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Applications of Dynamic System Monitoring in Power System Analysis

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Abstract-- **The main targets of power system operation are the security and stability of the power system as well as the reliability and quality of supply to all customers in an economic manner which is a big challenge nowadays. To achieve the above targets system disturbances have to be analyzed carefully to fix all problems in the minimum possible time and avoid the repetition of the same problem again (e.g. Faults and/or generating units tripping).**

This paper presents the concepts of one of the effective tools for disturbance analysis used in Saudi Electricity Company in the Western Region (SEC-WR) named as Dynamic System Monitoring (DSM). The DSM units are linked by telephone lines and modems to the Master Station PC computer and each disturbance event can be retrieved and analyzed by Data Analysis and Display Software (DADISP) working under Windows 2000, NT or XP. Three actual disturbances in the Western Region are described and analyzed in details using the records of the concerned DSM units and cross checked with the records of some numerical protection relays to ensure the correct operation and the technical recommendations are listed and implemented in most cases to avoid repeating of the same event in future. The paper presents also good and practical new method for the evaluation of the dynamic behaviour of the generating units (MW/Hz) using DSM.

***Index Terms*-- Disturbance – Sample Rate –Spinning Reserve - Voltage Recovery.**

I. Introduction

ONE of the most important issues is the continuous and instantaneous fast monitoring of the Power System Dynamic behavior before, during and after system disturbances. The tools differ from one power system to the other according to the used technologies. Saudi Electricity Company SEC adopted the use of Dynamic System Monitoring (DSM) for this purpose and it proved to be of great help in the analysis of actual system disturbances since 1992 where the computers used for DSM units and the Master Station are continuously upgraded including software for better performance.

II. Dynamic System Monitoring

SEC-WR bulk power system consists of 380 KV transmission network with local area transmission at 110kV. The major load centers are located in Jeddah, Makkah and Madinah while the generation plants are in Jeddah, Makkah, Taif, Shoaibah, Rabigh, Madinah and Yanbu. Though there are generating plants in each of these three areas, these by themselves are insufficient to cater to the respective area loads especially during peak season and therefore need to import power from outside reas (Rabigh and Shoaibah). The 27 DSM units are located in 13 main Stations and power plants.

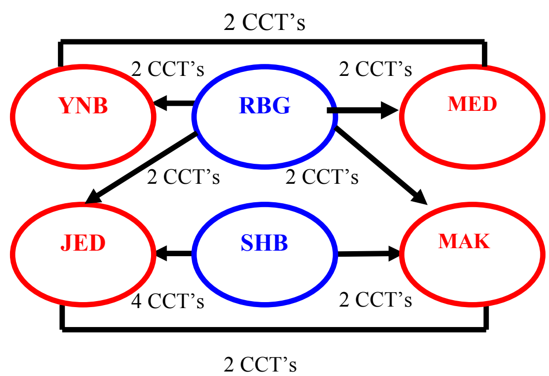

Fig. 1. 380 KV Network for SEC-WR Peak

DSM is basically a computer system connected in each station to record voltage, current as well as frequency with fast rate (240 samples per second for 60 Hz system). When any system disturbance takes place causing the trigger of one or more of the predefined triggers, each event will be saved in the computer hard disk in one or more files defined by date and time with recording duration from 20 to 30 seconds for each file of event. Master station is a normal personal computer with modem and telephone line connected to each DSM unit at substation through its modem to enable file transfer from DSM units to the Maser Station PC.

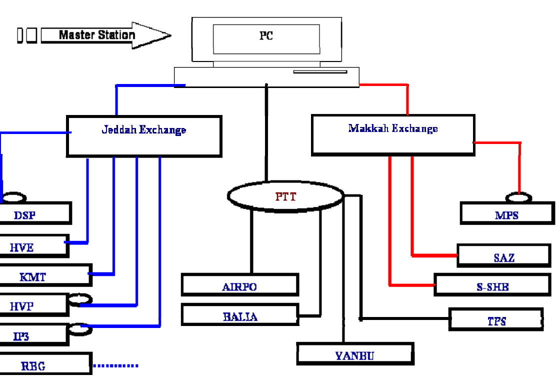

Fig. 2. DSM Communication links to Master Station

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DSM communication links to the master station PC are through pilot cable network and telephone lines. The circle beside the station name in Fig.2 indicates local exchange.

Fig. 3. DSM-200Pj (Portable Version)

A. Hyper Terminal Communication & Hardware Layout

The Hyper Terminal Link, which is part of the accessories of Windows XP is parameterized to be used as communication link between DSM units and the Master Station PC [1]. For files and commands transfer using modem to modem link through dedicated telephone lines.

