Kaui Electric - Kauai, HI

Who is Kauai Electric?

They are the generating utility for the island of Kauai in Hawaii. Power is obtained from their own power plant and from several co-generators around the island including sugar plantations and a couple of hydro-electric units. It is a complete miniaturized version of a full scale system.

What was the nature of the power problem being experienced at the facility?

Contactors and starters in the MCC's (motor control centers) controlling the lubrication pumps on the diesel generators would drop out during a voltage dip, resulting in undesirable system downtime.

What was the cause of these voltage dips?

Mr. Norman Giem, a consultant to the utility, investigated the causes of the system disruptions and had come to the following conclusions. Line faults on the system cause problems at unique times, specifically at night when loads are relatively low. During this period when less generation is on line, protective relays do not have large enough generation capacity to draw on and don't feed the fault sufficiently to make protection work well. As a result the protection is slow to operate and the delay in operation causes the voltage to sag, after which all the motor starters drop out and the system goes down. The protective relays can only be set to operate under high load conditions and therefore only work well during the day.

What solutions were investigated?

Although a stability analysis is still being undertaken to try to reduce the susceptibility of the system to the 'low load' period, a number of solutions were proposed. One, was the installation of special over current relays set to trip at a lower level than the ones already existing on the generators. These would be set at a lower level, so that during a fault, they would trip the power station off line and keep it running. The system however, would still need to be re-energized. The over current relays that already exist on the generators are set at a high level to protect against major faults on the bus. If they operate, the generator breakers trip and everything goes dead, which is obviously an undesirable situation. A more attractive solution was to maintain the switch gear control voltage during the voltage dip, thereby keeping the power station up *and* the system running. This would avoid the need to go back and re-energize it and, as a result, prevent unnecessary downtime and losses incurred.

Why was the Voltage Dip-Proofing Inverter™ (DPI) chosen?

The installation of a device such as the DPI would not only provide a solution that was quick to implement, easy to retrofit and be carried out at relatively low cost, but would also eliminate the maintenance costs associated with conventional battery back-up systems. Installing UPS's proved more expensive and the task of retrofitting was complex.

Although running the controls off an existing UPS system was considered, concerns were expressed about having inductive loads, i.e. coils, connected to a system supplying power to 'clean' computer loads. Using numerous small DPI's offered a neat installation and allowed the starter panels to remain individualized. As a result, reliability was also enhanced. Using fewer large DPI's was considered but some of the space and wiring problems associated with UPS systems were encountered.

McGHAN MEDICAL - Santa Barbara, CA - A continuous plastic molding plant where an oxidizer is used for manufacturing medical implants and prosthetics. The facility experiences dips of 300 to 600 milliseconds in duration at least once a month. This causes a disruption in the process critical to the quality of the product.

The oxidizer and extruder which requires ride-through has a relatively high amount of inertia, and therefore does not slow down significantly within one second. The trip-sensitive control circuit requiring support consists of relays, starters and logic. A load current measurement was performed and it was determined that a 500VA unit would be suitable for the application. The DPI was attractive because it is maintenance-free and

incorporates an adjustable timer for motor and drive protection.

"We had four power dips recently (Nov. '95) and the oxidizer rode through all without incident, indicating that the DPI is serving its purpose" - Jack Hasch

COASTAL CHEMICAL CORP. - Battle Mountain, NV - An ammonium nitrate chemical processing and manufacturing plant who chose the DPI because of its industrial robustness and suitability for inductive loads. The DPI is used to provide ride-through to control starters in the booster blower motor control center. The 1500 hp motor drives a blower which rotates at 3600 r.p.m. During a voltage sag, which typically lasts around 300 ms, the control circuit voltage dips and drops out the controls, bringing the blower to a halt. This leads to an interruption of the manufacturing process. A 3kVA DPI has been retrofitted to support the 2kVA control load for up to one second during sags, thereby avoiding costly process disruption.

Before the DPI was installed, we would notice the lights dim for an instant and find that we had lost part of our process, especially that involving the booster blower. Since implementation, we have seen the power 'blinks' but the blower has not gone down. We attribute this to the DPI. - Bob Handford

TEXAS UNITED PIPE - Houston, TX - A plastic extrusion plant with twelve lines which produce pipes and tubing. Voltage dips of around 500 ms during the storm season cause disruption of the continuous molding process. This results in excessive material waste and downtime. The facility, along with the local utility, were investigating options and possible solutions when the maintenance-free DPI was discovered. Common UPS's had been installed on their motor control centers, but because the plant experiences numerous dips within a short period, battery life was drastically reduced. Maintenance and replacement became a nuisance and were neglected.
An initial trial on one line's motor control center was undertaken, and it was determined that three circuits needed to be held in. These included the main control power system, main drive start and feed drive start which consist of numerous small relays, logic circuits and a large contactor.

