



PETROLEUM REFINERY SAVES MILLIONS WITH RETURN ON INVESTMENT IN LESS THAN ONE YEAR

Second only to crude oil, electrical power is typically one of the highest production costs and key elements in the refining business. In the extremely competitive petrochemical industry, products are produced 24 hour/day – 7 days/week and pumped directly into the market without an inventory buffer. Unscheduled interruptions or disturbances which affect process equipment can lead to millions of dollars in lost production and electrical equipment if not managed properly. Therefore, the continuous supply of high quality power is essential to survival in the refining industry. This paper describes one west coast Refinery's success in proactively managing 110MW of power consumption with their POWERLOGIC power monitoring and control System that paid for itself in less than one year after it was fully commissioned.



The POWERLOGIC Power Monitoring and Control System installed at this west coast Refinery provides real-time monitoring and control, peak demand management, cost allocation, incident evaluation, alarm reporting and historical logging. It has become an essential tool guiding electrical facility engineers and operators in daily operations, as well as aiding engineering, accounting, management in financial decisions to effectively manage electrical power costs in the refinery. The System was designed around saving electrical costs in three main areas: (1) energy cost, (2) equipment cost/asset utilization, (3) downtime and lost production with the following objectives:

Energy Conservation and Cost Reduction

- Understand and account for where and how energy is being consumed
- Reconcile/verify utility charges
- Allocate costs and assign responsibility to first line supervisors and operating personnel
- Establish energy conservation and cost reduction
- Have better knowledge of Usage patterns to exploit rate options
- Install load shedding and generator power balance controls
- Choose between alternative energy sources to manage cost during high demand periods
- Control remote substations

Incident Evaluation and Prevention

- Reconstruct problem and eliminate it from happening again with accurate event logs
- Quicker response time with time consolidated data and necessary information for technicians
- Automatic paging to explain and alert personnel to electrical incidents
- Disturbance monitoring that leads to effective remedies – filters, caps, UPS, etc
- Automatic control and power System restoration

Power Quality Analysis

- Specify and size new power quality equipment (200% neutral, K-factor transformers, filters, etc)
- Harmonic analysis
- Organized power quality data for communication with local utility

Manage Electrical Power Equipment Capital Expenditures

- Preventative/Predictive maintenance reduces equipment loss
- Better exploit existing capacity and aid in new capacity planning
- Prioritize/justify new capital projects
- Corporate as well as local plant benefits

Environmental Benefits

- Reducing energy use and prevent wasting energy is good for the environment
- Minimizing electrical upsets to reduce flare activity and noise



The POWERLOGIC System monitors eight on-site utility substations and the Refinery's five primary 15kV substations. It is equipped with over two hundred Circuit Monitors and Power Meters, network modules, Modicon PLCs, Sequence of Events Recorders, GPS time synchronization, System Manager Software and a customized Load Preservation application (added as phase 2 not described in this paper). The System was designed and integrated around key elements to accomplish the Refinery's objectives:

- the selection of revenue accurate Circuit Monitors with power quality measurement, high speed event logging (accurate to the millisecond or less), disturbance triggered waveform capture, high speed data logging, relay outputs and have ability for global position satellite (GPS) clock time synchronization
- advanced System user interface to provide necessary information to automatically and manually control loads and 1ms accuracy on sequence of events to help resolve the root cause of the problems with accessibility from anywhere in the plant
- System ability to expand as new substations were added, communicate on existing ethernet network and combine Circuit Monitors and programmable logic controllers together to help manage the electrical System

The Refinery has reaped millions of dollars in savings with the largest paybacks realized from reducing peak demand penalties, preventing disturbances and making the System more resilient to future disturbances. Other benefits are realized but are difficult to quantify, such as more effective management decisions and driving accountability throughout the organization.

By keeping in-tune with the electrical System via the POWERLOGIC System displaying load flows, voltages, breaker status, etc, when an emergency occurs, operators understand in less time how to transfer or switch loads. Operators also become more accountable and make fewer switching mistakes when know that the POWERLOGIC SYSTEM provides information that could implicate them to the cause of the outage. The System warns them if a feeder is becoming overloaded or if a phase imbalance occurs, etc. and allows intervention before an outage occurs.

The POWERLOGIC SYSTEM provides the ability to monitor electrical cost on a continuous basis allowing operations and plant engineers to recognize ways to reduce or control energy cost. For example, operators postpone switching from steam to electric during peak demand periods and optimize cogeneration based on actual plant energy demands. Plant engineers also use historical data logging, load profiles and other standard reports to utilize existing capacity on electrical substations to avoid unnecessary capital outlays for new equipment on large projects.

