Doing More with Less

by
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Under the current electric utility environment the pressure is on to be more efficient and more responsive to customer's needs. In short, do more with less. At Mississippi Power Company (MPC), we want to increase our knowledge of our generation and transmission system performance. Understanding how our electric system impacts our neighboring utilities, our customers, and ourselves helps us determine if we have the protective relays and control schemes in place that we must have for a reliable and dependable power system. In an effort to control cost and man-hours, we had to take steps to acquire more accurate and reliable event data information faster. By analyzing this data, we can better determine how our power system protective and control devices are responding. This will ultimately speed up our decision-making process by helping identify problems so corrective actions can be taken quickly and thus we will be able to achieve our goal of "doing more with less".

In 1998, we took a big step towards improving our knowledge by recognizing that our current digital fault recorders (DFR) were not adequate. In addition to experiencing a significant hardware failure rate, we were not getting records recorded when we knew their was a fault. It became a full time job for one person to try and keep our DFR system operating. We knew we had to improve the reliability of our DFR system in order to get the reliable data needed for system review and analysis. We also looked to decrease the amount of time it took to download a fault record and analyze the situation. By analyzing the situation faster, we hope to be more responsive to our customers and restore power faster and safer.

Also on the horizon, FERC was looking to all utilities to collect frequency data. With frequency events evolving over a long period of time, we knew we needed more memory to support the longer records.

After months of review, we selected the BEN5000 digital fault recorder from LEM Instruments (formerly Electronic Instruments International) for the following reasons:

1. It had passed the IEEE surge withstand test while collecting records.
2. The utilities already using the BEN5000 spoke highly of the DFR's reliability.
3. The BEN5000 had the capability to communicate via fast Ethernet and/or by phone modem.
4. The recorder offered up to four simultaneous recording speeds. We could use a fast sampling speed, 6000 samples per second, for fault records and a slower recording speed, 30 samples per second, for frequency disturbances. Thus we could collect longer frequency records without impacting the transient records and without having enormous record sizes to download.
5. The BEN5000 had a high channel capability that exceeded our needs - 192 analog channels and 576 digital channels without any time skew between channels.

In 1999, we started to install and network the BEN5000 DFR in all generating plants and in major 230 kV substations. To date, we have 13 DFR units installed and communicating via Ethernet. Each DFR is equipped with two independent data acquisition speeds having the following triggers and record lengths:

Transient recording function 6000 samples/sec

Triggers
- Over Line Phase I (200% In)
- Over Line Residual I (10% In)
- Over Generator Phase I (200% In)
- Over Generator Residual I (10% In)
- Under/Over Bus Phase V (±12% Vn)
- Protection contacts (loss of excitation, line relays, xmit & rec.. carrier, Brkr fail, Diff prot, …)

Record duration: = Fault duration + 50 msec; limited to 2 sec;
Pre-fault: 50 msec

Slow Disturbance recording function 30 samples/sec

Triggers Under Bus Voltage (±12% Vn)
Frequency deviation (±100 mHz)
Power Swing (10-20% Pn, 2 swings, >0.1Hz)
Reactive Power dQ/dt (10-20% Pn, 1 sec)

Record duration: = Fault duration + 5 sec, limited to 120 sec;
Pre-fault: 10 sec

Record transfer times were reduced significantly over the fiber Ethernet. For example, the transmission time for a 64 channel DFR record from a major customer substation was reduced from almost 6 minutes to 30 seconds. Analysis of a 48 channel DFR shows the transmission time of 16 seconds verses 20 times slower on a 9600 modem with the compression ON:

Test of transmission of a 48 analog channels x 1 second record (recorded at 6000 samples/s) [about 576kbytes of data] over various communication means.

		Z-modem modem compression ON NO Huffman compression	Z-modem modem compression OFF with Huffman compression	Actual data bps
	baud rate	time (sec)	time (sec)	
modem	9600	324	245	23510
modem	19200	157	125	46080
modem	28800	125	108	53333
ethernet	10 mbps	16		360000

Table 1

Looking at the records from October, November and December 2002, the average record length for the “Transient Records” is about 0.49 seconds where the average record length for the “Disturbance Records” is about 27 seconds. As the table below shows, the transmission time would be cut from days with modems to just hours via Ethernet if all of the records listed were downloaded.