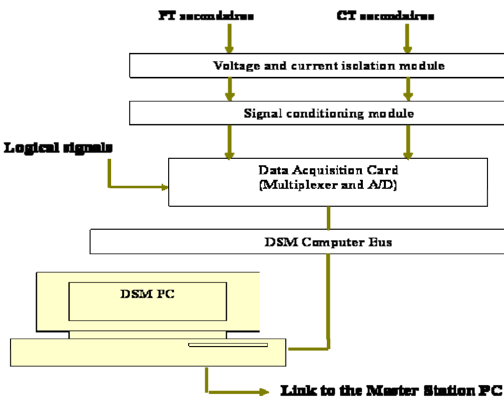

Fig. 4. DSM Hardware Overview

B. Master Station Hardware

The Master Station PC runs under Windows XP while the Hyper Terminal software is used for communication with DSM units for file transfer to the Maser Station PC. Special Software Package called Data Analysis and Display Software (DADISP) in the Master Station PC is used for the graphical analysis of DSM recorded files in a work sheet formats and lab books with many functions available for signal manipulations.

III. ANALYSES OF ACTUAL DISTURBANCES USING DSM RECORDS

DSM units located in the power system of the Western Region in K.S.A. are used as a main tool in disturbance analysis since 1992, following are three actual tripping incidents where DSM records were of great help in disturbance analysis.

1. Fault in Unit 12 TR at SWCC Jeddah Power Plant

Single phase fault (phase T) took place on the step up transformer13.8/380 KV of the steam unit number 12 on the 380 KV side at SWCC Jeddah causing fire on that transformer. Due to voltage dip and delayed voltage recovery, Under Voltage Load Shedding (UVLS) protection operated at 9 substations in Jeddah area [3].

DSM records for (phase T) voltage and frequency in fig. 5 and 6 where it was of great help to define the following facts:

- Specify the faulty phase and voltage dip value: Fig.5 shows that (phase T) was the faulty one as the voltage reached 16.5 KV (0.075 p.u.).
- Fault clearing time: Fig.5 shows the fault was cleared in 5 cycles (83 m. seconds).
- Delay in voltage recovery.
- Fig.6 shows the impact of interrupted load on system frequency.

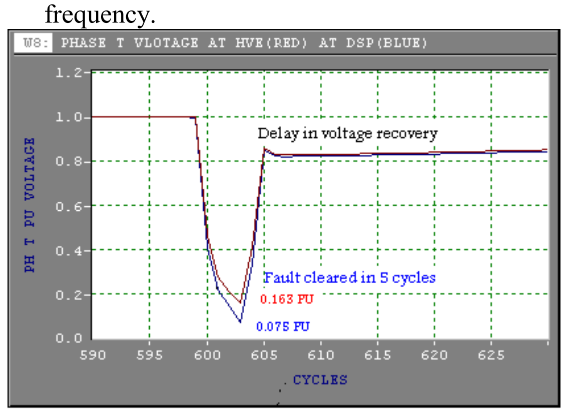

Fig. 5. Phase T voltage at HVE&DSP S/S

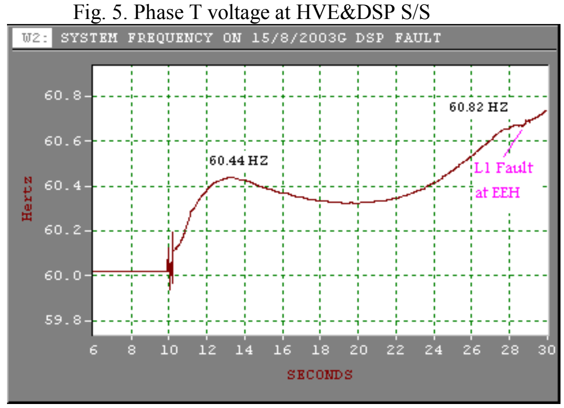

Fig. 6. System Frequency

2. TAIF Partial Blackout

Taif system was fed by two 110 kV circuits ARF-MSR and two 110 KV circuits ZYM-SKB in addition to 6 GT's in TPS plant. A concrete pump working at AHW 110/11 KV substation hit (phase S) conductor of the 110 KV over head line between AHW and QDT substations in Taif area and (phase S) was cut and hit the ground from both sides. Due to the voltage dip and the delay in voltage recovery, UVLS system operated to help in voltage recovery. This tripping caused the isolation of TPS gas turbine units with higher load than its capacity causing the trip of all the units and consequently the supply to 16 substations in Taif system was interrupted.

