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OPERATIONAL EXPERIENCE OF REAL TIME OSCILLATION MONITORING SYSTEM IN INDIA

by

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(IN)

SUMMARY

Small signal stability problem in power systems has remained a concern for power engineers in India for the past several decades. The power transfers have also become more unpredictable as the consumption and availability of power is linked to weather patterns. This skew in load-generation scenario throughout the country has been a major contributing factor for instability phenomena in power systems including oscillations. It is important to detect these poorly damped or growing oscillations in the early stages of the disturbance to initiate appropriate damping controls. The wide spread implementation of Synchrophasors across the power grid made it possible to observe and analyze system-wide dynamic phenomena in real-time. An automatic real-time Oscillation Monitoring System is illustrated for extracting the modal information and mode shape of electromechanical oscillations while they are still emerging in the real power system. The Oscillation Monitoring System includes two separate algorithms called damping monitor Engine and Event Analysis Engine for analysing ambient data and post-disturbance data respectively.

This paper summarizes the operationl expérience of the first real time Oscillation Monitoring System(OMS) in India at the Power Grid Corporation of India Limited (PGCIL) Southern Regional Load Despatch Centre (SRLDC). A real time oscillation monitoring system has already been implemented in real-time at SRLDC and it is being tested and tuned. The results are illustrated with several actual PMU recordings from SRLDC. Différent control stratégies are also explored to damp out inter-area oscillations when the Oscillation Monitoring System detects poorly damped oscillations.

KEYWORDS

Synchrophasors, OMS, Modal Analysis, Small Signal Stability.

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1. SRLDC Network

Southern Regional Grid comprises of four States viz. Andhra Pradesh, Karnataka, Kerala and TamilNadu and Union Territory of Pondicherry, interconnected with each other mainly through 400 KV grid network and some 220 KV inter-State lines. Because of the large power system interconnections with the long transmission lines and active HVDC and other FACTS device controls, some of the major areas can suffer from dynamic power system oscillations with respect to other areas. Some of these inter-area oscillations occur at very low frequencies ranging between 0.20-2.0 Hz. These low oscillation frequencies are typical of large power system masses connected by a relatively weak or long transmission system and thus limit the power transfers on the inter-connected transmission lines. These oscillations occur when two large areas in an interconnected power system swing with respect to each other. Figure 1 shows some of the major inter-connections and interaction paths of SR Grid.

