Lakeland Electric McIntosh Power Plant GE Frame 5 Controls Upgrade

TurboNet *DASH 1*® Control System Conversion

Presentation

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&
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Presenter:
Ernesto Colon – Vice President, Turbine Diagnostic Services Inc.

Ernesto is the Vice-President of Turbine Diagnostic Services Inc. (TDS). TDS is a turbine generator field engineering service company. TDS maintains a staff of engineers that specialize in steam and gas turbine generator mechanical maintenance, turbine controls troubleshooting/upgrades, generator excitation troubleshooting and upgrades, vibration analysis & balancing, operational performance inspections, and customer training. TDS has created the TurboNet *DASH 1*® line of controllers that specifically designed for the capability of controlling steam and turbines. The TurboNet *DASH 1*® has proven its reliability, versatility and flexibility time and again since its first installation in 2003. The TurboNet *DASH 1*® has been successfully applied to steam turbines applications for straight condensing, single automatic extraction, and double automatic extraction machines. The TurboNet *DASH 1*® has been applied on a GE MS5001 gas turbine and reciprocating emergency diesel generators as well. Ernesto is the designer and developer of the TurboNet *DASH 1*® control system.

Ernesto earned his BSME from Purdue University in 1992. Ernesto was hired by GE Power Systems in 1992 and entered the Field Engineering Program. He successfully graduated in 1993 and was assigned to the Chicago office. In 1994 he transferred to the GE Power Systems Tampa office where much of the gas turbine DLN system field testing was occurring. Ernesto worked as a controls engineer helping to install and commission DLN1, DLN2, IGCC and a synchronous condenser for GE. Ernesto left GE in 1999 to form Turbine Startup Services and joined forces with Mr. Ron Rubrecht to establish TDS as an expert company on steam and gas turbine generators and their operation and control functions.

At TDS, Ernesto has provided a multitude of deferent steam and gas turbine field support functions from mechanical maintenance, turbine controls troubleshooting and upgrades, excitation system troubleshooting and upgrades and operational & vibration troubleshooting. Ernesto is expert in steam and gas turbine generators. Aside from the field service support roles, Ernesto has designed and written all the code to produce a world class turbine generator control system, the TurboNet *DASH 1*®.

Should you have any questions for Ernesto, please contact him at:

Forward

Lakeland Electric and the McIntosh Power Plant Staff are proud to be co-authors and contributors of this paper with Turbine Diagnostic Services, Inc.

In 2008, Lakeland Electric implemented a control system upgrade to their Combustion Turbine, "MAC GT", at their C.D. McIntosh Jr. Power Plant located in Lakeland, Florida. The combustion turbine was a GE MS5001 with a GE EHC Mark 1 Speedtronic Control System. The unit had originally been supplied by GE as a liquid fuel only gas turbine. Lakeland Electric subsequently had added gas fuel operational capabilities in the mid 90's using a single electric servo driven motor direct coupled to a Fisher gas control valve and a low pressure hydraulic gas fuel stop valve. The system then became a hybrid control system where a PLC was responsible for the gas valve operation and the original GE EHC Mark 1 Speedtronic control system controlled the rest of the turbine. At the time of installation, Ron Kremann was the City's Engineering Manager and Ernesto Colon was TDS's Lead Engineer for the TurboNet *DASH 1*® control system installation and commissioning.

Lakeland Electric engineers were tasked with improving the reliability of their 22 MW Frame 5 gas turbine, known as the "MAC GT", before the hurricane season started.

While the modified Speedtronic system worked when new, it was suffering from reliability issued in 2008. The machine virtually would not start without controls technician support at each attempt. The reliability of the machine had dropped to around 5% as reported by the plant.   Some issues were related to the aging Mark I cards, and some were related to the electric servo driven gas control valve.

An outage was planned after a short cycle manufacturing of the TurboNet *DASH 1* ® Control System produced by Turbine Diagnostic Services, Inc., and the unit was upgraded to a new turbine controls and new generator controls. This included a complete gas control valve upgrade, a complete Frame 5 package rewiring, a new generator protection panel with a SCT-PPT excitation system upgrade, all of which were integrated into the TurboNet *DASH 1* ® control system. This was done on an expedited basis to return the unit to an available and reliable status before the onset of the Florida hurricane season in June of 2008.

In this presentation, we will discuss the upgrades made to the unit, the design philosophy of the turbine control system, and the main lessons learned in the GE EHC Mark 1 Speedtronic Control System upgrade conversion to a new TurboNet *DASH 1*® control system. Recommendations are presented for other users who are operating on older control systems. This presentation will discuss the unit availability and reliability since it was installed as compared with conditions before the upgrade. Items which challenged the project will be discussed, which components required repair or replacement, and solutions which will help other GE Frame 5 GTG users navigate a similar outage when necessary.

After the upgrade of the Frame 5 at McIntosh, the plant contracted with TDS to provide TurboNet *DASH 1* ® controls for their two EMD emergency diesel generators. One TurboNet *DASH 1*® control panel was provided to control both of the plant's emergency generators. This EMD TurboNet was tied into the TurboNet data highways already in place on the site for the "MAC GT". This allowed for the common use of Human Machine Interface (HMI) stations, common Engineering Work Stations (EWS), and common use of the TurboNet Historian installed for the gas turbine application. The EMD generators were also upgraded with similar excitation system upgrades and generator controls as was provided for the "MAC GT".

TurboNet was built for our users and to provide our users with the ability to conduct any and all troubleshooting, tuning, or enhancements as determined necessary by the owner. Lakeland Electric was one of the few TurboNet *DASH 1*® owner/customers to take the initiative of learning the TurboNet *DASH 1* ® system to provide their own in house troubleshooting and service capabilities. Over the past 9 years, Lakeland Electric was self-sufficient in supporting their control system service until recently as support recourses were spread thinner. Lakeland Electric has indicated, the "MAC GT" has had an improved reliability, being available and reliable 95% of the time with of the lacking 5% from factors mostly outside the TurboNet *DASH 1* ® control system. The plant indicated that the TurboNet *DASH 1* ® has been neglected for several years and the machine continues to run reliably.

Turbine Diagnostic Services, Inc. would like to thank Lakeland Electric and McIntosh Power Plant personnel who supported TDS in this project and for contributing in the joint efforts of putting this presentation together.

The Basic Architecture of TurboNet *DASH 1*®
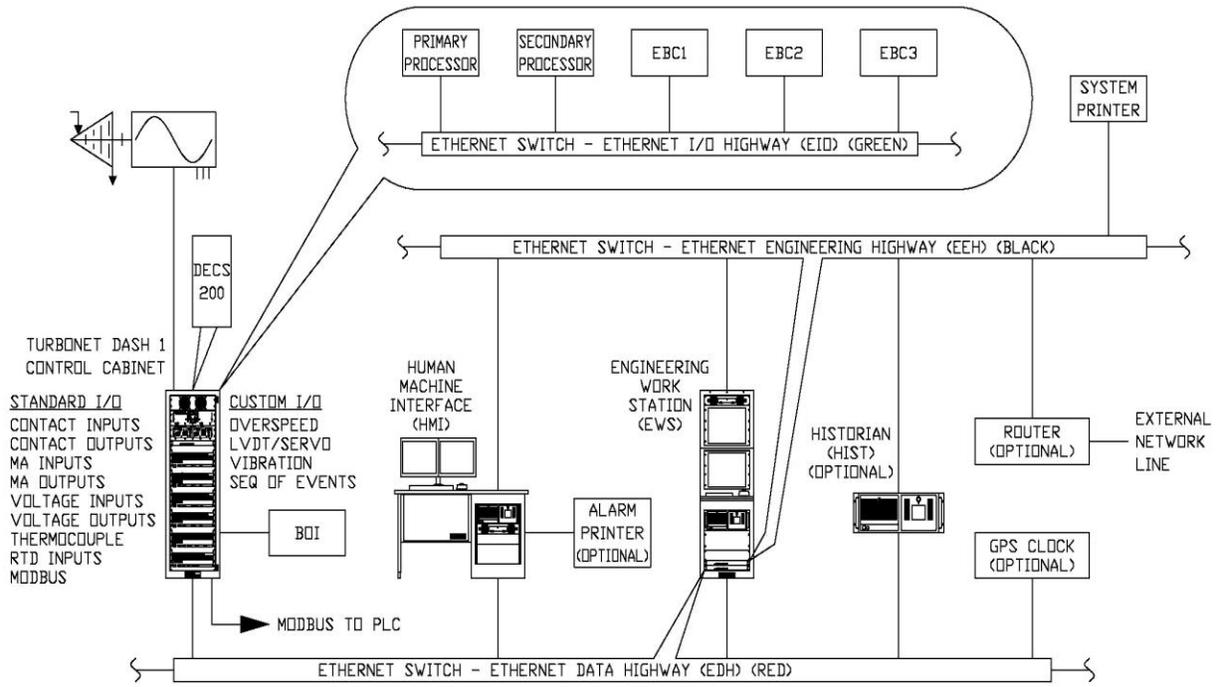
TurboNet DASH 1® **Architecture**

The TurboNet *DASH 1* ® control system is structured around segmented networks. The Ethernet IO Highway (IOH) is shown at the top of the diagram. This network is where all the IO modules are connected, as well as the two control processors and optional communications co-processors.   This is an isolated network that exists only to communicate with IO modules. This isolation ensures that no disturbance will happen in module communications.

The Ethernet Data Highway (EDH) is shown at the bottom of the diagram. This network connects all the TurboNet controller processors to the Human Machine Interface (HMI), Engineering Work Station (EWS), Historian and GPS clock.   Only control data, diagnostic data and the occasional configuration downloads go through this network. Communications on this network are synchronized to ensure no device completely hogs the available bandwidth. This ensures that the network will always be available for communicating data and commands.

Shown in the middle of the diagram is the Ethernet Engineering Highway (EEH). This network is dedicated to the balance of communications between the different processors, with additional optional printers. If the plant decides that they want the TurboNet Remote Cyber Link (RCL) for remote monitoring capabilities of the system, the connection would be made through the EEH. This network can be connected and shared with the plant.

All the field wiring comes in to specially designed termination boards. These boards provide signal type specific protection, such as transient voltage protection, arc suppression, fuses, as well as shield terminations points. Most TurboNet *DASH 1*® termination boards are designed to accept terminal lug connections. This allows the use of "real world" power plant wiring (AWG12 and 14) without issues.
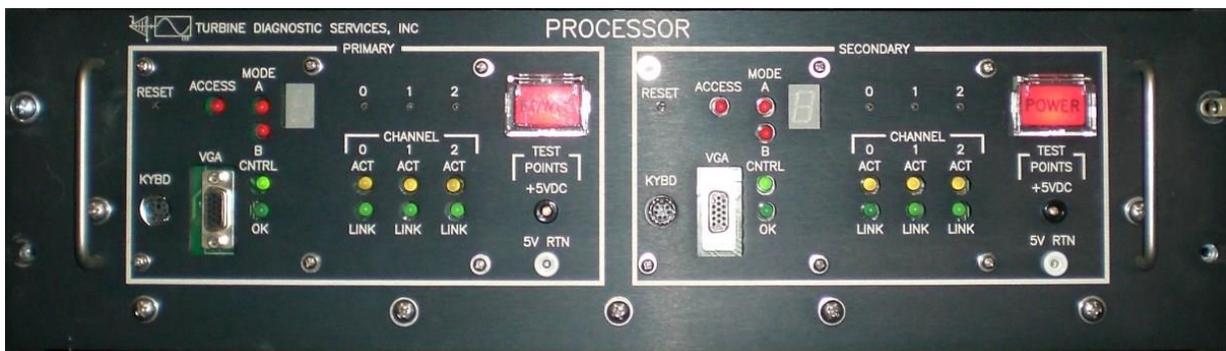
The signals are then sent from the termination board to the IO modules for processing. This is done through an identical connectorized multi-conductor cable from each termination board to the associated I/O module where the factory I/O base wiring arrangement determines the cable function. The modules send data to the processors for further analysis via Ethernet Based Controllers (EBC). The control processor then sends the data over the Ethernet Data Highway to the HMI, EWS, and Historian, and through Modbus links to the plant's DCS. If configured, the data then passes through these components to the Ethernet Engineering Highway where a router can allow for external access, allowing remote troubleshooting.

