

**ALTERREX EXCITATION UPGRADES
CONVECTION-COOLED BRIDGES AND
REPLACEMENT OF AUTOMATIC VOLTAGE REGULATOR**
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ABSTRACT

The Alterrex generator excitation system was the product of choice from the 1970s through the 1980s. The Alterrex design included an ac rotating exciter whose ac output was connected to stationary water-cooled rectifier bridges located in a doghouse at the end of the turbine generator. Each three phase rectifier bank was rated for 1600 amps with multiple bridges in parallel to match the generator rotor field requirements. See Figure 1. Bridge redundancy was provided in the event of failed power semiconductors or water leaks causing nuisance rotor grounds that could otherwise cause a forced outage. Today, 40 years later, water-cooled bridges are experiencing repeated plumbing issues as worn copper tubing, joint elbows, and Teflon hoses are troubled with bothersome water leaks. An EPRI Report dated 12/19/2002, "Alterrex Cooling Leak Survey Results" identified numerous water leak incidents, and the "Frequency of leaks has increased with Service Time." "and in fact ...leaks have occurred since early in many of our units' service histories".

The Exelon Power Mountain Creek Generating Station in Dallas, Texas, is one of many plants faced with continuing repair and the decision of replacing the existing water-cooled Alterrex bridges. This paper describes the decision process that was involved in the actual bridge replacement, the testing, the install and the commissioning of the new system.

Additionally this paper will discuss expectations for voltage regulator replacement of the Alterrex exciter system.

INTRODUCTION

Mountain Creek Unit # 8 is rated for 583 MW, 22 kV, 3600 RPM with rotor field requirements of 4600 Amps. Over the years, the Alterrex water-cooled bridges developed recurring water leaks which required repair by removing the bridge from the doghouse. The existing system consists of four (4) water-cooled bridges, two on each side of the generator doghouse. See Figure 1. Each bridge consists of 12 rectifier hockey pucks mounted on a heatsink and supplied with snubber circuits that are water-cooled via copper and Teflon tubing that carries deionized water from the stator cooling reservoir.



Old Water-Cooled Bridges
FIGURE 1

Each bridge contains a “No Load Break Disconnect” switch and a neon light panel to display any fail diode within the bridge. The disconnect switch provided the means to remove the ailing bridge from the system for repair. Where the OEM instruction manual suggests not opening the rectifier switch while the system is operating, it is common practice in most systems to open the switch with the bridge in operation.

I. THE PROBLEM

On the Southeast corner of the generator doghouse, a major leak on the water-cooled rectifier bank was occurring, resulting in 20 drops per minute. Operations had isolated the bank and taken it out of service. Since the system is an N+1 design, one out of four rectifier banks could be removed from service. Yet, there was one more water leak on the Southwest corner rectifier bank. The concern was that if the leak got worse like the Southeast leaking bridge, a total of two banks would be out of service, and that would require a derating of the machine MW output. Figure 2 shows corrosion track across the diode from the leaking water.

The OEM did not recommend fixing these water leaks in the field. They recommended removing the bridge and sending the leaking bridges to a licensed service shop that could repair and provide turnaround. The estimate was a six-week effort while an upcoming outage allowed for only one week in the spring of 2008.



Corrosion Tracking of Leaking Water
FIGURE 2

The existing “Knife Disconnect Switch” was also a concern. The existing 5 Pole Disconnect Knife Switch did not provide equal tension on the disconnecting AC and dc bus. Some "switch poles" will disconnect sooner than others, causing a hanging up condition, and for some plants, the switch has trouble even opening at all. Figure 3 is an infrared picture of the Nuclear Power Plant disconnect switch, which also illustrates different spot temperatures on the current carrying switch. Note the temperature varies from 138°F on one end to 226°F on the other side of the knife switch. With continuing maintenance and repair being an issue, the decision was made to replace the existing water-cooled bridges and disconnect switches for new hardware.