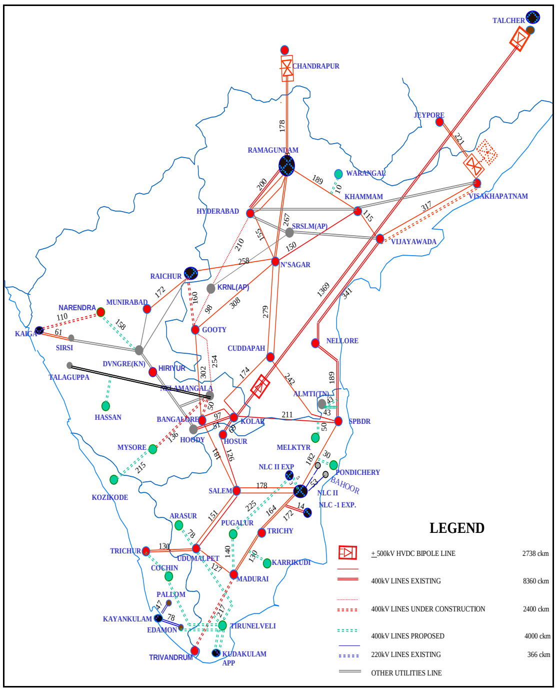

Figure 1 SR Grid

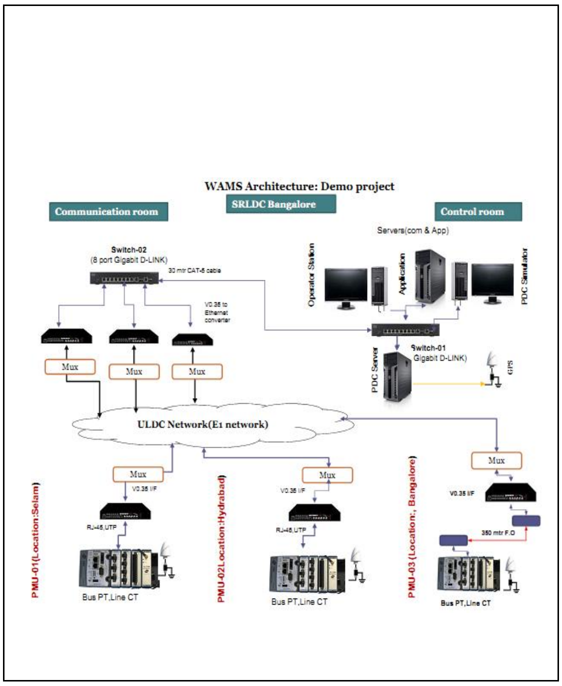

Figure 2 WAMS Architecture

2. Kalkitech WAMS

A wide area measurement system using synchrophasor data is implemented in Southern region of PGCIL by Kalki Communication Technologies Private Limited (Kalkitech) to monitor bulk power system stress and stability in the southern region and validate system models and simulations.

Figure 2 shows the Phasor Measurement Units installed at Southern Region and the location of PDCs. The PMUs have been installed accordingly on the 400 kV bulk power systems at

Bangalore, Hyderabad and Salem substations within Southern Region. Each PMU was connected to measure three-phase voltages and currents, along with breaker status. PMU at Hyderabad substation provides information to monitor stability of the Ramagundam area and the RSTPS – Hyderabad city islanding schemes. PMUs at Bangalore and Salem substations are installed to monitor SPS scheme for Thalchar-Kolar HVDC line.
At control centre, SYNC PDC will time align the c-37 frames and output to application software which includes visualisation tools data archiving and oscillation monitoring system(OMS). SYNC PDC is integrated with the existing SCADA system at SRLDC via IEC 104 protocol. Oscillation Monitoring System detects small signal oscillation from real time synchrophasor data.

3. Case studies on Oscillation Monitoring System

Oscillation Monitoring System (OMS) is an algorithm built into SYNC-4000 PDC for real time detection of power system oscillations using phasor measurements. Phasor measurements can be categorized into two different types according to their nature. The system disturbance type data are the measurements immediately after small or large disturbances to the system, including generator outage, transmission line tripping etc. The responses can be in the form of a growing oscillation, a sustained undamped oscillation or a 'ringdown'. Ambient type data are collected when the system is in a normal operating condition and the only inputs to the system are the random load changes across the entire system.

Event Analysis Engine

Event analysis engine is designed for Prony type of analysis of oscillatory ringdown responses followed by major events. Three signal processing algorithms are used, namely, Prony's Method, Matrix Pencil Method and Hankel Total Least Squares (HTLS) method for analyzing 10 seconds data window. Results from these engines are processed using a custom developed set of rules for handling the complexities of modal analysis from real-time PMU measurements. Event analysis engine can be configured for local PMU analysis or inter area mode analysis.

Damping Monitor Engine

Ambient data analysis by damping monitor engine using Frequency Domain Decomposition (FDD) is well-suited for estimating the frequency, damping ratio, and mode shape of oscillatory electromechanical modes when the respective damping ratios are less than about 10%. FDD also works well for noisy measurements and correlated inputs, and it appears to be useful specifically for analyzing real-time PMU measurements. Together with the post-disturbance data processing following system events, it provides a powerful framework of an oscillation monitoring system from wide-area PMU measurements.

Case :I

Figure 3 shows the phase angle replay screen for the archived files recorded by KALKITECH SYNC PDC at the beginning of the event. The system was operating at phase angle above 30 degrees between Hyderabad and Salem. The phase angle and the differences shown here are the angles that existed before the event occurred and can be considered as the static stress on this specific system.