Hardware Improvements

Redundant Control Processors

The TurboNet *DASH 1*® control processors are contained in their own custom chassis. The redundant control processors each have an on board power supply contained in the chassis that is powered by the system's 24 VDC power distribution of the redundant TurboNet *DASH 1*® system power supplies.

The processor chassis contains a fan for the cooling of the processor. The processor itself is cooled by a fan-less oversize heat sink. The processor chassis sits on a shelf in the 19" rack that can be pulled out to allow for access to the processor chassis for maintenance on or off-line. This maintenance requires the removal of the top cover plates, disconnection of several connectors and removal of four screws to swap the processor boards.


Redundant Control Processor

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Redundant Control Processors

The redundant control processors consist of two Advantech Single Board Computers with Pentium III processors. These processors operate on LYNX OS - Hard Real Time Operating System by Linuxworks Inc.. The control processors have a 20ms I/O Scan Rates & Sequence Processing Time. A Flash Card with all of the unit specific programming stored eliminates the Hard Drive and associated hard drive failures. The processor watchdog timer triggers a swap of controlling processors if the processor is not detected on two consecutive scans and swaps control to the standby processor on the third scan with a 50ms Swap Time on Failure of the Controlling Processor.

This original TurboNet processor chassis has a VGA and Keyboard connection for factory interface of the two processors which is not intended for field use. The chassis has a numeric display that provides output alarm codes for identification of faults. The processor has status lights to indicate that it is on, communicating, and in or out of control. There is also a test point for the 5 volt DC processor power supply for each.

This processor board used for the first generation of control processors has been very reliable and TDS has never had a failure of this component over the past 15+ years they have been in service.
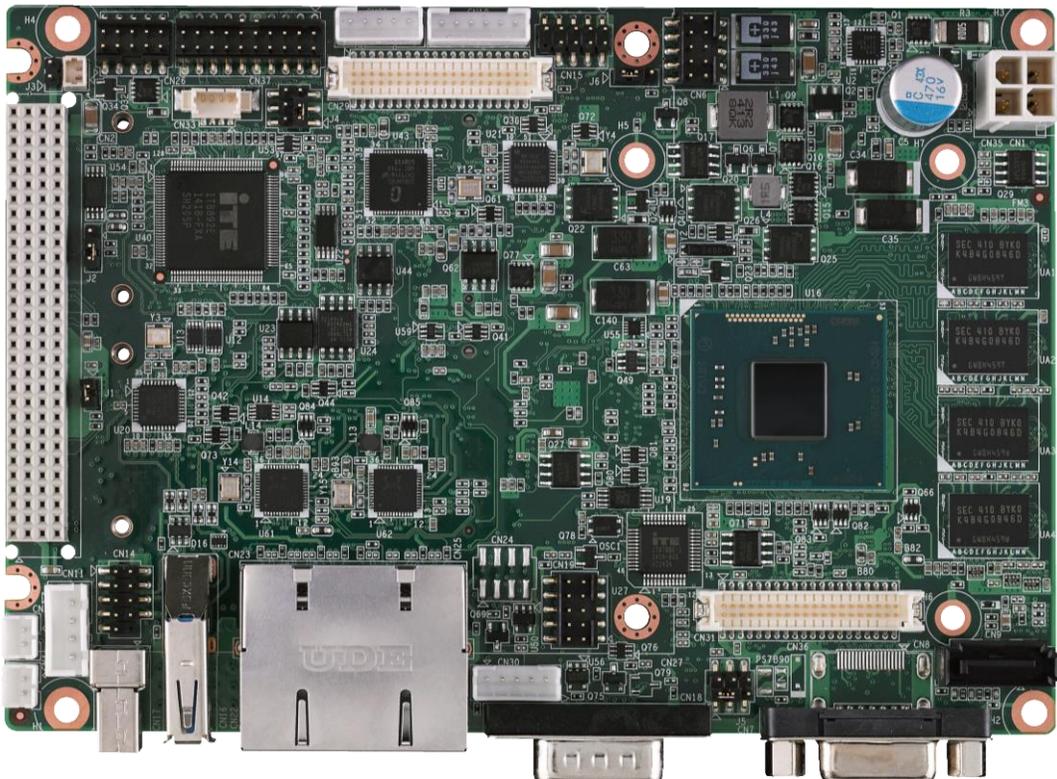


Advantech Single Board Computer

The originally supplied Advantech single board computer has been obsoleted. Without knowledge of future product offerings to replace this board, TDS decided to have a custom single board computer manufactured just for TurboNet *DASH 1*® and now supersedes the original control processor chassis with a new TurboNet *DASH 1*® processor chassis. The new chassis features "card" style processors that can be pulled from the front for servicing.

Triple Modular Redundant Processor Chassis

This processor chassis is constructed currently for a primary processor and a stand by processor, as pictured. This new processor chassis has a third processor slot which is currently unused. This slot has been included for a TurboNet *DASH 1*® Triple Modular Redundant Processor Chassis for future use. (TDS already has the TMR processor chassis which volts 1500 points at a scan rate of 50hz/20ms. TDS is currently in development of a true TMR panel from top to bottom with true triple redundant I/O.)

These new control processor boards along with a frame and faceplate make up the control processor. This processor board is also using the flash card for memory eliminating the need for a hard drive. This new board has a heat sink protected processor which does not require a cooling fan. This new computer board is constructed with a Sempron 2100 processor. The faceplate of each processor provides status indications and a numeric display for alarm codes.
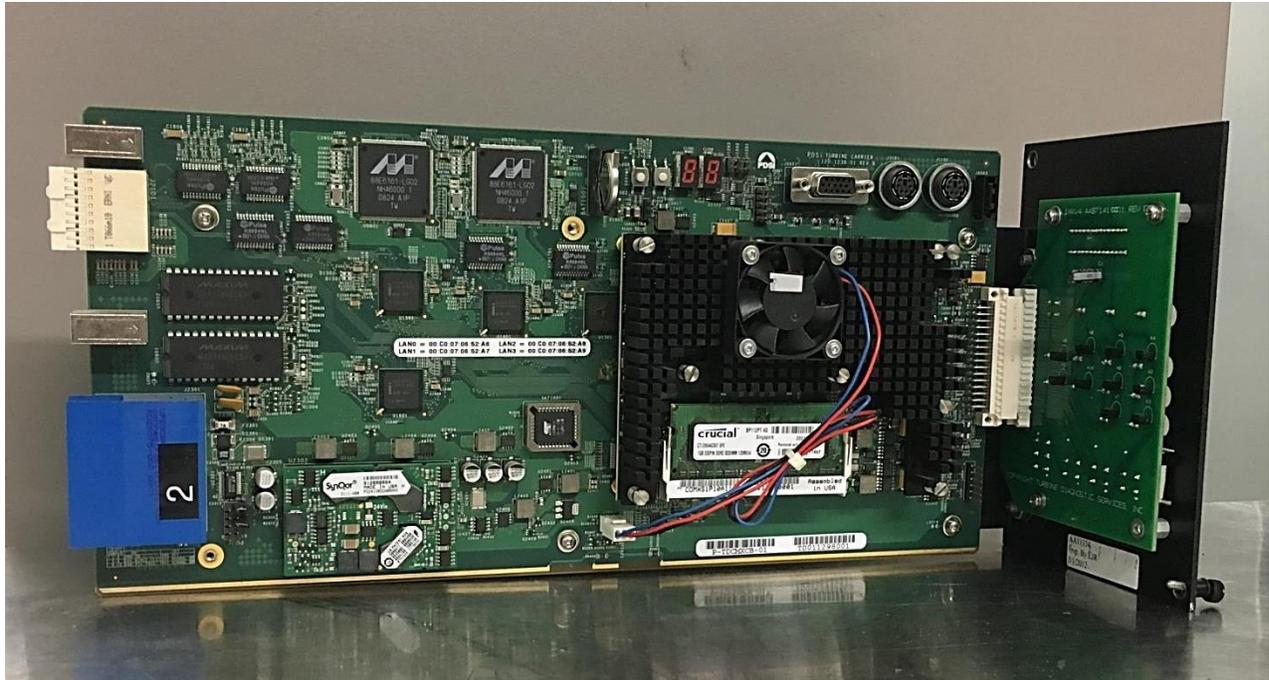
New Processor Board Bay

Easily Expandable I/O for Future Customer I/O Requirements

The Automation Direct, Terminator I/O, line of I/O modules and bases were used to interface the field devices and provide the field interface with the processors. This line of I/O was augmented with custom designed I/O modules to support closed loop position control, vibration monitoring, magnetic pickups & TMR backup over-speed protection, sequence of events, and flame scanners. These custom modules work seamlessly with the standard Terminator I/O components, look identical, fit the same bases, however, they have a processor embedded in them that allows each to conduct the custom functions required to control a turbine generator. This makes the TurboNet *DASH 1* [®] a well-rounded control system capable of controlling a turbine without signal conditioning modules. This makes the panel very clean, well-organized, without cluttered conversion modules, fuses or internal/external I/O circuit wiring. Even the digital contact output termination boards allows for a solenoid circuit to be wetted with internal voltage supply to and return from the device eliminating the need for an external power circuit interface for each output powering coils.

Each I/O module in the TurboNet *DASH 1 ®* control system is associated with a custom TDS manufactured termination board. These termination boards provide low density termination points for the field wiring in the application. The termination boards are low tech boards created to make the interface from the field to the I/O modules clean, uniform, and organized. Each termination board is interconnected to the I/O specific base of the associated I/O module via a standard interconnection cable which is factory wired at assembly. Each I/O module is hot pluggable and can be changed on line, depending on the functions served by each individual module and the other I/O residing on the base.

I/O Module and Base

The following is a list and explanation of each I/O module used in the TurboNet *DASH 1®* control system that was installed at the Lakeland McIntosh Power Plant on the "MAC GT".

- **Ethernet Based Controller (EBC)**

  Four separate Ethernet I/O EBC modules were used to provide EIO communications for four separately powered strings of I/O modules. This

allowed for the support of all triple redundant I/O such as the triple redundant speed probes and TMR Back Up Over-speed Protection modules.

The EBC communications developed for the Automation Direct standard modules was adapted to provide the EIO communications protocol. This is also true for the interface of the TurboNet *DASH 1* ® custom I/O module interface.

The EBC data communicated from each string of I/O is synchronized and passes through a network switch to provide the communications to the primary and the standby processors.

EBC Module

- **I/O String Power Supplies**

  Each of the four strings of I/O also must have a Terminator Power Supply to power each the associated I/O modules in that string. These power supplies are powered by the redundant TurboNet *DASH 1* ® 24vdc power supplies.

  Each string of I/O has an associated power switch to turn power off to the string for service.
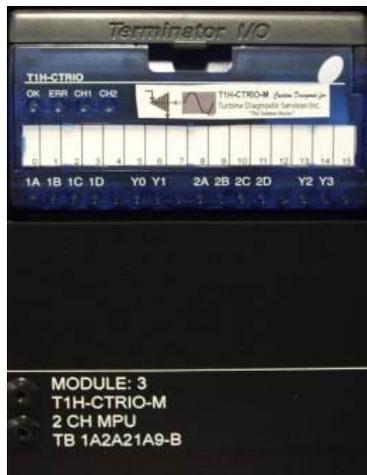
- **Speed/Over-speed Modules (OS)**

  Three custom OS modules were provided to monitor three passive speed pickups installed on the machine.

  These three OS modules are hard wired into a 2 out of 3 tripping logic via three ETR micro relays on the OS termination board where they activate the ETR

relays (2) (emergency trip relays). Each of the three micro relays are controlled by the each of the three OS modules based on a speed signal being detected and it being below the trip speed. If the speed increases to trip a module, two modules are required to confirm the condition before the machine trips. The three over-speed trip modules are capable of being tested on line from the HMI by the operator. The operator initiated test will lower the trip speed set point of each module one at a time in order to trip each channel individually. In each case, the TurboNet drops the set point on one module, the OS module trips and actuates the ETD relay to a tripped condition. Auxiliary contacts on the ETD relay signal to the TurboNet that the module and ETD is tripped to activate the TurboNet to restore the set point and when the ETD recovers to a reset condition, the TurboNet is triggered to test the next OS module/channel. This is repeated until all three channels have been tested and found to function properly. If the test malfunctions due to a problem, an alarm is generated to notify the operator of the issue so it can be addressed promptly.

