DFR Applications for Semiconductor Industry

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Introduction:

All industries that require electrical power have unique and varying requirements for manufacturing. Semiconductor manufactures are not alone in their quest for consistent reliable power that does not cause any interruption in the process flow. With process cycle times approaching 50 days and greater, any disruption to the process might result in weeks of possible rework of the product or the complete scrap of multi million dollars of product.

With this huge potential loss of product, that not only results in lost dollars, it also relates to not being able to meet shipping commitments to customers, and sometimes loss in market share if they change suppliers. Semiconductor companies are constantly looking for cost effective and innovative solutions to this non-ending problem and how to gain some type of competitive advantage without a large investment in capital increases, additional personnel or any additional downtime for production.

Monitoring Strategy

One of the major benefits of being smaller than the utility is that more time and effort can be allocated to monitoring the electrical system performance and determining exactly what is happening on the system and why is it happening.

We attempted to develop a strategy that allowed us to determine what happens on our system, but not overwhelm us with records. Triggers are set are various levels of voltage dip, and vary from 4% dip to 20% dip. The most sensitive recorder had 287 records for 2001, while the least sensitive recorder had only 14 records. The total records captured by all the recorders were approximately 1200 for all the recorders. For some events multiple recorders trigger, and with the various trigger levels we can make an initial estimate on the level of voltage dip just by which recorders capture the event.

What points to monitor is often chosen by a desire to reduce cost to a minimum while obtaining data, and it was decided to monitor the points required to ensure all the data was captured with the additional cost. At the present time, we are only adding DFR’s on the new installations and not retrofitting all the building 15 kV receiving busses. The following points were chosen to be monitored at the 138 kV substation yard, and the building 15 kV switchgear for all new installations.

DFR Monitoring Points

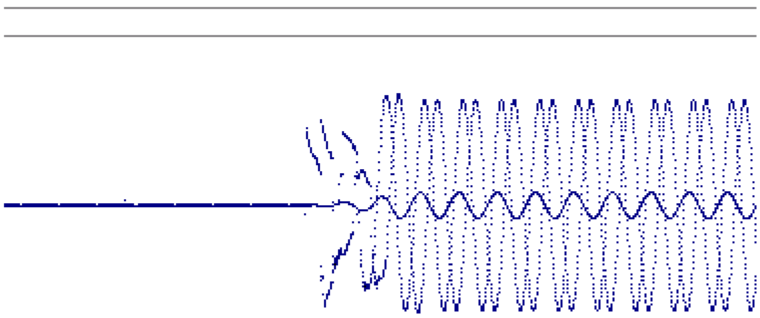
138 kV Substation

- Transformer Voltage A phase
- Transformer Voltage B phase
- Transformer Voltage C phase
- Transformer Secondary Current A phase
- Transformer Secondary Current B phase
- Transformer Secondary Current C phase
- Transformer CT Residual Current
- Transformer Primary 86
- Transformer Backup 86
- 15 kV Breaker Status
- 15 kV Breaker Trip Coil # 1
- 15 kV Breaker Trip Coil # 2
- 15 kV Breaker Pilot Wire Channel
- Sudden Pressure Relay Status
- 138 kV OCB status
- 138 kV Voltage A phase
- 138 kV Voltage B phase
- 138 kV Voltage C phase

