EVENT RECORD SAMPLING RATES,

RECORD LENGTH and FAULT ANALYSIS:

ACTUAL EXAMPLES

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INTRODUCTION

Microprocessor relays with recording capabilities are becoming one of the most frequently used sources of information for performing post fault analysis. When using these records one must be aware of how the relay captures the record. Is it captured before being filtered in the relay or after it has been filtered? What is the sampling rate and record length? How can it affect fault analysis? Through the use of actual examples this paper will demonstrate that while these relay event records are sufficient for the analysis of most events, it is a good practice to also review digital fault recorder records when analyzing a fault to better understand the event.

FAULT RECORDING

With the event records from microprocessor relays becoming one of the most frequently used sources of information for performing post fault analysis it is important to understand what the record being used captures.

Microprocessor relays offer a range of recording lengths, from 9 to 72 cycles for first generation relays, and from 8 to 630 cycles for newer relays. The sampling rates of these fault records range from four to 96 samples per cycle, spanning older and newer relays. Recorded pre-fault values in these relays vary from one-cycle to 30-cycles. Many of these values are programmable.

Another factor to consider is whether or not the retrieved fault record was captured before the relay filters or after. Post filter recordings display only fundamental frequency values that are necessary for the relay algorithms to perform their protective functions. System conditions including harmonics are not recorded in the filtered record. Figure 1a shows a simple block diagram of a microprocessor relay. When an unfiltered record is available the ability to capture harmonics and transients is affected by the sampling frequency of the relay. Manufacturer's literature is not always clear as to whether the fault record is captured in the relay before or after the filter when only one type of record is available. One manufacturer that offers both unfiltered and filtered fault records recommends that the filtered records be used for a quick analysis of routine faults. This manufacturer further recommends for detailed or computer analysis that the unfiltered record be used.

One manufacturer's default event record is filtered and recorded at 16-samples per cycle, but only saved as a 4-sample per cycle event. The maximum record length is 11 cycles with four cycles of pre-fault. Typical configurations would result in a second record being generated if the fault continues beyond the 11-cycles. The second record generated will again contain 4-cycles of pre-fault that are similar to the fault information in the first record, but synchronizing the time between the two records is difficult, because of the processing delays of the processor in the relay. The manufacturer does offer a solution whereby two time-synchronized fault records will be generated for every event.

The primary function of these microprocessor relays is to protect the system and therefore most event records will be recorded when a disturbance is detected by the protection functions of the relay. Hence a relay may not capture a waveform for an abnormal system condition. Microprocessor relays may not detect incipient faults due to the nature of their design and the function of the algorithms in the processor. Digital fault recorders by design can be set to capture abnormal system conditions and incipient faults as the sole function if the DFR is to record abnormal system conditions.

Digital fault recorders typically have a higher sampling frequency range than a microprocessor relay. Sampling rates in most DFRs are programmable and range from 12 samples per cycle to 192 samples per cycle, depending on the manufacturer. Sixty-four samples per cycle is a typical sampling rate, and it is sufficient resolution to verify system short-circuit models. DFR record lengths typically range from one to two seconds with the number of pre-fault cycles being programmable. Figure 1b shows a functional block diagram for a DFR.

