DOE/NASA/1028-28
NASA TM-81603

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Work performed for
U.S. DEPARTMENT OF ENERGY
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Prepared for
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Washington, D.C. 20545
Under Interagency Agreement EX-76-I-01-1028

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DATA ACQUISITION AND ANALYSIS IN THE DOE/NASA WIND ENERGY PROGRAM

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Abstract: The Lewis Research Center of NASA manages for the Department of Energy, the technology and engineering development of all large horizontal axis wind turbines. In support of this activity each wind turbine has various data systems used to acquire, process and analyze data. This report will identify four categories of data systems, each responding to a distinct information need. The categories are: Control, Technology, Engineering and Performance.

The focus of this report is on the Technology data system which consists of the following elements: (1) sensors which measure critical parameters such as wind speed and direction, output power, blade loads and strains, and tower vibrations; (2) remote multiplexing units (RMUs) mounted on each wind turbine which frequency modulate, multiplex and transmit sensor outputs; (3) the instrumentation available to record, process and display these signals; and (4) centralized computer analysis of data at the NASA-Lewis Research Center in Cleveland, Ohio.

RMU characteristics and multiplexing techniques are presented. Data processing is illustrated by following a typical signal through instruments such as the analog tape recorder, analog-to-digital converter, data compressor, digital tape recorder, video (CRT) display, and strip chart recorder. Sample output data from the 200 kW Mod-OA wind turbine at Clayton, New Mexico, are presented.

Key words: Wind energy; wind turbine generators; wind turbine performance; horizontal axis wind turbines; wind turbine data systems.

I. Introduction

The U.S. Government has established a Wind Energy Program within the Department of Energy (DOE) to encourage the development and promote commercialization of wind energy systems. One phase of this program is being managed by the NASA Lewis Research Center (LeRC). An agreement with DOE stipulates that LeRC shall manage both the

Technology and Engineering Development for all large (> 100 kW) horizontal axis wind turbines.[1] Four wind turbine projects, designated the Mod-0[2], Mod-0A[3], Mod-1[4], and Mod-2[5], are part of the current development program. In addition to these projects, efforts aimed at achieving lower machine costs have been initiated . These include an advanced 1,000 kW-class wind turbine project (Mod-5) and an advanced 200 to 500 kW wind turbine project (Mod-6). The four existing models are shown in Fig. 1 and the major features of all these machines are summarized in Table 1.

With regard to all these machines, LeRC maintains the continuing capability to monitor, analyze, understand and report on their performance. Despite the diversity in Wind Turbine Generator characteristics amongst the machines listed in Table I, we can nonetheless identify four distinct information/user categories that are common to all wind turbines. Namely: operations/the wind turbine itself; technology/field operations personnel; engineering/system and component designers; performance/utility or program manager. The requirements for each category are sufficiently unique that we have developed a separate data system to meet each need. At one extreme, with the highest sampling rates, are the computer based control systems which govern the routine operation of each wind turbine generator. The data portion of the control system provides information regarding adequacy of the wind, status of all critical systems, machine alignment with the wind, etc., and often monitors over 100 sensors. In the case of critical controls it must be capable of responding within milliseconds. This system is considered to be an integral part of the wind turbine and varies significantly from one design to the next. At the other extreme, with the lowest sampling rate, would be a Performance Data System to provide data for evaluation of wind turbines in terms of availability, reliability and energy production. These data requirements are generally limited to meteorological and electrical parameters with time scales from an hour to the lifetime of the machine. The two remaining information systems, namely Technology and Engineering are discussed in greater detail in the remainder of this report. The next two sections deal with the signal conditioning acquisition and data display. The fourth section discusses the subsequent statistical analysis.

II. Technology Information Systems

The Technology Data Acquisition/Display System has three functionally (and spatially) distinct components. As one follows the data signals from the sensors through the system, these are: signal conditioning, acquisition/display, and post processing for statistical analysis. Physically these functions occur: on the wind turbine at or near the base of the wind turbine tower and at LeRC, respectively. As mentioned earlier in connection with Table I, the wind turbines display considerable varibility as to source, location, blade composition and design. Despite, and to some extent because of this variability, it was decided that all data system implementations of must have the same (or functionally equivalent) hardware and software.