The OS modules provide the digital speed signal value on the EIO data highway for the control processors. These speed signals are used to provide speed control and primary over-speed protection in the control processor.


Speed/Over-speed Module

- **Servo Amplifier Modules (SVO)**

Two servo amplifier modules were supplied to drive the liquid fuel pump swash plate, the gas stop valve and the gas control valve on the machine. The servo loop controllers are provided a position reference signal from the control processor for each of the controlled devices. A feedback signal such as a Linear Variable Differential Transducer (LVDT) or, 4-20ma feedback signal from a device such as a pressure transmitter tells the controller that the device has responded to try and drive to meet the set point. Once the set point is reached the error is nulled out and the controller holds position until the reference

changes. The Module output is available to drive either a +/-20ma signal or a +/-200ma signal depending on the servo device it is driving.

For LVDTs and RVDTs the module provides the 7vac 3khz excitation signal and then demodulates the return signal into a position based on its initial calibration where 0% and 100% are defined.

The TurboNet *DASH 1* ® SVO module is capable of controlling any combination of single, dual, or triple redundant servo coils and single, double or triple redundant feedback signals in the scheme of the servo control.
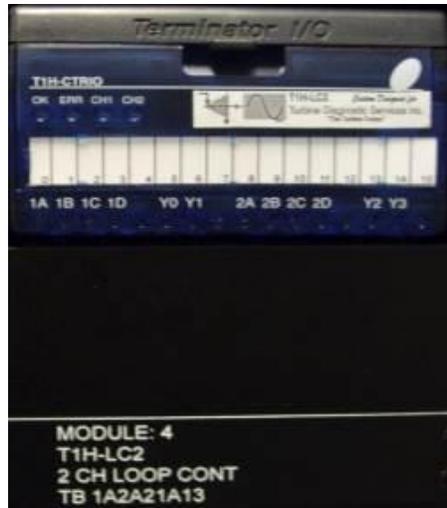
Servo Loop Controller (SVO)

- **Vibration Modules (VIB)**

  Two vibration modules were supplied to allow for the monitoring of the three case mounted velocity coil vibration probes, and monitor an optional reference probe. Buffered outputs back from the Vibration Module are provided on the vibration termination board for the connection of external vibration analysis equipment.

  The TDS vibration modules are two channel modules interfacing with a 4 channel vibration termination board for the input wiring and the buffered outputs. A 5th channel is included for the once per revolution zero degree reference signal.

  These modules will monitor the velocity coils or proximity probes for several purposes: Casing Vibration, Relative Shaft Vibration, Thrust Position, Eccentricity, Differential Expansion, Shaft Expansion, and the Reference Probe.

  The custom TurboNet Vibration I/O Module provides the -24vdc power source to power a proximeter for eddy current probes. The module provides an overall unfiltered vibration magnitude. The module, when coupled with the optional reference probe, can calculate the once times running speed filtered vibration component magnitude and angle (1X Vector) and the twice times running speed

filtered vibration component magnitude and angle (2X Vector) for each vibration signal. The proximity probe gap voltages are also monitored for rotor position and in the case of the vibration probes, it provides a shaft position relative to a starting reference point (turning gear). These shaft positions are available on the TurboNet *DASH 1* ® trending to provide shaft centerline plots of the data over a period of time or a transient such as start up or shut down. These gap voltages are also utilized in the position sensing of the thrust position and expansion probes.

The TurboNet trending package can also provide polar plot representations of the vector data for troubleshooting or balancing from the data available on the operator HMI. Additionally, all this data is available in the form of time trends.

Vibration Module

- **Milliamp Analog Input Module**

  One 8 channel -20 to +20 milliamp input module was supplied for the compressor discharge pressure and gas pressure inputs on the machine.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS.

Milliamp Analog Input Module

- **Milliamp Analog Output Module**

    One 8 channel 4-20 milliamp output module was supplied for spare outputs.

    This is a standard I/O module available from Automation Direct and carried in stock at TDS.
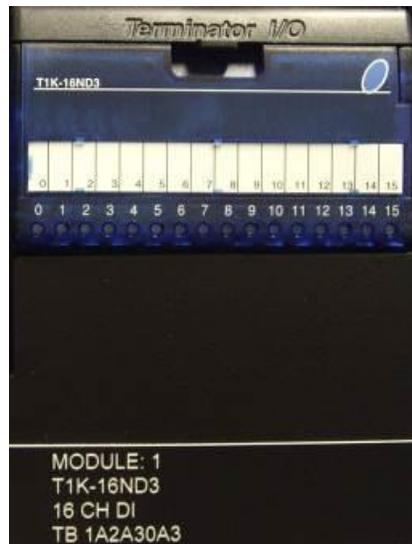

Milliamp Analog Output Module

- **Digital/Contact Input Module**

  Four 16 channel contact 24 VDC discrete input modules were supplied for all contact inputs needs. One channel on each module was configured to provide power diagnostics.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS.


Milliamp Analog Output Module

- **Digital/Contact Output Module**

  Five eight channel relay output modules provide contact driven response actions on the system.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS.

  These channels can be used as dry contacts in motor starter circuits or hard wired logic signals. The Termination board has Berg Jumpers that allow for the application engineer to wet the contacts of an output driving a coil so as to provide a coil power source supply and return directly from the termination board eliminating the need for externally powered/fused power and return circuitry which can clutter a panel.

  The micro relays of the module are used to drive the associated Ice Cube relays mounted on the termination boards to drive components and have the required current carrying capability.
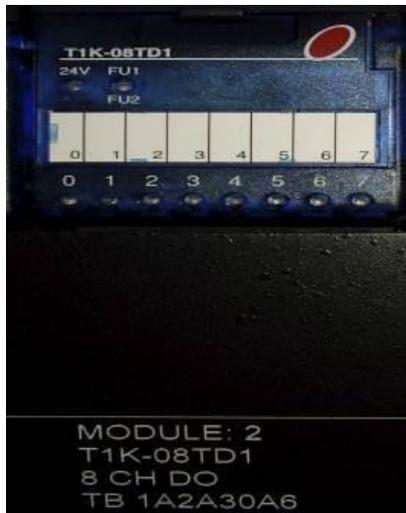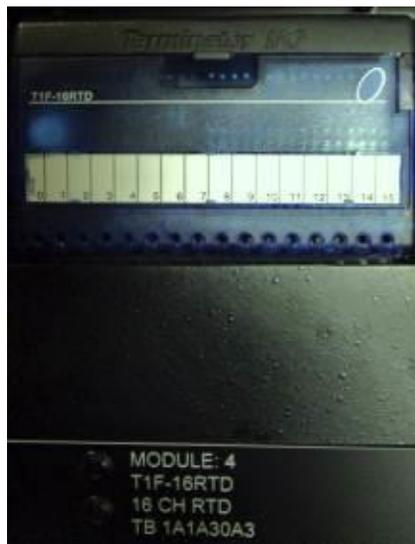
Digital/Contact Output Module

- **RTD Module**

  Two modules were supplied with the system to monitor generator and turbine temperatures.

  These modules are available to be configured for 10ohm copper or 100ohm platinum RTDs.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS.

RTD Module

- **Thermocouple Module**

  Three modules were provided for protection and monitoring of the gas turbine exhaust thermocouples and other miscellaneous devices.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS. This module can be configured for all standard types of thermocouple materials.

Thermocouple Module

- **Flame Scanner Module**

  The existing flame scanners were upgraded to Honeywell type.

  TDS installed a counter module to interface these scanners directly into the control system. The counter module interfaced with a Termination Board which was used to charge and discharge the flame scanners indicating the presence of flame while the counter modules counted the firing occurrences to confirm presence of flame.

  This is a standard I/O module available from Automation Direct and carried in stock at TDS.

- **Unused Optional Modules**

  The TurboNet *DASH 1*® has an additional module which was not used on this job.

- **Sequence of Events Module (SOE)**

  In addition to the modules supplied to Lakeland Electric, TDS has since developed an SOE module that is capable of time stamping the critical contact inputs and tracking time stamping their occurrence within 1 msec. The module features an isolated RS-485 network that synchronizes the time of all the modules, network wide, independently of the control processor.
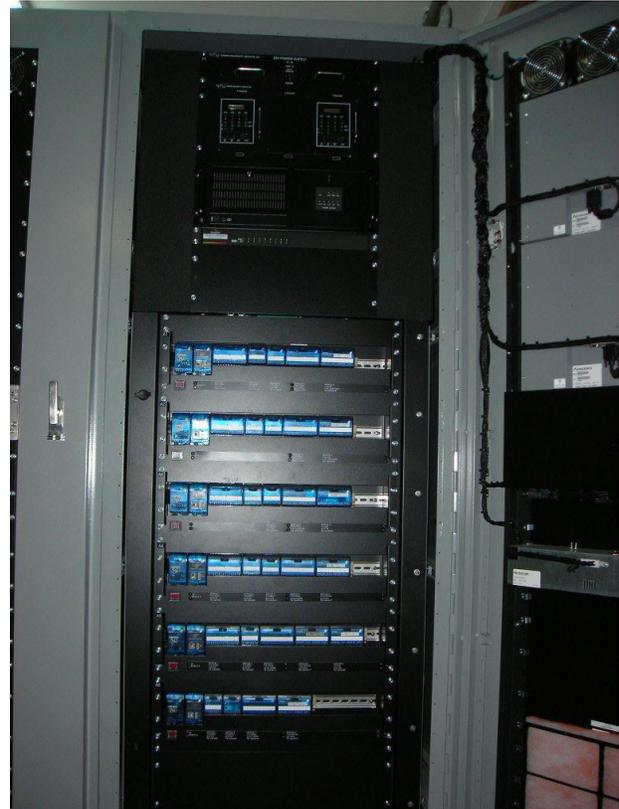
- **I/O Termination Boards**

Each instrument or signal is landed on a termination board, which interfaces with the TurboNet *DASH 1*® I/O module. Each I/O module has a custom termination board to provide the protection necessary for that specific type of signal/device. These termination boards are designed and built by TDS to provide a low density interface point between the control system and the field wiring. Termination boards were supplied as required for the I/O modules used and previously stated. All field wiring was connected to the control system through these termination boards.

In this panel, the I/O modules are mounted on a swing out door to allow access to the termination boards mounted on the rear wall of the cabinet.

Termination Boards   **I/O Modules**

The termination boards interface the I/O modules through a standard cable with a standard connector used at the termination board end of the connection. The cable is factory routed to the associated I/O module where the pinout wiring of the interconnection cable defines the type of signal use it is intended for.

Note that in the right hand picture, the I/O module strings are arranged in a horizontal alignment. This is the current standard of cabinet construction for this

application, whereas, the panel provided for the "MAC GT" was provided with vertical strings of I/O modules and did not have the cover plates which TDS has since incorporated to provide better reference as to the type and location of each module for troubleshooting purposes.

- **Igniters Inverter Power Supply**

  The "MAC GT" is a system restoration unit. That means that it is expected to start without any AC power available. The only load on the TurboNet *DASH 1*® control system that cannot be driven from the battery bank and TurboNet *DASH 1*® 24vdc power supplies directly are the ignition transformers for the spark plugs.

  A new power inverter was supplied to provide AC power for the igniter transformers. The batteries provide power to the inverter in order to produce the required AC power for the ignition transformers.

  With the HMI/EWS driven from their UPS systems, the arrangement allows for the "MAC GT" to remain with system restoration unit status.

Historical Data Collection

Lakeland Electric wanted the ability to retrieve the turbine generator operating data for both performance and troubleshooting purposes. The new TurboNet *DASH 1*® control system was equipped with an on-board TurboNet Historian which captures all the operational data on the unit to assist in troubleshooting and condition monitoring.

The Historian processor is a computer that sits in the Ethernet Data Highway (EDH) and its sole purpose is to collect data, events, and operator actions as seen through the EDH. It also sits in the Ethernet Engineering Highway (EEH) to service data requests from the various data analysis programs in the HMI or EWS.