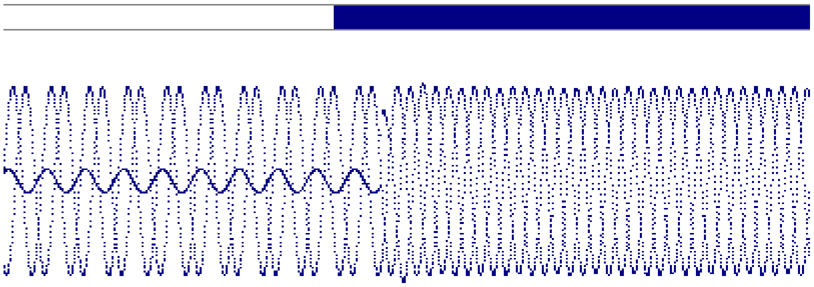
15 kV Building Switchgear

- Incoming Voltage A phase
- Incoming Voltage B phase
- Incoming Voltage C phase
- Bus Voltage A phase
- Bus Voltage B phase
- Bus Voltage C phase
- Incoming Current A phase
- Incoming Current B phase
- Incoming Current C phase
- Incoming Current CT Residual Current
- Breaker status
- Breaker Primary Trip Coil
- Breaker Secondary Trip Coil
- Breaker 86 Relay # 1
- Breaker 86 Relay # 2
- Roll Timer
- Main Breaker Close Coil
- Tie Breaker Close Coil
- Bus Backup Timer
- Bus Differential 86 Relay

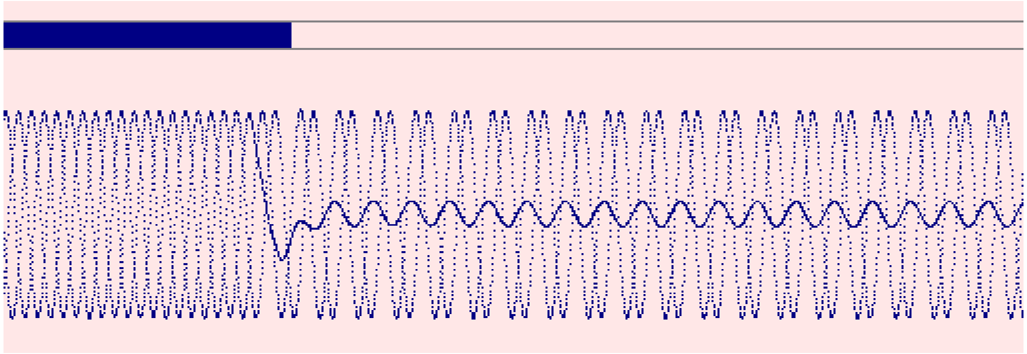
Over the past few years, we have discovered load break switches in which the load break bottles failed to function properly, a failed bolt in a 138 kV CCVT capacitor stack, and also have noticed system ringing and effects due to energizing 18 MVAR capacitor banks on the 138 kV system by the local utility. Below are several different DFR records which all describe something on the system if you have the time to actually monitor dozens of events. The following three figures are on incident in which TI discovered that a 138 kV load break switch on the transmission line had actually malfunctioned and the one of the load break bottles had not closed properly and was not allowing load flow thru the system.