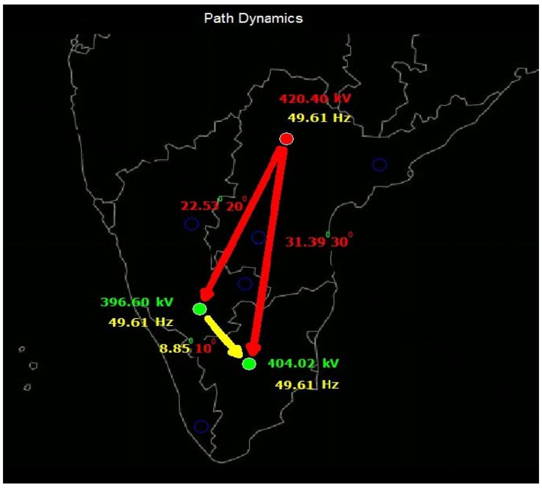

Figure 3 Angle difference plot

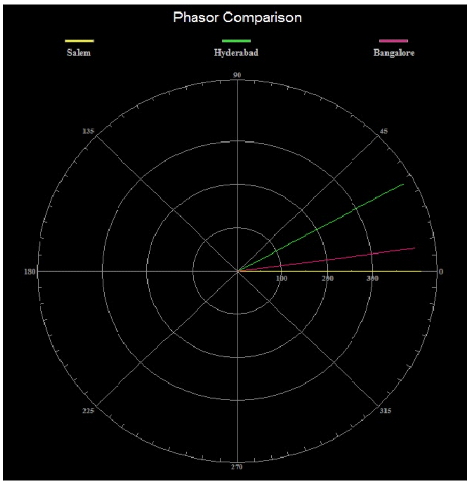

Figure 4 Phasor Plot

An event was detected at 18:13 after the 500MW unit at Bellary TPS tripped. The absence of spinning reserve and the primary control of generation resulted in a sharp drop in frequency about 0.5Hz. Figure 4 shows the voltage phase angle plot for various PMU locations. The reference is Hyderabad, which leads the Salem by about 26 degrees. The phase angle difference between Salem and Bangalore is about 7 degrees before the event which reduced by about 2 degrees. The combined effect resulted in an oscillation for about 20 seconds.

Figure 5 shows the total power flows on the three major AC transmission lines in Southern Region. The lines show a dynamic swing of about 30 MW peak, which is about two-thirds of the total power flow export to Bangalore.

The event analysis engine of OMS then carried out moving time-window analysis towards real-time Prony analysis at each PMU location. The results are plotted at the end point of the sliding widow for each analysis. The frequency and damping ratio estimates shown in Figure 6, 7 and 8 correspond to the results for Prony's method, HTLS and Matrix Pencil Method respectively. Again, the upper part of the plot shows the frequency estimates and the lower part shows the damping ratio estimates.