Accurate data and waveform captures from the POWERLOGIC System allow engineers to work together with the local utility to resolve power quality issues, relay problems, and nuisance electrical faults. Improved communications with the local utility company tend to exist after the realization that the customer is armed with disturbance data capable of determining whether the disturbance is outside or inside the facility.

Results

Service Reliability

The POWERLOGIC System is able to detect slow breaker operation on a pilot wire differential relay scheme during a routine Utility test. During the test, one of the 66kV oil breakers was noticeably slower compared to the other three breakers. The time stamp data was provided to the local utility and the problem was corrected. Left undetected, this problem could have resulted in a wide spread outage.

The Refinery relies on the Utility for approximately 15% of its load and co-generates to serve the remaining load. Prior to installing the power monitoring and control System, a nuisance-tripping problem cost the refinery more than \$20,000 per nuisance trip during power disturbances. When plant engineers monitored waveforms, high-speed time stamps, and real time information, they were able to view the exact sequence of events and pinpoint the root cause of the problem. With the Utility recloser set for a rapid reclose within 4 cycles, downstream process equipment such as an 11,000 hp variable speed drive was specified to be able



to ride at least six cycles and through voltage sags of 15% or less. Through high-speed one millisecond synchronized time stamps, they determined that the 40 relay (loss of field on generator) would trip first. Without the 40 relay or voltage regulator, the generator could not regulate its voltage and from waveform capture information determined that this occurred while the generator was heavily excited supplying VARs to a remote fault. This forensic data also revealed that the 11,000 hp drive was the actual culprit since it was not able to ride through 6 cycles during the Utility reclose. After the drive manufacturer recognized and repaired the glitch in its firmware, the expensive nuisance-tripping problem was solved.

The POWERLOGIC System alerted operations and avoided serious problems when re-energizing a primary System with an open circuit. An upstream 15kV distribution feeder's overhead connector had failed during a severe fault in a downstream substation. The connection was located upstream of the transfer switches used to redirect power to the other radially fed substations that needed to be re-energized. After the operators isolated the damaged substation and closed the transfer switches, the POWERLOGIC SYSTEM provided the current and voltage imbalance alarm. The operators immediately shut the System down and quickly located the problem.

Operations were alerted by the POWERLOGIC System when a remotely located substation's DC tripping supply's common trouble alarm was activated. The primary fuse had blown on the control power transformer feeding the battery charger. Maintenance was dispatched to the substation and the problem was quickly located and fixed. In the past the 50 DC Systems were checked on a monthly basis.

Energy Cost Reduction

Continuously monitoring the established peak demand relative to the present demand, the POWERLOGIC System warns operators if the present load is close to the peak setpoint providing ample time for switching to an alternate energy source or shedding load before a higher peak penalty was reached. The POWERLOGIC System enabled operators to understand their System and realize they can save money by operating batch processes during off peak periods instead of during expensive peak rates. They understand the cost impact of transferring from large steam drivers to electric drivers during peak periods.

Information from the POWERLOGIC System allowed management to determine that postponing generator maintenance until the weekend would be more cost effective. Operations believed that the month's peak had already been set and wanted perform maintenance on a generator that had low output due to a fouled turbine that had tripped earlier in the month on high vibration. In fact, the data from the POWERLOGIC System showed electrical load was lower at the time and if the generator were shutdown, a new peak would be set costing \$300,000 in additional peak penalties.

To maximize the time between cleaning cycles, the plant engineers use the POWERLOGIC System to trend generator output vs. mean time between cleaning cycles. The POWERLOGIC System enabled the engineers to monitor the decay in generator output and calculate actual energy loss comparing that to the cost of shutting the generator down for a short period of time to crank soak.

Reduced Downtime

From their office, the shift supervisors using the POWERLOGIC System were able to direct the local field operators to the substations that still had power. After a 15kV pothead failed on a primary feeder that was fed from a normally closed Main-Tie-Main substation, Operations were able to restore electrical loads in a short amount of time. In the past, prior to the installation of the POWERLOGIC System, the shift supervisors would have driven in their trucks to each of the 15 substations and then notified the control room which substations and feeders had power. By having electrical information for all substations at their computer, it enabled them to respond a quarter of the time and minimize plant downtime that cost tens of thousands per hour.

