PHASOR MEASUREMENT APPLICATIONS IN TAIWAN

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I. INTRODUCTION

The paper discusses the applications of the wide area phasor measurement system in Taiwan. It describes the configuration, and hardware architecture of the wide area phasor measurement system. The paper presents the current applications of the system. It also describes future applications of the wide area phasor measurement system.

II. WIDE AREA PHASOR MEASUREMENT SYSTEM

The electric power system in Taiwan is undergoing significant change. Due to ever-increasing environment and economic pressure, it becomes extremely difficult to construct new transmission or generation facilities. Moreover, Taiwan power system is a typical south-north longitudinal and isolated system with load center located in the north of Taiwan and most of the powers are supplied from the central and southern areas. As a result, Taiwan power system has a severe area generation-load imbalance and a heavy power transfer over six 345kV transmission lines. A system-wide incident triggered by a collapse of a 345kV transmission tower in Taiwan power system on July 29, 1999 (729-incident) has led Taiwan Power Company (TPC) to deploy a wide area phasor measurement system which is operated from the spring of the year 2002.

A. System Configuration

The system consists of four major parts : remote Phasor Measurement Unit (PMUs), central center, SQL database, WEB sever. Fig. 1 shows the configuration of the system [1].

Currently, five PMUs are installed at five EHV substations : 3rd Nuclear power plant substation, Lungchi

substation, Chungliao substation, Lungtan substation, 2nd Nuclear power plant substation. PMU data are transmitted to two central centers equipped with SQL database via utility intranet. One center is equipped with WEB server for utility PMU data intranet service.

Fig. 1 System configuration

B. Phasor Measurement Units

GPS based PMUs, ADX3000, developed by a local company are employed in the phasor measurement system. Three phase voltage and current phasors are computed by recursive Discrete Fourier Transform (DFT) algorithm on a common time base. An improved DFT algorithm [2] is going to be built in next generation ADX3000 which can compensate phasor/frequency estimation errors caused by DFT leakage phenomena. The hardware architecture of ADX3000 is shown in Fig. 2.

III. CURRENT APPLICATIONS

There are two applications of the TPC wide area phasor

measurement system at the current stage. They are on-line phasor monitoring and transmission line fault locator.

Fig. 2 Hardware architecture of ADX3000

Fig. 3 On-line phase angle monitoring

A. On-line Phasor Monitoring

Remote PMUs transmit positive sequence voltage phasors and frequency to two central centers 20 times per second. Phase angle difference between any two monitored substations can be on-line monitored as shown in Fig. 3. If the maximum angle difference exceeds a threshold value, then some actions will be taken, for example, generation reschedule, load shedding, etc.

If the frequency of angle swing falls into the interval $[0.2\text{Hz}, 2.5\text{Hz}]$, then the angle swing curve will be

Fig. 4 On-line angle swing monitoring

monitored as shown in Fig. 4. Once the low frequency angle oscillation lasts for a while, then central dispatch control center will take effective operational actions to suppress the oscillation.

B. Transmission Line Fault Locator

Synchronized voltage and current raw data stored in remote PMUs with a high sampling rate, i.e. 3840Hz, at both ends of the monitored line can be employed to calculate the precise fault location when a fault occurs on the line. The technique which is a revised version of the technique in [3] successfully located a a-phase ground fault over a 345kV transmission line between Lungchi substation and 3rd Nuclear power plant substation on April 19, 2002. The exact fault point found by crew taking a long and hard walk in rough terrain is 9 km away from Lungchi substation. Using the technique, the estimated fault location is 9.2 km away from Lungchi substation (the total length of the line is 127 km). The percentage error is below 0.2%. Fig. 5 and 6 show the synchronized waveforms at Lungchi substation and 3rd Nuclear power plant substation. Fig. 7 shows the numerical convergence process of estimating the fault location D.

IV. FUTURE APPLICATIONS

A. Defense Plan

After 729-incident, TPC deploy a defense plan against extreme contingencies and to reduce the risk of power system instability caused by increased loading of transmission systems and severe faults. The defense plan consists of three Special Protection Systems (SPSs) that are designed to achieve the following three tasks: to avoid transient and dynamic instability around Lungchi area, to relieve thermal overload problem on the first parallel

Figure 10 consists of two subplots, (a) and (b), showing waveforms at the Lungchi substation. Subplot (a) displays voltage (V) on the y-axis (scaled by $\times 10^5$) versus samples (sampling rate: 3840 Hz) on the x-axis (0 to 600). It shows three-phase voltage waveforms labeled phase-A, phase-B, and phase-C. The voltage ranges from approximately -5 to 5 $\times 10^5$ V. Subplot (b) displays current (A) on the y-axis (scaled by $\times 10^2$) versus samples (sampling rate: 3840 Hz) on the x-axis (0 to 600). It shows three-phase current waveforms labeled phase-A, phase-B, and phase-C. The current ranges from approximately -2 to 2 $\times 10^2$ A.

Fig. 6 Synchronized waveforms at 3rd Nuclear power plant substation on April 19, 2002

critical role in the future defense system.

Fig. 8 The structure of the current defense plan [4]

Line differential protections have a lot of advantages such as excellent dependability, and insensitive to load current, source impedance, and fault resistance. PMU based line relaying is one kind of differential protection schemes. Moreover, the combination of two-end voltage and current phasor measurements as differential function has advantage over that of employing current differential scheme.

Specifically, for high impedance fault current differential

Fig. 9 PMU based line relaying configuration

schemes have poor dependability than those schemes using both voltage and current phasors simultaneously. Fig. 9 shows a configuration of the PMU based transmission line relaying scheme [5].

V. CONCLUSIONS

The experience with operating the wide area phasor measurement system in Taiwan according to the TPC staff shows that the system is a building block for advanced power system monitoring, protection and control. It is anticipated that the service reliability of Taiwan power system will be greatly enhanced and probability of blackout incident will be minimized with the function augmentation of the wide area phasor measurement system.

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