Oct-Nov-Dec 2002

Location	# Analog channels	Transient Records: Record # (*)	Transient Records: Time (s)	Disturbance Records: Record # (*)	Disturbance Records: Time (s)
Chevron	64	483	285.847	3	46.132
Hattiesburg	40	54	27.417	11	832.662
Watson 115	32	8	7.667	4	42.599
Kiln	48	245	317.953	7	145.098
Watson 230	40	695	88.055	19	778.758
Meridian	48	63	17.563	144	2276.79
Daniels 1&2	88	270	99.662	53	1548.7
Daniels 4	48	82	100.662	303	9944.75
TOTAL		1900	944.826	530	14736.7
AVERAGE		237.5	0.497277	66.25	27.80508
Est. Transmission Time			in hours		in hours
	at 9600 bps		74.95425		11.32364
	at 19200 bps		38.24163		5.77731
	at 28800 bps		33.04098		4.99163
	at 10 mbps		4.89492		0.73949

(*) Not all of these records were actually transferred back

Table 2

Now that a reliable system was in place and the record transfer time no longer provided an excuse to go get coffee, we began to see other issues that needed to be addressed. With the extra data from the FREC frequency sampling, the expanded capacity of the DFR and the addition of more triggers, there was a possible risk of data overload. We needed to come up with a method of managing the records so that we analyzed what was important but did not loose records or weaken our trigger sensitivity.

In addition, we saw a need to share data within and beyond the system protection group. The data can help check the performance of a relay scheme, help maintenance monitor breaker timing, answer questions within the generation plant and provide the Southern Company system information on stability.

Lastly, we needed to continue to improve the speed of system recovery.

To meet these needs, we took the next step and implemented an intelligent data recovery system that automatically transmits the important records to the MPC server for analysis and action. This system uses several of the features that were in the BEN5000 - the Priority Fault Monitoring, the AutoCall function and the ability call multiple numbers.

The Priority Fault Monitoring allowed us to assign weighted values to our analog and digital triggers that are assigned to analog and digital channels in the DFR. These weighted trigger values are combined in a Boolean operation to calculate a "total weighted fault value" for each fault. The following sensor matrix shows how a phase to ground fault on the Meridian1 line would result in a total weight of 1016:

SENSOR MATRIX

e.g. A Phase to Gnd Fault occurred on the Meridien1 Line: Resulting record weight = 500 + 516 = 1016

Input Mask bit	Origin	Equation weight Individual weight	INV		**500 OR**		506 AND		**516 AND**		536 AND		546 AND		582 AND		602 AND		999 AND
1	**All sub-BEN1 sensors**	**0**		**>**	**1**	-		-		-		-		-		-		-	
2	All sub-BEN2 sensors	0		>		-		-		-		-		-		-		-	
3	Newton O/I or O/In	0		>		-	3	-		-		-		-		-		-	
4	**Meridian1 O/I or O/In**	**0**		**>**		**-**		**-**	**4**	-		-		-		-		-	
5	Meridian2 O/I or O/In	0		>		-		-		-	5	-		-		-		-	
6	Stonewall O/I or O/In	0		>		-		-		-		-	6	-		-		-	
7	Sykes O/I or O/In	0		>		-		-		-		-		-	7	-		-	
8	Enterprise O/I or O/In	0		>		-		-		-		-		-		-	8	-	
9	7106 Pri or Sec Trip	0		>		-	9	-		-		-		-		-		-	
10	**7116 Pri or Sec Trip**	**0**		**>**		**-**		**-**	**10**	-		-		-		-		-	
11	7136 Pri or Sec Trip	0		>		-		-		-	11	-		-		-		-	
12	7146 Pri or Sec Trip	0		>		-		-		-		-	12	-		-		-	
13	336 Pri or Sec Trip	0		>		-		-		-		-		-	13	-		-	
14	346 Pri or Sec Trip	0		>		-		-		-		-		-	14	-	14	-	
15	356 Pri or Sec Trip	0		>		-		-		-		-		-		-	15	-	
16	Bkr Fail OR Diff O/I	1		>		-		-		-		-		-		-		-	16

Table 3

Note that normal breaker operations do not create records greater than 1000 and, therefore, do not get transmitted back to the server.