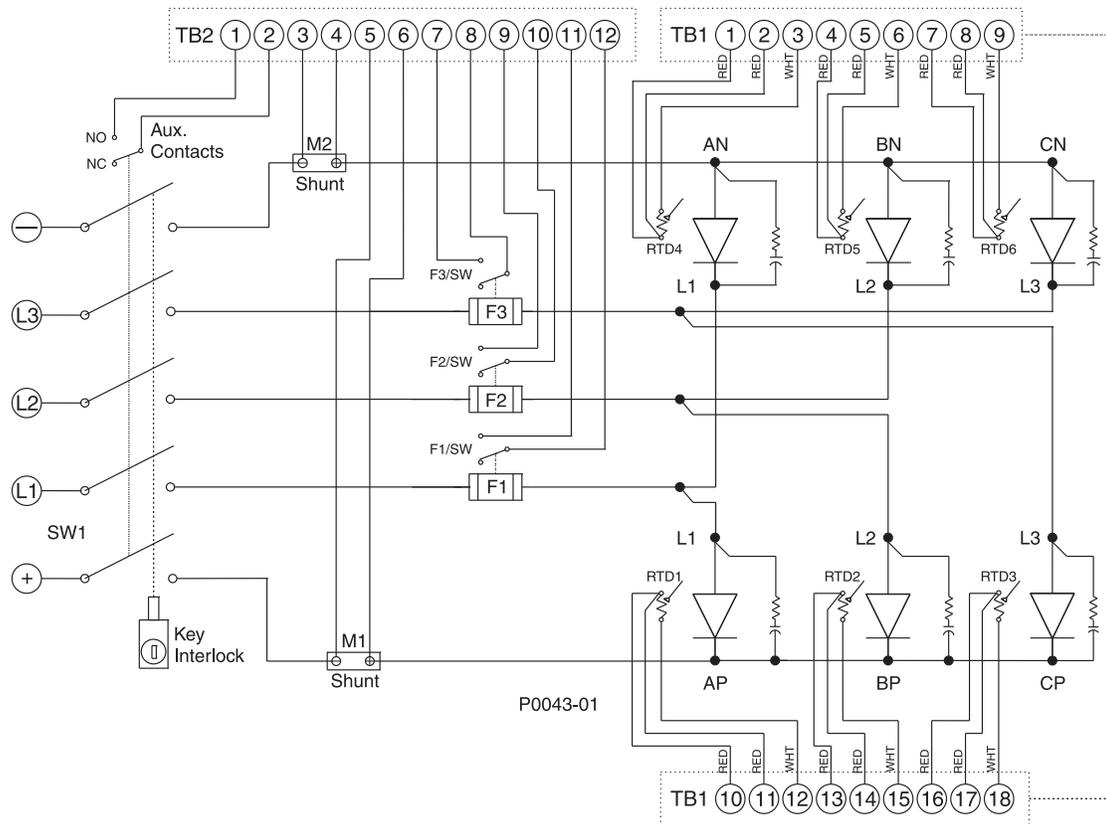


Temperature Readings of the Knife Disconnect Switch at Nuclear Plant in U.S.
FIGURE 3

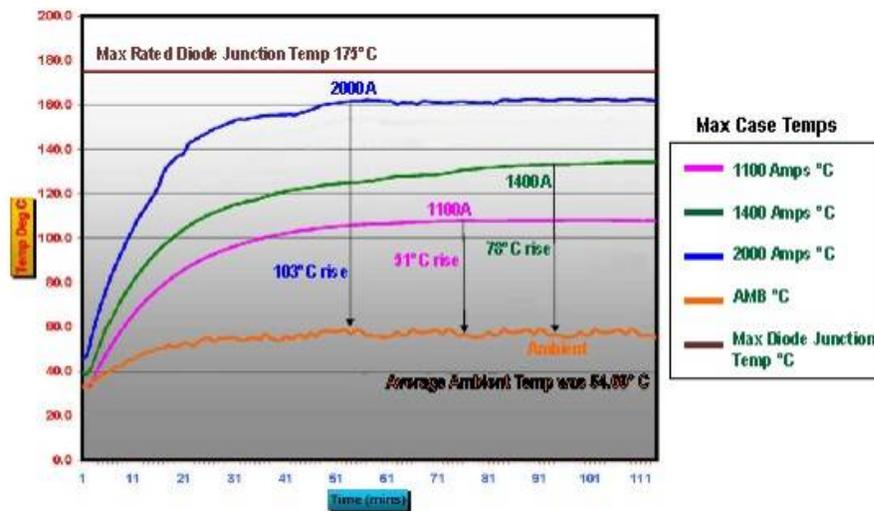
NEW DESIGN EVALUATION

Where a new “alternative water-cooled bridge system” was an option from the original OEM, it still required deionized water from the stator cooling system just as the existing system and it still used water filters to catch contaminants that could become clogged, affecting the bridge cooling. The objective was to eliminate all maintenance and avoid any downtime associated with future bridge design. The Basler Electric Company air-cooled bridges are designed for convection cooling that required no external mechanical or liquid cooling. Referencing Figure 4, the new air cooled bridge system is a three phase fullwave bridge consisting of just six 5380 ampere average current carrying diodes with a RC snubber circuit around each diode. The diode has a Peak Reverse Voltage of 2800 V. See Table 1 [Ref 1]. Three power fuses with fail indicators on each fuse are included. Two dc current shunts are provided, one for measuring the positive leg current and the other for measuring the negative leg dc current so current can be monitored, one for the Alarm Display Panel Meter and the other shunt for a remote meter. Six RTDS are wired to a terminal block that can be used to monitor temperature via a RTD relay provided with each new rectifier bank, or the RTDs can be wired to a DCS. A new disconnect switch is shown with status indication via an aux contact along with a kirk key interlock.

The new bridge and disconnect switch design reuses the existing mounting holes of the original OEM bridge, so that it would be a drop-in replacement. Unlike the original bridge rating of 1600 amps, the new convection-cooled bridge has a rating of 2000 amperes, which offers a very conservative design to ensure long and reliable life with up to a 250% overload thermal capacity for 30 seconds. Figure 5 represents heat run data and highlights the temperature rise on the new convection-cooled bridge based upon a 54°C ambient temperature. Depending upon the actual operating current of the bridge rectifier, the temperature rise can vary anywhere from 51°C for a single operating bridge of 1100 amps to 71°C rise above a 54°C ambient for a single operating bridge of 1400 amps. Even at 2000 amps, significant temperature rise margins are displayed using only ambient air and the natural air flow around the rectifier bridge compartment for cooling. It was noted that Mountain Creek #8 system has non-vented doors, so all air flow comes from within the generator doghouse.



Schematic of New Convection-Cooled Bridge
 FIGURE 4



Temperature Rise at Various Current Levels of a Single Bridge
 in Parallel with Other Rectifier Bridges
 FIGURE 5

The new 5 pole disconnect switch design offered a bolt action type design that ensures equal pressure on all stabs during switch closing operation; if the disconnect switch were opened, equal tension would be ensured unlike the binding that could occur with the original knife switch

operation. Three poles are provided for the three (3) phase input and two poles for the F+, F- connection to the field. AC Input and DC Output both opened at the same time in one switch operation.

The new switch is bus bar connected to the existing horizontal bus via links. To keep the system electrically safe, the new disconnect switch has a clear plastic shield that keeps the operator from touching any potentially hot areas on the disconnect switch when the rectifier door panel is open. The new Disconnect Switch is designed as an actual "Load Break Interrupter" that was fully tested to ensure that it could break 2000 amperes. Other concerns today involve opening the disconnect switch in an exposed high voltage area. Here, the new Basler system allows for opening the disconnect switch with the rectifier panel door closed. An extension of the disconnect switch handle allows for it to be fed through the front door, one for each rectifier bridge. Hence, it reduced Arc Flash hazard and provides a safer barrier of separation between the operator and the disconnect switch. The new disconnect switch also includes a Kirk Key Switch interlock to lock out the switch should it be opened.