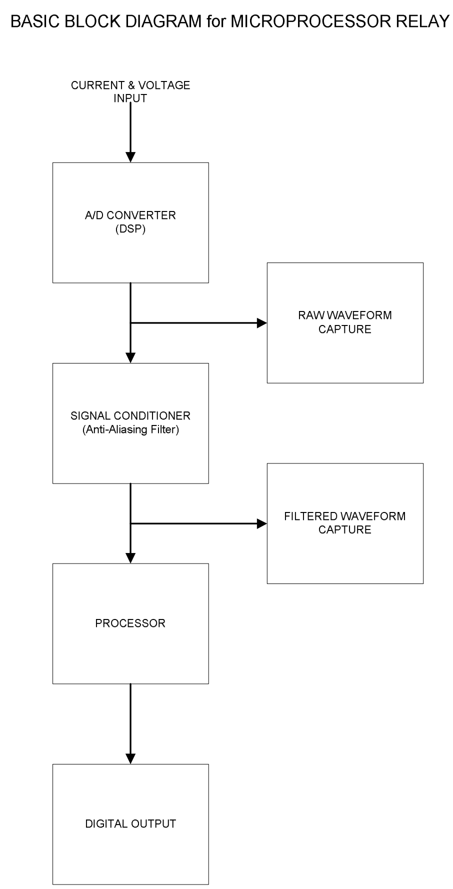

Figure 1a

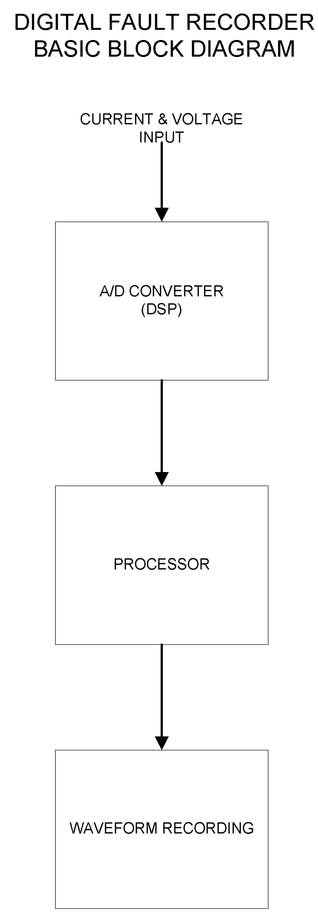

Figure 1b

EXAMPLE 1: EFFECT OF SAMPLING RATE and FILTERING

During a storm the fault pressure relay on a 230/115kV transformer had operated as a result of a close in fault, most likely caused by a lightning strike. The Substation Operations and Maintenance group had successfully tested the transformer. When returning the transformer to service, by closing the 115kV low-side breaker (Fig 4), the transmission line protection operated for a switch-on-to-fault condition. The protection for the line in this case encompasses the transformer. An initial review of the filtered low sample per cycle fault record (Fig 5) indicated that it was indeed a phase to neutral fault. However, after discussing the event it was realized that this 4-sample per cycle record was not a true representation of the conditions at the time of operation, as it only provided us with the fundamental frequency required for the relay algorithms.

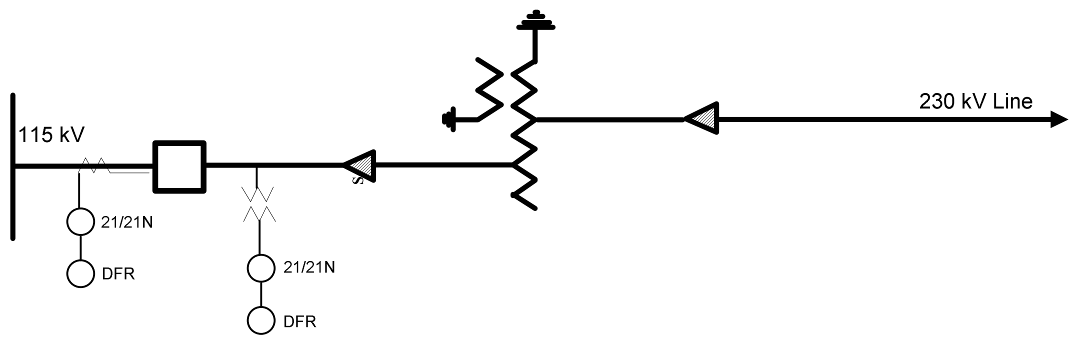

Figure 4

When energizing a transformer there is magnetizing inrush current that is not a pure sine wave. The filtered record did not show this, so the digital fault recorder record was retrieved (Fig 6). The DFR record shows the expected inrush waveform and verified that the Switch-on-to-Fault operation of the relay was not due to a fault, but the transformer in-rush current (the sine-wave of the DFR is 180-degrees out-of-phase with the relay record due to the way its polarity is connected). The unfiltered record from the relay was later retrieved for comparison (Fig 7) and being before the filters displayed a waveform similar to the DFR record. The filtered 16-sample per cycle record (not shown) was identical to the filtered 4-sample record.