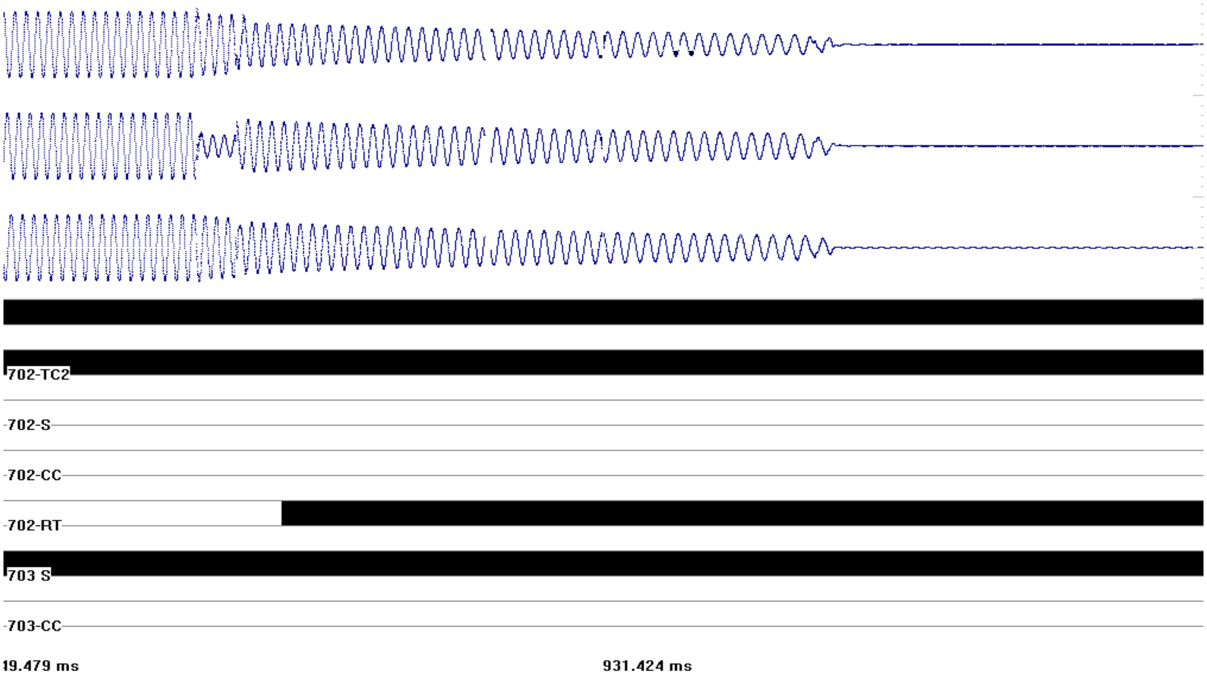
Closing 138 kV load break switch



Closing 138 kV OCB



Opening 138 kV OCB to repair switch



Correct operation of 15 kV roll timer

Looking for slow breaker operation

Most of the DFR records that are captured are of no value for solving any problems or revealing any new discovery. When we get involved with switching of load or clearing up feeders several records are taken which reveal no problems and just take up time to analyze, and like most everyone else we all have better things to do than look at no value added records. We have discovered enough unique problems and issues to justify the continued taking of multiple records and looking at every single one. Among the various problems discovered are, voltage ringing and multiplication due to the utility 138 kV capacitor banks at a switch yard over 5 miles away. These problem were serious enough of a concern that we commissioned an EMTP study of the system to verify the root cause, and recommend several courses of action for these events. Due to a phase shift only on an 138 kV CCVT, the utility discovered some serious wiring problems with the device and was able to repair the unit before a catastrophic failure occurred. Analyzing one record we determined that we had a 15 kV to 480V substation failure that no one had reported, due to the substation had 480 V transfer switches installed and they had all functioned and restored during the night and thus when people arrived for work, nothing appeared any different.

In summary, it takes quite a bit of time, but we have placed enough value in what we have found in the past to continue this effort.

Fiber Optic DFR Communication and Remote Monitoring of MASTER STATION.