Signal Conditioning

Signal conditioning is performed by a Remote Multiplexing Unit (RMU). As input, an RMU can accept up to 32 low-level or high-level data signals from a variety of transducers. Each RMU contains reference junctions for thermocouples as well as the necessary electronics for excitation and bridge completion of strain gauges. As a specific example, Table II contains a list of all the transducers monitored by the Technology Information System during the initial start-up of the Mod-1 at Boone, North Carolina. Each wind turbine has one RMU located in the hub, another in the nacelle and (with the exception of Mod-2) a third unit at the base of the tower in the controls room.

After a signal is received at the RMU it is conditioned (scale and/or offset; amplification or attenuation) to a common range and frequency multiplexed for output. Each RMU can generate two multiplex groups. Each multiplex group consists of up to 16 FM subcarriers ($\pm$ 125 Hz centered at 500 Hz intervals from 1000 Hz thru 8500 Hz) plus a precise reference tone at 9500 Hz. Other significant features of the RMU include a 4-pole active Butterworth low pass filter and an end-to-end system calibration capability (upon command from an external source).

Acquisition/Display

LeRC has two nearly identical Technology Acquisition/Display Facilities. One is installed at the LeRC Plum Brook station in Sandusky, Ohio and is used by the LeRC engineering staff to conduct the Supporting Research and Technology program based on the Mod-0 machine. The other is installed in a large van.[6] This latter relocatable system is used to support field engineers thru assembly, check-out and initial operation of the first units of each new wind turbine design.

A schematic representation of the electronic data processing capability of this facility is shown in figure 2. All RMU generated FM multiplexes entering this facility are, with the addition of a time code, recorded in direct analog form. This recording can be performed independent of any other equipment or processing activity within the facility. Simultaneously, the data can also be routed thru a set of 6 banks of 16 discriminators which de-multiplex the signals and generate analog ($\pm$5V) signals. Any or all of these 96 analog signals can be digitized and routed thru the mini-computer. From there it can be processed for real-time digital display on a CRT and/or for transmittal on digital tape to the LeRC main-frame computers for further analysis. In addition, any 24 of the 96 analog signals may be selected for display on strip charts and any single analog signal may be routed to a spectrum analyzer for frequency content evaluation. All the components shown with a gray stipling in Figure 2, can be set up and run under computer control at the discretion of the facility operator via the operator's console. The facility in the van has sufficient capacity to simultaneously support up to three wind turbines at a single site.

STATISTICAL ANALYSIS

Large volumes of data are of little value in their raw form. Even after processing, they may well be of negligible value if the end product is overwhelmingly voluminous, inadequately disseminated, or excessively delayed. To preclude these occurrences we routinely perform statistical analyses of both the technology and the engineering data. Condensed summaries are provided in a timely fashion in both graphic and tabluar form, using microfiche as the distribution medium.

Pre-Processing

Digital magnetic tapes are generated at one of the Technology Acquisition/ Display facilities. The digital data consist of 11 readings per parameter per (nominal) revolution and are stored as a tightly packed, randomly sequenced record. Each datum is accompanied by an identifying tag. Time markers (to nearest millisecond) are merged with the data.

As the first step, these data tapes are transferred to disk for short term (i.e. days) storage on the LeRC main frame system. During the transfer process, the internal representation is transformed (in software) from ASCII to EBCDIC. The next step in the processing compacts this initially large dataset ($\sim 5\times10^6$ data values + 5×10^6 tags + 1×10^6 time markers) into a more manageable form, as follows: The rotor shaft position is used to mark the start of each rotation. These markers are then combined with the associated time markers and processed to give rotor speed (rpm) as a function of time. Then, the data from approximately 30 sensors of general interest are screened to yield maximum and minimum values for each parameter for each revolution of the rotor. This smaller data set ($\sim 5 \times 10^5$ data values) is stored on disk and is the data base for all further processing.

Standard Analysis

In the final step, this latter data set is processed onto a microfiche containing the time history and statistical summary of each parameter of general interest. While the specific set of sensors and their associated scale factors will vary from machine to machine, the same presentation format is, nevertheless, applied to all data from all machines. This entire process is shown schematically in Figure 3.

The data, which have been stored as maximum and minimum values for each revolution, are combined to represent the midpoint and cyclic values for each revolution. The transformation equations are:

$$\text{midpoint} = (\text{maximum} + \text{minimum}) / 2$$

and

$$\text{cyclic} = (\text{maximum} - \text{minimum}) / 2) \times (1 + f(\text{rpm}))$$

where,

$$f(\text{rpm}) = 2 \times 10^{-5} (\text{rpm})^2.$$

The correction function, f(rpm), is introduced to compensate for the consistent underestimation of cyclic values resulting from the data sampling rate of 11 per (nominal) revolution.