This example demonstrates that a waveform captured after it has passed through the relay filters will not be a representation of the actual system conditions. The low sampling rate can also be a factor. This confirms the manufacturer's recommendation to use the unfiltered records for a detailed or automated analysis.

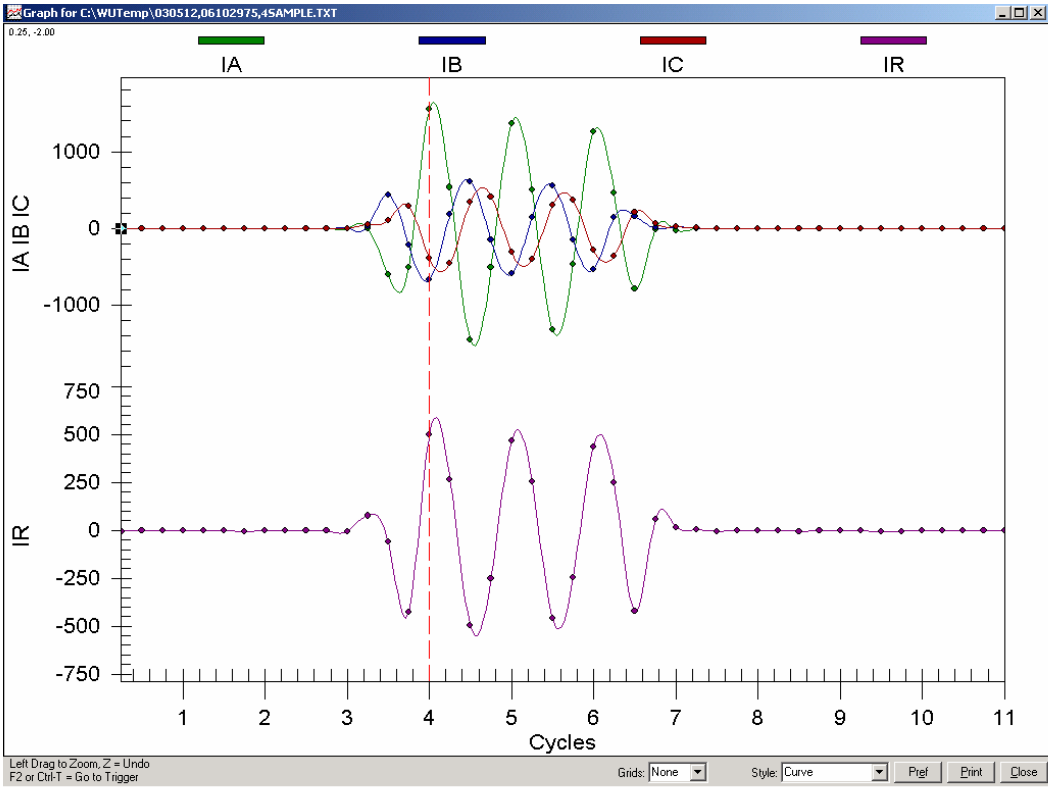

Figure 5: Default 4-sample/cycle Filtered Record

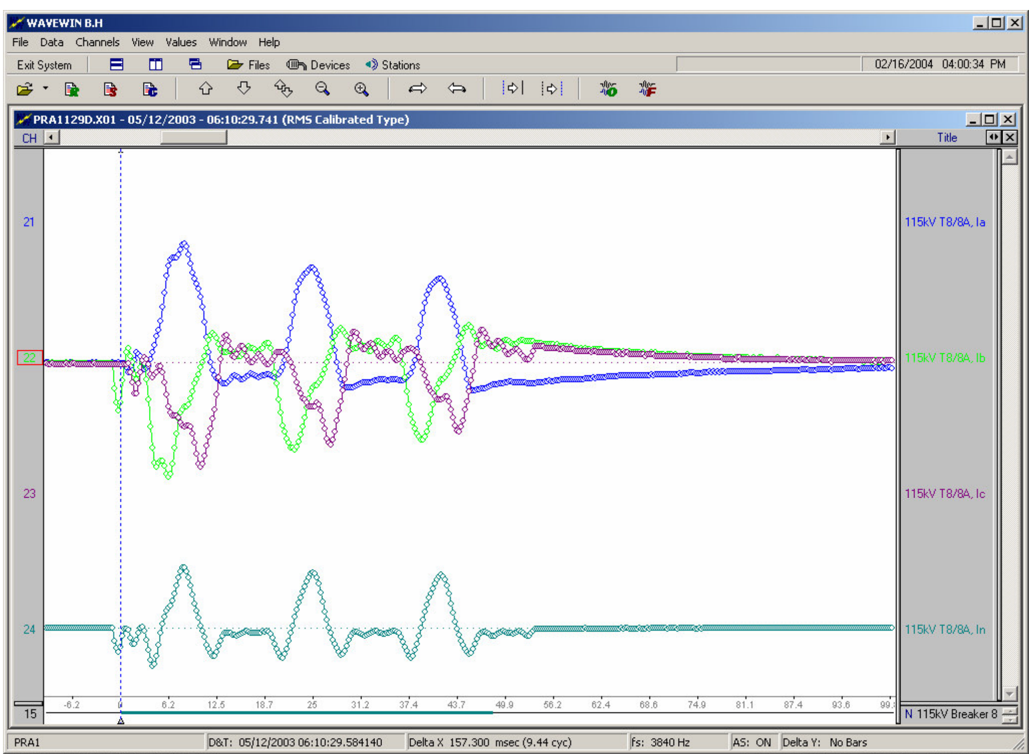

Figure 6: DFR 64-Sample/Cycle

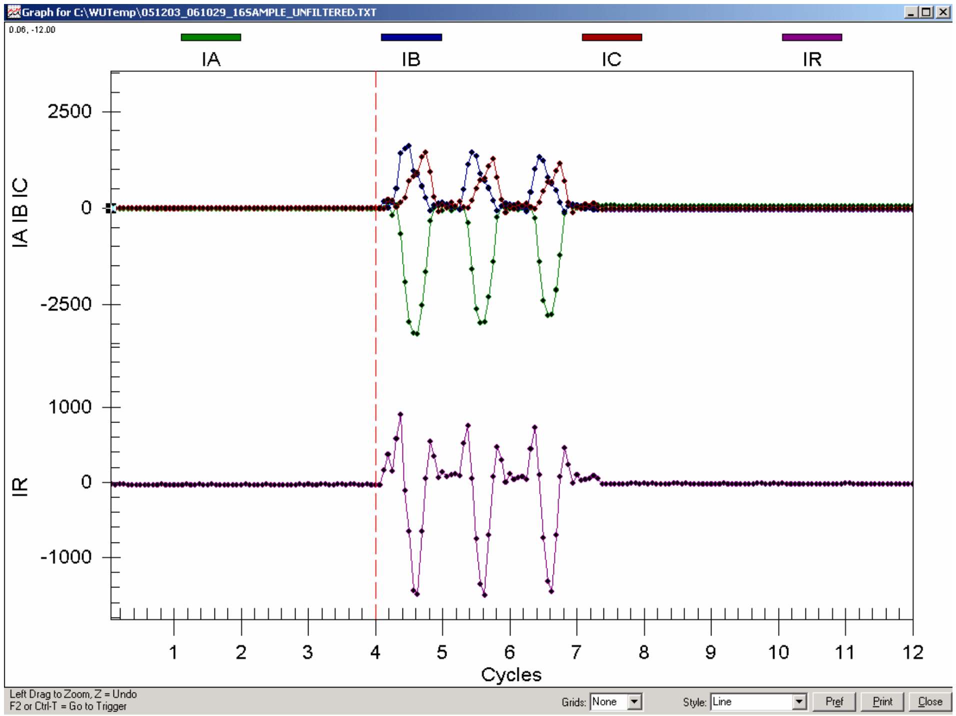

Figure 7: Unfiltered 16-sample/cycle record

EXAMPLE 2: EFFECT OF RECORD LENGTH

The event records from microprocessor relays are good for capturing the high speed clearing of faults, but if the clearing is delayed the result is usually two separate fault records that are difficult to synchronize. This is because the second record contains the predetermined pre-fault and fault cycles so it is not a contiguous recording of the original fault. The processing delays of the relay also affect the recording when a second record is generated for the same fault. These factors need to be taken into consideration when using the relay record to verify relay operating time to clear the fault. The trigger for each event record must also be considered. Often, as in this example the triggers are not the same for each record.

