A Wind Prospector's Instrument

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by
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April 1978

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A WIND PROSPECTOR'S INSTRUMENT

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In the initial evaluation of a prospective wind turbine site, wind measurements must be made at that site. This report describes an inexpensive data collection device that can be used to record such measurements, producing statistical summaries of wind behavior at the site. Prospectors have often used analogous devices to locate deposits of mineral resources; thus, we call this device a wind prospector's instrument.

Of prime interest at a prospective wind turbine site is the total amount of power which could be produced by a given wind turbine. Since that power may be linked to a utility network, or coupled with some other load representing a time-varying demand, the time behavior of the available power is also important. Wind speed and direction information is useful for wind flow patterns in the immediate vicinity of the instrument; short-term directional behavior aides the evaluation of the pointing strategy of a given turbine.

A complete time history of wind speed and direction could be combined with the wind turbine characteristics to provide this information. However, during the initial site evaluation one often cannot afford to either acquire or analyze a detailed wind history. Instead, one must attempt to characterize the the statistical behavior of the wind; therefore, one concentrates on wind characteristics which can be extracted from anemometer and wind vane output without recording and preserving a detailed history. Important statistics are joint frequency distributions of speed and direction, speed and time of day, and speed and dwell-at-speed. Joint distributions can

be obtained by sampling the wind speed and direction at regular time intervals, counting occurrences of various combinations of speed and direction, speed and time of day, etc. From these joint distributions, averages (and higher moments) can be calculated and combined with the characteristics of any given wind turbine to obtain total power, and power vs. time of day, etc. Turbulence may be characterized by deviations from moving averages of speed or direction. Peak wind statistics are also obtainable.

An instrument which would collect and record this information inexpensively could play a role in locating and evaluating "deposits" of wind energy, much like a geiger counter in locating deposits of uranium. Hence, we refer to it as a wind prospector's instrument. Most of the statistics could be accumulated by relatively simple equipment: an assembly of event counters preceded by classifying and steering circuitry. The wind would be sampled at regular intervals, classified as to state (e.g., between 4 and 6 m/s), and a count kept of the occurrences of each state. An instrument which samples uniformly with respect to wind run instead of time has been constructed and used,^{1,2} and other similar devices are commercially available.

When the wind classes are compounded of speed and direction (e.g., between 4 and 6 m/s out of the Northwest), the resulting data represent a joint frequency distribution and may be illustrated as either a wind rose for each speed interval, or a frequency distribution for each direction. Such data can help characterize flow patterns in the immediate vicinity of the instrument.

If the classes are compounded of speed and time of day (e.g., between 4 and 6 m/s, and between midnight and 3 a.m.), an indication is obtained of the diurnal variations in power availability, which can be compared to the diurnal power demand of the intended load.

A number of manufacturers presently offer multiple accumulators which, with minor modification, could be put into service to accumulate the tallies discussed above. However, none seems to be suited for general prospecting use. There are units now manufactured which can produce joint frequency distributions, or which, with modification, could produce diurnal distributions, but no single unit does both. Also, such instruments are expensive, and most are too bulky, heavy, and/or power consuming to be backpacked to a remote location.

In considering options for building a more suitable instrument, we find that a microprocessor-based device offers by far the greatest flexibility and least complexity. Its cost and power drain are comparable with that of other options employing hard-wired logic. The complexity of keeping a given statistic is embodied in programming, not wires and gates, and one can obtain information under program control, which would be prohibitively costly to hard-wire. The detailed design of such a device is complete, which, in its most elaborate version, can provide all of the statistics needed. This version can be built in reasonable quantity for approximately \$400. A stripped-down version could be constructed for perhaps half that cost, but would provide only the speed vs. direction histogram, and peak wind.

HARDWARE

A block diagram of the instrument is shown in Figure 1. A recently introduced single-chip data-acquisition unit (National Semiconductor ADC0816) is used to provide sixteen analog or low-speed digital inputs. Its inputs are assigned to the wind instrument input connector and used to measure potentiometer wiper positions, generator outputs, or contact closures. The unit may be used with all common types of anemometers and wind vanes and is capable of monitoring

Figure 1. Block Diagram of Wind Prospector's Instrument

several measurement points at once. In addition to wind data, it can gather such parameters as insolation and temperature. Ratiometric measurements may be made, avoiding the necessity for calibration of the digitizer.

Inputs are scanned once per time interrupt, controlled by a microprocessor. The desired frequency distributions are accumulated in its Random Access Memory (RAM), under control by a program stored in Erasable-Programmable Read Only Memory (EPROM). As a power-saving feature, excitation voltage to potentiometer-type sensors is switched on only when a measurement is to be made, and is turned off by the processor as soon as the sensor has been sampled.

