USING THE FAULT DISTURBANCE RECORDER AS AN OPERATING AID FOR CONTROL ROOM OPERATORS AT THE NATIONAL LOAD DISPATCH CENTER OF PENINSULAR MALAYSIA

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Presented at

2nd International Conference of People in Control

UMIST, Manchester, United Kingdom

June 19 – 21, 2001

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ABSTRACT

The greatest challenge faces by Power System Operators is during system disturbance. The operators must always be prepared to deal with unforeseen events and calamities. In extreme conditions, several lines can be lost every few minutes leading to a rush of alarm signals. The operators must quickly decipher what has happened and act swiftly to restore the network in a safe manner. Therefore, the most important role of an operator is making and implementing correct decisions swiftly so as to safeguard the system.

In order to assist him in that regard, the operators in the NLDC (National Load Dispatch Center) are equipped with powerful software tools. Of late, the Fault Disturbance Recorder was introduced to the control room and served as an additional operating aid to the operators. This paper will primarily focus on the utilization of the disturbance recorder and how it has benefited the operators in helping them to arrive at some operational decisions. This paper will also highlight some of the disturbance signatures that was obtained from observations of faults in the system using the disturbance recorder and how this has tremendously help the operator in his decision making process.

The required skills and training for the operators in relation to the disturbance recorder will also be discussed.

1.0 INTRODUCTION

At the NLDC, the control team on shift has to ensure that electricity is generated and transmitted to meet customers' demand in the most safe, reliable and economic manner. Making sure there is enough generation to meet demand and to ensure voltages and flows on the transmission grid system are within limits at all times are routine functions and usually do not pose much problem to the operators. Their greatest challenge is when attending to system disturbance. In the event of a disturbance, a power system operator is required to make a quick and rational assessment of the situation and determine the extent of the disturbance. He appraises the situation and prioritizes his actions and deals with the most crucial problem first.

Sometimes, in dealing with the most critical problem first, he needs to analyze the problem and performs ***the most important role*** an operator undertakes during his course of action that is ***making the right decision***. Depending on the severity of the fault, the operator sometimes has to analyze and make decisions against a backdrop of constraint and limitations. In order to assists him, the operators in NLDC are equipped with powerful software tools such as the SCADA Sequence of Events and Alarm List, Lightning Detection System and so forth. Among them, the most superior being the Fault disturbance Recorder which was later introduced to the control room to help the operators analyze fault disturbances and help them in their decision making process.

1.1 Limitations in existing facilities

In the past, operators in the NLDC conducted their fault analysis mainly from relay operations captured in the SCADA system and those that were reported by the substation operators. The many varieties of relays in the system especially the digital based relay can cause difficulties to a substation operator in reading out and interpreting the correct relay operations. Moreover, the SCADA systems sometimes do not provide a complete view of the operations of all circuit breakers and relays connected to some disturbances. The control room operators are then subjected to ***many ambiguities*** and this sometimes led to ***inaccuracy in the fault analysis.*** The consequence of his actions could be detrimental to the system security if a wrong action is taken. He may decides to close back a transmission line that has tripped without knowing that he is about to risk the system security by closing onto a permanent fault.

1.2 Fault Disturbance Recorder

Having understood the vagaries of fault disturbances and the difficulties involved in making fault analysis, it became clear that a more appropriate tool was required to enable a more systematic approach towards system fault analysis. Hence, TNB (Tenaga Nasional Berhad) embarked on the acquisition of Fault Disturbance Recorders as a means to fulfill this requirement. With close to five years of experience since adopting this approach, the control operators now in the NLDC are able to arrive at quicker and accurate decisions than ever before.

The recorder is a device used to record graphically all the voltages and currents as well as protective relays operations during any power system disturbance. The recording system utilizes analog sensors, digital sensors, and high and slows speed recording. The high-speed recording has a sampling rate of 5000 Hz while the slow recording samples at 20 Hz. The recording time is up to 4 seconds and 60 seconds respectively.