The on board Historian can trend data on the TurboNet *DASH 1*® HMI (Human Machine Interface) station. This avoids the problem of having to go to a personal computer and trying to find the re-named turbine signal name in a list. The signal names can be obtained directly from the graphic screen and either dragged into the trend configuration window or inserted into the existing active trend by right clicking on the signal name.

Because the historian works off the same point directory as the HMI and the control processors, when a new signal is added into the system, it is immediately available to the Historian. It does not have to be added into a gateway or a Modbus list for access. Because the historian sits directly in the same data highway as the HMIs, it receives

signal updates at the same rate as the HMI. It is not subject to the update rate of the data link to a third party historian. It provides more accurate data because it is sitting closer to the source of the data. It eliminates the data artifacts sometimes seen on other historians where events are sometimes reported out of order because of all the latencies in the signal path from the control system to the historian program. This is sometimes seen on some trends where the suggested order of the events is impossible.

The Historian is shipped with enough hard drive storage capacity to theoretically store almost 20 years of data (the drives would reach mechanical end of life before being full). The storage consists of three hard drives arranged in a RAID 5 configuration. The configuration of hard drives is not limited and additional on board hard drives can be added at any time. The long term data is stored on the HIST. This data is available for the HMI or EWS to retrieve in order to produce long term trends. This is useful for troubleshooting degrading trends in the operating parameters of the machine

Improvements made in the last few years allows for the data to be printed in tabular format, or stored as a text file table for importing into Excel for further manipulation. The new versions of the historian can also be setup to store operator actions.

Software Improvements

Operating System

The "MAC GT" TurboNet *DASH 1*[®] has two operating systems incorporated into the several processors on the data highway.

The redundant control processors have a hard real time operating system called LYNX OS 4.0 produced by Lynuxworks.

The control system HMI, EWS, and Historian, had the Linux Redhat 7.2 operating system installed. This is the original system configuration that TDS developed for the TurboNet *DASH 1*[®]. As the system aged, the problem with the Redhat operating system was a limitation of the computer hardware supported. As the industry computer hardware changed over the last 15 years, the Redhat operating system software has become obsolete and does not support the new computer hardware in the industry today. This now requires obsolete components to be sourced to repair hardware issues with the HMI, EWS, and Historian computers as they age.

TDS has since developed the next generation of the HMI, EWS and Historian operating system software. The new operating system applied to TurboNet *DASH 1*[®] systems today is the Ubuntu 14.04 distribution of Linux. It supports current hardware, and has improved support for printers and removable disks (thumb drives) to be able to extract reports and data from the control system. This version of the HMI software has been in service at other sites for the past three years, and has proven reliable and easy to use.

The Ubuntu 14.04 Linux distribution has a look and feel similar to windows, which should help with operator familiarity. The operator still has all the same programs available previously. All the graphics can be ported over to the new HMI because the files are compatible.

With the upgrade from Redhat to Ubuntu, the original control processors can remain as originally supplied with the LYNX OS operating system in service. While the highly reliable control processor single board computers are obsolete, the service duty provided by these components does not warrant change at this time. In the event that the customer desires to move to the new processor chassis and new TurboNet control processors, that upgrade is also available. TDS has initially released this control processor upgrade with the LYNX OS operating system, TDS is now engaged in development of a Real Time Linux operating system to run on the new control processors. This new Real Time Linux operating system will be put into service in the Fall of 2017 for all future control processor upgrades.

Please note that in the original HMI, EWS, and Historian Linux operating system application and for the new Linux operating system, the operator and the troubleshooting technicians do not need to know how to use Linux or make manual Linux command entries. All of the control functions, trending functions, alarm functions, and the troubleshooting functions are all menu driven. The menu driven functions of the

TurboNet *DASH 1®* HMI and EWS have been reorganized and improved in the new Ubuntu operating system firmware.

Operating Convenience

The new control system is set up with control logic functions that were similar to the old Mark I. However, the operating graphics are much more operator friendly than the buttons, meters and lights of the old Mark I system. All functions are now pushbuttons on a graphic, and the ability to see all related signals at the same time (i.e. exhaust thermocouples) has tremendous troubleshooting value.
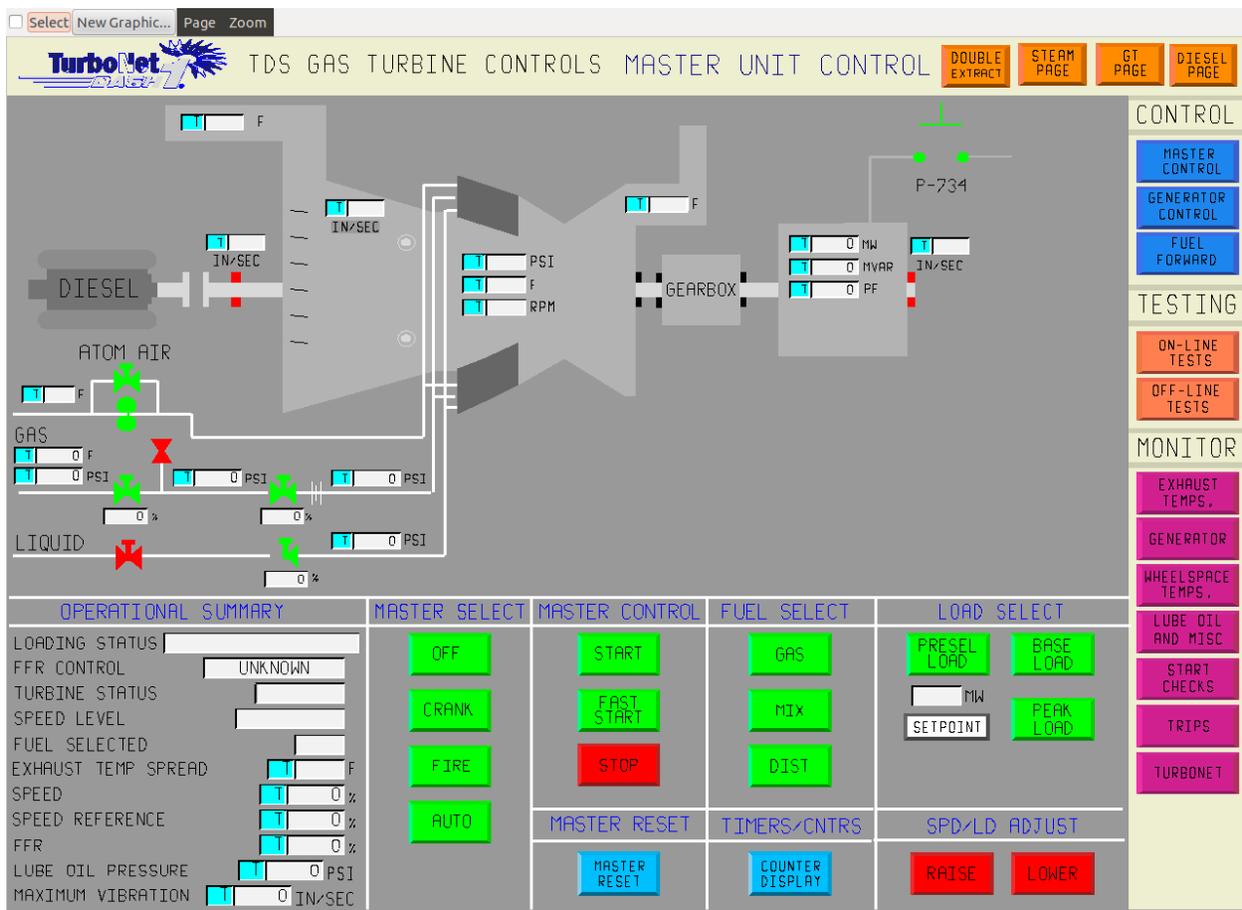
TurboNet *DASH 1 ®* Master Unit Control Graphic

Open Platform Control System that is Custom Configurable w/Standard and Specialized I/O Modules

The control system is an open platform control system. The customer has complete access to programming and graphics for troubleshooting or modification. The system is assembled from individual I/O blocks to achieve a configuration that satisfies the requirements for both proper turbine control and customer requirements. The system is built using off the shelf I/O modules for standard I/O and custom designed specialty I/O modules for turbine specific I/O.

The control system graphics and sequencing are self-documenting, which means that all that had to be done to document the logic was run the utilities and print the resulting documents. The new control system was also documented with panel assembly drawings, I/O termination and point listing.

The **Specialty Modules** are supplied by Host Automation Products and are designed to TDS specifications. They are hot pluggable modules mounted in standard terminator I/O bases and have a seamless interface to the terminator I/O standard hardware and Ethernet based controller EIO Data Highway. There are five specialty modules custom designed for TDS.

The **Speed/Over-speed Module (CTRIO-M)** has 2 inputs per module and uses passive speed probes. The two inputs allows for the over-speed protection of two shaft machines. It is capable of measuring a 2Hz minimum frequency, with 15mV minimum signal amplitude. It can be used to perform zero speed detection and is an integral part of the backup over-speed protection system.

The **Loop Control Input Module (LC2)** is used for driving electrohydraulic controlled valves. It has 2 LVDT excitation sources and demodulation inputs per module, 4 analog inputs for demodulated outputs, 2 servo outputs per module, 2 magnetic speed probe inputs (for use with a gas turbine flow divider speed pickup), 200Hz min scan rate, and a selectable range for servo outputs: +/-10, 20, 40, or 100. Depending on the termination board used, it can also be used with 0-5 VDC, 0-10 VDC or 4-20 mA position feedbacks, not just LVDTs. However, the frequency response or the DC position feedback needs to be high enough to support its use as a hydraulic valve positioning feedback device.

The **Sequence of Events (SOE)** module has 16 channels and sensing power detection with 250V max sensing voltage with a programmable voltage threshold. It self-tests its hardware once per second. It provides 1ms time stamping of state change on its inputs. It includes a serial input & output for cascaded time sync that is synchronized to GPS time with an optional GPS clock.

The **Vibration Input Module (VIB)** has 2 Proximeter channels or 2 velocity coil inputs. It also has a dedicated reference probe input that is used as a reference for the FFT analysis of the raw signals. The module provides open circuit and shorted coil detection for velocity coils. FFT cab process up to 128Hz signals. Buffered outputs for all signals are provided. The module analyzes axial position, eccentricity, and differential expansion in addition to vibration.

The **Flame Scanner Board/Counter Module** provides excitation for the Honeywell GM Tube-type Flame Scanner. It measures flame intensity by measuring the frequency of the feedback signal and provides voltage diagnostics. The counter module provides for four channels.

Monitoring

TurboNet DASH 1 ® System Specifications: Programming Software Display Capability

The TurboNet *DASH 1®* system for the "MAC GT" was provided with a panel door mounted HMI with a panel mounted Keyboard. The picture below is this HMI:

Door Mounted HMI Panel

This door mounted HMI with the panel mounted touch mouse pad and keyboard was the first of such that TDS had designed and produced. The TDS engineer for the project was not satisfied with the functionality of this keypad design. Further feedback from the operators at Lakeland indicated that it was not preferred and the operators typically will utilize the HMI/EWS that is mounted next to the TurboNet *DASH 1®* panel.

The local HMI/EWS is pictured below. This small console is a 19" rack with a table top on the top. The computer components are mounted in the 19" rack below. This HMI has a conventional keyboard and trackball mouse. The new TurboNet *DASH 1®* Mark I/Mark II gas turbine control panel has been modified with a small pull down, drop down drawer mounted keyboard and integral trackball mouse.

Local HMI/EWS

The control room was also provided with an HMI with the monitors mounted in the control room bench-board with the computer hardware behind the bench-board panel.