The crystal-controlled processor clock is counted down to determine the interrupt rate, and that rate is counted down in software to provide sampling interval and time of day. The basic unit of timekeeping is 7.5 sec, the longest interval which is commensurate with both $1/256$ day and 1 minute. The interrupt rate is 298.67 per second, an exact multiple of one per 7.5 seconds, and a nominal match to a serial data output bit rate of 300 per second. This rate allows direct readout on a sampling basis of low-frequency contact type anemometers (60 pulses per mile), and higher frequency types require only minor prescaling.

The processor used is an RCA CDP1802D, which employs Complementary Metal-Oxide Semiconductor (CMOS) logic for low power drain. It offers convenient program-load features which allow a portion of the RAM to be loaded with program via the system connector for testing and one-of-a-kind data gathering tasks.

No readout device is included in the field unit. Instead, the processor's serial input and output lines are assigned to a readout connector. At the end of each period, nominally a week or month, a control keyboard and data readout device are

brought to the field unit and plugged into the connector. Keyboard commands are available for data dump, data clear, time set, etc. Two alternate output devices are planned: one, a small battery-operated printer, the other an ordinary audio tape recorder on which the data are recorded in a modification of the "Kansas City Standard" format popular with computer hobbyists.

The completed unit will eventually be a single-printed circuit card which will be housed in a weatherproof enclosure. Ordinarily the entire enclosure will be mounted directly on the instrument tower. Average power requirements will be a few milliamperes at 5 volts, which may be supplied by small primary cells, or by four nickel-cadmium rechargeable cells and a solar panel.

The memories, both RAM and EPROM, dominate the power drain, and RAM will ordinarily dominate the unit cost. The memory select and clock circuitry has been arranged for minimum-power cycling, and the RAM has been organized into four 256-byte blocks so that stripped-down versions are possible.

SOFTWARE

The first 256 bytes of memory are allocated to a histogram of 16 wind speed classes by eight directions. Each cell comprises two bytes, for a count capacity of 65535, or one per minute for 40 days. Since no directional data are needed for the "zero-speed" class, 14 bytes of working storage are available for peak wind, timekeeping, counts, flags, etc. As a result, the program may be written to run with only this first memory increment.

The second 256-byte block is normally assigned to a histogram of 16 wind speed classes by eight times of day. The third block holds a histogram of eight speed classes by eight

values of run duration in speed class. The speed resolution of this histogram will necessarily be blurred by logic used to avoid class edge effects. Otherwise, a fairly steady wind at a class boundary might register as a large number of short dwells in each class.

The fourth memory block is allocated to measures of turbulence. A moving average is maintained of wind speed and direction. At appropriate intervals the difference is formed between a new measured value and an average. This value is used to update the average, then is classified to maintain a histogram of deviations from the average. The decay time of the average may be chosen to set the scale of the turbulence, and a slew rate limit may be imposed to model the limited angular following rate of some large turbines. A number of averages and deviation tables will be maintained for each measured quantity, corresponding to various time scales, following rates, etc.

The tables in the first two memory blocks are already well enough defined for a universal program to be written for most single-measurement-point applications. Sensible choices are possible for the run duration and turbulence measurements as well. Once this universal program is verified, it can be committed to mask-programmed RAM for greater economy and lower power drain. A standard prospecting unit is then available for routine application without reprogramming.

READOUT AND DATA HANDLING

The histograms of the desired joint frequency distributions are expressed directly in units of minutes per readout period (nominally per week or per month). A printer-type readout will display the data in decimal form. An alternate magnetic-tape readout will be in binary, in a version of machine-readable "Kansas City Standard." In either case, the

output record will include a unit serial number, a program revision number, and a serial day count since last power-up. Tape output will be multiply redundant, and printed output will contain a checksum for data verification. The total number of counts in each separate histogram must all be equal to the number of data accumulation intervals (1-minute periods) since the last reset. This multi-way check will provide a stringent test of the processor, memory, and data recovery. The unit and program identification together with day count should allow unambiguous identification of a data record.

For program development, EPROM programming, data tape reading and field unit testing, a host unit will be required which is capable of communicating with a standard terminal. The RCA CDPL8S020 evaluation kit meets this requirement inexpensively.

CONCLUSION

The microprocessor unit seems to satisfy all the requirements of a wind prospector's instrument. This device:

- is inexpensive,
- works with all commonly used wind instruments,
- is small and light,
- uses little power, and
- is capable of providing detailed statistical summaries of wind data at a prospective wind turbine site.

This instrument promises to be a useful tool for early phases of site evaluation.

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2. U.S. Patent #4,011,752.

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