A second example shows how a breaker failure on the Stonewall line results in a higher weighted fault value of 2045:

SENSOR MATRIX

e.g. breaker failure on a faulted Stonewall line. Resulting record weight = 500 + 546 + 999 = 2045

Input Mask bit	Origin	Equation weight Individual weight	INV		500 OR		506 AND		516 AND		536 AND		546 AND		582 AND		602 AND		999 AND
1	**All sub-BEN1 sensors**	**0**		**>**	**1**	-		-		-		-		-		-		-	
2	All sub-BEN2 sensors	0		>		-		-		-		-		-		-		-	
3	Newton O/I or O/In	0		>		-	3	-		-		-		-		-		-	
4	Meridian1 O/I or O/In	0		>		-		-	4	-		-		-		-		-	
5	Meridian2 O/I or O/In	0		>		-		-		-	5	-		-		-		-	
6	**Stonewall O/I or O/In**	**0**		**>**		**-**		**-**		**-**		**-**	**6**	-		-		-	
7	Sykes O/I or O/In	0		>		-		-		-		-		-	7	-		-	
8	Enterprise O/I or O/In	0		>		-		-		-		-		-		-	8	-	
9	7106 Pri or Sec Trip	0		>		-	9	-		-		-		-		-		-	
10	7116 Pri or Sec Trip	0		>		-		-	10	-		-		-		-		-	
11	7136 Pri or Sec Trip	0		>		-		-		-	11	-		-		-		-	
12	**7146 Pri or Sec Trip**	**0**		**>**		**-**		**-**		**-**		**-**	**12**	-		-		-	
13	336 Pri or Sec Trip	0		>		-		-		-		-		-	13	-		-	
14	346 Pri or Sec Trip	0		>		-		-		-		-		-	14	-	14	-	
15	356 Pri or Sec Trip	0		>		-		-		-		-		-		-	15	-	
16	**Bkr Fail OR Diff O/I**	**1**		**>**		**-**		**-**		**-**		**-**		**-**		**-**		**-**	**16**

Table 4

Within the AutoCall feature of the BEN5000, we can set the threshold level for the immediate transmission of the record to the MPC server. The threshold is now set at 1000. Any record over 1000 is automatically transmitted to the server. Records under the 1000 value remain in the DFR for access if needed.

Thus only the important records are downloaded first helping us to avoid data overload and since the record is at the server within a minute of the fault occurrence, our analysis speed is greatly improved.

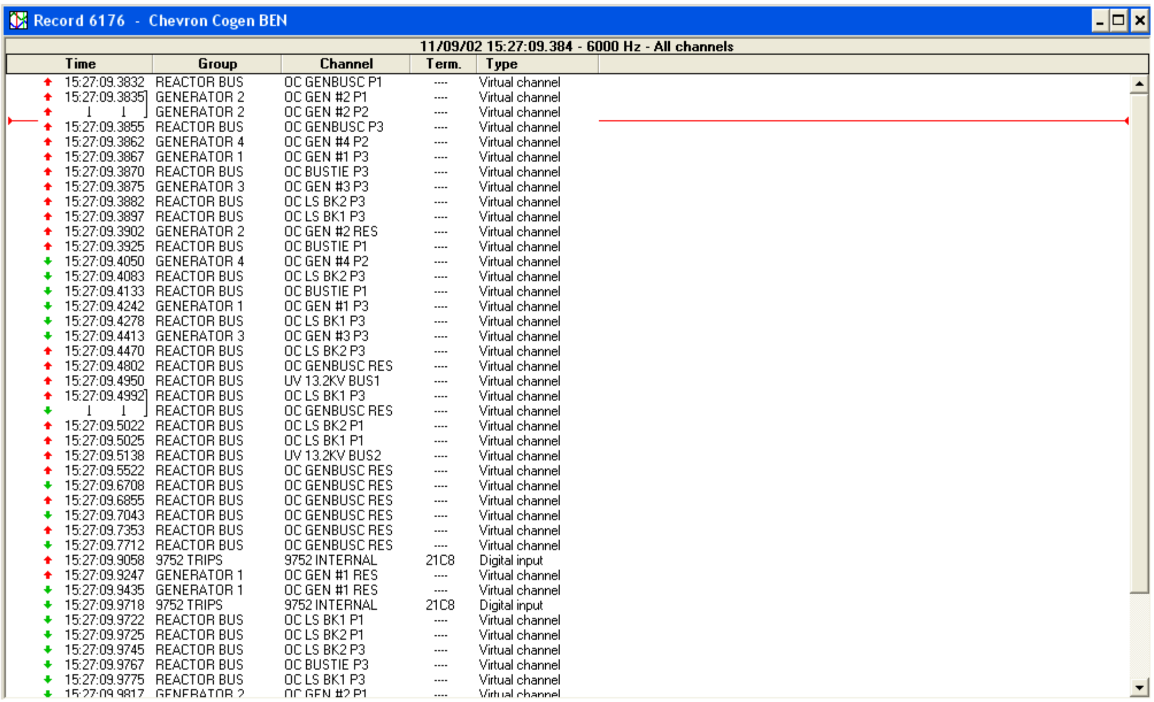
With all the important records on the server, multiple analysts can review the records from different locations - even from home. When there is a problem that effects multiple substations, there is no need to call all the different DFRs since all the important records are already on the server for quick review.