The results of the analysis of each sensor are displayed as two frames, one graphical and one tabular on the microfiche card. The first of the two frames (see fig. 4) for each sensor contains three graphs. On each graph there are two plots, one of the midpoint values with circles as symbols and the other of the cyclic values with diamonds as symbols. The three graphs are:

1. Time history. This graph summarizes the information in the continuous trace associated with a strip chart recorder. One plot is of the average, over 30 second intervals, of the midpoint values. The other plot is of the corresponding cyclic values.

2. Partitioned distributions.[7] The abscissa for this graph is the wind speed midpoint value as measured at the nacelle. These wind speed values are used as the basis for sorting corresponding data values of the sensor of interest. The data values for the sensor of interest are grouped into subsets such

that for each subset all the sensor data values were obtained at approximately the same measured wind speed. Then the data values within each subset are separately ranked in ascending order. We find the 16th and 84th percentile for each such sequenced subset and display these percentiles as horizontal tabs at the end of a vertical bar. We also estimate the confidence interval (at the 0.95 level) for significant differences of the median[7] and display it as an interval (denoted by the occurrences of a circle or diamond) on the same vertical bar. This entire process is performed separately for the midpoint (circle) and cyclic (diamond) data values.

3. Cumulative distribution. This graph corresponds to a normal distribution , i.e. the abscissa is in units of normalized standard deviations and is segmented with tick marks and labelled by percentiles. Such a graph has the characteristic that if the plotted data have a normal (i.e. gaussian) distribution, the plot will appear linear. For this graph the entire set of all midpoint values is sequenced and plotted by percentile. This process is repeated, separately, for the cyclic values.

The second frame (see fig.5) for each sensor presents two tables listing all the plotted data points from both distributional plots. Some additional related but non-plotted, data are also tabulated. Because some of these present extreme values (i.e. maxima and minima), these tabulated values must be addressed with caution as they might represent spurious noise.

III. Engineering Acquisitional/Display System

After the initial check-out, LeRC retains the responsibility to monitor, analyze, understand and report on all the wind turbines under our supervision . Since the Technology Acquisition/Display System described above is too elaborate and expensive for long term monitoring at each site we have identified a subset which we call the Engineering Acquisition/Display System. This system is installed in the control area of each wind turbine. This latter facility provides on-line analog display on strip chart (8 channels per wind turbine) and continuously records 48 signals (as 3 FM multiplexes) plus time on 4 tracks of analog magnetic tape. The analog magnetic tape record operates in either of two modes, depending on local conditions and requirements. At some sites they record until the tape is full (32 hours) and then automatically rewind (10 minutes) and restart, erasing old data as new data are recorded. At other sites the recorders operate for 96 hours (by making 3 passes thru the tape using a total of 12 tracks) and then automatically turn off. They remain off until the tape is replaced and the unit is manually restarted. These analog tapes can be played back onto strip charts at the site, and they can also be sent to one of the Technology Acquisition/ Display facilities for further processing of the data.

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Table I - DOE/NASA Large Horizontal Axis Wind Turbines

WTG	Rated Power, kW	Rotor Features	Rotor Diameter	Blade Material	Location
Mod-0	100	variable	38.5M	Aluminum, Steel, Wood	LeRC Plum Brook
Mod-0A 1	200	downwind		"	Clayton, NM
Mod-0A 2	200	downwind		"	Culebra, PR
Mod-0A 3	200	downwind		"	Block Island, RI
Mod-1	2000	downwind	61.5M	Steel Fiberglass	Boone, NC
Mod-0A 4	200	downwind		Wood	Kahuku, HI
Mod-2	2500	upwind teetered	92.3M	Steel	Goldendale, WA
SVU	4000	downwind teetered	78.5M	Steel	Medicine Bow, WY
Mod-5A	4000^P	?	107.7M	?	?
Mod-5B	4000^P	upwind	38.5M	Steel/Wood^P	?
Mod-6H	500^P	?	?	?	?

