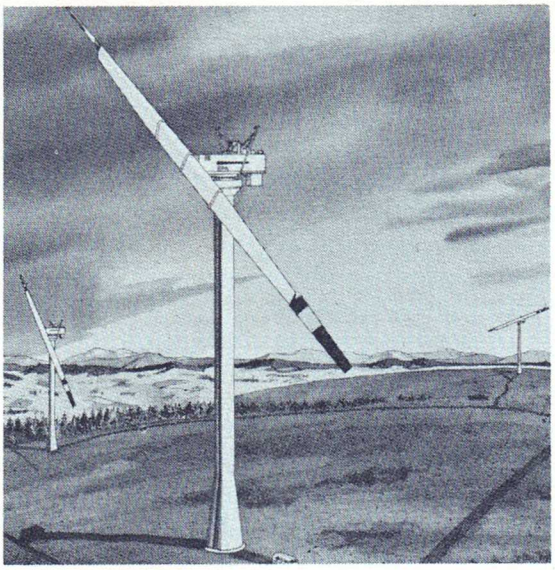
WIND ENERGY INSTRUMENTATION



DATA SYSTEMS BY

SANGAMO WESTON
Schlumberger

OPERATION & SERVICE BY

FAIRCHILD WESTON
Schlumberger

SUMMARY

Large quantities of data must be collected, stored, and analyzed in connection with research and development programs on Wind Turbines. This document describes the hardware and software configurations of the Wind Energy Remote Data Acquisition Systems assembled by Sangamo Weston and operated by Fairchild Weston on the large, horizontal-axis Wind Turbine Program administered by the NASA-Lewis Research Center for the Department of Energy.

FEATURES

The data collection equipment on the Wind Turbine includes:

- Complete, integrated, functional packages
- Modular, flexible, easy to operate
- Standard data multiplex formats
- Standard intermediate tape storage format
- Standard computer output tape format
- Wide choice of measurement types
- Operation in any Wind Turbine environment
- Remotely-operated calibration
- 32 measurements per unit --
- 96 per Wind Turbine --
- 16 measurements per slip-ring from Hub
- Lightning protection

The ground-based analysis equipment features:

- Up to 2000 feet separation from measurement sources
- Several stations for various stages of data analysis
- Easy-to-operate computer system for analysis
- Spectrum analysis and input to computer
- Variety of display types --

Printer	Printer/Plotter
Strip Charts	CRT Display

- Hardware data compression to prevent computer overload
- Time-tags with all data

TELEMETRY SYSTEMS

JULY 1981

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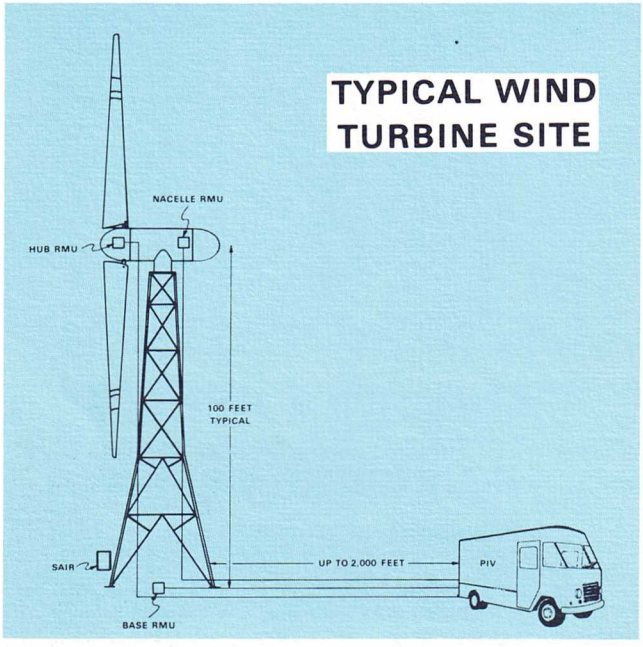
DATA COLLECTION AND ANALYSIS - AN OVERVIEW

The typical Wind Turbine installation is shown below. For analysis of performance, data is collected from the Hub, Nacelle, and Base of the turbine, and analyzed visually and/or by computer.