Since the AutoCall function of the DFR allows us to call up to four different phone numbers, we have the DFR call the beeper of the protection engineer assigned to its area to warn that engineer that there is a problem occurring. This gives the engineer a head start on the problem (without the added pressure of management looking over your shoulder and demanding answers). It also improves our response time to outage conditions.

To date, we have not had any major faults that would fire off my beeper. Great for our customer but bad for the statistical analysis needed for this paper. However, there are a couple of examples that show the impact of the system on our customers and on our people.

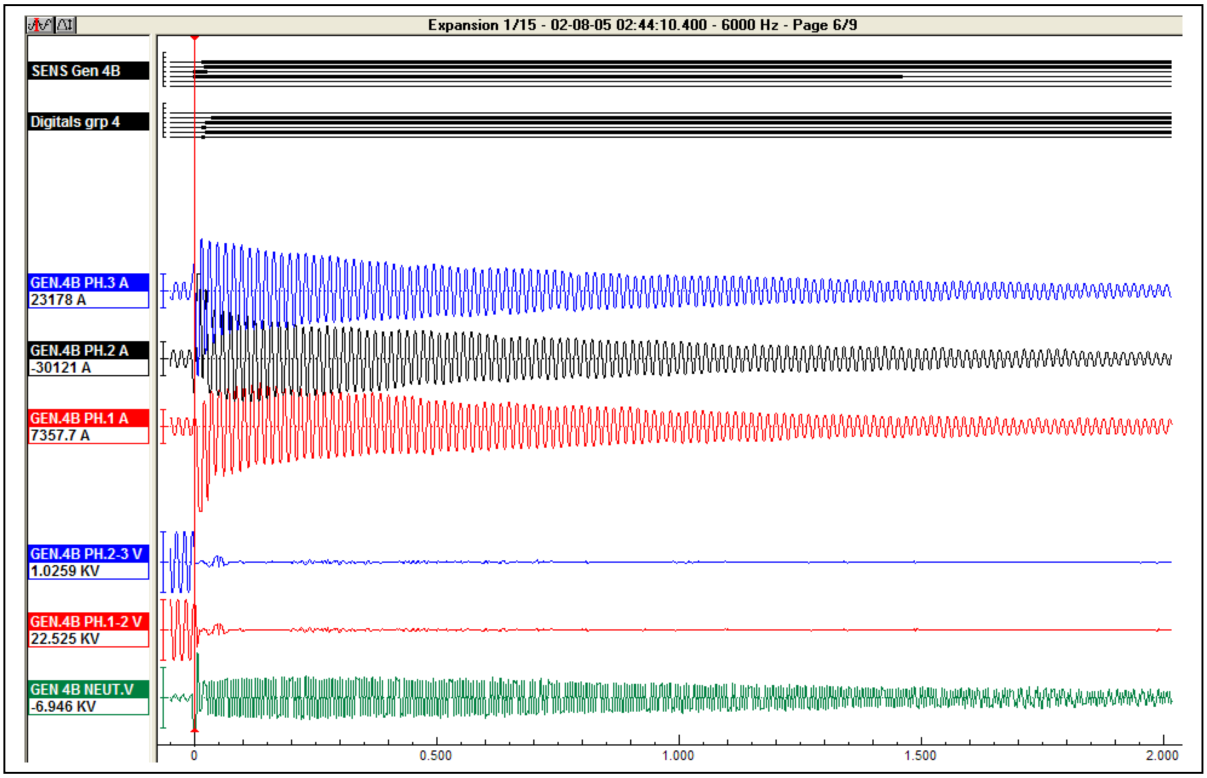
On Super Bowl Sunday we had a transformer neutral problem. As one technician drove to the substation, another engineer analyzed the fault from his computer at home and determined that it was okay to energize the transformer. The fault record was on the server for fast analysis and crews were not dispatched on Sunday.

At one of our major customers we have connected some of the DFR digital points to their substation controls and can give them immediate feedback on “what happened?”. The SER view of the DFR’s operation helps us give faster response for customer support.