These recording devices are installed on all the 275kV and the major 132kV substations in the Peninsular Malaysian Grid. Information needed for retrieval is downloaded from the required substation to NLDC via fiber-optics links. The software or the analysis center use to read and analyze the recordings is located at the dispatch center. On average, the speed of transmission is about ***3000 – 6000 bytes/s*** so that a fault disturbance file of 2500 kb would take about 7 - 13 minutes to be downloaded.

2.0 EXPERIENCE IN USING THE FAULT DISTURBANCE RECORDER

Over a span of 5 years since its installation, the fault disturbance recorders have captured a myriad of tripping events on the TNB transmission grid system. Many valuable fault records are being archived and available for viewing by the operators at the control room. From careful observations of the many fault traces, there were excitements among some of the operators as they began to discover some interesting common features pertaining to some particular disturbance. They are now able to tell just by looking at a fault trace and determine the nature and cause of the fault and in most cases their prediction resembles quite closely to the actual fault. This gave them ***greater confidence in their decision*** to reenergize a line that has previously tripped or even identify the source of a fault in a multiple line tripping conditions.

The disturbance recorder also incorporates a fault location facility build into the software. Although it is based on impedance, the experience reported by the operators has suggested that the disturbance recorder can ***pinpoint the location of the fault*** to a high degree of accuracy (less than ***1.5%***). In that manner, root causes of disturbances were determined and ***correlations were made between causes and the fault traces*** it resembles. There were significant savings in fault location whereby expensive patrol by land or air was avoided and equipment downtime reduced to a much greater extent.

By far, one of the most important usefulness of the disturbance recorder to an operator is the ***identification of an open-circuit*** in the transmission grid system. For example, at about 23:29 on 9th September 1998, circuit No.2 of the 275kV lines between Paka to Kampung Awah tripped and auto-reclosed on the red-phase only at Kampung Awah end. Subsequently, the operator downloaded the record from PAKA and observed that the red-phase current sensor was just showing line charging current. He immediately dispatched the maintenance crew who reported later that a jumper below the line trap at Kampung Awah had disengaged and causing an open-circuit condition. The incident was just one of many that demonstrated the importance of the disturbance recorders to the power system operators. It can be said confidently that had the disturbance recorders been used, the 1996 Malaysian Blackout due to a stuck circuit breaker pole at Paka s/s could have been averted.

To reiterate, the recorders were applied extensively and some of the major benefits derived from the perspective of a power system operator are as follows:

i. *Identification of disturbance signatures*
ii. *Provide confidence to system operators in arriving at their decisions*
iii. *To locate and determine location of fault*
iv. *To reduce downtime in patrolling and equipment repair*
v. *Identification of open circuit in the transmission system*

3.0 DISTURBANCE SIGNATURES

As mentioned earlier, throughout the number of years of experience in using the disturbance recorder, NLDC's operators have been exposed to all kinds of disturbances and are now capable to interpret the fault recordings in terms of identifying the nature and cause of a fault. Interestingly enough, they have compiled enough recordings so as to be able to identify the trend and common features of a particular fault and developed the ***capability to distinguish between various kinds of fault*** in the system. For example, fault on the transmission line due to a lightning has its own peculiarities in the recording and can be easily identified by the operators. This ***information is vital*** to the operator since it will then help him to ***decide on his next course of action.*** To name a few, below are some of the different kinds of disturbance where their signatures have been identified.

i. *Lightning faults*
ii. *Trees encroachment*
iii. *Contamination or salt pollution*

3.1 Lightning Faults

It was observed from many recordings that lightning faults usually ***involve a sudden upsurge of current ranging from 30 to 50 times the normal pre-fault value***. Typically, the associated voltage reduces to ***20*** till ***40 %*** of the original value. Figure 1 shows the voltage and current trace during a lightning disturbance on the red-phase of circuit no. 3 of Paka - Teluk Kalung 275kV transmission line. The faulted red-phase experienced ***a sudden sharp rise in current (30 times prefault value) which lasted for 2 ½cycles*** when it was finally cleared by the ***Distance protection within a time frame of 52ms.*** The voltage dropped to ***42%*** of the original value.