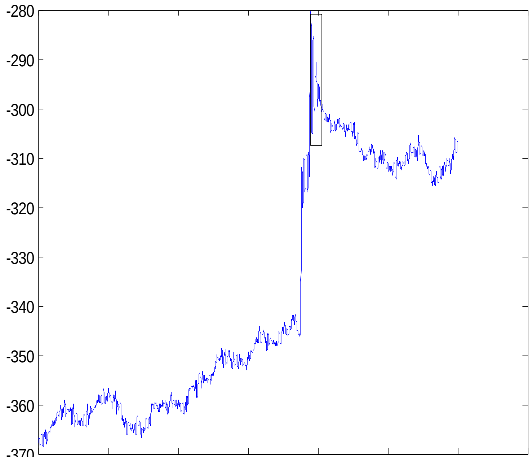

Figure 3 Active power Salem- Hosur Line

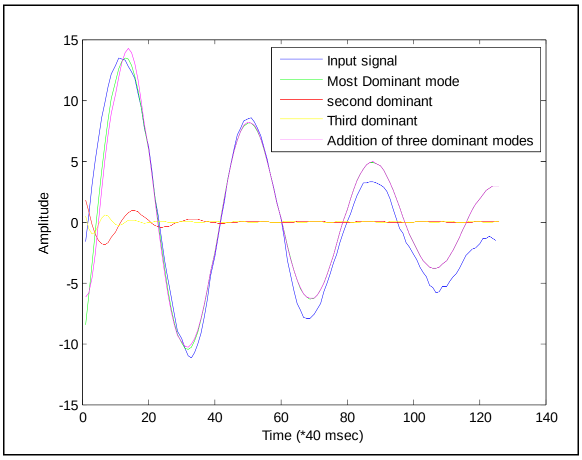

Figure 6 Prony's method

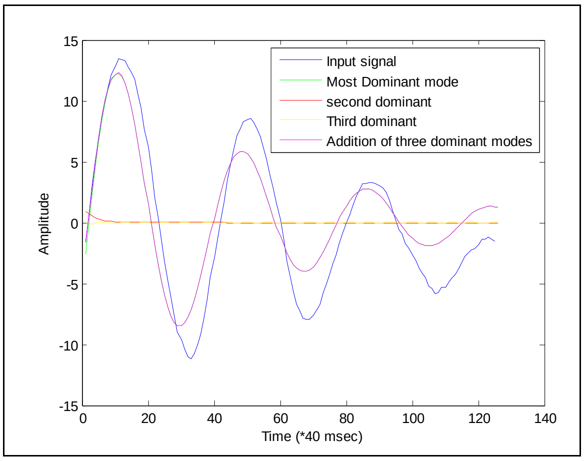

Figure 7 HTLS method

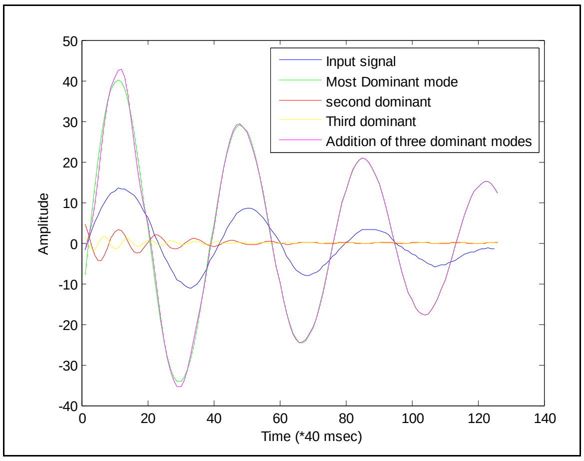

Figure 8 Matrix pencil method

After the inter-area crosscheck, the event analysis engine concluded the oscillation to be an inter area mode of mean frequency **0.6704 Hz** with 8 % damping ratio and triggered an alarm at100 seconds.

Further, the damping monitor engine of OMS analysed the real-time ambient PMU data continuously, and estimated the dominant oscillatory mode to be the same inter area mode identified by Prony at **0.66Hz** Hz with damping ratio of +5.7%. Analysis of four minutes of ambient data is repeated every 10 seconds. The results for the most dominant mode are shown in Fig. 6.

Another powerful feature of FDD is identifying the mode shape associated with the dominant modes. Damping monitor engine estimated the mode shape associated with **0.66 Hz** mode at Southern Region as shown in Fig. 7 which illustrates the nature of the inter area mode with the Hyderabad region (light blue vector in Fig. 7) swinging against the other PMUs in the Southern Region Grid.

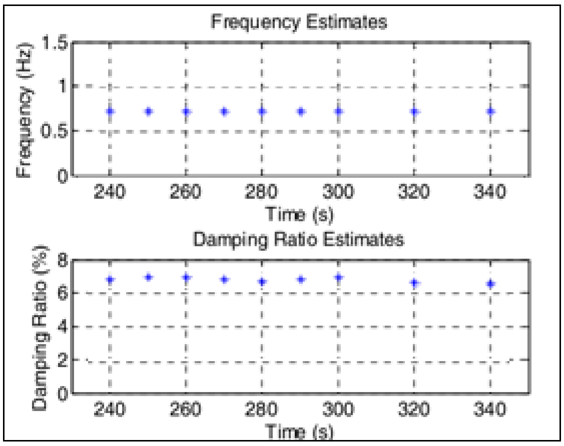

Figure 9 Mode frequency estimate

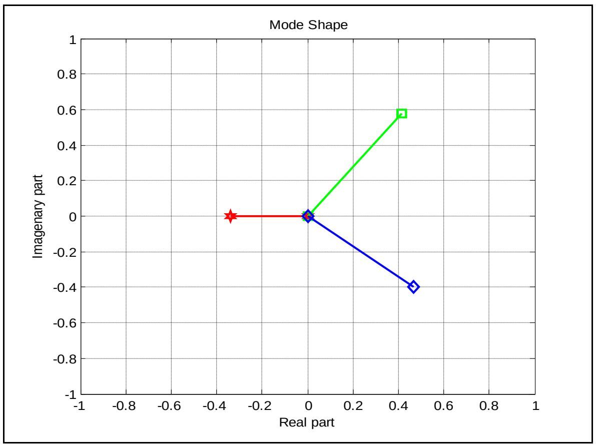

Figure 10 Mode shape

5. Conclusions

The paper describes the Synchronized Phasor Measurement Technology project implemented by Kalkitech at Southern Region Grid INDIA. Considerable development and progress has been made in using this technology for monitoring the system stability, modes of dynamic oscillations and their damping. One of the many cases recorded by Kalkitech WAMS System has been presented. The two engines of OMS facilitated real time monitoring of oscillatory modes and system dynamics

Kalkitech is working closely with system operators and engineers at SRLDC to develop displays for communicating OMS alerts as well as for determining suitable corrective actions.

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