RTDs are embedded "into" the double insulated extruded heatsinks to monitor temperature of the conducting diodes. The RTDs are connected to an RTD relay with a 5000 V Teflon patented insulator design, six for each rectifier bridge. Three power fuses, one for each phase is I_2^t coordinated with the power semiconductors to fail before the diode, and a RC snubber circuit for the ac input is supplied.

An alarm display panel is provided for each rectifier bank that includes an ammeter to monitor rectifier bridge current, a RTD lamp to alarm bridge over temperature and three lamps, one for each phase to illuminate should a power semiconductor short and fail a fuse. Last, there is a lamp that indicates whether the disconnect switch is open or closed.

TABLE 1
Electrical Data Characteristics

| | |
|--|--|
| DC RATING | Bridge Voltage rating |
| • 2000 Amps continuous, natural convection cooled | • 0-600 VAC |
| Diode Rectification | Five Pole Line/Load Disconnect Switch (Optional) |
| • General purpose disk (puck) type silicon diodes | • New drop-in replacement provided |
| • Diodes are compressed between aluminum heatsinks, offering double-sided heat transfer. | • Full load break capability |
| • Diode average current: 5380 A | • Continuous rated at 2000 Amps, 1000 Volts AC and DC |
| • Diode repetitive peak forward and reverse blocking voltage: 2800 V | • Lab certified tested, opened under full load with two switches in parallel |
| • I_2^t for fusing: 20.34 x 106 A ² sec | • Extended through the door handle for operation of switch outside "doghouse" enclosure |
| • High surge current (IFSM): 70kA | • Standard Kirk key lockout and auxiliary contact provided |
| • Maximum junction temperature: 175 °C, less demand for cooling | |
| • Silicon wafer diameter: 78mm | R/C Snubbers |
| • Quantity supplied per bridge: 6 | • Capacitors: 2100 VAC, 0.22μF, Oil filled industrial |
| | • Resistors: 250Ω, 55 Watt |
| Diode Clamp | Fuses |
| • Double insulated | • Qty 3 semiconductor fuses with blown fuse indicators |
| • Tested to 10kV Isolation | • Fuse Voltage rating: 1000 VAC |
| • Provides a double failsafe mode | • Fuse Amperage rating: 2400 AMP |
| • Built-in force indicators | • Selected to clear before the diodes short. |
| | |
| Designed Ambient: 50 °C | Control Terminal Strips |
| • Convection cooled, no fans | • NT style - 1000 Volt rating |
| • High reliability due to robustness of convection-cooled design | • Terminal connections for individual RTDs and blown fuse indicators |
| | |
| Overload Rating | Thermal Detection |
| • 250% overload for 30 seconds | • Teflon body, patented design, Resistance Temperature Detectors (RTD), strategically located near each diode junction |
| | • Supplied as standard |
| | • More accurate and faster temperature reading |

SOLUTION

The evaluation involved corresponding with a number of end users who purchased replacement bridges to obtain their feedback and review site data of recorded RTD temperature data of the bridges where it was available [2]. The decision was made that the best solution was the new Basler Electric Company convection-cooled bridges. The delivery lead time of the bridges was 6 weeks that coordinated with the outage schedule. Prior to shipment, the bridges were heat run tested at the factory for 2000 amperes until the temperature stabilized after approximately two (2) hours. The test applied full rated current at a reduced voltage to all four (4) bridges connected in parallel. See Figure 6. The importance of this test was to provide confidence in the bridges operating at the rated current, since Mountain Creek Unit #8 would not be at full capacity until a much later time in summer peak load season after the outage. Table 2 provides a sample of the starting temperature and final temperature of one of the tested rectifier bridges. Besides the full current capacity test, oscilloscope waveform information was gathered to verify that the diode bridge was at 100% conduction. Data shows 2.8 ms between each peak for a three phase full wave bridge. See Figure 7.



Test Setup of 2000 Ampere Heat Run
FIGURE 6

TABLE 2
Heat Run Data of One of the 2000 Ampere Bridges

| Thermocouple Locations ► | | AP Phase A Positive Heatsink | AN Phase A Negative Heatsink | BP Phase B Positive Heatsink | BN Phase B Negative Heatsink | CP Phase C Positive Heatsink | CN Phase C Negative Heatsink | Ambient Top of Unit |
|--------------------------|----------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|---------------------------|
| Date | Time | CH 1 Deg. C | CH2 Deg. C | CH3 Deg. C | CH4 Deg. C | CH5 Deg. C | CH6 Deg. C | CH7 Deg. C |
| 02/06 | 07:21:10 | 20.1 | 20.1 | 20.1 | 19.9 | 20.1 | 20.0 | 19.6 |
| 02/06 | 09:55:10 | 87.0 | 90.7 | 88.5 | 91.4 | 94.7 | 98.7 | 23.1 |



Three Phase Full Wave Bridge Output Waveform
FIGURE 7

The new bridges were received with a certified test report from the manufacturer. The outage lasted for 7 days and a four-man team from local electrical contractor was assigned for the tearout and install of the new bridges. The demolition began on Saturday; it took one day to remove the copper water lines, the rectifier bridges, knife switches, and to cap the incoming water lines. The resultant demolition was a huge pile of fuses, bridges, and switches as space was prepared for the new hardware. The tearout was fast and expedient. See Figure 8 for sample of removed hardware. Shortly after the demolition was complete, the installation of the new convection-cooled bridges and new switches commenced. The drop-in air cooled bridges were located into the same mounting holes as the previous bridges. The new disconnect switch mounted above the new rectifier bridge using the same mountings as the previous hardware. A shipped-loose symmetrical three phase snubber circuit consisting of three power resistors and three industrial grade oil filled capacitors connected across the each power diode. The snubber circuit provided a means to eliminate switching harmonics caused by diode commutation.