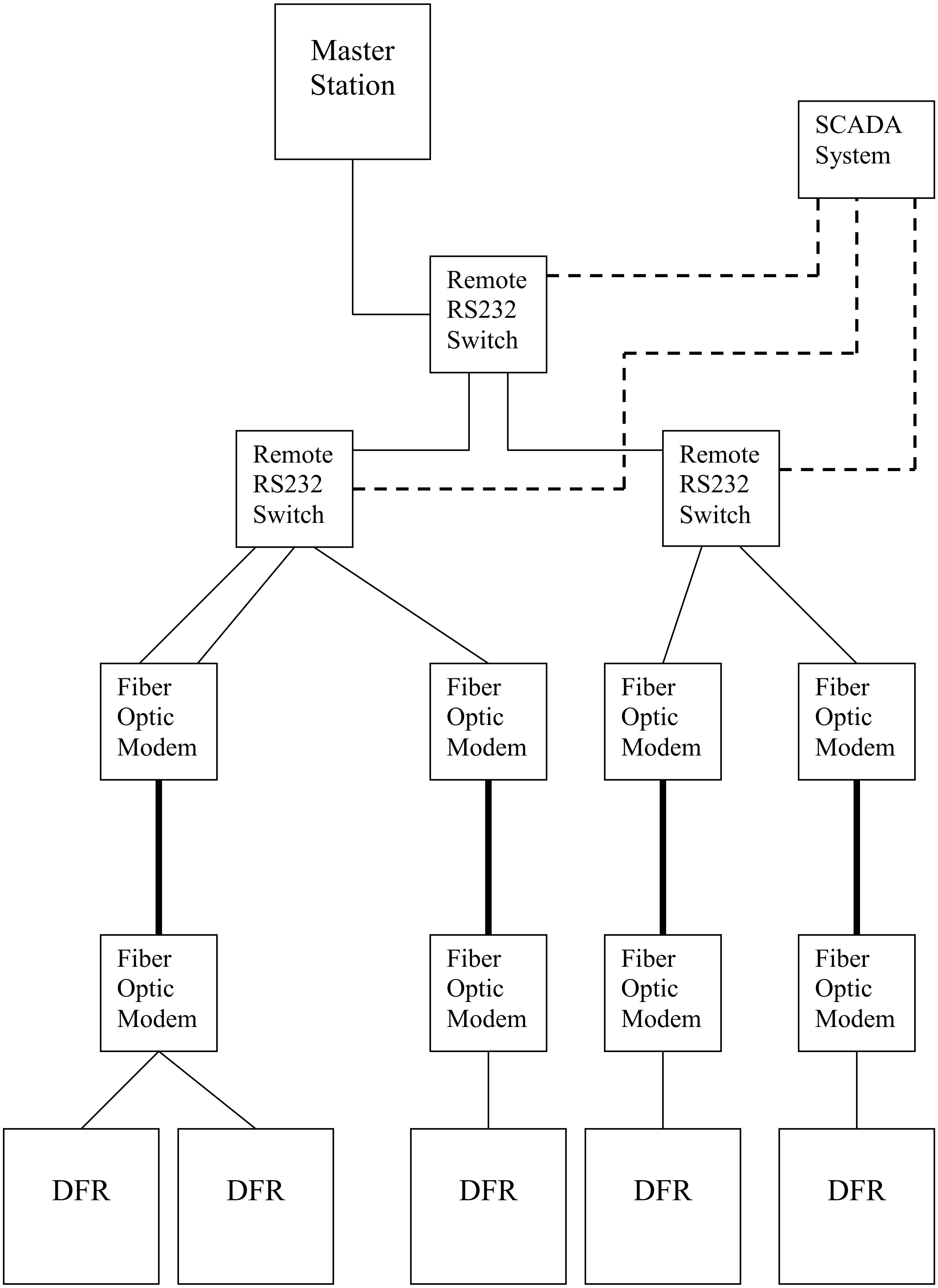
In semiconductor manufacturing locations, it is critical to maintain the uptime, and restore any outage within the shortest period of time. One of the key parts of quick restoration is having all the data of what happened in the shortest period of time. With Digital Fault Recorders (DFR's) there is a trade off with being able to capture sufficient data of being able to determine what happened, record size, and scan resolution. Since waveform information is important and the fact that we do have interrupting devices that will function in less than 4 milliseconds, we have chosen to use a scan rate of 5760 such that we can obtain precise information on sequence of events, and accurate waveform shape and characteristics. These items alone do not pose much of a problem, but we have added to complexity of the issue by making the minimum recording time of approximately 1.3 seconds in order to ensure that we do not miss any important information of the event and also obtain an accurate GPS time stamp. These items cause the minimum record size to be at least 576 K bytes and sometimes file sizes will exceed 1 Mbytes, and as such can result in long data transfer times.

The common practice of using phone lines was not desirable since the site used digital phones and obtaining special analog phone lines at every location was very expensive and with analog phone lines, data transfer rates would be less than 56 kbps. We had previously installed fiber optic cables to each location for the SCADA system, and choose to use a spare pair of fiber for the communication to the DFR's. This also removed any problems of noise or possible equipment failure due to potential differences during faults or lightning by using the fiber optic cables.

For every problem we solved it seemed that 10 problems surfaced. The problems were finding a fiber optic modem that would transmit asynchronous 115 kbps, how to access the Master Station from a remote SCADA monitoring location, and how to switch between 13 fiber optic modems at the computer while at the remote location, all using devices that supported 115 kbps, had complete handshake and not having pins jumpered together.