The TurboNet control system has the capability of monitoring and displaying many more signals than previously available with the old Mark I system. The new system also has the capability of testing the electronic portion of the backup over-speed protection

system online, as well as fully testing the complete over-speed system off line. This unit, being a system restoration unit, also has the ability to test start the diesel cranking engine when the turbine is running. All these functions are accessible from the screens displayed below:

Testing (On-line and Off-line)

The following is the On-Line test graphic display. It allows for the testing of all three back up over-speed channels to the point of tripping each ETR relay. This graphic also provides the start/stop for testing the cranking diesel engine while the unit is running.
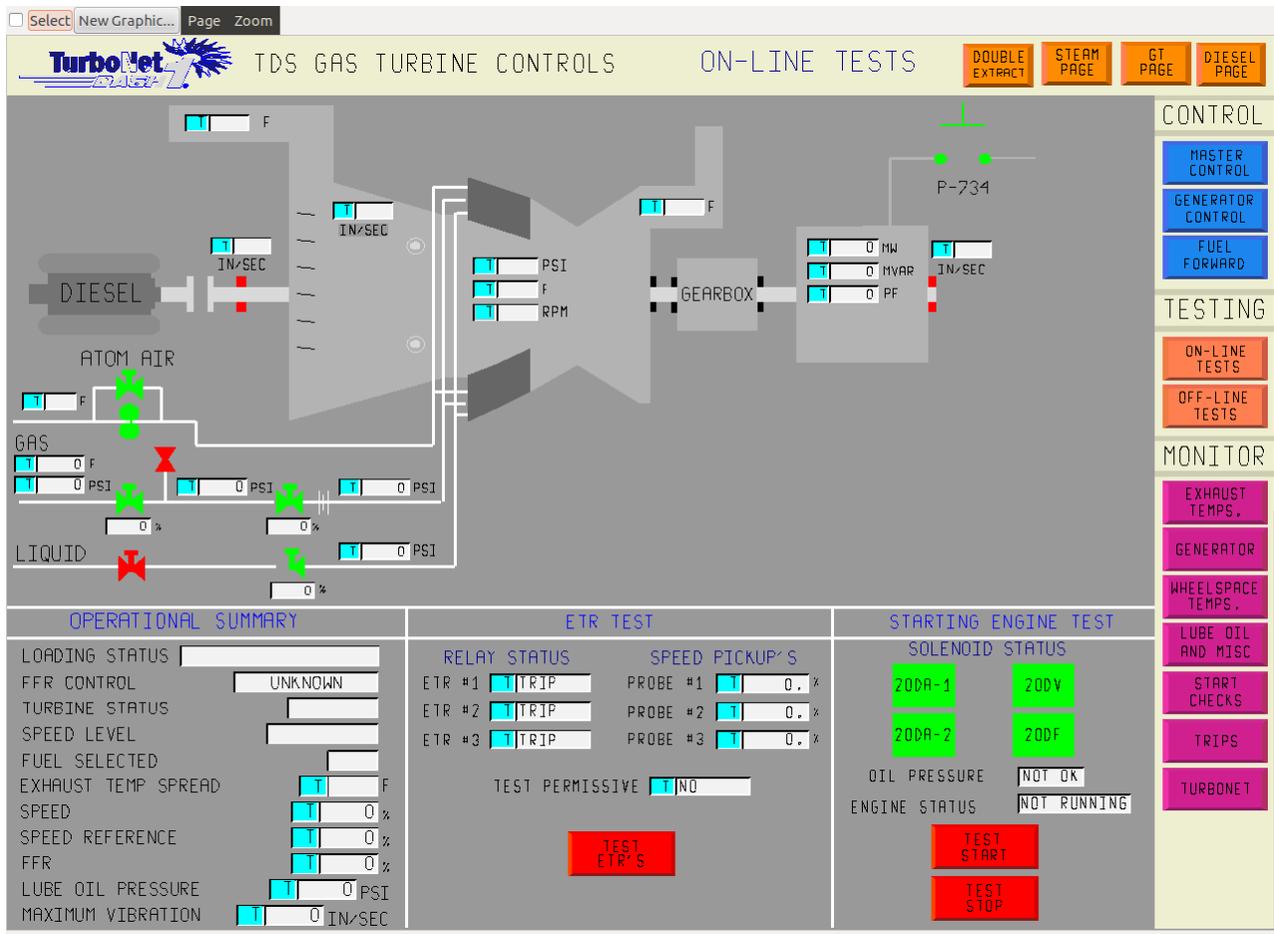
On-line Test Graphic

The following is the Off-Line test graphic which allows for the system to functionally test both the electronic emergency over-speed protection and the mechanical overspeed

protection. These test selections will ramp the speed automatically up to test each of the two trip functions. The state of the three ETR relays is displayed and a readout is provided for the speed at which the unit actually trips.
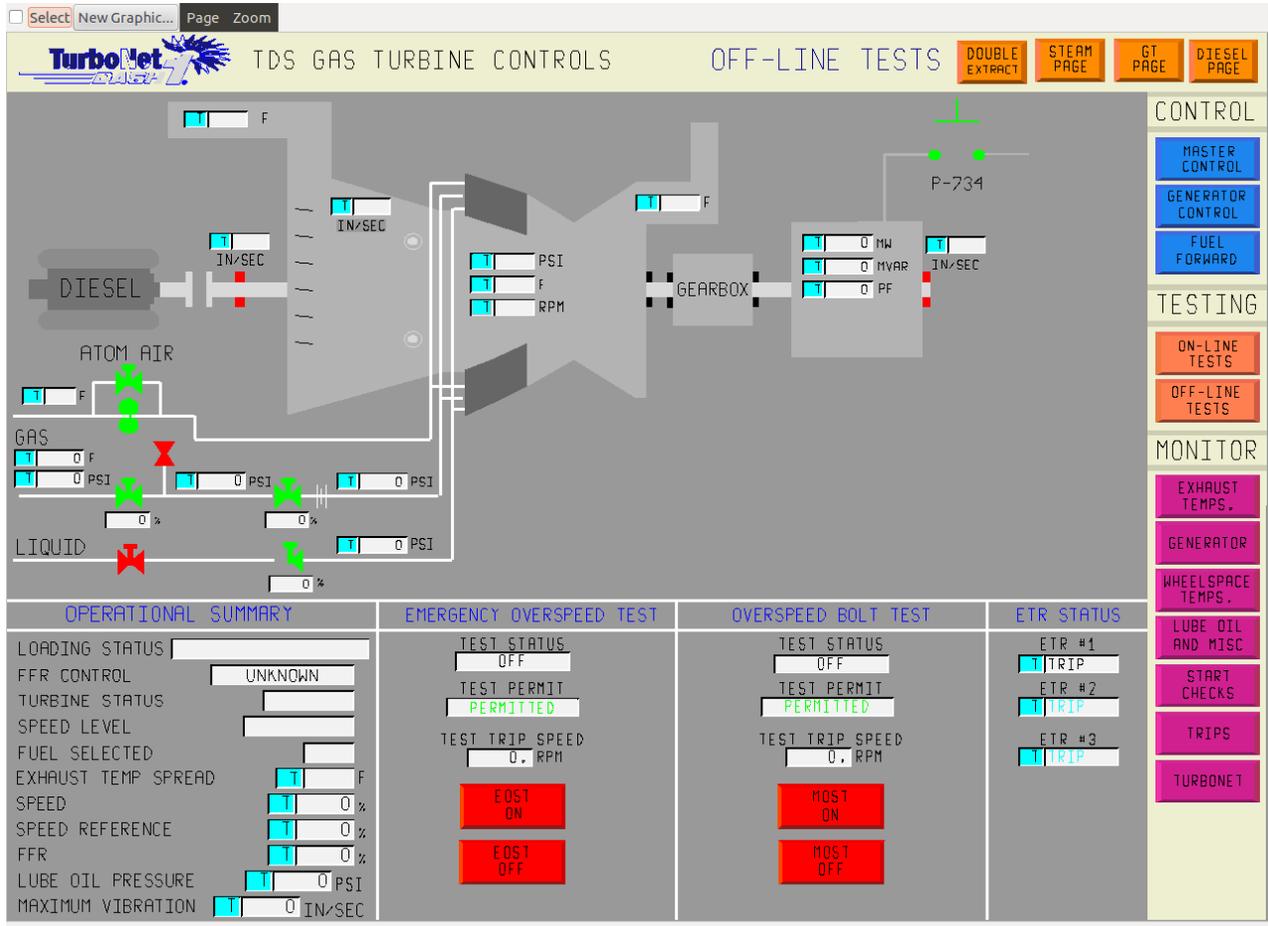
Off-line Test Graphic

Generator Control

The monitoring and control of the generator is integrated into the TurboNet to allow the operator seamless interface to the excitation system and generator protection relays. The following is the generator control screen. Notice how all the generator voltages and the B phase generator current is displayed. This is helpful when troubleshooting, as you can see the DECS-400 sensed values displayed on the screen. The status of the voltage regulator is also displayed.

The starting and stopping of the gas turbine exciter is controlled by a speed switch and the unit is programed to always go to auto voltage regulator. The graphic allows for the operator to raise and lower the voltage regulator set-point. Once at rated speed, the operator can also select for the generator to be synchronized automatically or manually.
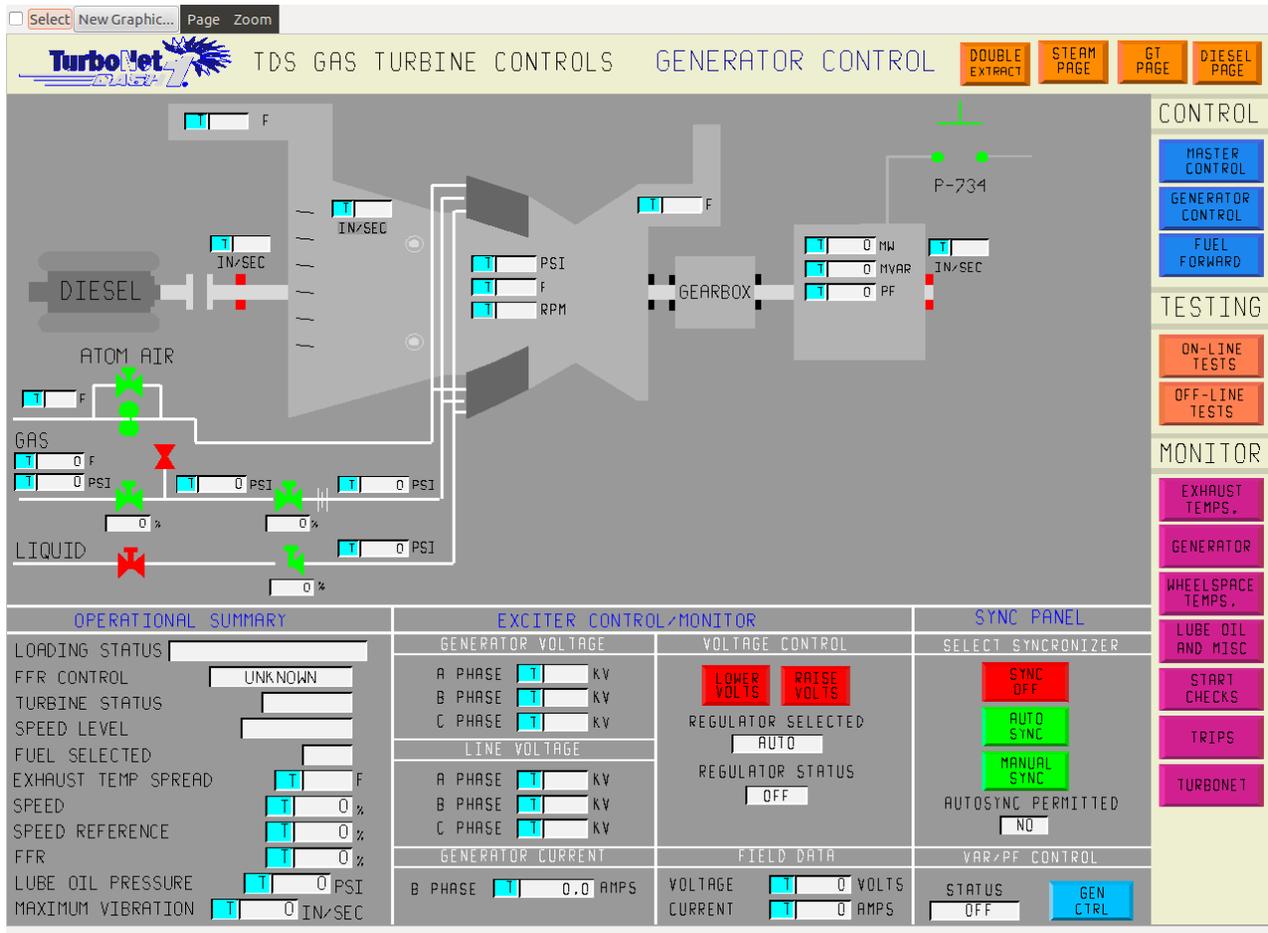
Generator Control Graphic

LoopCad Display

Shown below is the programming environment for the TurboNet *DASH 1®* control processor logic. The program used to construct the programming and for troubleshooting of the logic is called LoopCad, a written by TDS specifically for TurboNet. The logic is built by dropping in SAMA logic control blocks and custom big blocks created by TDS to conduct more complex algorithms and simplify the

programming by the application engineer. The blocks are interconnected to establish the logic path. These interconnection points are not required to be named and the program applies dummy variable names to make these logic paths. Inputs to and outputs from the logic must be defined by point name, however, the only other time a point name is required would be for if a point in the logic were to be displayed or used for an input or output from another logic page.