Old Disconnect Switch and Fuses Removed
FIGURE 8

Figure 9 shows a photograph of the Stator and Alterrex deionized water cooling system. The new convection cooled Alterrex bridges eliminated the need for water lines going to the Alterrex doghouse located at the back of the generator housing. The “In” and “Out” water lines going to the Alterrex bridges were abandoned and capped, hence eliminating maintenance issues involving false field grounds and leaky water hoses. The results of these changes were improved reliability and reduced downtime.

Since water was no longer required for the new convection cooled bridges, the water cooling system provided increased availability of deionized water for the generator stator cooling system. The Alterrex cooling water flow transmitter and other related instrumentation and control is no longer needed means less equipment, less maintenance, and more reliability.



Generator Stator and Cooling Water System, Alterrex “In” and “Out” water lines are capped for retrofit to new Convection Cooled 2000 Amp Bridge System

FIGURE 9

Shortly after the demolition was complete, the installation of the new convection cooled bridges and new switches commenced. The drop-in air cooled bridges were located into the same mounting holes as the previous bridges. The new disconnect switch mounted above the new rectifier bridge using the same mountings as the previous hardware. A shipped-loose symmetrical three phase snubber circuit consisting of three power resistors and three industrial grade oil filled capacitors connected across the each power diode. The snubber circuit provided a means to eliminate switching harmonics caused by diode commutation.

At time of installation, it was decided to have additional indication of the semiconductor fuse monitor and RTD relay. Here, four (4) relays were added, one for the hottest temperature RTD relay output and three for each blown fuse indicator. Since the panel to contain this requirement was decided at time of install, two days were spent creating the panel and wiring it into the available space. See Figure 10.



Temperature Relays and Remote Annunciation
FIGURE 10

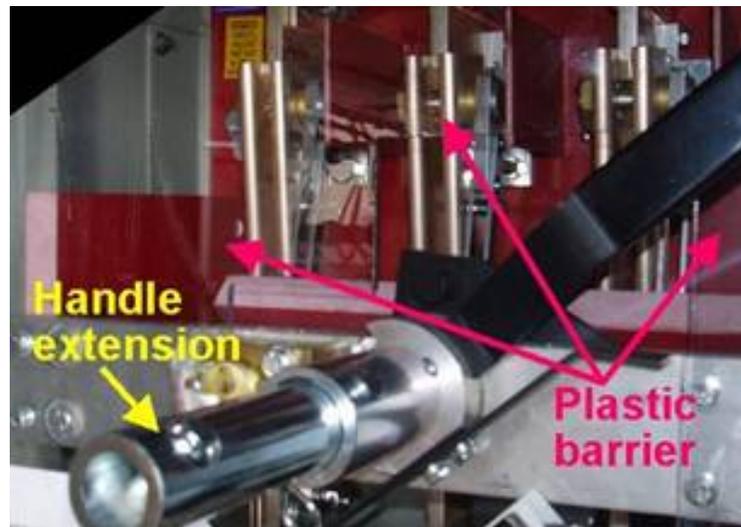


New Bolt Action Disconnect Switch and Convection-cooled Bridge
FIGURE 11

With the new bridges and disconnect switches installed, bus bar links were customized to tie the horizontal bus to the new connecting disconnect switch. One day was used for bus bar measurements, and the next day the links were fabricated. See Figure 12. A new clear plastic shield was provided as a cover for live electrical parts. See Figure 13.



New Bus Bar Links for Connection between Disconnect Switch and Existing Bus
FIGURE 12



New Clear Plastic Operator Protective Shield over Disconnect Switch
and Extended Shaft Coupling
FIGURE 13

To allow the new disconnect switch to be opened with the door closed, a center hole was drilled using a template measurement scale. See Figure 14.



Center Hole for Outside Disconnect Switch
Drilled by Local Electrical Contractor Technician Shermco Industries
FIGURE 14

A new Alarm Panel was installed for the front of each enclosure door which included an Ammeter, three (3) status lights for fail semiconductor fuse indication, one lamp for High Temperature Alarm, and one lamp for Disconnect Switch Status. See Figure 15.



Display Alarm Panel and Hand Disconnect Switch
FIGURE 15

By Friday, the seventh day, the installation was complete and testing verification of the installed rectifier bridges began. All new connection bolts were torqued based upon a provided chart. A Digital Low Resistance Ohmmeter (DLRO) was used to determine resistance of each bolt connection. See Table 3. Note the micro ohm meter registered a maximum of 29 micro ohms.

TABLE 3
Testing of Bolt Connections

| Bridge # | Switch Stabs, in micro ohms | | | | |
|----------|-----------------------------|------|------|------|------|
| | +VC | A | B | C | -VC |
| 1 (NE) | 23.2 | 22.7 | 21.3 | 26 | 22.2 |
| 2 (SE) | 26.9 | 24.7 | 22.5 | 27.6 | 23.9 |
| 3 (NW) | 27.3 | 22.9 | 20.5 | 28.4 | 24.3 |
| 4 (SW) | 28.8 | 25.3 | 24.3 | 29 | 26.3 |

The new disconnect switches were tested for proper open and closed operation. A three phase variac was applied into each bridge ac input with a power resistor as a burden across each bridge output to verify full-wave rectification at the output.