	Time	Group	Channel	Term.	Type
↑	15:27:09.3832	REACTOR BUS	OC GENBUSC P1	----	Virtual channel
↑	15:27:09.3835	GENERATOR 2	OC GEN #2 P1	----	Virtual channel
↑	↓ ↓	GENERATOR 2	OC GEN #2 P2	----	Virtual channel
↑	15:27:09.3855	REACTOR BUS	OC GENBUSC P3	----	Virtual channel
↑	15:27:09.3862	GENERATOR 4	OC GEN #4 P2	----	Virtual channel
↑	15:27:09.3867	GENERATOR 1	OC GEN #1 P3	----	Virtual channel
↑	15:27:09.3870	REACTOR BUS	OC BUSTIE P3	----	Virtual channel
↑	15:27:09.3875	GENERATOR 3	OC GEN #3 P3	----	Virtual channel
↑	15:27:09.3882	REACTOR BUS	OC LS BK2 P3	----	Virtual channel
↑	15:27:09.3897	REACTOR BUS	OC LS BK1 P3	----	Virtual channel
↑	15:27:09.3902	GENERATOR 2	OC GEN #2 RES	----	Virtual channel
↑	15:27:09.3925	REACTOR BUS	OC BUSTIE P1	----	Virtual channel
↓	15:27:09.4050	GENERATOR 4	OC GEN #4 P2	----	Virtual channel
↓	15:27:09.4083	REACTOR BUS	OC LS BK2 P3	----	Virtual channel
↓	15:27:09.4133	REACTOR BUS	OC BUSTIE P1	----	Virtual channel
↓	15:27:09.4242	GENERATOR 1	OC GEN #1 P3	----	Virtual channel
↓	15:27:09.4278	REACTOR BUS	OC LS BK1 P3	----	Virtual channel
↓	15:27:09.4413	GENERATOR 3	OC GEN #3 P3	----	Virtual channel
↑	15:27:09.4470	REACTOR BUS	OC LS BK2 P3	----	Virtual channel
↑	15:27:09.4802	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↑	15:27:09.4950	REACTOR BUS	UV 13.2KV BUS1	----	Virtual channel
↑	15:27:09.4992	REACTOR BUS	OC LS BK1 P3	----	Virtual channel
↓	↓ ↓	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↑	15:27:09.5022	REACTOR BUS	OC LS BK2 P1	----	Virtual channel
↑	15:27:09.5025	REACTOR BUS	OC LS BK1 P1	----	Virtual channel
↑	15:27:09.5138	REACTOR BUS	UV 13.2KV BUS2	----	Virtual channel
↑	15:27:09.5522	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↓	15:27:09.6708	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↑	15:27:09.6855	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↓	15:27:09.7043	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↑	15:27:09.7353	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↓	15:27:09.7712	REACTOR BUS	OC GENBUSC RES	----	Virtual channel
↑	15:27:09.9058	9752 TRIPS	9752 INTERNAL	21C8	Digital input
↑	15:27:09.9247	GENERATOR 1	OC GEN #1 RES	----	Virtual channel
↓	15:27:09.9435	GENERATOR 1	OC GEN #1 RES	----	Virtual channel
↓	15:27:09.9718	9752 TRIPS	9752 INTERNAL	21C8	Digital input
↓	15:27:09.9722	REACTOR BUS	OC LS BK1 P1	----	Virtual channel
↓	15:27:09.9725	REACTOR BUS	OC LS BK2 P1	----	Virtual channel
↓	15:27:09.9745	REACTOR BUS	OC LS BK2 P3	----	Virtual channel
↓	15:27:09.9767	REACTOR BUS	OC BUSTIE P3	----	Virtual channel
↓	15:27:09.9775	REACTOR BUS	OC LS BK1 P3	----	Virtual channel
↓	15:27:09.9817	GENERATOR 2	OC GEN #2 P1	----	Virtual channel

While at a Southern Company meeting in Savannah GA, I overheard one of the engineers discussing trouble at Plant Daniel. Since I was on the network checking my email, I simply switched over to the DFR records on the server and we were able to see the fault record from two states away while the crews were in the yard looking at the damage.



Without adding more manpower, Mississippi Power has captured more information and improved our responsiveness to outage conditions. Records from the DFR are transferred at the speed of light to the server and no useful information is missed. The system alerts analyst upon the occurrence of a significant event, which improves our reaction time. More people have access to the data and can apply their specialty to its analysis. We have shortened the reaction time to the problems and have set upon a path for faster recovery. We are doing more with less.