(P) = Preliminary / ? = Not determined yet

TABLE II - INSTRUMENTATION LIST MOD-1 BOONE, NC AS OF 5 AUGUST 1980

PARAMETER	SIGNAL *UNITS	SIGNAL LOWER	SIGNAL UPPER	ENGINEERING *UNITS	ENGINEERING LOWER	ENGINEERING UPPER
ROTOR BNG IN RACE	*MV	+0.391	+5.281	* DEG F	+50	+250
PITCH CHANGE BNG	*MV	-0.674	+3.967	* DEG F	0	+200
SPAN STRAIN 469	*MV	-20	+20	*FT-LBS	-4.728 E5	4.728 E5
SPAN STRAIN 390	*MV	-10	+10	* PSI	-2.8409E4	2.8409E4
CB 907.5	*MV	-10	+10	*FT-LBS		
CHORD STRAIN 390	*MV	- 5	+ 5	* PSI	-5.6818E4	5.6818E4
DIAG STRAIN 469	*MV	- 5	+ 5	* PSI	-5.6818E4	5.6818E4
FB 907.5	*MV	-50	+50	*FT-LBS		
SPAN STRAIN 482	*MV	-20	+20	* PSI	-1.1364E5	1.1364E5
CB 469	*MV	-20	+20	*FT-LBS	-2.1561E6	2.1561E6
HUB OUTSIDE BRL	*MV	-20	+20	* PSI	-1.1364E5	1.1364E5
HUB INSIDE BRL	*MV	-20	+20	* PSI	-1.1364E5	1.1364E5
HUB TAIL X BEND	*MV	-20	+20	*FT-LBS		
HUB TAIL Y BEND	*MV	-20	+20	*FT-LBS		
PITCH ROD #1(T/C)	*MV	-20	+20	*IN/IN	-2.5 E4	2.5 E4
NOT USED	*	--	--	*	--	--
FB 117	*MV	-50.0	+50.0	*FT-LBS	-1.3967E7	1.3967E7
CB 117	*MV	-20	+20	*FT-LBS	-6.4008E6	6.4008E6
FB 469	*MV	-50	+50	* PSI	-1.1364E5	1.1364E5
FB 469	*MV	-50	+50	*FT-LBS	-2.7444E6	2.7444E6
SPAN STRAIN 482	*MV	- 5	+ 5	* PSI	-2.8409E4	2.8409E4
FB 117	*MV	--	--	*FT-LBS		
FB 907.5	*MV	-50	+50	*FT-LBS	-5.4356E6	5.4356E6
SPAN STRAIN 46	*MV	-10	+10	* PSI	-5.6818E4	5.6818E4
CB 907.5	*MV	-10	+10	*FT-LBS	-2.2338E6	2.2338E6
SPAN STRAIN 299	*MV	-10	+10	* PSI	-1.1364E5	1.1364E5
CB 117	*MV	-20	+20	*FT-LBS		
CB 469	*MV	-20	+20	* PSI	-2.8409E4	2.8409E4
HUB INSIDE BRL	*MV	-20	+20	* PSI	-1.1364E5	1.1364E5
HUB OUTSIDE TAIL	*MV	-20	+20	* PSI	-1.1364E5	1.1364E5
SHAFT TORSION	*MV	-20	+20	*IN/IN	-1.0 E3	1.0 E3
PITCH ROD #2(T/C)	*MV	- 5	+ 5	*IN/IN	-2.5 E4	2.5 E4
INLET OIL TEMP	*MV	-.674	+5.281	* DEG F	0	+ 250
SERVO OUT (TP 1)	* V	0	+10	*	--	--
RTR BNG OUT RACE	*MV	-3.91	+5.281	* DEG F	+50	+250.5
TRANS LUBE TEMP	*MV	-.674	+5.281	* DEG F	0	+ 250