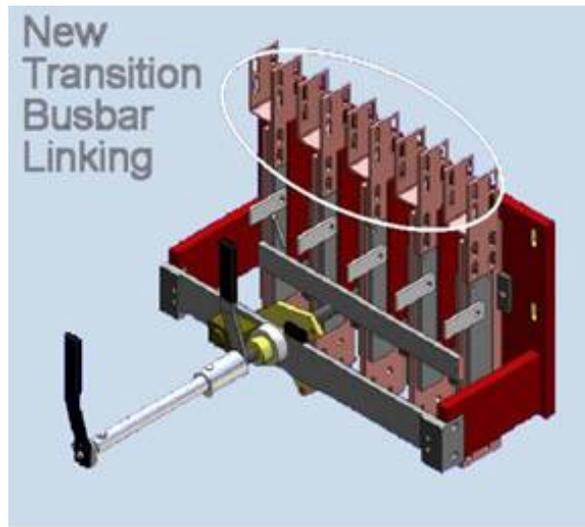
On Saturday, the eighth day of the outage, the install was complete and the equipment was released back to the plant. See Figure 16. After Unit #8 was released, sometime later full load operation occurred, and the RTD relays were calibrated, based upon collected operating temperature of the bridges. Final calibration for the RTD relays was set for 125°C temperature (Maximum Design Rated Temperature 175°C). Any higher temperature would alarm, indicating excessive bridge thermal conductivity. Figures 15 and 16 show front views of the “extended outside handle for the disconnect switch operation” with the front panel meter display.



System Line-up of the SW Panels with Rectifier Panel Doors Closed
FIGURE 16

OBSERVATION

Creating bus bar links to transition between the disconnect switch and the horizontal bus slowed the project. Today, the bus bar links are part of the disconnect switch assembly, so it will no longer require a custom fabrication at the job site, saving installation time. See Figure 17.



New Disconnect Switch with Connecting Links Now Provide for Easier Installation.
No Special On-Site Customization Required.

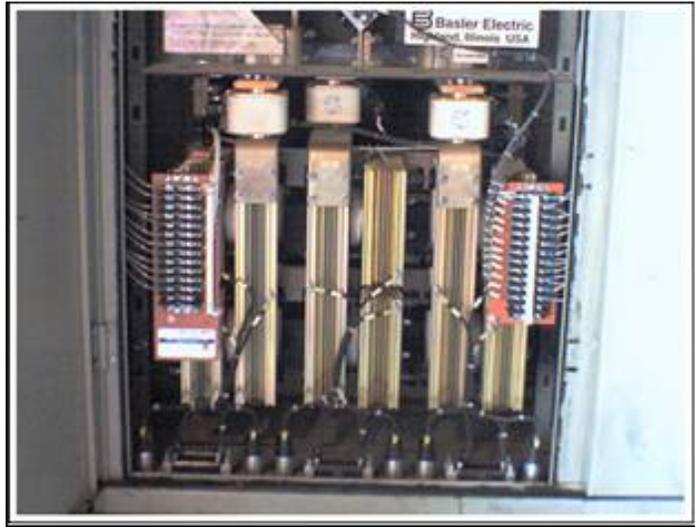
FIGURE 17

A factory heat run of the four (4) bridges at 2000 amperes can be valuable for those machines that may not be reaching full capacity for many months after install. Here, confidence in the project can be fulfilled by a factory certified test run.

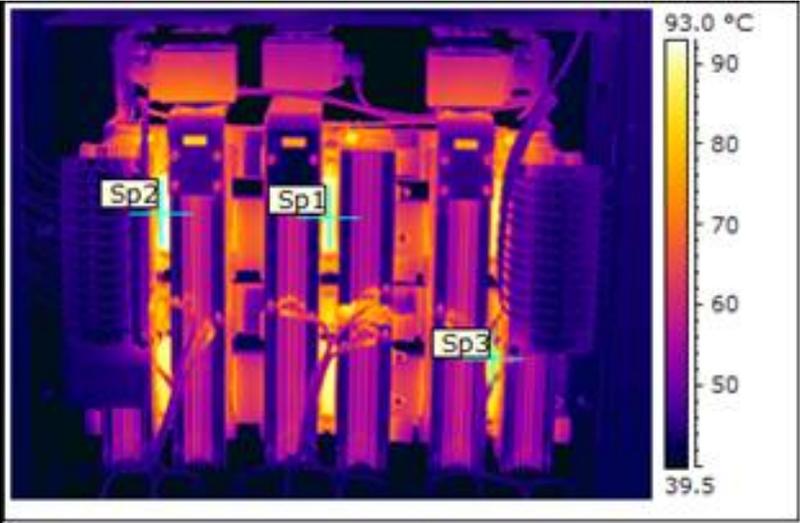
Additional relay alarm contacts were added at the job site to meet site specific requirements. For future projects, this panel could be prewired and ready for installation.

PERFORMANCE DATA

Figures 18 and 19 highlight performance data of Mountain Creek #8 SW Bank #4 operating at full load rated power factor on one of the four rectifier bridges. In Figure 18, the rectifier current for each of the four bridges is 760 A DC, where the maximum rating of each bridge is 2000 A DC. Referencing back to Figure 5 temperature data graph, where a bridge is operating at approximately 800 Amps, the expected total temperature of the bridge would be about 90° C for a 50° C ambient temperature. Note in Figure 19 how closely the actual temperature being measured correlates with the expected performance goals for Figure 5.



Rectifier Bank SW Bank # 4 operating at 760 A DC (Max Rating of 2000A)
 FIGURE 18



| | |
|-----------------|------------------|
| Date | 6/16/2009 |
| Sp1 Temperature | 90.5°C (194.9°F) |
| Sp2 Temperature | 92.5°C (198.5°F) |
| Sp3 Temperature | 87.5°C (189.5°F) |

Rectifier Bank SW Bank # 4 operating at 760 A DC (Max Rating of 2000A)
 showing heat sink temperatures for each phase (1-2-3)
 FIGURE 19

ROTOR TEMPERATURE

The water-cooled system removed watt losses via the stator water cooling exchange while the convection-cooled bridge's heat losses were via the porous areas of the generator doghouse. Data was correlated from past history of rotor field amps and volts, MW and vars, ambient temperatures noting any significant changes that affect the rotor temperature by reviewing the calculated resistance change.