The programming is created in Loop Sheets which in many cases are applicable to many types of machine and can be imported from system to system to assist in creating a new unit.

By selecting the "Show Live" function, the logic and analog values of the control programming loop are displayed at the input and output of each block allowing for easy troubleshooting of the logic to determine the unit issue creating the malfunction.
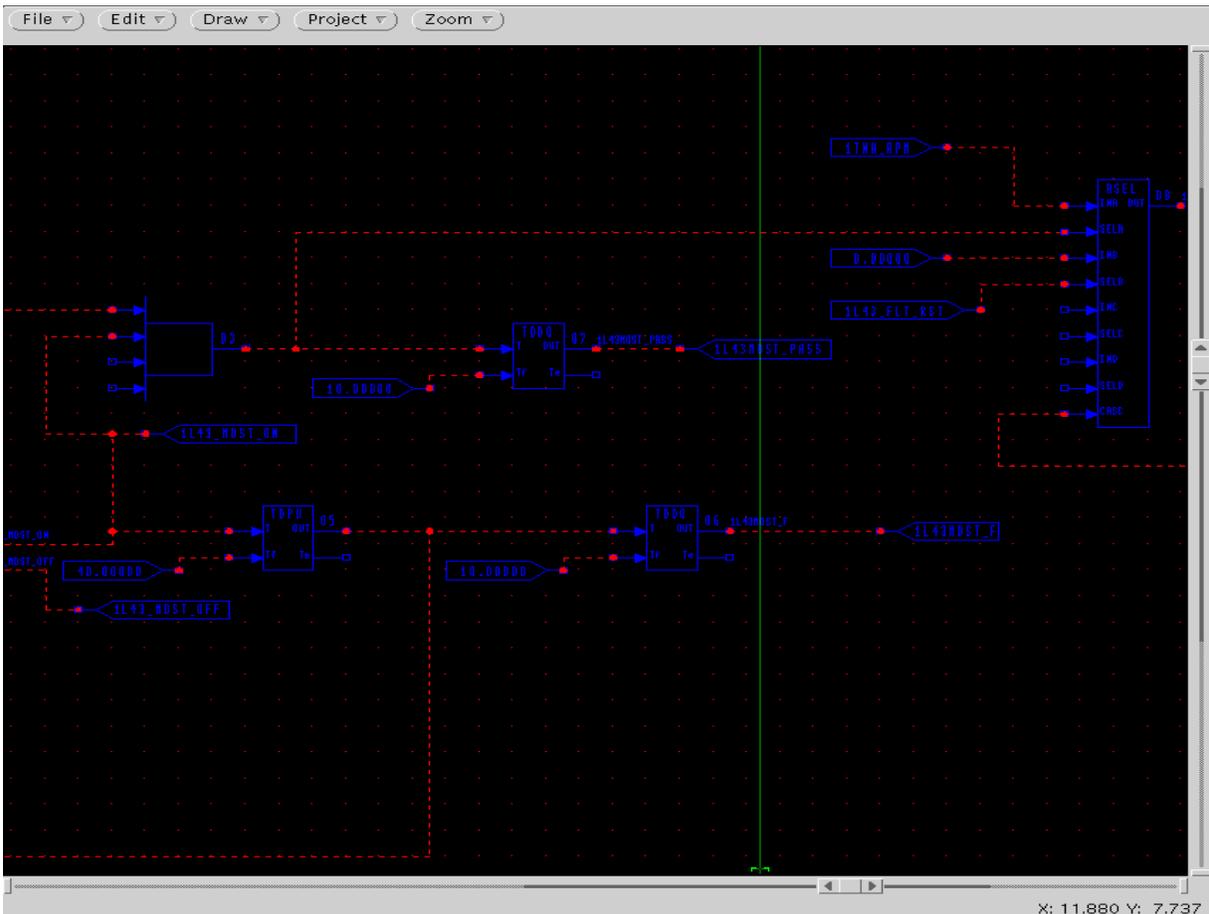
LOOPCAD Logic

Improved Troubleshooting and Alarming

The old GE Mark I Speedtronic control system design had a lot of faults wired in parallel to give a single alarming in the annunciator panel. The customer requested that all these signals be fanned out and brought into the system individually to assist in fault identification and troubleshooting. It also provided very little in the form of feedback as to what was going on inside the system. Whatever feedback provided was in the form of test points in the front of the cards or in the form of lights on the relays. It was not something the operator was expected to understand or troubleshoot. The new control system has the ability to monitor all the signals and intermediate value calculations. This allows the technicians and engineers to see what the logic is doing and pinpoint the issue much more quickly. The control system also has the ability to log data from the controller at the scan rate of the system which allows engineers to see what the controller is doing scan by scan. This is helpful when troubleshooting high speed events, such as flameout trips, etc.

A new Alarm Explain feature implemented since this installation has been developed to allow a unit specific explanation of the alarm to be written and provide detailed description of the condition and possibly suggested response to the alarm for the operator. The operator will can click on the alarm, and through a menu, pull a description and explanation of the alarm. This is a manually edited file available to the customer for editing, if desired.

A combined TDS HMI/EWS was installed in the control cab adjacent to the turbine and generator control panels to allow for the engineer or technician to troubleshoot and reprogram the loops and graphics while not inhibiting operator actions. This EWS has full access to all the logic for programming and troubleshooting and also functions as an operator HMI.

TDS Combined HMI/EWS

This EWS is constructed with a 19" rack supporting the table top for the console. This rack contains the HMI/EWS computer, the Historian computer, the GPS clock, the alarm speakers and the inverter for the ignition transformer. In most cases and especially with the more modern panel assemblies, the TurboNet *DASH 1®* uses many sectionalized components which fit into 19" rack configurations.

Project Execution

Expedited Engineering, Manufacturing, Installation and Commissioning

The customer had requested that this outage occur in May of 2008, before the start of hurricane season. TDS intended to use the last three weeks of May to conduct the installation and upgrade activities. On site work started in April of 2008 with the mobilization and installation of conduit and cable tray as available with the machine ready for operation. The machine was removed from service with the installation outage starting on 5/12/08 and expected completion of the job on 5/31/08. This was a 9 week expedited cycle time for equipment design, manufacturing, programming, delivery and installation. TDS conducted this job on single 10 hour shifts per day, 6 days per week for the three week outage duration.

Expedited TDS Panel Assembly and Testing

The blank panel and all its components were ordered and expedited to support the compressed schedule that the customer required. This in turn required additional coordination between TDS's suppliers and the panel makers to ensure that they were not sitting idle waiting for parts. The parts had to arrive in an order that would support the assembly of the panel in an efficient manner. This was all accomplished with minimal delays or issues.

The largest issue was with the system restoration inverter supplier, which did not properly package the inverter for transportation. Since it did not arrive in a useable manner, and the vendor could not source a second one quickly enough, a new supplier was identified and used. It did not impact the schedule.

In parallel with all the panel assembly effort, there were two engineers working on the logic for the controller. The engineers worked in parallel, and checked each other's work for accuracy. Complicated loop operations were checked using the TDS I/O simulator panel to ensure that the logic performed as desired. During commissioning, very few logic issues were found.

The panel was powered up at the TDS facility. All the HMI, EWS and HIST processors were connected and checks made to ensure all the components were working correctly before it was shipped to site. No issues were identified during this power-up that impacted the schedule. All the equipment was loaded with software and custom configured for the unit specific application. All logic and graphics were loaded and tested at the TDS shop before shipping.

The factory wiring and functionality of all the I/O was tested using the TDS I/O test panel. This panel allows TDS to test all the internal factory wiring for each I/O board in a consistent manner. The 24 pin cable is disconnected from the termination board, and connected to the I/O test panel. Each individual signal is then simulated and verified for proper indication. Once the I/O has been confirmed to work correctly, the cable is disconnected from the test panel and reconnected to the termination board and the next termination board interface wiring and I/O are tested.

The TurboNet *DASH 1*® assemblies supplied were as follows:
- Control panel door mounted operator HMI to control the turbine and generator from the control cab of the gas turbine.
- Standard TDS "Beer Stand" 19" rack mount HMI/EWS console to control the turbine and allow for programming modifications and to allow for troubleshooting of the unit in the control cab of the gas turbine. This console functioned as an HMI and engineering work station (EWS) providing a dual purpose.

- Standard console to be mounted in the McIntosh main control room bench board.
- Generator control and protection bay
- Turbine control and protection bay

In addition to the prewired assemblies, a new support stand for the hydraulic valves was supplied. This stand was built at a local fabrication shop and shipped for assembly on site to accommodate the new hydraulic stop and control valves. Due to the expedited delivery, the assembly could not be tested at the TDS facility beforehand, and was first assembled on site. No issues were identified from this assembly and the components functioned as intended.

Good photos of the panel were not collected at TDS prior to the shipping of equipment and space congestion in the control cab prevents collection of good pictures at the site. The following picture is a current model of the same control system installed on the "MAC GT". This control panel is constructed with the identical footprint as established with the original Mark I and Mark II control panels and is a standard retrofit assembly for TDS. The only variances would be the potential variations in excitation system front end upgrades and the generator protection preferred by the customer.

TurboNet *DASH* 1® Control Panels

Expedited System Integration Design

Because the new control system had to be designed, constructed, installed and commissioned in a short amount of time, an experienced group of engineers was required. This project had no margin of error on the timeline. Because the engineers were already familiar with the GE turbines and voltage regulator systems, the new design was done correctly the first time.

As with most all of the TurboNet *DASH 1*® commissioning, this machine was started and came to rated speed on the initial start.

Expedited Drawing Package

The control system and all the interconnection wiring was already engineered before going to site. A complete set of wiring drawings was generated. This allowed for the electricians to hit the ground running since they already knew where the cables were going and where the terminations were. This also resulted in an accurate set of as built drawings since there were minimal changes done when installing and commissioning the unit.

Digital Control Conversion

New, all digital turbine controls were installed and the previous hybrid analog-digital control system was removed. The old analog voltage regulator was also removed and replaced with a complete digital voltage regulator. Additionally, all new digital voltage regulator controls, generator protection and synchronization were provided in the generator bay of the TurboNet.

The generator panel is supplied with a Basler BE1-25A auto synchronizer and a TDS manual sync panel. The auto synchronizer, voltage regulator and multi-function protective relay are provided with panel mounted knife switches adjacent or below the device for safe isolation of the PT and CT signals. These switches also provide a location to inject signals for testing and simulation. The exciter controls were interfaced with the TurboNet *DASH 1*® controls to provide the operator with seamless monitoring and control capability to make the required set-point adjustments. The Basler DECS-400 digital voltage regulator provides the necessary information for generator power factor and var control capability from the turbine controls.

Generator and Transformer Protection

The old electromechanical relays were replaced with state of the art digital generator and transformer protection relays.

The old protection relays were replaced with a SEL-387A Transformer Protection. This relay was designed to be integrated into the TurboNet, and assembled and packaged

by Turbine Diagnostic Services Inc. using predominantly off-the-shelf, readily available components.

An SEL-300G Generator Protection was also integrated into the TurboNet system.

The generator and transformer protection relay digital signals were also imported into the control system for display on the HMI for the operator. This electrical data is also stored in the Historian for future use and troubleshooting. The relay alarms are shown on the alarm page.