We solved the problem by finding a manufacturer of a fiber optic modem that contained up to 8 channels of communication at 115 kbps and a manufacturer of a remote digital RS 232 switch that treated all 25 pins independently. The eight channels of communication for the fiber optic modem also allowed for up to two DFR's to communicate over a single pair of fiber thus saving several fiber optic pairs for future expansion. Three data channels of communication on each modem were used for allowing for the complete handshake of communication required by the DFR and master station. The master station was converted to Windows 98, and a copy of the Windows version of the Master was installed for communication. The remote location could then use Net Meeting to control the Master station as both locations were on a common LAN. Changing the RS 232 digital switch was accomplished by using the 15 kV SCADA system to signal a PLC which in turn controlled digital outputs to change the remote switches, allowing for any SCADA terminal on the system to determine which DFR is connected to the MASTER STATION.

The diagram below demonstrates basically the system functions but does not contain all 13 DFR's.



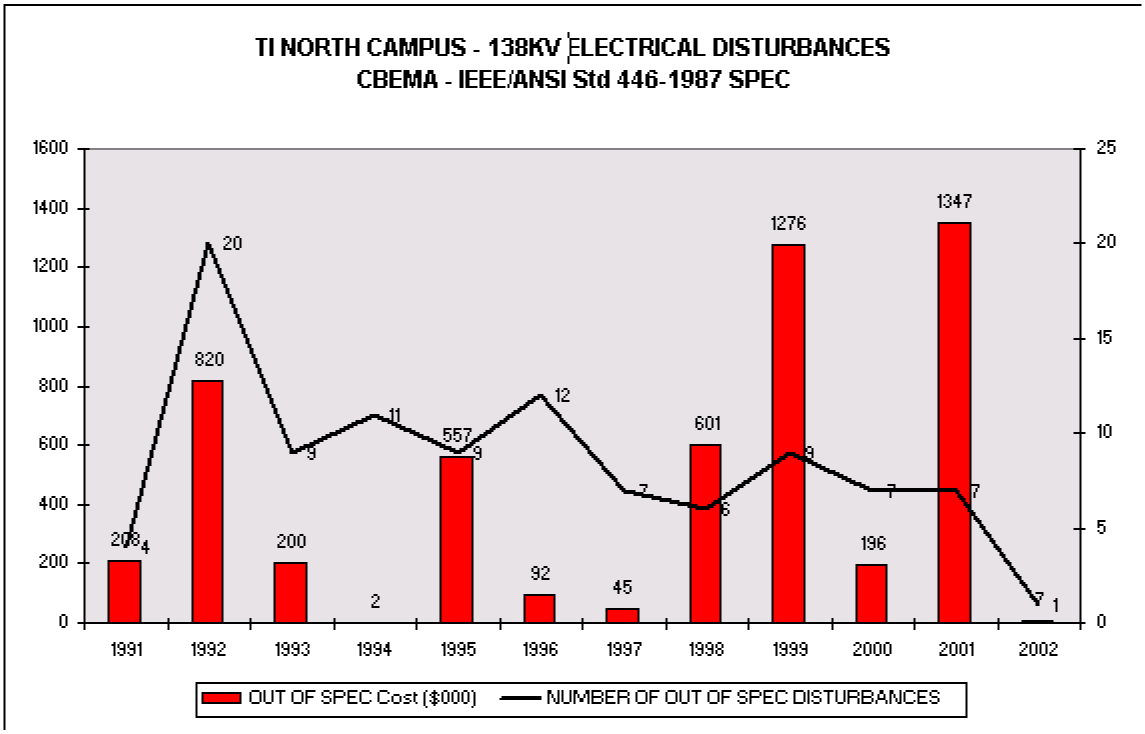
Level of voltage sags.