"On one occasion, we had seven dips in one day and the line which is dip-proofed continued to run, when all the others stopped. This incident along with others has prompted us to pursue the protection of the next line using this method, and eventually, the remainder of the facility" - Chuck Vest

TEXACO PSP REFINERY - Anacortes, WA - Oil and petroleum refinery. The plant occasionally experiences momentary power interruptions from the utility. Although most are of short duration, around 500ms, the critical loads would drop off line and result in a disruption of the refining process. Once the loads have tripped off-line, personnel must scramble to restart these loads as soon as possible. The disruptions invariably result in unnecessary downtime and monetary loss.

After an investigation by Westinghouse, it was decided that the 5kV, 3000 hp supplemental air blower and critical cooling pumps should be allowed to ride through the utility interruptions. The control circuits, with approximately 200VA of holding, and 2.7kVA of inrush power, required support for a maximum of one second. The DPI was found to be ideal for the application because of its ultra-fast transfer time, its ability to withstand high inrush currents and the fact that an adjustable timer for accurate ride-through was incorporated. The maintenance-free aspect of the DPI, its industrial robustness and the availability of a no-break bypass switch allowing for adjustment and test without critical process interruption, broadened its appeal. 500VA units were selected giving 30% over capacity to provide for future upgrades .

DEERFIELD PLASTICS (UPDATE) - South Deerfield, MA - A manufacturer of polyurethane bags with six production lines. Each line requires the use of four DPI's as numerous 3-phase Reliance DC drives are employed in conjunction with control relays, contactors and supplies. Four new DPI's have been added to a second line and, along with the original four on line one, are undergoing monitoring and evaluation.

NEW YORK WIRE COMPANY - Mount Wolf, PA - Manufacturer of fabricated wire products. When the lights flickered at New York Wire Company's plant in Mt. Wolf, Pennsylvania, the company knew it could mean

trouble. Even a momentary voltage sag could result in a shut down of the production line. It wasn't the production line itself that experienced the problem, but the complex system of environmental controls that oxidize the VOCs and other airborne contaminants to ensure that the company complies with environmental regulations. With the pollution control system shut down, the production line could not continue to operate. Getting the line back into production would take hours.

While sags only occurred two to six times per year, the resulting disruption was annoying and costly. Frank Gaiteri, VP of Engineering, made GPU Energy aware of the problem. GPU representative Bob Gallo suggested that New York Wire invest in a ride-through device like a Voltage Dip-Proofing Inverter (DPI) and helped determine what size would be appropriate. After a demonstration by Russell Holt of Dietrich & Associates, the company purchased and installed a unit in mid February. The DPI will help enable the company to ride through power dips or interruptions lasting up to 3.6 seconds.

GPU Adjusts Line Breaker Setting. The line circuit breaker at the substation serving NY Wire was set to re close at the standard five seconds after its first trip, due to temporary faults. Because there were not any components prohibiting the re close time from being reset for a shorter delay, Jim Sarver, Distribution Asset Strategy Engineer, reset the re close time to one second to enable the company to ride through power dips.

A Preventive Solution. Designed specifically for use in industrial and commercial environments, the DPI provides a preventive rather than a curative solution. It consists of a static switch in series with, and an inverter parallel to, the load. Switch over occurs in 700 us. Since energy is stored in a capacitor instead of a battery, there are no replacement costs, maintenance costs, or hazardous waste to dispose of. During the stand-by operation, the static switch supplies power directly to the load, the inverter is switched off and the capacitors are charged to the full operation voltage. The supply voltage is constantly monitored for deviations; should there be a discrepancy of more than 35% from nominal (adjustable from 50% to 90%), the static switch is switched off and the inverter is activated.
Protecting an entire facility or a production line requires a large, expensive system such as a 3 phase UPS. However, problems with momentary voltage sags and interruptions can often be solved easily and economically at control level by using a DPI to support critical controls.

When a shut down occurs, labor and material costs alone are approximately $800. When evaluating the potential financial losses incurred with power quality problems, the approximate cost of $2700 for the DPI is an attractive investment with payback achieved in a relatively short period.

Dip Proofed. The lights flickered the last week of May-but instead of a shut down; New York Wire rode through the disturbance, thanks to the DPI.

J M MANUFACTURING (UPDATE) - Meadville, PA - A plastics pipe manufacturing facility with twelve extrusion lines which trip off-line during severe weather storms. The lines use 3-phase Powertec DC drives in conjunction with peripheral relays and contactors. These, along with the drive logic has been "Dip-Proofed". The original line chosen for trial has successfully "ridden-through several severe dips" using a single DPI. Subsequently, two other lines have been modified and retrofitted with units.

VARIOUS UTILITY POWER QUALITY GROUPS - The DPI is seen as a solution for their customers. It is ideal for the above-mentioned reasons and the fact that some facilities do not require extremely expensive and large devices to protect the entire facility. Rather, with the aid of monitoring studies and some 'micro-surgery', the sensitive equipment and controls can be identified and only these items protected, thereby reducing equipment and retrofit costs and enhancing reliability. Many have Energy Services divisions that offer turnkey solutions and buy and resell mitigation devices such as the DPI.