Table 4 shows the results of a number of different data points over a six year period. The new convection-cooled bridges were installed in 2008.

TABLE 4
Rotor Resistance Before and After Convection-Cooled Bridge Installation

| Year | Ambient Temperature | MW | Mvar | Main Field Amps | Main Field Volts | Rotor Field Resistance | Exciter Housing Ambient Temperature |
|------|---------------------|-----|------|-----------------|------------------|------------------------|-------------------------------------|
| 2005 | 98°F | 586 | 5 | 3390 | 278 | 0.0820 | 48° C |
| 2006 | 95°F | 572 | 24 | 3401 | 282 | 0.0828 | 51° C |
| 2007 | 92°F | 579 | 48.7 | 3467 | 287 | 0.0829 | 48° C |
| 2008 | 98.5°F | 580 | 44 | 3401 | 283 | 0.0834 | 51.5° C |
| 2009 | 94°F | 582 | -5.6 | 3405 | 281 | 0.0826 | 48° C |
| 2010 | 103°F | 582 | 31 | 3490 | 292 | 0.0836 | 53.4° C |

* Shaded area indicates data collected after new convection-cooled bridges were installed.

Using the rotor temperature data history above, based on the calculated resistance change, it is difficult to ascertain that a warmer environment exists with the convection bridges installed.

II. ALTERREX VOLTAGE REGULATOR REPLACEMENT

Just as the Alterrex water-cooled bridges have come to their end of life, the same is true of the voltage regulator that drives the rotating exciter shunt field to regulate the generator output voltage. Today, because of reliability concerns, extensive NERC testing compliance, and obsolescence of the existing system, replacing the voltage regulator becomes a logical choice.

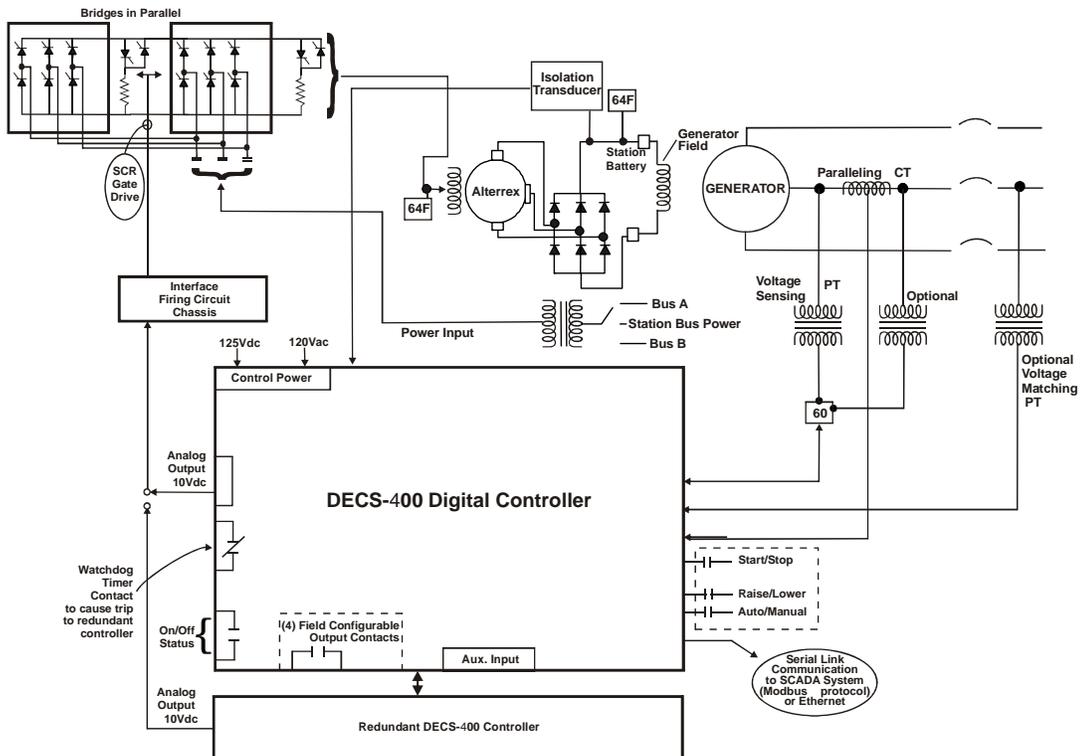


New Digital Voltage Regulators Mounted in Cabinet
FIGURE 20

In defining the voltage regulator, much has changed from the basic voltage regulator function of the past. Today, in addition to the basic voltage regulator and manual control function provided, other functions include:

- 0.25% voltage regulator
- Field Current Regulator
- Excitation limiters; Minimum & Maximum
- Volt/Hertz limiter
- Voltage matching
- Autotracking for bumpless transfer between automatic voltage regulator (AVR) and manual control
- Power system stabilizer, Type 2B, Integral of Accelerating Power
- Oscillography and Sequence of Event information for data capture
- Communications: Ethernet or serial port

The above functions represent the typical features of most excitation systems today. Accompanying these basic features for large machines are additional enhancements to provide a more fault-tolerant control system. See Figure 21.



Block Diagram of a New Excitation System
FIGURE 21

EXCITATION REDUNDANCY

Figure 21 illustrates a typical excitation system with complete redundancy of the voltage regulator and rectifier bridges. Note that each digital controller contains all the features described above. A monitoring system is included that monitors the output parameters of the primary digital controller. Should an issue be detected within the primary channel, an automatic transfer occurs forcing control to the backup channel in order to maintain constant voltage regulation.