The POWERLOGIC System provides necessary information to diagnose why the hydrogen compressor was not starting. The 4500hp hydrogen compressor would not start from the field during the night shift. The operator went to the substation and verified that 4 different electromechanical targets had dropped. During



the early morning, the plant was short on hydrogen, losing money and management wanted the compressor on-line ASAP. Reviewing the POWERLOGIC System time stamps and waveform captures, plant engineers were convinced that compressor's breaker never had closed nor was there an actual electrical disturbance. After showing Operations and Maintenance the data, they focused on the motor start field permissives and found a failed lube oil permissive contact. The electromechanical relay flags were found to have been tripped via maintenance bench testing them earlier in the week and not resetting the flags discovered since there were no electrical waveform captures indicating an actual fault or motor inrush current. In the past, without the POWERLOGIC System, with the same given scenario, it would have required electricians to break electrical connections and test cables and equipment individually. With the use of the POWERLOGIC System, the hydrogen compressor was on-line with confidence in a fraction of the time it would have taken to troubleshoot the situation without it.

Equipment Utilization

The POWERLOGIC System provided substation load profiles to avoid new capital outlay on new substations. The ability to accurately understand the electrical loading, power factor, and demands, plant engineers are able to maximize existing substation capacity for new large projects without jeopardizing System flexibility. In the past, substation loading was checked based on induction disk type wattmeters with recording peak demand registers that were not time-of-use. The problem with this method was not knowing when the peak demands were set and if the readings were accurate since operations frequently switched feeders around by paralleling for maintenance purposes. Also in the past a recording ammeter would be connected prior to adding loads. This was hard to determine if the recorded period was indicative of the actual substation loading. The POWERLOGIC System however would time stamp and store breaker operations and the peak demands. Some substations that were thought of as near capacity were actually under utilized. Loads were added to the substations and feeders without jeopardizing their redundancy or reliability.

The POWERLOGIC System was used by operations in utilizing alternate feeders to restore power. During the middle of a planned maintenance shutdown on a 15kV overhead feeder, the backup feeder failed. Since Operations were familiar with the amount of total load lost and with the aid of historical and present data from the POWERLOGIC System, they were able to reroute power from different adjacent feeders that were not used in the past as backup for either the failed feeder or the feeder out for maintenance. Thus, they were able to utilize existing equipment and restore power in a timely fashion. Prior to POWERLOGIC System, they would have pushed the electrical contractor on premium time to restore either the failed line or the line out of service to restore power and the downed pant. The POWERLOGIC System gave them the necessary confidence and real time data, as they were re-routing power on feeders that were not normally used to supply power to the down equipment.

Power Quality

The POWERLOGIC System was used to monitor and alarm on total harmonic distortion (THD). The main 15kV substation had both cogeneration and a 15,000 hp variable speed drive. During normal operation a line reactor was in service between the two main buses. If the generator was down, the harmonics would exceed 16 percent and the reactor would be bypassed. The POWERLOGIC System would alarm if the THD exceeded the IEEE guidelines.

Other Benefits Realized

The POWERLOGIC System fostered honest and up front answers. During tap root investigations it became apparent to all that the data the POWERLOGIC System provided via time stamps, waveform captures, electrical history, etc., indicated that personnel accidentally shutdown equipment. Those mistakes could no longer be blamed on phantom power disturbances. Through honesty, and management supporting openness, it turned out that mistakes were mainly due to either ambiguous steps in procedures, vague labeling or missing information on one-lines. These problems were easily corrected and the situation was prevented from re-occurring.



After the POWERLOGIC System was installed, the utility company worked closer with the plant engineers to resolve power quality issues. When the customer has equal or better trending capability, waveform captures, and time stamps on events; the utility was utilizing this data along with the customer to resolve power quality issues. For example, an electrical failure occurred due to a bird in an open substation at the plant. However, the utility company's main breakers tripped first via differential protection. The utility line crew found a Mylar balloon near the tripped feeder and believed that it was the cause for the differential trip. The POWERLOGIC System waveforms indicated the fault was on the customer side, and the balloon could not have caused the fault. The fault was found and it turned out that the utility company's pilot wire was loose and their relay System became a sensitive over current relay. The problem was corrected instead of ignored. Another example, the utility company switched their own breaker that supplied power to a couple of plants by accident from their SCADA System and then reclosed the breaker. The POWERLOGIC System had a time stamp of the breaker operation as well as waveform captures supporting that the breaker operation was not caused by an electrical disturbance. Because the plant was able to prove it was human error, they were able to re-coop some of the loss from the utility. It turned out the breaker tag name was similar to the tag name for an emergency back-up feeder breaker that the utility uses for the generator controls. The POWERLOGIC System through monitoring primary feeders continuously and providing alarms when the System is not operating with normal parameters helps operations, maintenance and engineering to plan a course of action instead of just reacting after an event occurs.