Generator Control and Protection Bay

The customer selected protection relays manufactured by Schweitzer Engineering Laboratories, a standard in the utility industry. These relays were integrated into the TurboNet, however, the setting studies and settings were all conducted by the Lakeland Electric relay group along with the relay testing and commissioning.

SEL-300G Generator Protection Relay

The generator and transformer protection relays were both provided with panel mounted knife switches adjacent or below the device for safe isolation of the PT and CT signals.

Excitation

With older Generator Excitation Control Systems, it is not uncommon for power generating equipment operators to experience start-up problems and have inconsistent availability and capacity issues. Most operators have observed unexplained transients associated with operating their older analog excitation systems. To this end, remedying these situations within their previous control system was becoming a concern at Lakeland Electric. These concerns will continue to elevate as most owners are discovering that it is becoming more and more difficult to find parts and OEM support services for these older systems. Usually the cost of troubleshooting (and lost generation) of either an analog or digital excitation system can quickly become greater than the cost of an upgrade. In most of these systems TDS engineers have found that the original power conversion equipment is in good working order and only the controls are experiencing operating problems.

Typically, with older analog excitation systems, these systems use small voltage signals to convey set points, feed backs, limiter settings, etc. through wiring between circuit cards, transducers, and gate pulse amplifiers. Degrading wire terminations and transient noise (which is inherent in power electronics) can reduce the quality and stability of these small voltage signals. Problems caused by intermittent fluctuations in these small voltage signals can be very difficult, if not impossible, to troubleshoot. In order to solve these issues a DECS-400 excitation voltage regulator, manufactured by Basler Electric, and a Basler Pan Chassis 32amp bridge, were installed.

TurboNet *DASH 1*® controls provide the operator all the monitoring and control functions necessary to select excitation functions and make set-point adjustments. With the total integration of this voltage regulator, the operation of the generator is seamless to the operator from the operation of the turbine within the TurboNet graphics.

400 Series Digital Excitation Control System

The DECS-400 Digital Excitation Control System is a microprocessor based controller that provides excitation control, flexible logic control and optional power plant system stabilization for synchronous machines in an integrated package. These are most often incorporated in front end upgrades for SCT/PPT, potential source SCR bridges, Amplidyne, ALTERREX, GENERREX and the larger brushless and rotating DC exciters.

The "MAC GT" has a SCT/PPT (Saturable Current Transformer/Power Potential Transformer) that provides current to a rectifier passing the DC directly to the generator field. The current provided to the rectifiers is regulated by the application of the current to the control winding of the SCT. The SCT transformer will conduit no current when the control winding is saturated (current high) and full on with no current to the control winding. Therefore, the DECS-400 was the best choice so as to invert the output to provide the inverse proportional control of the SCT current. The DECS-400 provides a 0 to -10 volt signal to the pan chassis bridge which intern passes the appropriate amount of current to the control winding of the SCT so as to control the generator output voltage and VAR production.

In this case the old analog SCT/PPT controls were removed with the removal of the Generator Control Panel connected to the Mark I control panel. In the new TurboNet *DASH 1*® upgrade, the integrated SCT/PPT excitation system front end upgrade was mounted in the Generator Control Bay of the new panel. The DECS-400 was mounted in the door and the pan chassis was mounted on the back wall of the generator bay.

This excitation system has worked flawlessly since installation and is very similar to the excitation system upgrades applied to the Lakeland Electric McEMD emergency diesels with they were upgraded with TurboNet *DASH 1*®. The reliability of this excitation system upgrade is also testimony to the reuse of the power conversion equipment (rectifiers & STC/PPT transformer) are viable options for front end upgrades.

The exciter was provided with panel mounted knife switches next to the DECS-400 for safe isolation of the PT and CT signals.
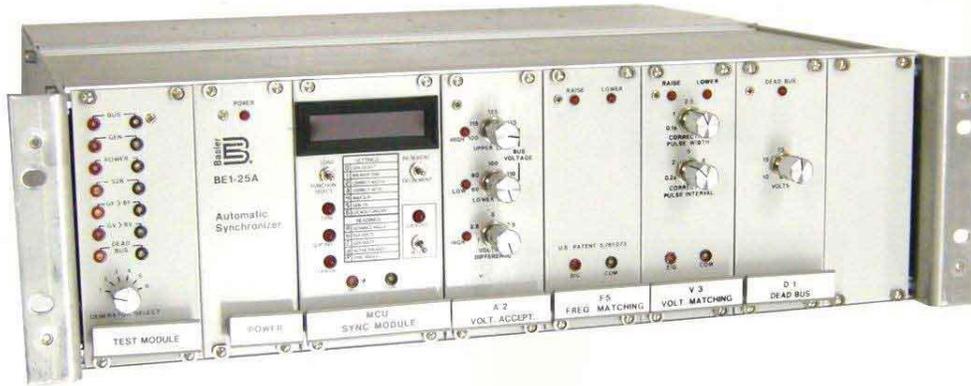
Auto Synchronization

The old synchronization control scheme relied on the turbine speed oscillating to generate a voltage zero crossing in order to close the breaker. This was replaced with a true auto-synchronizer.

A Basler BE1-25A auto synchronizer was provided to allow for auto-synchronization of the generator automatically with start sequence of the Frame 5 gas turbine. Additionally, a secondary synchronization check protective relay was provided with a Basler BE1-25 Sync Check relay. This relay is wired in series with the auto and manual

breaker close command for verification of correct generator phase timing (two-out-of-two required to close) functions for the auto/manual synchronization of the generator.

The auto synchronizer is well suited to the TDS 19" rack mount construction of the TurboNet panels. The BE1-25 is a conventional relay case and is provided with a mounting plate to allow for the 19" rack assembly. The "MAC GT" TurboNet *DASH 1*® panel construction was prior to the current 19" rack mount standard and the generator control and protection bay components were all door flush mount. With these door mounted components, a manual synchronization capability was installed for back up.

The auto and manual synchronizer signals were provided with panel mounted knife switches adjacent or below the device for safe isolation of the PT signals.

Basler BE1-25A Automatic Synchronizer

Current TurboNet *DASH 1*® 19" Rack Mount Construction

With the integration of the unit synchronization into the TurboNet *DASH 1*® , the normal synchronization of the machine is automatically and seamlessly selected as part of the auto start logic in the TurboNet *DASH 1*® .

Package Rewiring

The age of the equipment and the condition of the field wiring was a factor in the reliability of the "MAC GT" before the TurboNet *DASH 1*® upgrade. Much of the conduit was burned from gas leaks and the terminations were corroded. Therefore, Lakeland Electric agreed that to achieve the desired unit reliability and availability, a complete package rewiring was required to remove the failures associated with the degraded field wiring.

TDS conducted the complete package rewiring as part of the TurboNet *DASH 1*® upgrade. All new conduit, cable trays, necessary cables, and manpower to rewire the turbine and generator control devices were provided. The TurboNet *DASH 1*® control system would then interface with the existing field equipment and wiring.

The turbine package was rewired with Type K thermocouples and thermocouple wiring. TDS provided and installed new type K thermocouples for the compressor discharge, the wheel space thermocouples, and the exhaust thermocouples.

TDS provided electrical replacement and calibration services for the field instrumentation and devices as an extra. This rewiring would provide all new cabling for instrumentation devices originally connected to the generator control panel and existing Mark I Speedtronic control system in turbine and generator package. All of the field devices were calibrated and documented. A TDS calibration sticker was applied to all of the devices calibrated as per standard TDS methodology.

This now included new CT, PT, and SCT control winding wiring from the generator package to the generator control and protection bay of the TurboNet *DASH 1*® panel. The large exciter cabling connecting the SCTs, PPT, and exciter current bridge and collector rings was not replaced.

TDS rewired all the turbine base instrumentation components to allow for the implementation of the new turbine controls. This did not include the 480vac MCC and

pump wiring with the exception of the control wiring directly between the TurboNet and the MCC.

Gas Valve

The electric gas valve installed with the Speedtronic PLC upgrade for gas fuel operation was eliminated. TDS had recommended that all turbine control valves be made hydraulic. These valves are designed to be failsafe. TDS proposed to replace the existing stop valve and electric control valve combination with an all hydraulic OEM style valves and actuators. TDS worked with Young and Franklin to spec a current standard speed ratio valve assembly manufactured by Young and Franklin. This is a hydraulically servo operated arrangement intended to utilize the 1200psig unit hydraulic system operating pressure.

The new valve arrangement included a gas control valve and a gas stop valve. The gas stop valve operated off of a low pressure emergency trip header controlled by a trip solenoid valve. The gas control valve was a servo operated controlled valve with dual LVDT feedback for closed loop servo position control. This closed loop valve position control was conducted by the TurboNet LC loop controller using both of the LVDTs in a high signal select feedback.

TDS subcontracted CCC to install the valve in the new valve compartment fabricated for the assembly. CCC conducted all of the pipe welding and then the instrumentation wiring was installed by the subcontracted EDE electricians.

The temporary hydraulic pump was used to provide hydraulic pressure to the control valve to allow for it to be stroked and calibrated in the TurboNet without cranking the machine.

The Unit was started and was tested for dual fuel operation and found to perform as expected in operation.

The following is a drawing of the combined speed/ratio valve assembly provided by Young and Franklin.
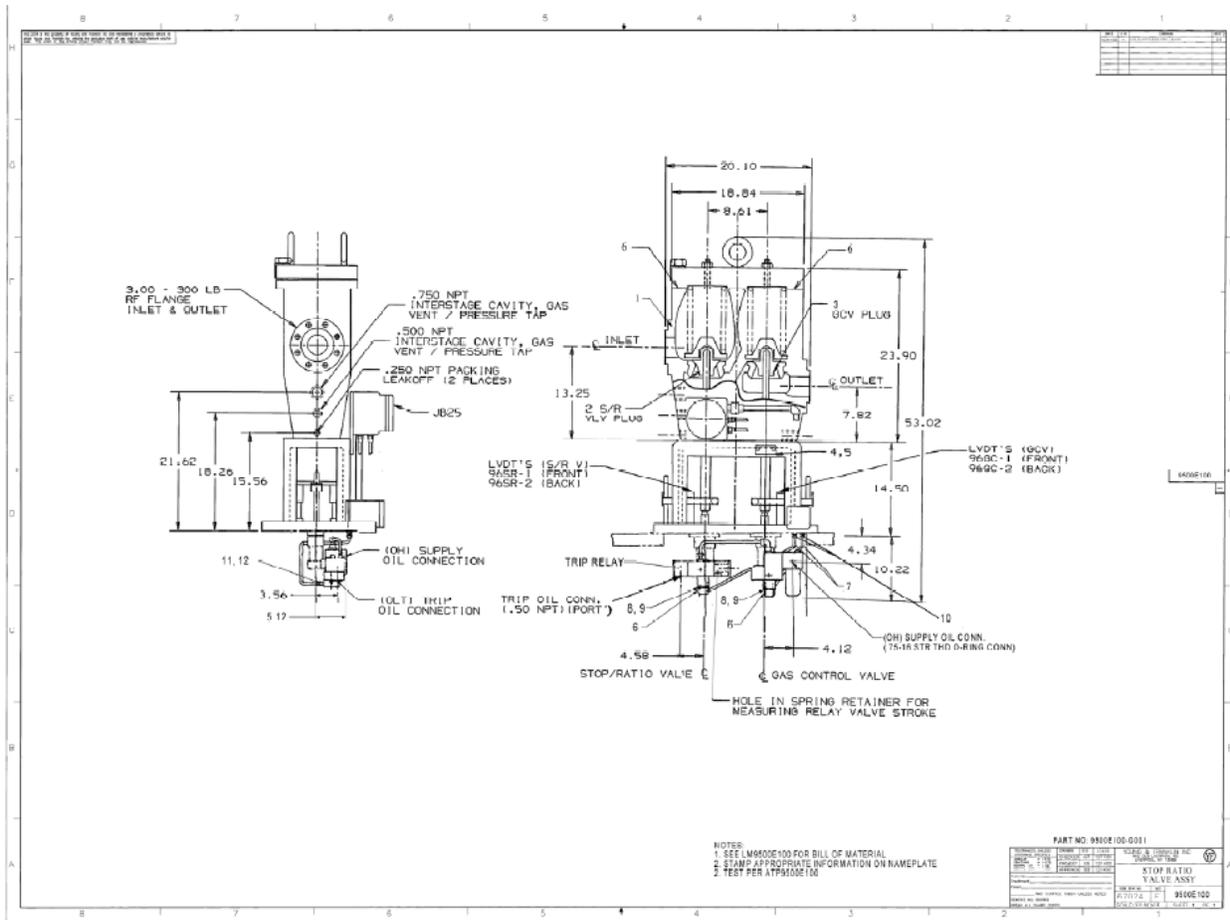
Gas Valve Drawing

Additional Instrumentation

TDS replaced outdated instruments such as the obsolete McGraw Edison Flame Detector System and the Type J Thermocouples. Additional instrumentation was added to better monitor the running condition of the turbine as more modern machines have available. As an example, RTD's were added to the turbine inlet, lube oil tank, and radiator outlets. Additional instrumentation was provided to monitor the fuel pump discharge pressure as well.

