Wind Turbine Drivetrain Test Facility Data Acquisition System

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The Wind Turbine Drivetrain Test Facility (WTDTF) is a state-of-the-art industrial facility used for testing wind turbine drivetrains and generators. Large power output wind turbines are primarily installed for off-shore wind power generation. The facility includes two test bays: one to accommodate turbine nacelles up to 7.5 MW and one for nacelles up to 15 MW. For each test bay, an independent data acquisition system (DAS) records signals from various sensors required for turbine testing. These signals include resistance temperature devices, current and voltage sensors, bridge/strain gauge transducers, charge amplifiers, and accelerometers. Each WTDTF DAS also interfaces with the drivetrain load applicator control system, electrical grid monitoring system and vibration analysis system.

Data acquisition, Data communication, Drives, Wind energy

I. Introduction

The Savannah River National Laboratory (SRNL) is responsible for the design of two data acquisition systems (DAS) to support the Wind Turbine Drivetrain Test Facility (WTDTF). The WTDTF DAS acquires high speed (greater than 10,000 samples per second) and low speed (less than 100 samples per second) data used by wind turbine original equipment manufacturers (OEM). Real time displays and recording of data are important for the safe and reliable operation of the facility. To synchronize the acquired data, SRNL selected reflective memory (RFM) technology. Reflective memory is an optical ring-based, ultra high-speed shared memory network solution. With RFM, a distributed network can share real-time data at a deterministic rate, regardless of bus structures and operating systems. All saved data is in a format that allows for technical data management (TDM). The WTDTF DAS has the capability to record and share data with data acquisitions systems brought into the facility by the wind turbine manufacturers. By choosing this data acquisition topology, the WTDTF DAS is seamlessly expandable for future hardware upgrades as new measurement technology is developed.

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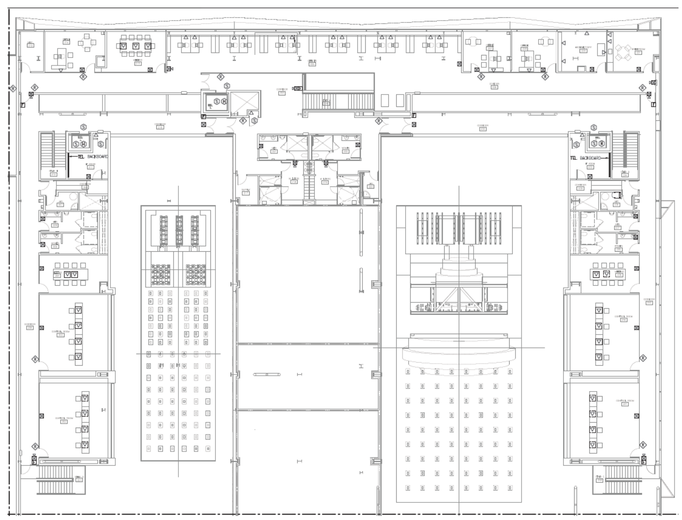

Fig. 1. General Layout of WTDTF Test Bay Areas

The WTDTF facility is over 100,000 sq. ft. with the test bays physically separated so two wind turbine OEMs can securely test their equipment. Data acquisition hardware is mounted in environmentally controlled, electromagnetic/radio frequency interference shielded racks located close to the wind turbine nacelles. Control rooms are located on a second floor with a view of the test area and access to all data acquisition computers.

II. Data Acquisition System Components

A. Temperature Monitoring

The wind turbine nacelle temperature monitoring system includes a stand-alone computer and a 96 channel Ethernet based resistance temperature detector (RTD) data collection hardware. The RTD inputs are isolated and have a 24 bit delta-sigma analog to digital converter per channel. Simultaneous sample rates for all channels are from 1 to 10 samples per second. During a nacelle test sequence, temperature monitoring data is continuously written to the WTDTF reflective memory.

B. High Speed Vibration and Strain Monitoring

The vibration and strain monitoring system consists of two high speed computer based data acquisition chassis with 32 channels of acoustic/vibration sensors and 128 channels of strain sensors. Simultaneous sample rates for all channels are from 1 to 12,500 samples per second for vibration sensors and from 1 to 2,000 samples per second for strain sensors.

The high speed system continuously transfers data to reflective memory for real time recording and display. It also provides on demand "snapshots" at the maximum data acquisition rate for all vibration and strain sensors. The "snapshots" are displayed in the control room as well as streamed to a database computer for future analysis and processing.

C. Grid Monitoring

The grid monitoring data acquisition system consists of a computer connected to 29 high voltage relays installed on the facility electrical grid. These relays monitor and control power for the drivetrain and the electrical feed back into the grid by the generator on the wind turbine nacelle. The computer obtains continuous, GPS (global positioning satellite) time stamped data from the relays including current, voltage, phase, frequency and power. The data is transferred to another computer in the WTDTF via the DNP3 power generation industry standard format. This computer processes the data and writes it to reflective memory.