INLET OIL TEMP	*MV	.391	+5.281*	DEG F	50	+ 250
GEARBOX FLANGE	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
AIR TEMP (OUT)	*MV	-1.667	+3.967*	DEG F	-50	+2001
PITCH ROD DEC P	* V	0	+ 5	* PSI	0	+4000
GEN BNG SHAFT END	* V	0	+10	* DEG F	-30	+300
GEN WINDING TEMP	* V	0	+10	* DEG F	-30	+300
AFT HORIZONTAL	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
GEN SHAFT SPEED	* V	0	+10	* RPM	0	39.5
PITCH ROD INC P	* V	0	+ 5	* PSI	0	+4000
RTR BED VIB (Z)	*MA	-3.325	+3.325*	G	-2.5	+2.5
RTR BED VIB (Y)	*MA	-3.325	+3.325*	G	-2.5	+2.5
RTR BED VIB (X)	*MA	-3.325	+3.325*	G	-2.5	+2.5
BLADE PITCH ANGLE	* V	+6.54	+9.11 *	DEG	+24.0	-4.2
RTR BED VIB (Z)	*MA	-3.325	+3.325*	G	-2.5	+2.5
FWD BED VIB (Y)	*MA	-3.325	+3.325*	G	-2.5	+2.5
SERVO OUT (TP 4)	* V	0	+10	*	--	--
YAW TORQUE CCW	* V	0	+ 5	* PSI	0	+4000
YAW ERROR	* V	0	+10.0	* DEG	-270	+270
BLADE PITCH ANGLE	* V	0	10	* DEG	+96.0	-14.0
WIND SPEED(NAC)	* V	+0.25	+10.0	* MPH	2.5	100
COVER FLANGE	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
GEARBOX WEB	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
RTR SHAFT POS	* V	0	+10	* DEG F	0	+360
AFT 45°	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
YAW TORQUE CW	* V	0	+ 5	* PSI	0	+4000
AFT VERTICAL	*MV	-20	+20	*IN/IN	-9.9E-4	+9.9E-4
YAW POSITION	* V	0	+10	* DEG	0	+ 360
SERVO CURRENT	* V	0	+1.5	*	--	--
SOUND (5/27/80)	* V	-2.0	+2.0	* PSF/db	--	--
SOUND (5/27/80)	* V	-2.0	+2.0	* PSF/db	--	--
SOUND (5/27/80)	* V	-2.0	+2.0	* PSF/db	--	--
UTILITY VOLT EXP	* V	+7.2	+8.8	* KVOLT	3.78	4.62
GEN CURRENT A	* V	0	+10.0	* AMPS	0	600
GEN CURRENT B	* V	0	+10.0	* AMPS	0	600
GEN CURRENT C	* V	0	+10.0	* AMPS	0	600
TOW VIB SITE#1(X)	*MA	-3.325	+3.325*	G	-2.5	+2.5
TOW VIB SITE#2(X)	*MA	-3.325	+3.325*	G	-2.5	+2.5
EXCITER FLD CURR	* V	0	2.5	* AMPS	0	10
NOT USED	*	--	--	*	--	--
NOT USED	*	--	--	*	--	--
UTILITY VOLT	* V	0	+10.0	* KVOLT	0	5.25
NOT USED	*	--	--	*	--	--
NOT USED	*	--	--	*	--	--
NOT USED	*	--	--	*	--	--
TOW VIB SITE#1(Y)	*MA	-3.325	+3.325*	G	-2.5	+2.5
GEN PWR KVARS	* V	-10	+10	* KVARS	-4200	4200
GEN PWR WATTS	* V	-2.38	+10	* KW	-1050	4200
--						

TOW VIB SITE #1(Z)	*MA	-3.325	+3.325*	G	-2.5	+2.5
WIND SPEED 250'	* V	0	5 *	MPH	0	100
TOW VIB SITE #2(Z)	*MA	-3.325	+3.325*	G	-2.5	+2.5
ROTOR SHAFT SPEED	* V	-10	+10 *	RPM	20.0	40.0
NOT USED	*	--	-- *		--	--
NOT USED	*	--	-- *		--	--
AIR TEMP 150'	* V	0	5 *	DEG F	-30	110
WIND DIRECT 250'	* V	0	5 *	DEG	0	360
WIND DIRECT 150'	* V	0	5 *	DEG	0	360
WIND SPEED 60'	* V	0	5 *	MPH	0	100
TOW VIB SITE #2(Y)	*MA	-3.325	+3.325*	G	-2.5	+2.5
WIND DIRECT 60'	* V	0	5 *	DEG	0	360
WIND SPEED 150'	* V	0	5 *	MPH	0	100
GEN PWR WATTS	* V	-10	+10 *	KW	-3600	+3600
STRAIN 669	*	--	-- *		--	--
STRAIN 664	*	--	-- *		--	--
WHITE GEN NOISE	* V	-5.0	+5.0 *	V	-5.0	+5.0
CHORD STRAIN 469	*MV	-10	+10	*FT-LBS	-5.1768E6	5.1768E6
DIAG STRAIN 390	*MV	- 5	+ 5 *	PSI	-2.8409E4	2.8409E4
SPAN STRAIN 299	*MV	-10	+10 *	PSI	-5.6818E4	5.6818E4
FWD BED VIB (X)	*MA	-3.325	+3.325*	G	-2.5	+2.5