Along with the dual-channel controllers, redundant power rectifier bridges are provided. Each rectifier bridge consist of six (6) SCRs to control the exciter shunt field, accompanied by RC snubbers, an exciter field discharge circuit and ac power interrupt. The power rectifier bridges are 100% rated output. If a bridge power fuse should fail, the backup bridge immediately picks up the balance required to meet the field requirements. The rectifier bridge is designed to provide 200% field forcing into the exciter shunt field.

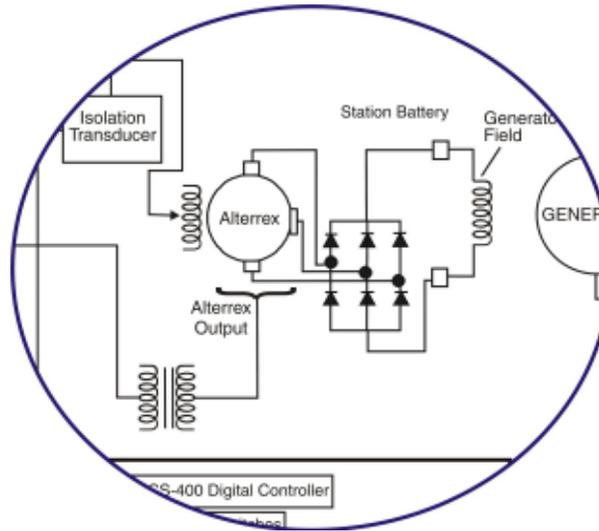
REDUNDANT VOLTAGE SENSING INPUT

Manual control has been the typical backup method used in the event of a failed sensing fuse for the voltage regulator instrument transformer (VT). Today, a backup set of instrument VTs are utilized for the voltage regulator sensing inputs. Should a VT fuse fail, the system will transfer to the alternate set of VTs to allow the excitation system to continue operating in voltage regulator mode. A voltage balance relay or internal function is used to accomplish this.

PERFORMANCE

The existing Alterrex voltage regulator obtained operating power from the output of the Alterrex exciter to provide power into the SCR rectifier bridge. [3] As the power output from the

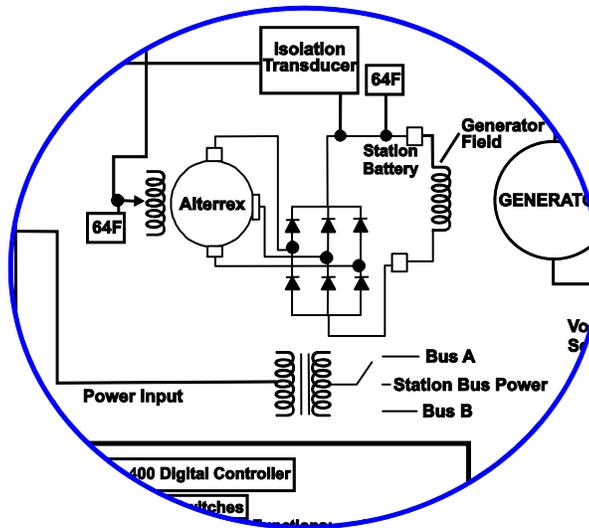
Alterrex exciter varies, so will the power input to the rectifier bridge. This affects the level of field forcing available to drive the exciter shunt field. See Figure 22.



Alterrex Power Output Driving the Excitation Rectifier
FIGURE 22

When the generator voltage dips due to a system disturbance, so also does the rectifier bridge field forcing that comprises the system voltage response. This causes a slow voltage recovery.

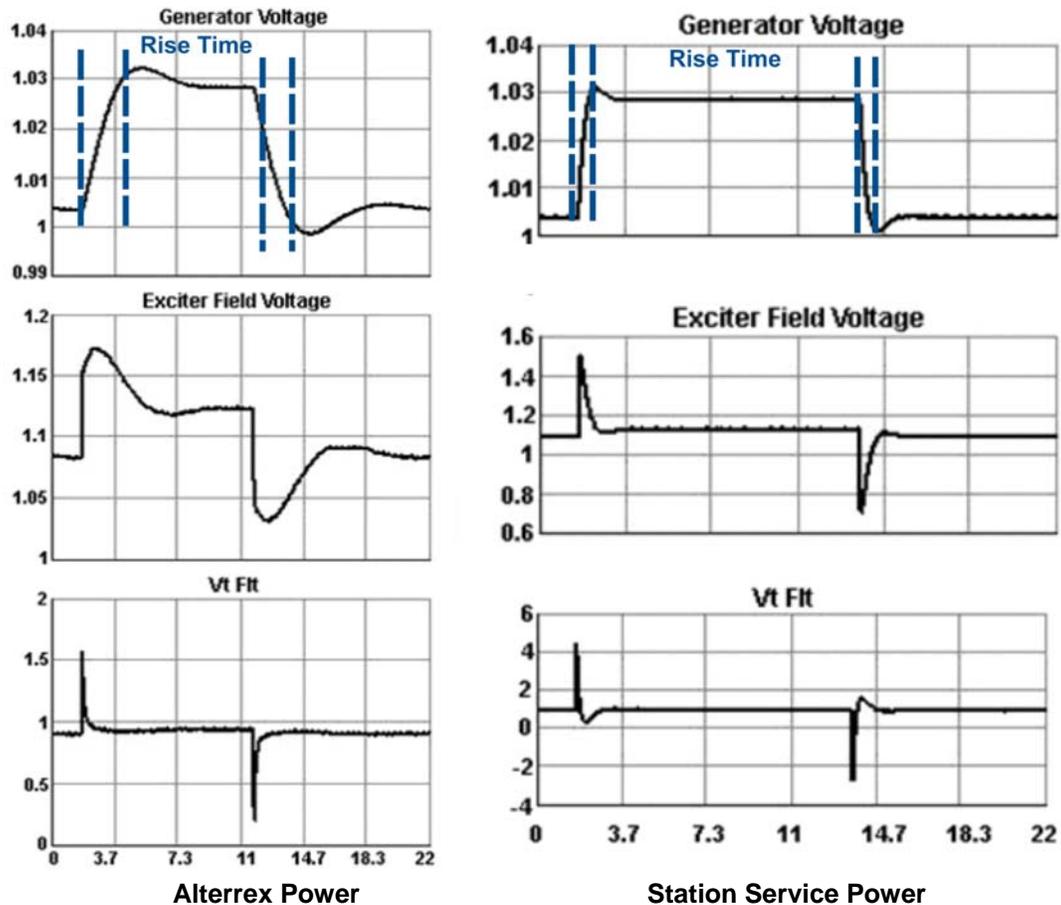
Figure 23 illustrates the recommended solution to provide the best performance for generator voltage response. Here, the excitation power source is derived from station power. For additional reliability, two power sources are utilized. If one power source goes away the other power source is available to immediately provide power to the rectifier bridge. An automatic transfer switch is used to make this transfer with a very short cycle time to avoid any bump at the machine output.