Data collection is accomplished by Remote Multiplexing Units (RMU) at each Wind Turbine.



When a Wind Turbine is being installed, a "Maxi-Van" is taken to the site for several months. The equipment in this van allows detailed analysis of data from the new Wind Turbine, and also provides a facility for playback of tapes from other sites.

Another mobile laboratory is housed in a "Mini-Van" and can be used for quick-look analysis of data from a Wind Turbine after the Maxi-Van has been removed. This station offers analog display of several measurements, as well as some computation and display in digital form. All data is recorded on instrumentation tape for playback and more detailed analysis in the Maxi-Van or at the NASA-Lewis Research Center's Plumbrook Station (Sandusky, Ohio).

Where no on-site data analysis is available an Instrumentation Recorder collects data subcarriers of interest. These tape recordings can be analyzed at the Maxi-Van. In addition, each site has the capability to display a limited number of channels on an analog chart recorder.

The Plumbrook system also includes facilities for replay and detailed analysis of tapes from other Wind Turbine sites.

Significantly, all recorded data tapes are in the same format, such that any tape can be analyzed at the Maxi-Van or at Plumbrook.

REMOTE MULTIPLEXING UNIT (RMU)

Approximately 32 data measurement points of interest are located in the Nacelle, another 32 in the Hub, and another 32 in the Base. Consequently, an installation could contain an RMU in each of these three locations to accept low-level or high-level data from various types of transducers, condition each data measurement (scale and offset) to a common range, frequency-multiplex the measurements (two groups of 16 per RMU), add a reference frequency to each group, amplify each group (plus a separate multiplex composed of some measurements from each group), output the basic groups to data analysis equipment, and output the separate multiplex or the individual multiplexes to the tape recorder.

All basic RMU's are identical, yet are flexible by choice of options and plug-in components, so that an RMU can be used to monitor either Nacelle, Hub, or Base data. One option is available in the RMU to add thermocouple reference junctions so that thermocouples can be used as data collection devices in the Nacelle. Two types of signal conditioner plug-ins are used, one for thermocouple or other low-level data transducers, and the other for bridge-type transducers.

Each signal conditioner output modulates a Voltage-Controlled oscillator(VCO). The 16 VCO's in each group are spaced at intervals of 500 Hz in the spectrum, and zero to full-scale data from a signal conditioner frequency modulates a subcarrier.

Each multiplexed group (subcarriers and reference) is amplified for driving an output cable up to 2000 feet long.

MAGNETIC TAPE RECORDERS

To provide interim storage of subcarrier multiplexes in analog form, an IRIG standard instrumentation tape recorder is provided at each Wind Turbine site to store important data.

Different recorders are used, with the selection at each site based on the phase of study at that site. In each case, however, certain characteristics are common. All data is recorded on IRIG-standard 1-inch tape, and can be played back on any similar IRIG transport. Recording is in the direct mode, Wideband I (approximately 12 kHz response at 15/16 inch per second tape speed).

SUBCARRIER DEMODULATION

All Wind Turbine data measurements in the six frequency-multiplexed subcarriers from the Remote Multiplexing Units (RMU's) are electrically identical and can be treated identically during the separation and demodulation process.

Each multiplex is routed to the Discriminators, where bandpass filters are tuned to select the subcarriers. Each is demodulated to yield analog data. A 40 Hz low-pass output filter prepares the data for output. Each output can be adjusted, but is set to ±5.0 volts for this system. Drive current is 50 milliamperes. It should be noted that discriminator output data is available for use in analog form. The system can include strip chart recorders, meters, or other analog devices as desired.

One feature of the system which improves data accuracy on playback of multiplexes from Recorders is automatic tape speed error compensation. The aforementioned reference tone is demodulated in the Reference Discriminator. Any variations from the precise tone are proportional to tape speed errors, and are provided as electronic correction signals to the Data Discriminators in the subsystem.