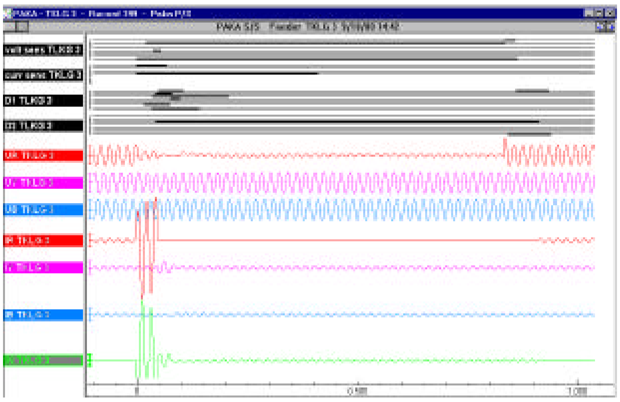

Figure 1: Voltage and current trace at Paka s/s for Teluk Kalung No.3 on 9th October 2000 at 1442 hrs. Single phase (red-phase) to earth fault due to lightning.

Similar observations can also be seen in Figure 2 where a lightning struck on the red-phase of KL East to Kawa 275kV circuit 2. The red-phase current jumps to ***40 times the prefault value***. The red-phase voltage reduced to ***25 %*** of its pre-fault value. Similar to the previous disturbance, the fault clearance time took about ***50.2 ms to clear by the distance protection***. Another striking similarity observed from the various lightning disturbance records is that the fault impedance was found to be generally low, typically ***from 1 to about 5 ohms***. The recorder calculated the fault impedances of the two cases mentioned previously ***as 0.8*** and ***1.3 ohms*** respectively.

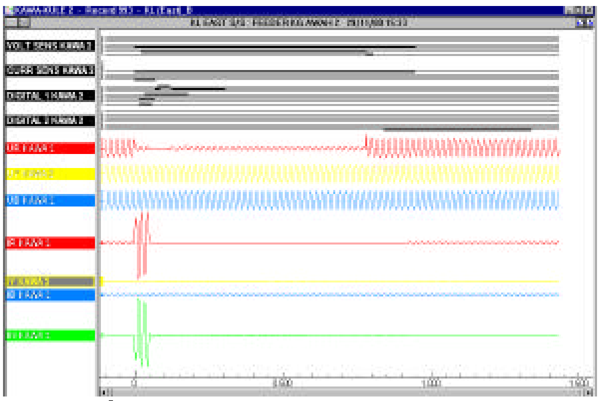

Figure 2: Event captured at KL east s/s for Kampong Awah No.2 on 29th November 2000 at 1533 hrs. Single phase (red-phase) to earth fault due to lightning.

3.2 Trees Encroachment

Observations on records involving tree encroachment saw a very striking characteristic in the shape of the fault current. Figure 3 and 4 shows almost the same shape whereby ***the fault current started small and gradually enveloping the current peaks exponentially***. The current on the faulted-phase rises up to 5 times the original level. Also what is prominent is that the voltage ***depression*** for the associated phase voltages ***was less compared to a lightning fault and remained rather flat throughout the duration of the fault***. The voltage depressions for Figure 3 and 4 were ***73%*** and ***82%*** respectively.

The reason for such a voltage profile is due to the high impedance nature of the fault. The resistance offered by the fault arc and the tree was high. The fault impedances calculated out for figure 3 and 4 was 54.4 ohms and 60.6 ohms respectively and as such both were transparent to the distance protection. Invariable, both the faults mentioned were cleared by the Directional Earth Fault protection within time frames of ***250 ms*** and ***400ms*** respectively.