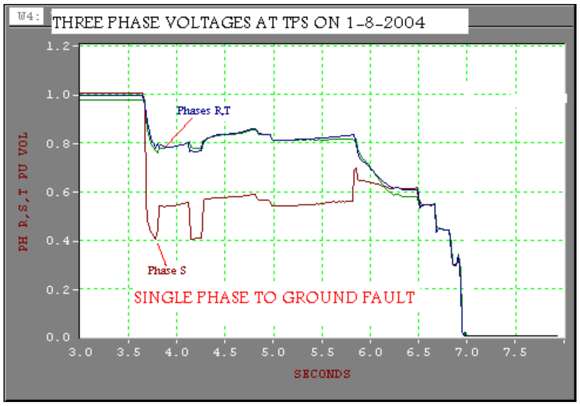

Fig. 7. Phase voltages at Taif

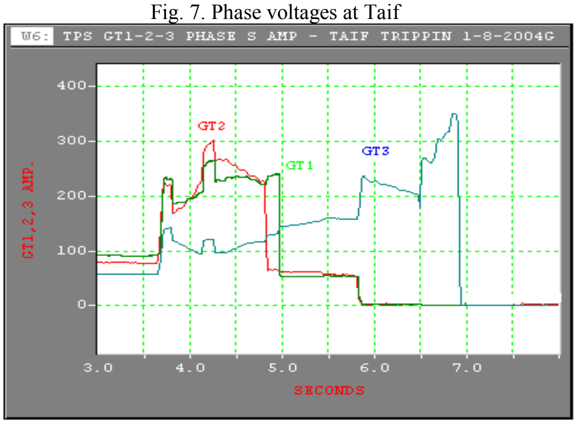

Fig. 8. GT's currents

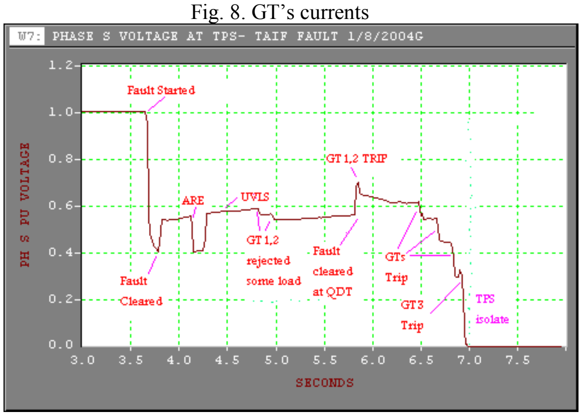

Fig. 9. Taif event scenario

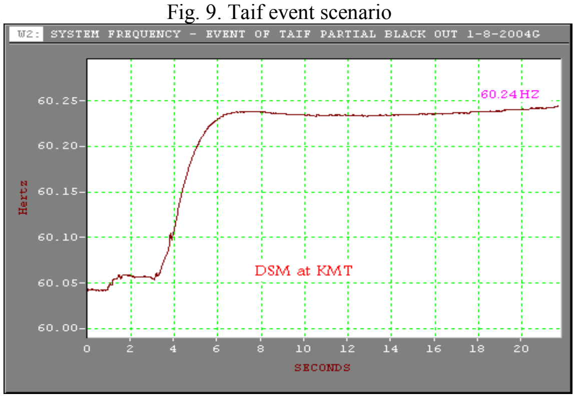

Fig. 10. System frequency

The following items describe the value of DSM in the event analysis:

- Fig.7 indicates that the faulty phase is (phase S) , it reached 0.4 p.u. while the other two phases reached only about 0.8 p.u. at the beginning of the fault and all the three phases reached zero at the end.
- Fig.8 the machine current behavior during the whole event is recorded.
- Fig.9 includes the cross links with all DSM figures and protection relay operations to explain the sequence of event in all the stages.
- Fig.10 shows the frequency of the interconnected system, where frequency increased to 60.24 HZ due to the interruption of 16 substations at Taif system.

