CHAPTER 1

Introduction

1.1 Historical Background

Since size and complexity of power system have been continually growing, it becomes necessary to study about system behavior. The system behaviors are the important conditions for improving power system quality. At present, Phasor Measurement Units (PMUs) are the best measuring instruments that collect the important information such as current and voltage synchronized by Global Positioning System (GPS) satellite transmission. However, PMUs are still more expensive. It is not economically feasible to place them at all locations in large power systems. Therefore, the more economical technique is to combine partial measurements at optimal locations with state estimations for determining the measurement value at unmonitored location in electric power system [1-3].

Electromagnetic transient is one of the interesting topics about power system quality. It is caused by disturbances (e.g., system faults, loss of load, or switching events). The technique of state estimation can be expanded to instantaneously estimate voltage and current data at unmonitored locations. The state estimation techniques which concern transient phenomena are called Transient State Estimation (TSE) [4-6].

TSE is based on an appropriate system model for a functioning power system. Previous researches used the PI-transmission line model [4-5],[7] which is suited for a short distance line. However, the longer line transmission requires distributed parameter representation, which is based on the concept of traveling waves [8-9]. Normally, the distributed parameter of transmission lines with the state space model is used for the study of transient phenomena [6],[10-15]. Therefore the study concerning with TSE with the Bergeron transmission line model should be examined.

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In addition, the proposed algorithm will be evaluated by also considering the result of other factors. For examples, measurement's noise due to transducer device and nonlinear equipment like transformer which has become saturated.

1.2 Objectives

The main objectives of this study are as follows:

1.2.1 To develop the transmission line models with Bergeron model for improving the state estimation performance.

1.2.2 To develop transient state estimation algorithm with considering nonlinear equipment such as transformer which is saturated.

1.2.3 To improve the performances of the transient state estimator with measurement noises.

1.3 Literature Review

Ueda *et.al* [16] presented a non-linear observer to estimate the transient state of an infinite bus system. The transient state of the power system is represented continuously as a set of non-linear differential equations and observation of the output is obtained as a discretized value at every cycle of the system frequency by using a mean value detecting circuit device. The non-linear differential equation of state is discretized at each observation instant by Taylor expansion and then the discrete linear observer is applied to the discretized system. The observer provides a basis for transient power system state estimation.

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Ueda *et.al* [17] developed the estimation technique and applied it to a multi-machine system. A Kalman filter type gain was used to replace the gain adopted in previous their work [16] to improve the estimation performance. The proposed method showed good estimation performance and tracking when applied to a three machine system. However, if this technique is to be applied to a large power system, the following problems need to be addressed: (i) the numerical method constituting the approximate discretized difference equation to the non-linear differential equation and; (ii) the selection of the observer gain.

Yu, *et al*. [4] has proposed a method to estimate power system transients. State estimation techniques are used to determine the state values at unmonitored location. To evaluate the performance of the proposed TSE, transients caused by a sudden lost of load have been simulated on the test system. The result of TSE provided a good estimate of system state. However, the component models in test system are represented by simple equivalent lump circuits. It should include detailed component representation for in-depth detail.

Yu, *et al*. [18] has proposed a methodology in fault identification via TSE. Since the fault is not modeled in the TSE, system topology remained unchanged during the fault period. This cause inconsistent estimation results and current mismatch at the fault location. These indicate three important fault characteristics i.e. the fault position, fault type and magnitude of the fault currents.

Farzanehrafat, *et al.* [19] has introduced the use of TSE for voltage dip/sag assessment. The proposed algorithm uses mismatch nodal voltage to identify the type and location of voltage dip/sag origin via limited number of measurement points within the network.

Monzani, *et al.* [7] introduce transmission lines associated to the state variables and the trapezoidal integration techniques are applied for electromagnetic transient simulations. The numeric routine is applied to a mathematical metrical program and it is possible to simulate the propagation of electromagnetic transients on transmission lines.

Mamis, *et al.* [10] use distributed-parameter state variable to calculate transients on Bergeron transmission lines model based on the concept of travelling waves. A discrete-time state space technique corresponding with the trapezoidal integration is used for transient simulations of transmission line. The transpose line model uses phase to modal transformation techniques for decoupling to three independent modes. The evaluate test involving single-phase and multi-phase transmission lines with linear and nonlinear elements.

1.4 Theories / Principles and Rationale

The state of a system has important information to ensure that components of power system operate satisfactory and system operators can use this data for improving the quality of power system. But monitor placement at all locations in large power system definitely relates to instrumentation cost. Hence, a better technique is to combine partial measurements at optimal location with state estimation to collect complete knowledge of the system states.

When applying state estimation technique to electric power system, it refers to the set of voltage and current data from selected location and computing a state vector at unmonitored location. In case of switching event, lost of load or system disturbances that concern with the transients, state estimation techniques are also used to estimate instantaneous value. This is called Transient State Estimation (TSE).