****

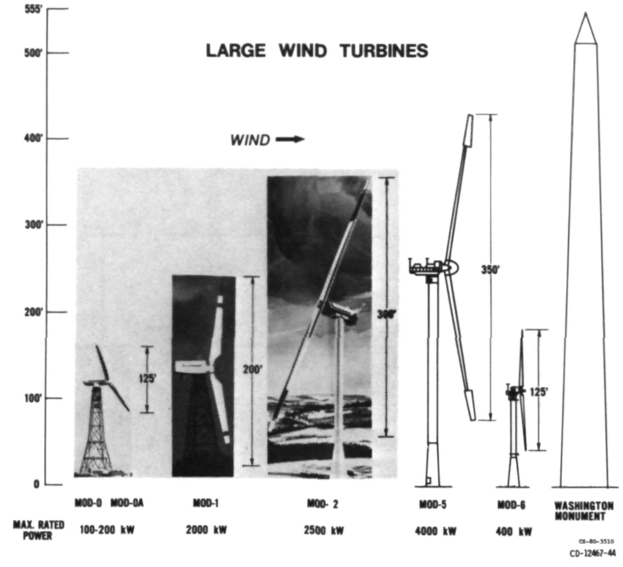

Figure 1. -

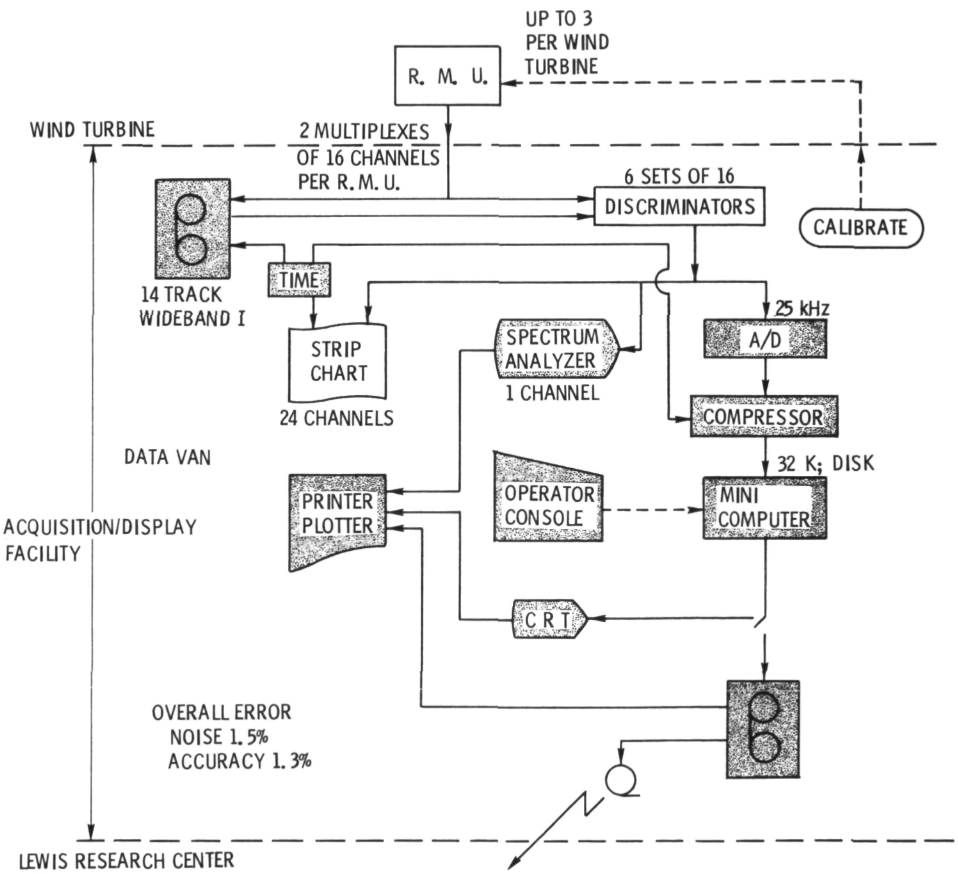

Figure 2. - Schematic representation of the electronic data processing in the Technology Acquisition/Display Facility. Every device shown with gray stippling can be controlled by the operator vis the computer console.