3. *Tripping of 5 Steam Units AT SWCC SHB*

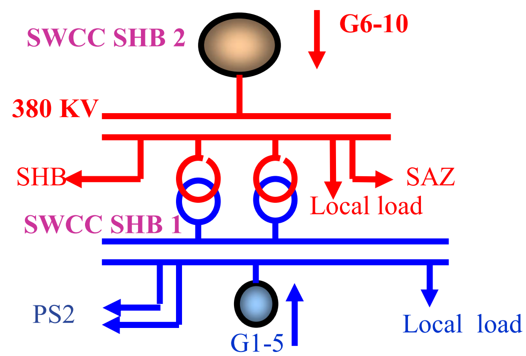

Fig. 11. SWCC SHB plant

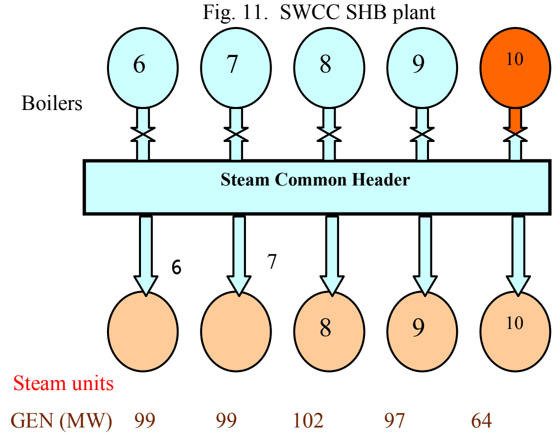

Fig. 12. Common Header Steam at SWCC SHB 2

SWCC SHB Generation on the 380 kV side is composed of five steam units 112 MW each. (number 6, 7, 8, 9&10) and all of them are connected to a common header for steam generated from five boilers numbered from 6 to 10 where boiler number 10 was out for maintenance as shown in fig.12. Some one at SWCC SHB opened the steam valve of boiler number 10 (off for maintenance) by mistake causing drop in the steam pressure of the common header. DSM record in fig.13 indicates the drop in frequency from 60.03 to 59.95 Hz within 2.2 sec. due to the load rejection on the five running generators and also the further decay to 59.49 Hz when the units tripped within another 2.58 sec.

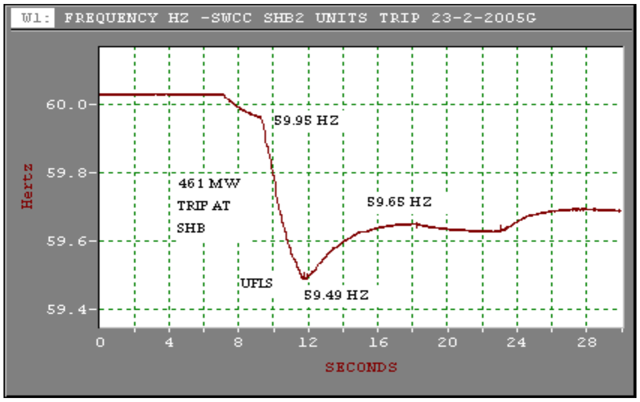

Fig. 13. System frequency

IV. EVALUATION OF MACHINES DYNAMIC BEHAVIOR

This is a new method for tracing the dynamic behavior (MW/Hz) of the generating units in order to evaluate the total spinning reserve (SR) using the records of the DSM units for voltage, current as well as frequency in case of big generating unit trips where the load picked up in MW for each unit is computed and plotted within this time frame. Based on such records, the actual values of SR were tabulated to confirm that its compliance with expected pick up values. Shoaibah unit normal rating is 393 MW and this study was conducted for different loading of such units at different system load levels (9 cases) to check if the results of the unit's behavior are unique [4].

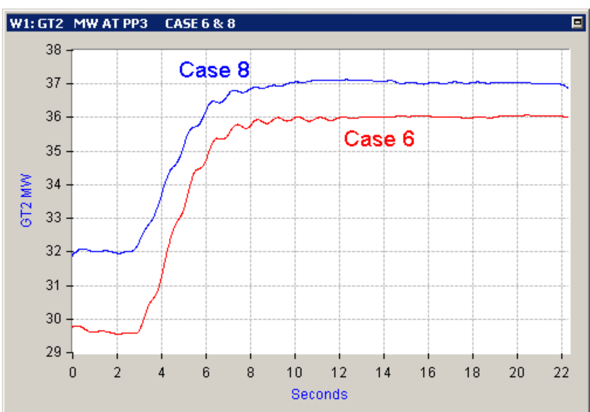

Fig. 14. GT2 Max./Min. (MW)

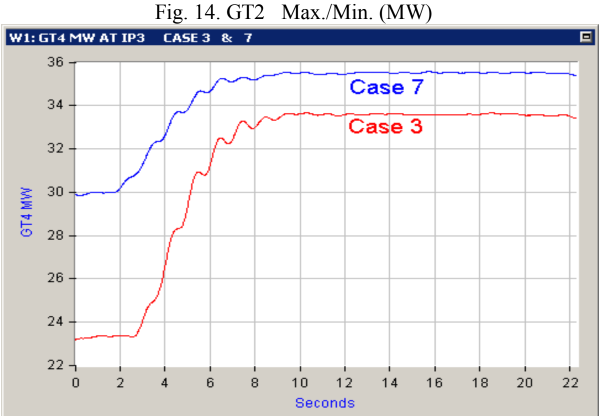

Fig. 15. GT4 Max./Min. (MW)

from the recorded units load pickup in all cases, the maximum and minimum load pick-up in MW were plotted to determine the limits of each unit share during loss of generation which helps to determine the total available amount of spinning reserve (Fig. 14-15 are examples of the case study results using DSM). This tool provides good method to evaluate the (MW/Hz) for each unit after events as well as during steady state through the activation of DSM manual trigger option.