Manufacturing processes will be affected by voltage sags, surges, and very fast impulse transients, but this discuss will be limited only to voltage sags which account for 100% of the problems associated with the delivery of electricity to our main manufacturing location. One of the first things that a manufacturer determines is that power directly from a utility is not perfect and does vary. The amount of variation varies from utility to utility and also within various locations around the utility grid. These variations can be influenced greatly by items such as, age of utility equipment, overhead versus underground utility service, transmission versus distribution voltage service, static wire protection of lines, density and size of trees in the area, and many other factors too numerous to mention.

Once we determined that voltage sags or dips were inevitable, we started monitoring the magnitude of these dips and became interested in details as to what the root cause and location of the event was. The more we learned, the more we discovered that we did not know enough or have sufficient information to really understand what the data was telling us. A process was put in place in which we began charting all utility voltage dips greater than 10% dip or greater than 10 cycles in duration and comparing the amount of losses to the original CBEMA curve. We have continued this and have added the new CBEMA or ITIC curve on the charts for comparison.

It became difficult to determine exactly how large of impact each dip had, whether to use wafer slices reworked, wafer slices scrapped. These could all be converted to a common unit of measure and this unit was dollars. This does not relate to the possible impact to overall cycle time, units shipped or customer impact due to late or non-shipping of product, and we are still working on a suitable measurement parameter. These events are classified into three levels or event, major event (> $100 K), minor event ($1K - $99K) and non-events. Over the years with the monitoring of these numbers, and using the data to make various system changes we have been able to significantly reduce both the number and dollar impact to the manufacturing operation.

Beginning in 1991, the CBEMA curve which identified the areas where equipment might be marginal at surviving voltage dips was defined for us as out of spec, and over the years this has demonstrated to be fairly accurate in that sometimes equipment will ride through, and other times for the same type voltage dips, the equipment would be lost. The graph below illustrates the past history of the number of events and also the relative dollar magnitude.