D. Drivetrain Control

The drivetrain controller is a load applicator for the wind turbine nacelle. Forces that approximate those of the blades for a wind turbine are applied dynamically to the nacelle blade shaft. The drivetrain control system writes critical drivetrain information directly to the WTDTF reflective memory. GPS time stamped data includes torque, axial force, radial force, speed, bending moment and system status.

E. Facility Sensors

A low speed data acquisition system for facility sensors (building temperatures, hydraulic pressures, humidity, etc) is connected to a computer that writes the data to the RFM network with a GPS time stamp. Facility sensors are scanned sequentially and updated at 5 second intervals.

III. Data Acquisition Timing and Synchronization

The WTDTF DAS must combine data from several sources and maintain a common synchronized timestamp. The synchronized data allows the owner to analyze input from different sensors and determine their interdependence and correlation. Synchronized records of the facility data are essential to support the validity and veracity of the testing process.

In order to synchronize the acquired data, SRNL used a reflective memory and GPS network time protocol (NTP) timing solution. Reflective memory is a computer based shared memory space that uses fiber optic cables for transmission of data between systems with reflective memory hardware. Reflective memory has a deterministic transfer rate with only 450 to 500 nanoseconds of latency between nodes, up to 170 Mbyte/sec sustained data rate and 2.12 Gbaud serial connection speed.

Each independent data acquisition system of the WTDTF DAS contains a reflective memory card, connected to each other on a ring network, with the ability to write acquired data to the card via application programming interface (API) functions.

In the WTDTF data communication system, a network time protocol server provides the GPS time for each computer on the network. Every data point written to RFM has the GPS time stamp. Timestamps are maintained with microsecond accuracy. A database computer on the network retrieves data from the reflective memory and copies the time stamped data to a TDM binary data file for storage.

IV. Data Transfer Methods

Primary data transfer method between data acquisition components is via multi-mode fiber optic cable and reflective memory cards. Secondary communication for configuration and control of data acquisition system components is via Gigabit Ethernet 1000BASE-SX and multi-mode fiber optic cable.

Information transferred outside the WTDTF facility via the high speed Ethernet network is routed through a security controller that encrypts the data and utilizes multi-factor authentication.

V. Human Machine Interface

Each bay of the WTDTF has a central control room for monitoring all aspects of the facility. The control room user interface computer configures the WTDTF DAS components for a specimen test.
Responsibilities of the control room computer software are:

- Prompt the operator for test information
- Initialize the DAS component hardware
- Interface with the DAS component hardware units for maintenance and configuration
- Display real time data from reflective memory on local monitors
- Configure the database computer
- Configures the network time protocol server
- Print pre-formatted reports, setup parameters and collected data

Several DAS hardware components provide information in the test bay via a keyboard/video/mouse switches and local displays. Standalone systems, such as the grid monitoring system and load application system, have local processors, keyboards and monitors.

VI. Data Storage and Archiving

WTDTF data consists of raw values and associated metadata that includes calibration coefficients, timestamp, unique sensor identifier, unique test file identifier and other values as required for the test. Files are optimized for size by using binary headers and they are easily searchable and portable.

DAS components have removable, local archiving capability when possible to prevent data loss if the database computer fails.

The database computer moves data from reflective memory for off-site transfers and removable storage. Removable storage is a redundant array of independent disks (RAID) 5 system of hard drives with a 12 terabyte capacity. The storage drives use full disk encryption. An asymmetric encryption scheme has a key pair – one to encrypt the data (facility use only) and one to decrypt the data (customer use only).

The wind turbine OEM can recall the stored data using a data retrieval tool optimized for engineers and scientists to read, manipulate, report and analyze large amounts of data.

VII. System Operation and Serviceability

All DAS components have uninterruptible power supplies to maintain operation for a minimum of 20 minutes after loss of utility power.

Design life for the hardware is 5-10 years from the date of installation. Reuse of equipment in the design of the DAS components is maximized. Hardware and connection redundancy is used as much as possible. Ease and minimization of replacement cost was a priority for hardware selection.

System obsolescence is expected to be 15-20 years from the date of installation. Updated replacement computer systems and hardware are to be evaluated, specified and installed every 8 -10 years.

The base system software for operation, data transfer and data storage is maintained in a software configuration management database.

VIII. References

[1] R. Kent Lowrance, Cynthia Whitley, "Distributed Data System for Large Wind Tunnel," presented at the 54th International Instrumentation Symposium, Pensacola Bach, Florida, USA, 2008.

IX. Biographies

John B. McIntosh received a Bachelor of Science degree in Electrical Engineering from Washington University in St. Louis in 1992. Since graduating college, he has worked at the Savannah River Site in Aiken South Carolina at the Savannah River National Laboratory (SRNL). SRNL is a Department of Energy research laboratory that supports environmental management, defense programs and energy research. His responsibilities include the design, development and deployment of custom instrumentation systems for in-plant and off-site use. He has received the NNSA Pollution Prevention Environmental Stewardship Award and Federal Laboratory Consortium Southeast Regional Award of Excellence for Technology Transfer.