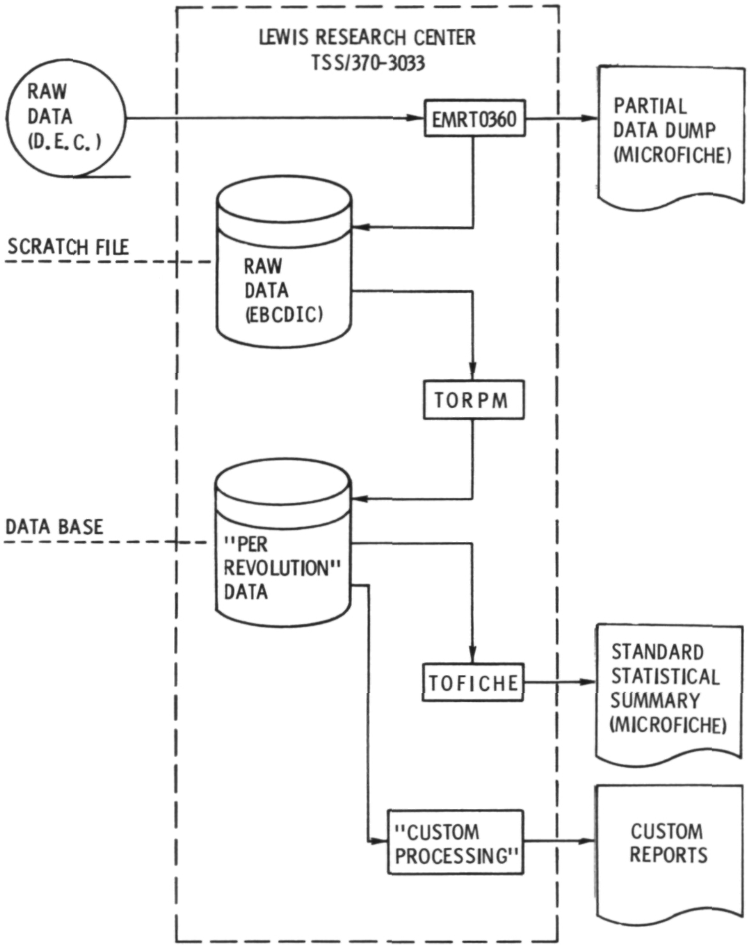

Figure 3. - Schematic representation of the data processing at the LeRC main computer facility.

CLAYTON, NEW MEXICO MACHINE: MOD OA1 1980

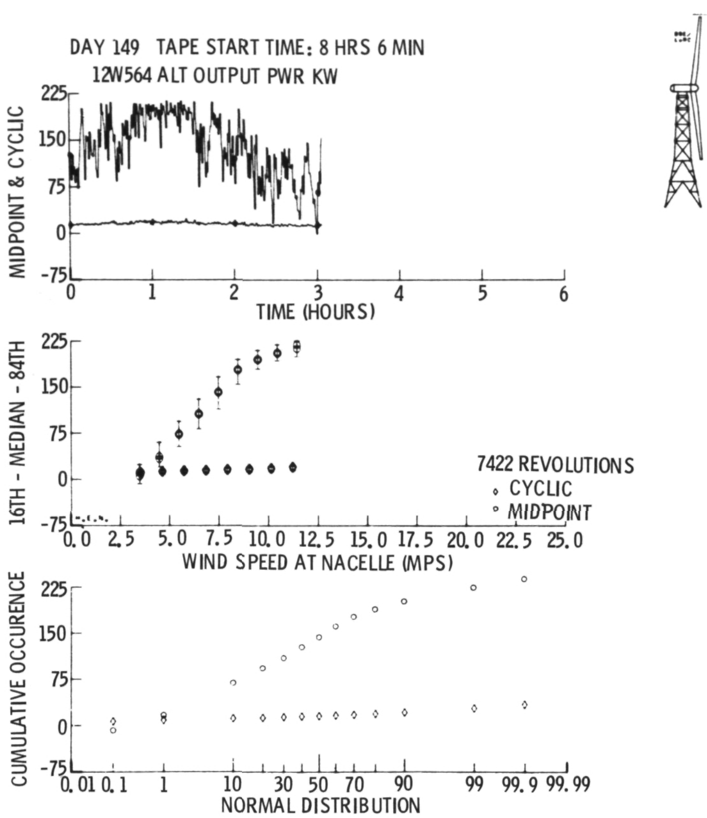

Figure 4. - Sample frame of the statistical data summary routinely available on microfiche.