The fault used in this example is considered a routine operation. The protection had operated when the maximum record length was reached. The second record was generated because the voltage going to zero initiated a new record as can be seen by the LOP (Loss-of-Potential) digital point in the records displayed in Figure 8. If the relay was the only recording device the breaker opening would not be accurately recorded. The effects of processing delays in the relay can be seen in figure 8. The area between the Data and Reference bars in each record (marked by red arrows) is approximately the same moment in time during the event. A 90-degree shift is evident between the two records.

When comparing the relay operation to the DFR record (Figure 9) it can be seen that it took 11.4 cycles to clear the fault. This is only 0.4 cycles longer than the maximum record length of the relay. The manufacturer offers a solution where by using variable logic to the time overcurrent trigger is delayed in order to generate two time-synchronized fault records. The relay will then always generate two records for each event.

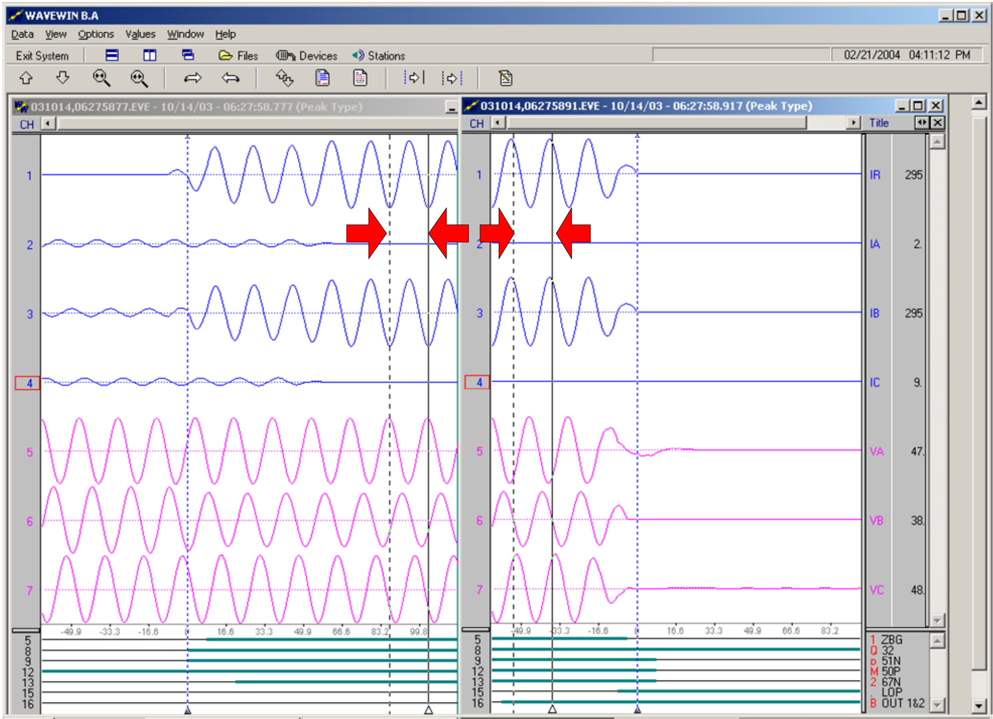

Figure 8

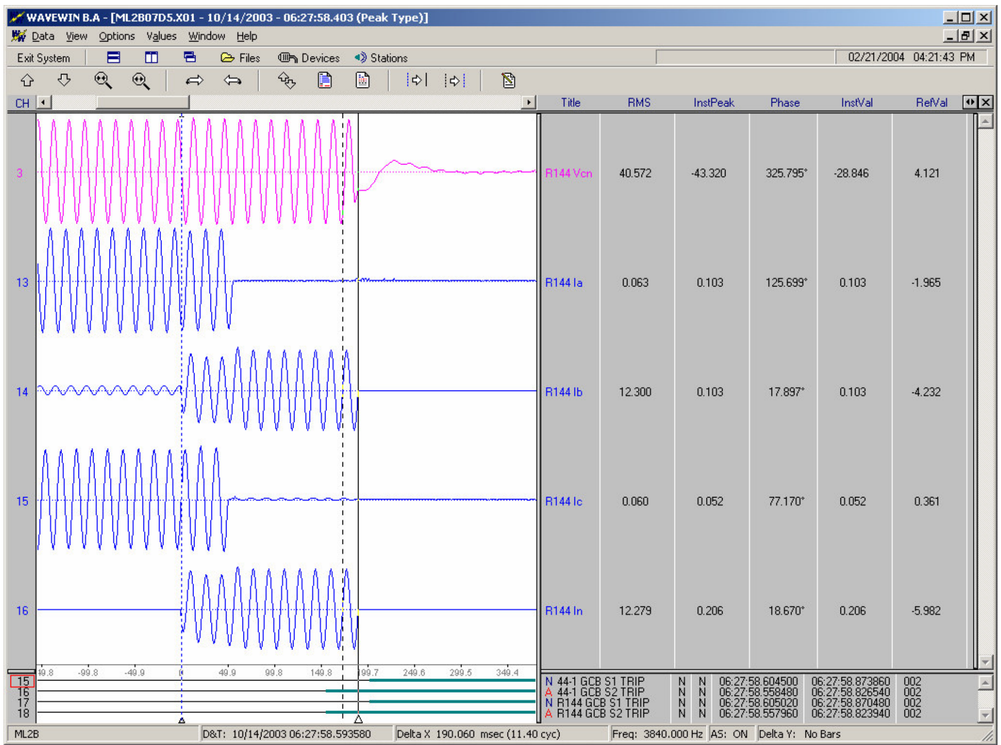

Figure 9

CONCLUSIONS

When reviewing faults it is important to understand where the event and fault records are captured in the relay. Whether or not the record was captured before or after the relay filter can affect your interpretation of a fault. Also, it is important to understand what events trigger the record and how the processing delays can affect the recording of two event records that are generated for the same incident.

When using event records to perform a dynamic test to verify relay operation it is necessary to know the origin of the record. When using a recorded fault record captured after the filter you are verifying the relay algorithms and not that the filter circuits are performing their function as can be seen by the records discussed in example one. In this case you are verifying the relays operation for a specific fault condition. Therefore, a digital fault recorder record may be the best choice to verify operation performance under actual system conditions.