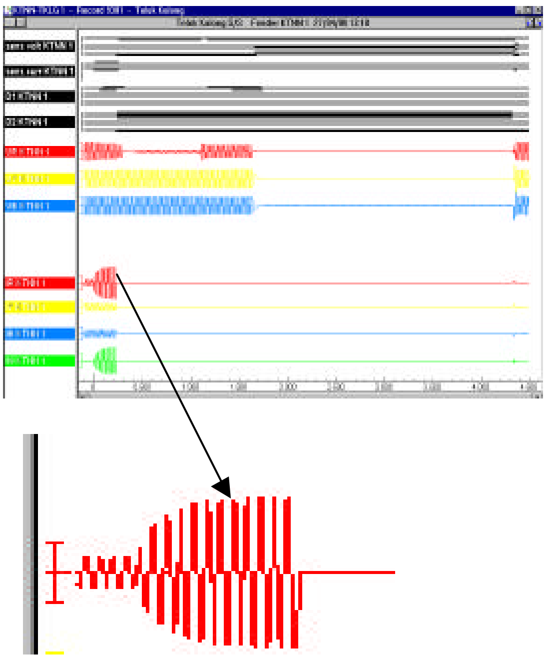

Figure 3: Event captured at Teluk Kalung s/s for Kuantan North No.1 on 27th April 2000 at 1318 hrs. Notice the enveloping current as it started small and gradually builds up exponentially. This is very typical of tree related fault.

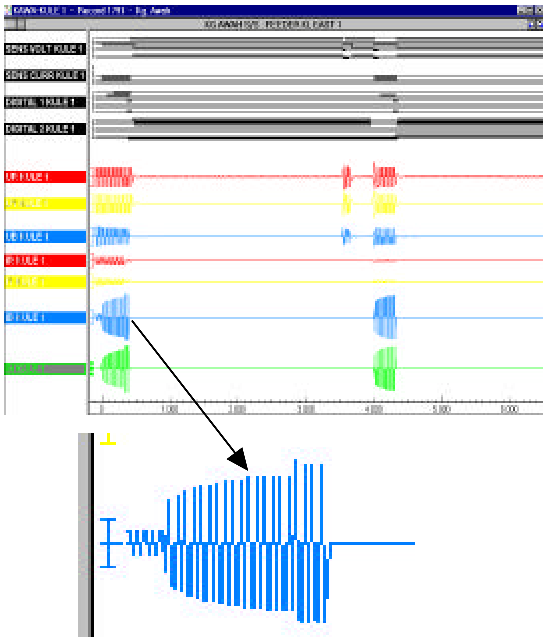

Figure 4: Event captured at Kampung Awah s/s for KL East No.1 on 25th November 2000 at 1409 hrs. The enveloping current jumps towards the end as the circuit breaker on the other side tripped.

3.3 Contamination or Salt Pollution

The location of the transmission lines or power installations determines the nature of contamination. On the Malaysian eastern grid where the transmission lines traverse through the coastal districts, surface films of salt are always formed. Figure 5 illustrates the fault recording taken for a disturbance captured at Paka s/s due to a nearby salt-contaminated fault of a transformer bushing. It is believed that when the pollution layer present on the bushing became moist due to rain, it turned conductive and caused an arc to be established across the bushing and led to an electrical fault.

Figure 5 shows some distinct characteristics of a salt pollution fault. Prior to the complete breakdown of the air across the bushing, periodic intervals of arcing activity took place. It is observed that these short bursts of arcing happen only during the peak negative cycles of the current wave. Also, during the final electrical breakdown, the fault current short-circuited and spiked to ***25 times*** the pre-fault value almost like a lightning fault except that the associated voltage this time was completely drawn down to a marginal 15kV. The fault impedance calculated by the recorder was at ***0.3*** ohms.

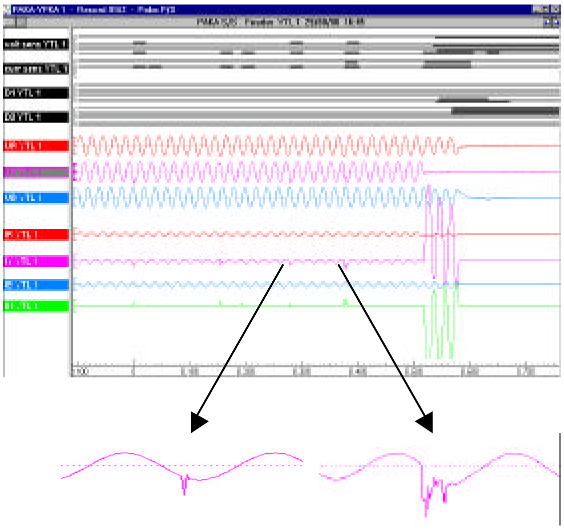

Figure 5: The salt pollution event captured at Paka s/s for YTL No.1 on 29/08/00 at 1649 hrs. Notice the short bursts of current due to arcing prior to the actual fault.