CLAYTON,NEW MEXICO MACHINE : MOD OA1 1980
DAY 149 TAPE START TIME: 8HRS 6MIN
12W564 ALT OUTPUT PWR KW

---------- SEGMENTED DISTRIBUTIONS ----------

	MIDPOINT						CYCLIC				
WIND	MINIMUM	16TH PCTL	MEDIAN	84TH PCTL	MAXIMUM	WIND	MINIMUM	16TH PCTL	MEDIAN	84TH PCTL	MAXIMUM
3.5	-1.4E 01	-6.0E 00	9.4E 00	2.5E 01	4.6E 01	3.5	5.9E 00	8.4E 00	1.1E 01	1.5E 01	1.9E 01
4.5	1.9E 00	2.1E 01	3.6E 01	6.1E 01	9.2E 01	4.6	5.7E 00	1.0E 01	1.3E 01	1.6E 01	2.3E 01
5.5	1.0E 01	5.5E 01	7.4E 01	9.5E 01	1.4E 02	5.7	5.7E 00	1.1E 01	1.4E 01	1.7E 01	2.9E 01
6.5	2.4E 01	8.3E 01	1.1E 02	1.3E 02	1.8E 02	6.8	6.2E 00	1.1E 01	1.4E 01	1.8E 01	3.5E 01
7.5	5.0E 01	1.2E 02	1.4E 02	1.7E 02	2.0E 02	7.9	6.0E 00	1.3E 01	1.6E 01	2.0E 01	4.0E 01
8.5	6.0E 01	1.6E 02	1.8E 02	2.0E 02	2.3E 02	9.0	6.8E 00	1.4E 01	1.7E 01	2.1E 01	3.6E 01
9.5	1.4E 02	1.8E 02	2.0E 02	2.1E 02	2.5E 02	10.1	8.9E 00	1.5E 01	1.8E 01	2.2E 01	3.5E 01
10.5	1.5E 02	1.9E 02	2.1E 02	2.2E 02	2.5E 02	11.2	1.2E 01	1.6E 01	2.0E 01	2.3E 01	3.2E 01
11.5	1.9E 02	2.0E 02	2.2E 02	2.3E 02	2.4E 02	12.3	0.0	0.0	0.0	0.0	0.0

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0.1000	69.7	11.0	83.1	56.4
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0.6000	162.2	16.3	178.6	145.7
0.7000	177.8	17.5	194.5	161.1
0.8000	190.1	19.1	207.6	172.5
0.9000	203.0	21.2	221.5	185.2
0.9900	225.5	27.6	246.0	207.0
0.9990	239.3	33.6	262.7	222.1

Figure 5. - Tabular data produced in conjunction with the plots shown in figure 4.

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-81603		

4. Title and Subtitle	5. Report Date
DATA ACQUISITION AND ANALYSIS IN THE DOE/NASA WIND ENERGY PROGRAM	
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Harold E. Neustadter	E-594
	10. Work Unit No.
9. Performing Organization Name and Address	
National Aeronautics and Space Administration Lewis Research Center Cleveland, Ohio 44135	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Technical Memorandum
U.S. Department of Energy Office of Solar Applications for Industry Washington, D.C. 20545	14. Sponsoring Agency ~~Code~~ Report No. DOE/NASA/1028-28

15. Supplementary Notes

Prepared under Interagency Agreement EX-76-I-01-1028. Prepared for Symposium on Dectection Diagnosis and Prognosis sponsored by National Bureau of Standards, Santa Monica, California, October 7-9, 1980.

16. Abstract

The Lewis Research Center of NASA manages for the Department of Energy, the technology and engineering development of all large horizontal axis wind turbines. In support of this activity each wind turbine has various data systems used to acquire, process and analyze data. This report will identify four categories of data systems, each responding to a distinct information need. The categories are: Control, Technology, Engineering and Performance. The focus of this report is on the Technology data system which consists of the following elements: (1) sensors which measure critical parameters such as wind speed and direction, output power, blade loads and strains, and tower vibrations; (2) remote multiplexing units (RMUs) mounted on each wind turbine which frequency modulate, multiplex and transmit sensor outputs; (3) the instrumentation available to record, process and display these signals; and (4) centralized computer analysis of data at the NASA-Lewis Research Center in Cleveland, Ohio. RMU characteristics and multiplexing techniques are presented. Data processing is illustrated by following a typical signal through instruments such as the analog tape recorder, analog-to-digital converter, data compressor, digital tape recorder, video (CRT) display, and strip chart recorder. Sample output data from the 200 kW Mod-0A wind turbine at Clayton, New Mexico, are presented.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Wind energy; Wind turbine generators; Wind turbine performance; Horizontal axis wind turbines; Wind turbine data systems	Unclassified - unlimited STAR Category 44 DOE Category UC-60

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified		

* For sale by the National Technical Information Service, Springfield, Virginia 22161