The new control system is designed to use all the existing turbine devices without modification. The only exception was the obsolete McGraw Edison flame detectors. New Honeywell style flame detectors were used. New type K thermocouples were used because of their superior characteristics, but the old type J thermocouples could have been also been used.

The existing LVDT and servo swashplate control was retained without modification.

Because the existing devices were reused, the customer's stock of spare parts still applies to the new system. This means that there is no additional cost in unnecessary device replacement, and the customer is already familiar with the old devices.

A new bus fed exciter system cost was also averted by doing a front end upgrade to the existing SCT-PPT exciter. The exciter high voltage devices such as the SCTs, PPT, and Rectifier Bridge were reused. This is a big cost reduction, as the cost of a new PPT and associated bus work to add the new PPT and remove the old devices is substantial.

Manpower

Due to the expedited nature of the job, TDS commenced work before the unit was shut down. Activities included running conduit and cable trays, as accessible, without disabling the unit. Some cables were pulled in advance as accessible. Experience counts here also as many devices are in inaccessible or hard to find locations, and since TDS employed knowledgeable engineers, no time was spent trying to find or identify devices.

TDS worked on this installation on a 6 day per week, 10 hour days shift basis over a three week period for the purpose of rewiring the unit, installing the panels, powering up the panels, and establishing communications and loop checks. TDS supported the startup of the new control system until the system was stable.

TDS subcontracted Electro Design Engineering Inc. to provide the Journeyman Electricians required to support the demolition of the old controls panels, the installation of the new control panels and the rewiring of the package electrical under the direction of TDS engineers.

TDS provided mechanical support for the installation rigging of the control panels and the mechanical modifications require to the control cab to remove walls and handrails in order to implement the change.

Communication

Due to the fast track nature of this project, communication was essential to the successful outcome of this project. TDS made several site visits to ensure that the

drawings matched the field wiring (as accessible) and to make sure TDS had all available documentation.

During these site visits, the engineer met with the plant representative to present options on how issues could be solved and get their input as to their preference. Sometimes these issues would be addressed via email or phone calls.

When the panel was fully assembled, powered up and tested, the customer made a manufacturing site visit to document the progress on the project and assembly of the system. This was a requirement from their part and served as a safety check to ensure that TDS would be able to comply with the June 1st deadline. If the panel, the engineering and logic was not to their satisfaction, the unit would not be shut down for installation. TDS met the expectations and the project proceeded.

Training

Training of the customer's operations personnel, and McIntosh control technicians was handled by TDS with on-site training which occurred, hands on, during the new system commissioning. The customer, engineers and technicians were all welcome to sit through factory programming efforts and graphics development so long as productivity was not affected to allow for system training. TDS always encourages the customer to learn the TurboNet *DASH 1* $^{®}$ system and provide independent troubleshooting, as well as programming capabilities for the system in order to take advantage of the full capabilities of the TurboNet *DASH 1*$^{®}$ Control System.

The customer assigned plant technicians to work with the TDS personnel during commissioning to gain familiarization with the system.

The operators were trained when the turbine was commissioned using the graphical control screens and demonstrating their use to the available operators.

The City also wanted an in depth technician training program. The training was held approximately one month after the turbine was commissioned. This allowed for the drawings to reflect all the as built changes, and therefore, the manuals would include accurate drawings. This TurboNet training included how to troubleshoot the panel and devices, as well as how to make simple changes to the logic and graphics. The technicians gained all the practical knowledge required to find an alarm in the logic,

understand what generates it, and troubleshoot as required. The second half of the training included information on the DECS-400 excitation system. It included information on how the SCT-PPT system works, how to run the programming and troubleshooting utility and how to use the drawings supplied that document the installation. The SEL protection relays fall under the T&D group within the City. This group is very familiar with these relays, and therefore required no training. The TDS technician training was done at a Lakeland Electric provided training facility.

Initially, the customer dedicated a couple of instrument technicians and a controls engineer to learn the system. They read the TurboNet documentation and studied the TurboNet documentation and construction. They added labeling which they found to be a weakness of that vintage of the TurboNet *DASH 1*[®].

Over the nearly 10 years since the system has been installed, TDS has received an occasional order for part, however, TDS has not provided any on-site service for Lakeland Electric on the TurboNet *DASH 1*[®] with the exception of the flame detector issues encountered early on in the operation of the machine and discussed later in this document. This is not the case for most of the other TDS TurboNet *DASH 1*[®] customers who rely mostly on TDS support for failure troubleshooting.

The customer has indicated that with the ageing technicians trained on the TurboNet *DASH 1*[®] and the loss of the trained controls engineer that it is time to obtain retraining on the control system maintenance and troubleshooting as Lakeland Electric intends to move on this training in the near future. Lakeland Electric has only recently learned of the TurboNet Ubuntu HMI/EWS/Historian upgrade and will likely entertain the upgrade option and plan to train on the new Ubuntu TurboNet tools.

Lessons Learned

Aftermath, Successful Operation from 2008 until today

Recently in preparation for this presentation, TDS had a meeting with Lakeland Electric regarding the "MAC GT" and the TurboNet *DASH 1*® controls upgrades. Lakeland Electric is convinced of Turbine Diagnostic Services Inc.'s capabilities for controls upgrades and product reliability. Lakeland Electric has found the system to be highly reliable and the majorities of the failures have been with regard to field devices as opposed to the TurboNet proper. (Recent calculations of TurboNet reliability over the past 15 years indicates a fleet reliability of 99.996%.)

TDS installed TurboNet *DASH 1*® Control Systems on the "MAC GT" and the two Emergency EMD Diesels diesel units. During a recent review of the system hardware in service, while there was a monitor down and the system was dirty, all three of the units were ready to operate and there were no significant system flaws.

The Lakeland Electric meeting participants indicated that over the years they have lost their expertise with TurboNet and the system has continued to run for the past several years without any attention. They indicated that they needed to retrain their controls/instrumentation personnel on TurboNet and were very interested in the option for a HMI/EWS/Historian Ubuntu upgrade.

Meeting minutes were collected and were incorporated into the comments and feedback provided by the customer.

Feedback

The feedback from Lakeland Electric consisted of two things, high reliability and lack of training. Prior to the project, the reliability of the Speedtronic controlled unit was 5% compared to the post upgrade TurboNet *DASH 1*® performance having a 95% reliability rate according to plant engineers. The customer also agreed that the majority of the lacking 5% was more due to field device failures rather than the TurboNet proper.

The processors on the TurboNet were said to be "bullet proof" and have lasted with no problems since installation, 10 years ago. As with all computer equipment, the hardware of the HMI and EWS have required maintenance and in some cases currently

still require maintenance, but this in no way is inhibiting the unit availability and it's Ready-To-Run status.

The key points discussed with Lakeland Electric regarding their perceptions of the new controls are summarized below:

1. This unit did not have an auxiliary hydraulic pump. What it means in practice is that the cranking motor needs to spin the turbine in order to establish hydraulics to calibrate the control valves. A simple solution for this was to find an off the shelf 120 VAC powered hydraulic pump that could be connected into test ports in the lube oil and hydraulic system. This temporary hydraulic supply system allowed TDS to calibrate the control valves (gas and liquid fuel) without the need to run the cranking motor.

2. During commissioning, a failed solenoid was found in the cranking motor. The plant was in the middle of an inventory reduction process. The solenoid had not failed in over 20 years, and was slated to be scrapped. The solenoid was removed from the scrap pallet and was installed. The EMF dissipation of this solenoid coil also created some issues with DC components and when replaced, the parallel damage ceased.

3. In order to interface the new Honeywell flame scanner sensors, a new board was designed to provide the excitation and signal conditioning for the associated counter module. The counter module counts the peaks of the device charging and discharging. A few years later, the flame scanners would indicate flame at light off and subsequently diminish in strength until the unit tripped. It appeared that the flame scanners had failed in a way that allowed the DC offset at the input card to rise above the threshold voltage used to detect transitions. Replacing the flame scanners solved the issue. However during the investigation and troubleshooting, the board was also redesigned so that this failure mode cannot happen again. It was noticed that the collapse of the voltage across the flame scanner has a few ripples in the decay. These ripples were being counted as part of the frequency readout. As part of the redesign, a filter was implemented to filter out the ripples and to give a true reading of the main event. This proved to be reliable, however, the actual issue which confused the troubleshooters was that both of the flame detectors were bad causing initial false conclusions.

4. Lakeland Electric had requested that smart transmitters be used throughout the project. This included the P2 gas pressure control. Due to the low P2 chamber

volume, this pressure signal has to respond quickly. Even with the time constant inside the transmitter set to minimum, it was still had to slow of response. Extra software had to be programmed in to alleviate this problem. In the end, the programming modification was successful; however, analog transmitters should be utilized in the next implementation for better results.

5. The generator PT drawer contacts were a problem on this installation. The standard GE drawer contacts come from the side and have very little spring load and deflection (movement). This lead to intermittent contact on these PT signals. This should be considered revised on a future installation projects.

6. The phasing checks were performed by the plant measuring across the 230 KV generator breakers. While effective, it took some time to arrange the bucket trucks, high voltage voltmeter and all the personnel required to perform this. This could have been accomplished easier by disconnecting the neutral and back feeding. A newer solution could be to use a non-contact high voltage voltmeter to accomplish this.

7. Lakeland Electric had issue with the panel flush mounted keyboard and touch pad that was originally installed. They indicated that the operators would not use the panel mounted HMI to make control set-point changes and would normally use the Beer Stand HMI/Engineer console in the corner adjacent to the panel. TDS also did not like the way the keyboard and touch pad functioned and has abandoned that arrangement. The TDS solution has been to create a drop down shelf that holds a keyboard with integral track ball. This has been preferred by TDS, however, the customer indicated that they, in general, did not track balls either.

8. While the customer realizes that the training of personnel is their responsibility and that they have been losing those support capabilities on TurboNet, the city engineers have recently advised TDS that there had been minimal training done on the TurboNet *DASH 1*®. They agreed that they have a training budget and that they needed to get TurboNet on the docket. TDS took this concern seriously and will be providing training proposals. TDS also provided an engineer for the remainder of the day who worked with the plant technicians to conduct a TurboNet system walk down and provide as much explanation as possible and any troubleshooting/recommendations that could be make. This walkdown was conducted with knowledge gained by both TDS and the city technicians.

9. While nothing has changed with the system as intended, the responsible controls engineer for the city indicated his disapproval for a control system with an open source operating system. His concern was security. After much discussion with this engineer after the initial meeting and in-house at TDS, it appears that this opinion is like religion in the computer control world and everyone has their own beliefs. TDS is working to further understand the customer's concern and provide a satisfactory solution that is acceptable to Lakeland Electric for TurboNet *DASH 1*® to be a continued control upgrade for the city on their other steam and gas turbines in their fleet.

Overall, the customer feedback meeting was a success and it allowed TDS to meet the new players on the Lakeland Electric Team. The feelings by both TDS and Lakeland Electric is that the TurboNet *DASH 1*® controls upgrade has been a great success in providing a reliable unit and meeting the hurricane season deadline required on an expedited basis for the success of this project.