4.0 FAULT LOCATION

The power of the fault disturbance is its ability to accurately estimate fault position. This feature has been used extensively by the control operators to determine the location of faults. Since the software or the analysis center is at their disposal, the operators are in ***the best position to estimate the fault distance*** and zoom in a crew to investigate the cause of a fault. Such a move has expedited fault repair time greatly and reduces equipment downtime significantly in TNB.

As an illustration, Kawa to Yong Peng East 275kV line tripped on 6th October 1999 at 1355 hrs. The disturbance recorder measured the fault distance at 145.34 km from Kawa s/s near tower 408. Much to the amazement of the patrol team, the fault was found near tower No. 409 which was about 145.14 km away from the s/s. The error was close to ***0.14*** % and about ***one span*** length difference.

5.0 AN EDUCATIONAL TOOL

Besides using the disturbance recorder as an operational aid, it can also be used as a teaching and training tool to the control operators. Protection concepts on Distance and Directional Earth Fault protections such as dead-time, reclaim-time, single and 3 pole auto-reclose operations can be easily illustrated from the records obtained from actual faults in the system. It was fortunate that significant events like malsynchronisation, power system oscillations and system frequency response due to generation lost in the TNB's system were captured because these recordings can be used to illustrate complex power system phenomena to the operators. The recordings can also serve as valuable training materials for future operators.

Another ***important application is the incorporation of these disturbance recordings into the DTS*** (Dispatcher Training Simulator) training sessions. We have started to introduce this new approach into our DTS training in order to familiarize the trainees with the analysis of the recordings and develop their capability to make good decisions.

6.0 TRAINING TO USE THE DISTURBANCE RECORDER

Training for the operators to use the disturbance recorder has been given the uppermost priority. The most ***important prerequisite required in order to use the disturbance recorder effectively is the knowledge on transmission system protection.*** Although the operators in NLDC are capable in power system operations, they are essentially non-protection engineers. Hence, courses were conducted for the operators to enhance their understanding on transmission system protection. Thereon, the operators were trained on the use and application of the analysis center to diagnose and analyze fault recordings.

Given the training received, the operators are constantly engaged in interpreting the fault records whenever they are confronted with system disturbances. It must be said that usage of the recorder has upgraded the skills and knowledge of the NLDC's operators. They command sound knowledge not only in power system operations but also in the field of transmission protection.

7.0 CONCLUSION

The overwhelming benefits of the fault disturbance recorders installed in the TNB transmission grid system and the analysis center installed in the control room have made significant improvements in the operations of the NLDC in Peninsular Malaysia. Specifically, the advantages gained from the utilization of the recorder can be summarized as follows:

i. It helps the control operators in making some operational decisions.
ii. It can be used as a training and educational aid for the operators.
iii. It can be used for verification of power system modeling. With a better model, more accurate system studies can be carried out. This is necessary for better planning and operational procedures.

In conclusion, the disturbance recorder have proven to be extremely effective in providing the power system operators the tools they require in order to perform their work effectively and efficiently.

BIOGRAPHIES

Noor Azlan Hamzah – born in 1960 and graduated from the University of Sussex, UK in 1984 with a B.Sc. (Hons.) in Electrical Engineering. He started his service with one of the Transmission Regional Office of Tenaga Nasional Berhad (TNB), an Electric Utility in Malaysia,. as a Transmission Maintenance Engineer. In 1993, he was transferred to the National Load Dispatch Center in Kuala Lumpur to work as a power system operator. Currently, he continues to work as a power system operator and is responsible to manage and implement the training of his co-workers using the Dispatcher Training Simulator. He also has keen interest in the use of the Fault Disturbance Recorder as an operating aid for the control room operators.

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