Excitation Powered by Station Power
 FIGURE 23

Figure 24 shows the comparison in voltage system response between the existing Alterrex power output and a new digital excitation system utilizing station power. [4]

With the old excitation system, a +2% generator voltage step is introduced with the generator circuit breaker open. Notice the generator voltage rise time is very sluggish at 2 seconds as it attempts to voltage recover. The digital controller, however, with the same generator voltage step applied has only 0.2 second voltage rise time. For a -2% voltage step down, the generator voltage has an approximately 3 second decay time versus the new digital AVR that provided a 0.3 second decay time. Noted in Figure 24, the type of power source dictates the AVR response. Station power provides the best solution, especially when a power system stabilizer is needed.



Slow AVR Response Using Alterrex Output Compared to New Digital Control using Station Power

FIGURE 24

TABLE 5

Performance Data of the Power Sourcing Types in the Alterrex Excitation System

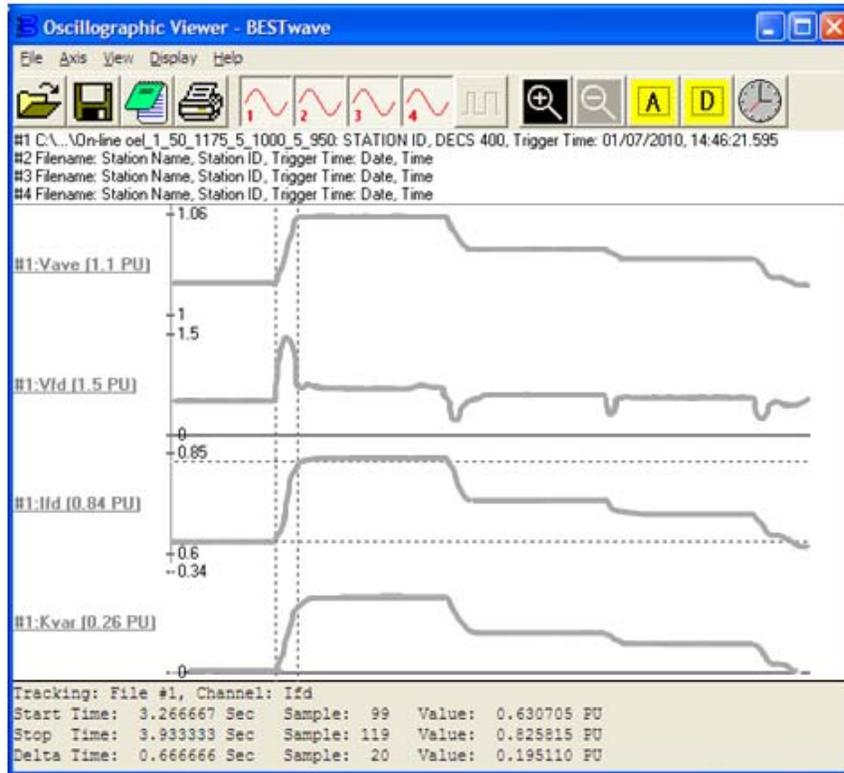
| Generator Open Circuit Step Response | | | |
|--------------------------------------|-----------------|------------------|------------------|
| | AVR Power | +2% Voltage Step | -2% Voltage Step |
| Alterrex AVR | Alterrex Output | 2 Seconds | 3 Seconds |
| New Digital AVR | Station Power | .2 Seconds | .3 Seconds |

MAIN FIELD CURRENT MEASUREMENTS

To further modernize the Alterrex excitation system for better control, the new excitation system measures the main field current directly from the generator rotor for the maximum excitation limiter (MML). No longer is it required to measure the exciter shunt field current and estimate the main field current to hopefully achieve adequate main field current limiting, instead an isolation transducer is located on the main field that provides input data of both the main field current via a shunt and field voltage measured directly across the rotor output. See Figure 25.

While the voltage regulator is applying power in the exciter shunt field, the voltage regulator is acting upon the exciter field current for regulating the maximum field current. Figure 26

illustrates the maximum excitation limiter performance during a system validation test. Notice that the MML responds in only 0.666 seconds with no over or under overshoot of either the main field current or generator reactive current.



Over Excitation Limiter Testing
FIGURE 26

With the field current measurement obtained from the generator rotor, the manual field current regulator set point is based upon regulating the main field current as the standby mode even though the voltage regulator is driving the exciter field.

III. CONCLUSION

Today, the convection-cooled Alterrex bridges have a proven track record to replace the conventional Alterrex water-cooled bridges.

Since the installation in March 2008, the Mountain Creek plant has been up to full load and the new convection-cooled bridges have demonstrated successful operation. Plant personnel are pleased with the new equipment that eliminates the hassles and issues of the water-cooled bridges.

The Alterrex voltage regulator replacement is an equally important factor to consider for upgrade to provide reliable continuous power for generation plants.

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AUTHORS' BIOGRAPHIES

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