They include:

Virginia Power - Richmond - VA
Houston Lighting & Power - Houston, TX
GPU Energy - "Powerteam" - Reading, PA
Northeast Utilities Co. - Hartfield, CT

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GENERATION ELECTRICAL
ENGINEERING MANAGER

EXECUTIVE SUMMARY

MULTIPLE UNIT TRIPPING

PROGRESS ON IMPLEMENTATION

REF: SM590/211 DECEMBER 1993 REV: 0

ESKOM's EXPERIENCE WITH THE PROTECTION AGAINST VOLTAGE DEPRESSIONS AT LARGE FOSSIL POWER STATIONS

1 BACKGROUND

Eskom has experienced many unit trips on lame fossil power stations during voltage depressions on the auxiliary supply system. These voltage dips, introduced by faults either on the auxiliary system or on the station's interconnected HV transmission network, interrupts the operation of the auxiliary plant to the extent where the unit trust be tripped.

A single fault in the HV yard can thus lead to the tripping of more than one unit at a power station, which is referred to a Multiple Unit Tripping (MUT). An investigation into the sources of MUTs indicated that more than 50 % of such incidents are caused by short circuits in the HV yard. Due to the small amount of spinning reserve operated on Eskom's Interconnected Power System (IPS), the loss of more than one 600 MW -700 MW unit can result in severe deviations in the system frequency. Thus MUT is a major risk to the secure operation of the IPS in South Africa and has to be operated accordingly.

During 1990, Eskom started introducing protection measures against voltage dips at all its large fossil power stations.

LV SWITCHGEAR The auto tripping and reclosing voltage dip proofing system installed on the LV boards at the power stations during the design was removed and Dip Proof Inverters (DPIs) were installed. The auto reclose systems were not reliable, difficult to commission, difficult to maintain and not effective for all types of voltage dips. The factors which influenced Eskom's decision to introduce the DPls were:

- The relatively strong supply and short fault clearing times at a power station excluded the possibility of motors stalling when held onto the system during a voltage dip
- the stresses to drives as well as the power supply system are less when holding the contactor closed
- DPIs are simple to introduce and do not require complicated studies during the design phase as is the case for the auto reclose system and
- the disturbance to the generating unit process is minimized when holding the contactor closed and hence the probability of the unit riding through the clip is

enhanced.

This voltage dip proofing exercise on its own made a significant impact on the number of unit trips as well as MUTs but was not the final solution.

3 PROCESS CONTROL SYSTEM

Instantaneous trips in the unit process control system was found to be also a cause of unit trips during supply disturbances such as voltage dips. As an example, a lubrication oil pump supplying oil to a mill's bearing will loose speed during a momentarily voltage depression on its terminals. Should an instantaneously operated pressure trip be used on the lubrication, the mill will be tripped during a voltage dip.

The easiest way to identify such circuits which can lead to the unnecessary tripping of a unit is to check all process control protection gear with instantaneous trips. This can finally be proven by applying a controlled three phase short circuit on the unit MV auxiliary system.

4 UNINTERRUPTABLE SUPPLIES

Critical monitoring and control equipment in many cases require reliable power supplies. At one of Eskom's coal fired stations, the power supply for the boiler flame monitoring equipment was taken directly from the 380 V essential boards. Although the supply at these boards are secured by feeds from various points in the station as well as a diesel generator board, the supply voltage is subjected to voltage dips similar to any other board in the plant. Thus, when a short circuit occurred in the HV yard, the flame monitoring on all running units failed and all boilers were tripped.

It is essential to ensure during the early design phase that all control and monitoring equipment is supplied from an appropriate Uninterruptable Power Supply (UPS).

5 COST SAVINGS INTRODUCED

Before the dip proofing protection was introduced to Eskom's large fossil stations, a voltage dip related trip of a 500 - 700 MW unit occurred every 34 days on the system. An average of 0.9 voltage dip related MUT incidents occurred per annum.

The cost of restarting a unit is:	R 90 000
Replacement generation cost for such a trip is:	R 130 000

Cost per trip:	R 220 000
Losses due to at MUT, incident load shedding	R 2 000 000

Since the dip proofing protection has been installed (by the end of 1991), no voltage dip related trip or MUI has occurred.

This means that the total estimated saving to date (2.5 years):

Unit trips It 220 000 x (365/34) x 2.5 =	R 5 904 412
MUTs R 1 500 000 x 0.9 x 2.5 =	R 3 375 000

Total saving in 2.5 years =	R 9 279 412

or R 3 711 765 per year.

The total cost of the voltage dip proofing project was R 4 200 000 and this means that the investment return within 1.2 years which is outstanding. This does not include Eskom's national image and other related benefits.

6 CONCLUSIONS

I. The voltage dip proofing protection project introduced at Eskom's large fossil power stations was a great success and the return on the investment has been excellent.
2. Once the DPIs was developed and prototype tested, it was quick and easy to implement this dip proofing protection.
3. Besides the application of the DPls, other small modifications such as delaying trip signals and optimizing the use of UPS, had to be implemented.
4. The DPIs have proven to be reliable in a power station environment.