V. RECENT TOOLS SIMILAR TO DSM

DSM detects the slow network instability where sampling rate is 30-100 Hz while Data Acquisition Units (DAU) installed in some other substations provides the selection of sampling rate from slow to fast scan of 7.68 kHz (128 samples per cycle) in the Local Storage Unit (LSU) depending on the application required.

The following device is also faster than DSM and gives more detailed records for phase voltages, currents and system frequency. Wide Area Monitoring (WAM) is a Protection and Control applications use Phasor Measurement Units (PMUs) for the detection of fast network instability and the defence actions against voltage collapse [5] outlined as in fig.16 where phase voltages, currents and phase angle are continuously measured at specific locations in the power system with high sampling rate to be used as an input to the voltage stability software to evaluate the stability conditions of the power system in real-time and take the proper action to avoid system instability or voltage collapse in the steady state as well as in case of system disturbance. The voltage stability software monitors the flow in MW through the main interconnecting lines, cables and evaluates the maximum possible power transfer.

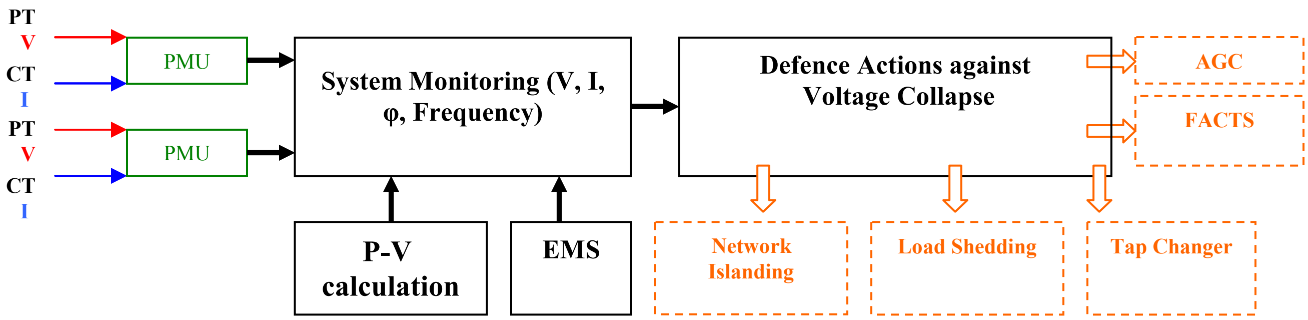

Fig. 16. Overview of Wide Area Monitoring applications

VI. Conclusions and Recommendations

The actual practice of using DSM in different aspects as mentioned in this paper implies the following conclusions and recommendations:

1-DSM records can be used to monitor MW flow and the relative angle on both ends of the main transmission lines to ensure that it works within the transfer limits as calculated from voltage stability point of view.

2-DSM is an important tool for monitoring system dynamics before, during and after faults.

3-DSM provides good method to monitor the dynamic behavior of the generating units (MW/Hz).

4-DSM records ensure the proper activation of UVLS relays.

VII. Acknowledgment

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IX. Biographies

Bander Allaf (S'95, M'99, SM 08) received the B. SC. degree from King Abdulaziz University, Saudi Arabia in 1999. He obtained the M. Sc. Degree from the Arab Academy for Science and Technology in Alexandria and Ph.D. Student in New York International University. He joined Saudi Electricity Company in 1999 as shift engineer in Jeddah Control Center and then he worked in System Control Division in the werstern region of Saudi Arabia. In 2006, he joined short Term Planning devision as senior planning engineer for electrical networks. His research interest includes power system analysis, and system operation , Power System monitoring and deregulation issues in electricity sector. He has published many technical papers in the power system and he supervized the final project of many electrical engineering students at King Abdulaziz University.

He is member of Saudi Council of Engineers in Saudi Arabia, member of CIGRE and he received GCC CIGRE prize for best applied research in 2006-Abu Dhabi. Eng.Allaf is active in IEEE activities both locally and nationally. He is the Industrial Relation Officer and the Membership Development Coordinator in IEEE Western Saudi Arabia Section. He is the founder and chairman of IEEE/PES Western Saudi Arabia chapter.

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