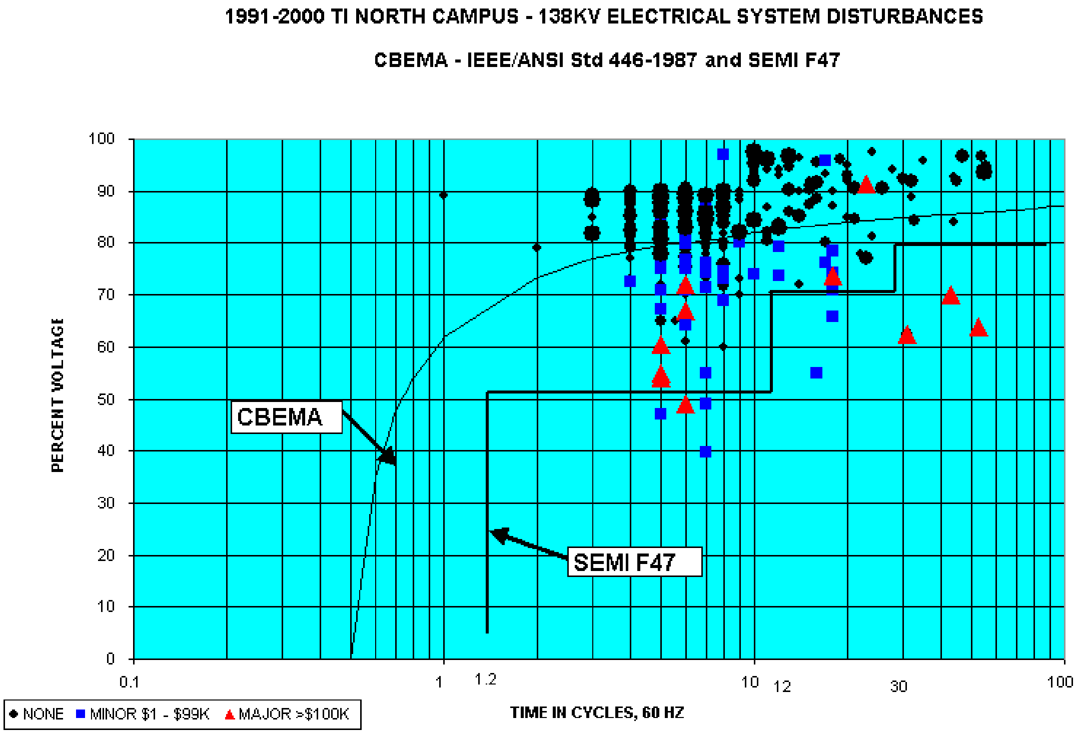


History of Disturbances

By tracking magnitude and duration of the voltage sags, we have been able to identify some types of equipment that are much more succeptable to disturbances than others and concentrate the majority of the effort where the greatest return can be achieved. Even with this effort it is not feasible to solve for all levels of voltage problems. Due to the nature of manufacturing equipment, not all losses are caused directly by voltage dips, but indirectly by cooling water system pressure fluctuations, exhaust system fluctuations, and also by process gas and chemical systems. As a result of all these external systems that can result in product losses, it is not possible to separate the critical equipment to separate feeders and serve them by a UPS or similar technology. In a typical wafer fab, the total direct and indirect load might be approximately 30 MW and the portion of the load that might result in some type of equipment shutdown would be greater than 21 MW, which makes it slightly difficult to segregate loads. The solution of segregating so called critical loads in the factory is actually more expensive than it would be to install power conditioning and ride thru to the entire factory. The greatest benefit has been to obtain service at the transmission level and stay away from the typical distribution level services.

Utilities typically do not spend as much effort on the distribution system as the transmission system since any distribution interruption only disturbs several hundred customers and not in the thousands of customers for any specific given instance. The key once again is having data and knowing what type of voltage problems that need to be solved and not just having one size that fits all. Solving the correct problem involves having data to analyze and being able to spot trends and what those trends were.

The voltage recorder data from over the past ten years were analyzed and we tried to determine where the majority of the problems occurred and if the new ITIC data curve would be of any benefit. The following graph illustrates the old CBEMA curve, the new ITIC curve and also a plot of data from the past ten years of data collection and it was evident that if all equipment met the new SEMI 47 specifications, then few equipment losses would have occurred.


1991-2000 TI NORTH CAMPUS - 138KV ELECTRICAL SYSTEM DISTURBANCES

CBEMA - IEEE/ANSI Std 446-1987 and SEMI F47

Summary

When the first DFR was purchased in 1990, it was a means to tell us more of what happened, and allow us more long term recording time than previous voltage data recorders. We never really realized exactly of what benefit that we would achieve from the information, and quite a few records were analyzed, the data recorded and then discarded. In 1992, due to weather and equipment failure, the utility had quite a run of bad luck and we had more events and also one of the highest loss years than we had ever; had in the past. Our company was considering expanding the manufacturing operation at that time, and these events were not looked at very favorably. Knowing the cause and characteristics of the voltage sags allowed us to begin working with the utility and looking at solutions both on the Texas Instruments side and with the utility to allow for both sides to benefit from an improved electrical system in the Dallas area. Communication and sharing of information of problems and future plans have allowed both sides to plan and grow for the future.

We never expected the monitoring of voltage and current to pay off in such large returns, and when the problems began occurring, several years of data had already been accumulated. With the deregulation of Texas, we have noticed more and more low frequency events, and they have also tended to be of longer duration. In 1996 we purchased a Swing Recorder and began collecting data on frequency events in ERCOT Dallas area, and not sure what the data tells us at this time, but continue to search and analyze the data for any benefit of information for the data collected. We never knew the value of the DFR when purchase and not sure if frequency will ever become an issue, but if it does become a problem hopefully the past data collected will serve a benefit.

About the Author

Mark Beutnagel is a graduate of Texas Tech University in Lubbock, TX with a degree of BS in Electrical Engineering. He is also a member of the Power Engineering Society, and Industrial Applications Society of the IEEE. Mark has been employed by Texas Instruments for over 23 years and held various positions dealing with the 15/138 kV and 480 V power distribution systems along with working on various facilities type control systems. He currently holds the title of Distinguished Member of the Technical staff for TI.