When sharing records or using a short circuit analysis program, which allow the user to play the transient records to simulate the fault for model verification it is important to have the original records. Some of these programs can interpolate the record adding more samples per cycle than were captured in the original record. Sending an already interpolated record could lead to an incorrect assumption as to what the record represents.

Fault records used from digital fault recorders (DFR) and relays are valuable. The DFR typically records at a higher sampling frequency, records a wider range of harmonics, and offers greater flexibility in setting parameters for triggering a recording. DFR records also contain a synchronized recording of all circuits being monitored. The microprocessor relay event record offers a recording of how the relay functioned for the fault. The filtering, lower sampling rates, and shorter record length may not capture the actual system conditions. As microprocessor relay recording capabilities continue to advance the only issue that will remain is how to synchronize the event records from multiple relays. Digital fault recorder and relay event records should be used together when performing a detailed investigation of a disturbance.

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BIOGRAPHY

Jeffrey Pond has been an employee of National Grid USA for 23 years. He worked for the Relay and Telecommunications Operations Group for 15-years, and was responsible for commissioning, maintaining, and troubleshooting protection and control systems. He joined the Protection, Telecommunications, and Meter Engineering groups Integration Team in February of 2001, and is responsible for establishing communications and the retrieval of data from relays and fault recorders. He is also responsible for performing post-fault analysis of transmission system operations.

Jeffrey received an Associate degree in Electrical Engineering Technology from Wentworth Institute of Technology, in Boston, MA, in 1980 and a Bachelor of Science degree in Business Management from Lesley University in Cambridge, MA, in 2001.