



- SE= State Estimator
- LP=Limit Checking Program
- ED=Economic Dispatch
- MD=Mimic Display
- CAP=Contingency Analysis Programs

State Estimation (SE) is mainly used to filter redundant data, to eliminate incorrect measurements and to produce reliable state estimates. It allows the determination of the power flows in parts of the power system which are not directly metered. The bus voltage magnitude, real power injections, reactive power injections, active power flow, reactive power flow and line current flows are common measurements available in SCADA systems. SE is a very useful tool for the economic and secure operation of transmission networks. From early days of Schweppe, developments of SE are done as a notion of robust estimation, hierarchical estimation, with and without the inclusion of current measurements, etc. The state variables of State estimation are the voltages and phase angles. Once the estimates of the state variables are known proper

actions, if required (during emergency, normal insecure states), can be taken to bring the system back to its normal secure state. For proper monitoring of the system, the intervals at which the telemetry data are collected and the estimates of the state variables made must be very less. As the size of a power system increases, collecting data and solving the state estimation problem in a very short time in one control centre, not only becomes very difficult, but also requires extra investment in setting up long telemetry and communication lines.

CONVENTIONAL STATE ESTIMATION

The conventional state estimator uses Weighted Least Square (WLS) to find the best state vector to fit a scatter of data. The scatter of data is due to the imperfect measurements of rapidly changing voltages and currents on the network. The measurement equation is given below.

$$z = h(x) + e \quad (5.1)$$

where,

z Measurement vector formed by voltage magnitude, real and reactive power flows and power injections

$h(x)$ The non linear function relating the error - free measurements to the system states.

x State Vector

e Noise in measurements

m Number of measurements

n Number of state variables

The objective of the Weighted Least Square state estimator is to minimize the error in the measurements i.e, is the sum of the squares of weighted residuals

$$J(x) = \sum_{i=1}^m (z_i - h_i(x))^2 / R_{ii} \quad (5.2)$$

where,

R_{ii} Measurement error covariance matrix given by

$$\text{diag}(\sigma_1^2, \sigma_2^2, \sigma_3^2, \dots, \sigma_m^2)$$

σ_i The standard deviation of the i^{th} measurement

The state of the power system can be estimated by an iterative solution scheme known as the Gauss Newton method which neglecting the higher order terms of the Taylor series as expansion as follows:

$$x^{k+1} = x^k + \{G(x^k)^{-1} * H(x^k)^T * R^{-1} * [Z - h(x^k)]\} \quad (5.3)$$

where,

$G(x^k) = H^T(x^k) * R^{-1} * H(x^k)$ is the gain matrix,

$H(x^k) = \left[\frac{\partial h(x)}{\partial x} \right]$ is the Jacobian matrix which is the first derivative of $h(x)$

k is an iterative number.

I. LINEAR STATE ESTIMATION

In CSE, the inclusion of power measurements makes the problem of state estimation highly non-linear, leading to iterative procedure. Thus, the CSE is highly time consuming and infeasible for on-line implementation. The Linear State Estimation (LSE) overcomes the drawbacks of CSE. In LSE, the current and voltage phasors are used in the measurement set vector. This makes the problem of SE linear and hence a non-iterative procedure can be used for estimating the states. This also helps in ease of on-line implementation.

The operation of EMS is based on the working of the operating states. The power system operates in two important areas, namely normal and abnormal states.

Summary:

State Estimation in power systems forms an important role in EMS