Next Steps

The POWERLOGIC System was designed for flexibility and to expand. The following are ideas in which the System can be utilized further:

1. The POWERLOGIC System can provide real time data to third party computer aided electrical analysis software for accurate load flow calculations, motor starting studies and what if scenarios for training operators on the electrical System.
2. Integrate other utility data (WAGES – water, air, gas, electric, steam) into the POWERLOGIC System to calculate other utility usage costs such as the cost to produce steam. This will enable an operator depending on the varying electrical rates vs. other utility rates (water, natural gas, etc) to economically choose between or a combination of steam and/or electric drivers. The POWERLOGIC System along with third party energy management software can calculate the actual cost to produce steam and electricity compared to the utility's sell/purchase rates at any given instant in time and be able to decide on cogeneration output rates based on economics. For example, does it make sense to produce excess steam for maximum electricity when the utility buys the electricity at avoidance cost?
3. The POWERLOGIC System can provide corporate management the ability to obtain real-time aggregate electrical usage, generation and demand costs from other US production facilities for leveraging utility contracts in the free-market.
4. The POWERLOGIC System can provide control components to shed load based on real time System data for each feeder. By comparing actual plant load vs. generation capacity, it can shed the minimum amount of load to maintain the System stability. (NOTE: This load preservation capability, implemented as Phase 2, is now up and running at this west coast Refinery. This case study describes savings from the initial installation.)
5. Continue expanding the POWERLOGIC System by monitoring the entire medium and low voltage substations, which are critical to the plant. During power dips, the POWERLOGIC System could generate a report on which motors tripped as a result of the dip and resulted in upsetting process parameters (flow, pressure, vibration, etc.). This enables engineering to delineate which motors need special ride through devices.
6. Expand POWERLOGIC System to include continuous monitoring for corona discharge in metal clad switchgear, critical motors and generators for preventive maintenance.
7. Expand POWERLOGIC System control capabilities by automating power factor and voltage control through the use of adjusting the excitation on the generators and synchronous machines, change auto-tap changers and switching fixed capacitor banks.



Conclusions

The POWERLOGIC System was essential for controlling energy cost, understanding reliability problems and providing data to work alongside the local utility. Preventing reoccurrence of the electrical outages saved money through reduced response time during electrical events that minimized plant downtime and cost allocation, which created electrical accountability on energy costs.

In the past, plant engineers tried to justify a POWERLOGIC System only on the premises for reconciling and verifying energy costs and providing operators with real time data. It was hard to nail down the rate of return and hence the project kept being postponed. After keeping power outage records, and lost profit opportunities, POWERLOGIC System was justified on the basis of aiding in taproot investigations, eliminating or minimizing electrical disturbances and improving power quality. The monitoring System paid for itself in the first year of operation by providing key information on nuisance trips, better operator awareness of energy costs and through reducing energy demand. POWERLOGIC System was quickly finding new uses beyond the original justification and through its design, combining meters with control, was easily enhanced when new uses were discovered.

POWERLOGIC System largest rates of returns were experienced from its design around providing detailed information on electrical anomalies. Through the use of the time stamps waveform captures, historical data prior to and after the event, the plant engineer was able to provide concise solutions. Prior to POWERLOGIC System many problems were thought to have been fixed through detailed investigations only to find a symptom was fixed because crucial information was not obtainable via equipment testing or through interviewing operators and maintenance personnel.

The POWERLOGIC System has reduced energy usage by focusing operators on actual electrical costs associated with their activities. This was accomplished by continuously displaying energy and peak demand costs associated with total plant loads and generator output. After operations realized the cost impact of switching between large drivers, starting up a batch process during peak demand periods, or reduced generator output, they adopted a different operating philosophy by taking ownership of the electrical System. The operators were focused on energy costs since they were kept abreast of the usage and cost impacts. In the past, it was hard to make operations focus on energy saving methods if only a few of them ever saw the monthly utility bill or realized how their actions could affect the bill. Now operators have more accountability since the electrical System is continuously monitored and recorded. This has led to better reviews on operating and switching procedures, accuracy of equipment labels and understanding load profiles. This in turn has reduced the number of incidents from human error.

The POWERLOGIC System is gaining use as a bargaining tool for wheeling of power. With the data it provides, it can be utilized for obtaining the best spot market rates. If you do not know the amount of power you are selling or buying at any given point in time, how can you leverage the best utility deal?

In conclusion, if other critical type processes are being monitored, it makes sense that electrical power Systems should be monitored too since its quality directly impacts the performance of the other measured processes. “.. If you cannot measure it, you cannot manage it.”