MINI-VAN SYSTEM

For those cases where a Wind Turbine is to be operated without full on-site data analysis equipment, a Fairchild Weston mini-van is used as a data analysis system.

In the Mini-Van system, the six data multiplexes from the Wind Turbine are routed to an input patch panel, and to a Tape Recorder. Any of the multiplexes, either in real time or in tape playback, can be patched to Detranslators, such that 16 of the measurements can be demodulated. Any data outputs can be patched to two strip chart recorders, which have eight channels per unit.

In addition, all 16 data outputs from the Discriminators are routed to a Analog-to-Digital Converter, where each is sampled every 0.2 second, converted into a digital word, and entered into a Microprocessor System. The microprocessor computes for each measurement periodically the average value and displays this, plus maximum and minimum values, on a Cathode-ray tube (CRT) terminal.

DATA ANALYSIS VAN ("MAXI-VAN")

Real-Time Wind Turbine data from the Hub, Nacelle, and Base, or playback from the recorder can be separated, demodulated, and prepared for computer entry. A total of 96 channels can be separated, demodulated, and filtered by the equipment in the Maxi-van.

DATA ANALOG-TO-DIGITAL CONVERTER

A 96-channel A-to-D samples all discriminator outputs sequentially, looking at each cycle of 40 Hz data at least five times in order to obtain a faithful representation of the data for computer entry. Five observations at each cycle of 40 Hz data per second is 200 observations per second per channel, or about 20k words per second.

Each data sample is converted to a 12-bit word and provided as parallel word data, suitable for data compression and computer entry.

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DATA COMPRESSION

In the typical Wind Turbine, most of the data points represent redundant information. Each data point must be examined, however, in order not to miss the significant occurrences. Time does not permit this examination in the Computer, since too much time would be used in software manipulation of the data. By performing this examination in a pre-processor and discarding all except the significant data, the load on the analysis computer is reduced dramatically and a relatively small computer is able to do a king-sized job.

In this system, a unique hardware device is used as a Pre-Processor/Data Compressor. The device examines each measurement as it occurs, and applies certain algorithm tests to the data. Only those occurrences which pass these tests are presented to the Computer. Since this is a hardware device, processing time on each sample is extremely short, and up to 90% of the data can be discarded.

TIME MERGING

Time is merged with incoming data every millisecond or every frame. Minor time (milliseconds) is provided with a unique tag; every second (or subframe, etc.) major time (seconds/minutes and hours/days) is provided.

TELEMETRY INTERFACE

After the system is set up, processing action is completely automatic. The Buffered Data Channel recognizes an event which prepares it for data entry. Then an event which signals the presence of the word which should go into the first buffer location is entered, and so on. Each time a lull occurs in data entry (frame synchronization pattern, for example), a pulse from the Time Code Translator automatically switches action from the data port (A) to the time port (B) for time merging. When each buffer area is filled, the Buffered Data Channel automatically shifts to other buffer area, and action is started to process and/or store data from the just-completed buffer.

CENTRAL PROCESSOR

The Computer has 16-bit capability, with memory addressable as bytes or as words. The 16-bit word, when used as an address, gives direct addressing up to 64k bytes (32k words). The user has access to 28k words in a 32k memory.

MASS STORAGE

The system contains a Cartridge Disk controller with one Disk Drive. The disk provides a total of 2.6 million words of storage. Another Disk Drive could be added to the system later if desired; the controller handles multiple drives.

One Digital Magnetic Tape Controller/Tape Drive is used to read or write industry-compatible digital magnetic tapes. The tape unit provides for recording data during analog tape playback. The tape can then be played back for data processing and analysis.

DISPLAYS

The system includes a CRT Display Unit. The CRT is an alphanumeric display 8.5 inches wide and 4.5 inches high; has 24 lines, 80 characters per line. The character code is ASCII, 96 printing (including space) upper and lower case. The display has a keyboard and a composite video output. The refresh rate is 60 Hz.

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TEAM MEMBERS

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