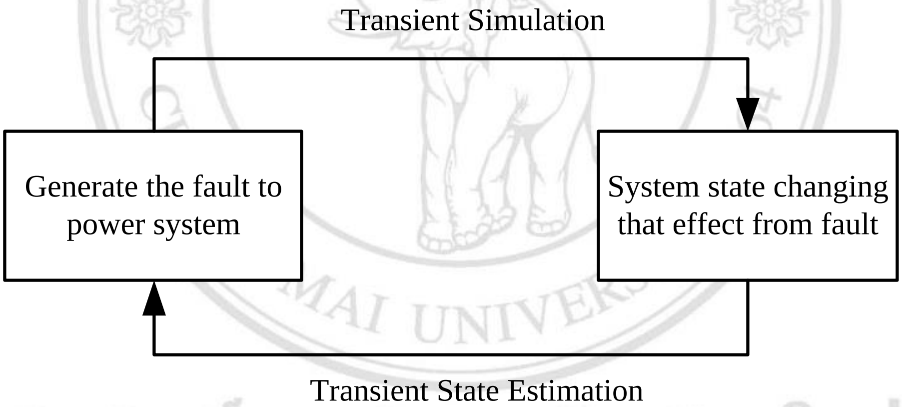

Figure 1.1 Difference between transient simulation and TSE.

In essence, TSE is a reverse process of transient simulation (figure 1.1). Transient simulation procedure is used to analyze the effect of fault or other disturbance on a power system, whereas TSE is used to estimate the transient voltage and current at the unmeasured location.

Figure 1.2 shows the framework of TSE that formulated from system topology and set of component model state equations. Then combine with measurement data to build up the measurement system for TSE. According to this, establishment of suitable component model should be done for gaining accuracy estimator. For the transmission

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line which has suitable long can represent the travelling wave models. Therefore, the distributed parameter as Bergeron model is chosen for transmission line model. Moreover, the consideration of measurement noise and nonlinear equipment such as transformer which saturation are ought to study since it relate to performance of estimator.

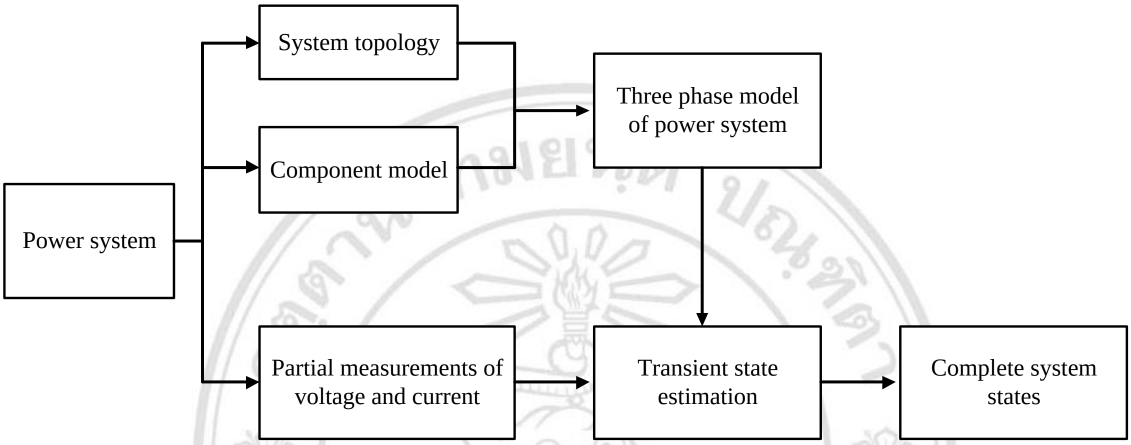

Figure 1.2 Framework of TSE.

1.5 Scopes of Study

1.5.1 Develop and implement the proposed TSE algorithm using Bergeron transmission line model.

1.5.2 Develop the proposed algorithm by considering nonlinear characteristics of equipment such as transformer with saturation.

1.5.3 Develop the proposed algorithm by considering the effect from the measurement noise with Gaussian distribution.

1.5.4 Implement the proposed TSE algorithm with the test system includes partial measurement at selected location and estimate measurement value at unmonitored.

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1.6 Expecting Benefit

1.6.1 Obtain the developed transmission line model with Bergeron for TSE algorithm.

1.6.2 Obtain the developed algorithm by considering nonlinear characteristics of equipment such as transformer with saturation.

1.7 Research Methodology

1.7.1 Study theories and methodologies for state estimation applied in several researches.

1.7.2 Study on transient phenomena in power system.

1.7.3 Develop simulation program on PSCAD.

1.7.4 Develop transient state estimation algorithm on MATLAB.

1.7.5 Test the performance of proposed TSE algorithm with test power system.

1.7.6 Writing the thesis document.

1.8 Thesis Organization

This thesis is organized into four chapters including this chapter. Chapter 2 reviews the state estimation and solution method. The system modeling with proposed TSE algorithm, modal transformation, evaluation method, measurement noise, and nonlinear equipment are also described. Then, the detail of 10 bus test system with a fault event is explained in Chapter 3. The estimation results with measurement noise, nonlinear equipment such as transformer which saturation are also presented. Finally, conclusions of this thesis and recommendations for future work are given in Chapter 4.

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