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FERMILAB POWER MONITOR

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Introduction

Because of the complex price structure under which Fermilab buys its electrical power from the Commonwealth Edison Power Company, the Laboratory must carefully control its energy consumption rate. The rate has to stay below strict limits which vary from day to night and weekday to weekend. At the same time it is important to run as close to these limits as possible to derive the most benefit from the pricing structure. This paper describes the microprocessor system which compares site power with programmed limits, graphically displays relations and trends, informs operators of corrective actions if needed, and trips the major power load if limit violation is imminent.

Description of System

The Fermilab power monitor system was built to satisfy several requirements. Firstly, a site power meter is desirable. There are many circumstances when knowledge of the instantaneous site power is useful. Secondly, and more important, Fermilab must stay within the power demand constraints placed upon it by the Commonwealth Edison price structure. These constraints are the following: during working days between 0900 and 2200 hours Fermilab is limited to 30 MWHRs in each half hour (i.e., a 60 MW rate). These half hours begin and end on the hour and half hour. This time period is referred to as PEAK hours. OFF PEAK hours are from 2200 each evening to 0900 the following morning, all day Saturday and Sunday, and all day on certain holidays specified by Commonwealth Edison.

These constraints have generally determined the nature of the power monitor. It must be aware of the day of the week, and all holidays. The display it produces emphasizes the fact that the energy used is critical only over the half hour period.

Description of Hardware

Because of the many variables involved, a 6800 microprocessor based system was chosen. The information it calculates is displayed on a standard video monitor driven by alphanumeric and graphics generators that reside on the STD bus. The video signal is also fed into Fermilab's cable TV system and is therefore available anywhere on site.

The major components of the system are shown in Figure 1. In order to maintain the necessary time information the system utilizes a National Bureau of Standards radio clock. The clock is synchronized to a signal from WWVB, decoding the day of the year and the time. This information is available to the microprocessor via an RS-232 port in ASCII format. After a power outage this clock is automatically reinitialized to the proper time. The only times operator intervention is required are the changes between Daylight Saving and Standard time.

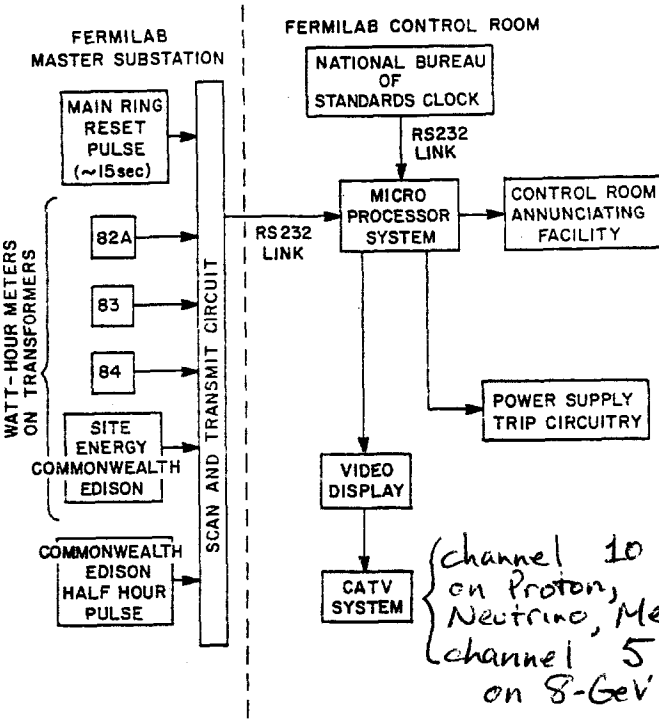

Figure 1

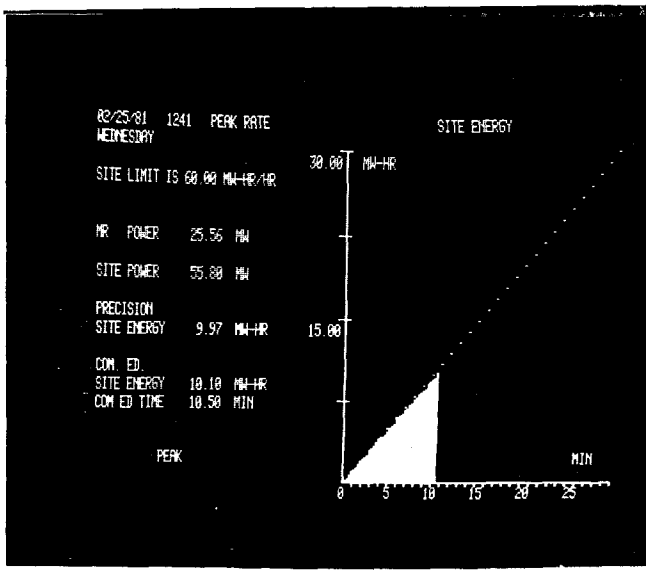

Figure 2

*Operated by Universities Research Association, Inc. under contract with the U.S. Department of Energy.

All other data required by the microprocessor is sent from the Fermilab Master Substation via another RS-232 link. The information consists of coded pulses of three types.

1. Energy counts as Commonwealth Edison counts them. Each pulse indicates 100 KWHR has been used, and is derived by the same electronics that derive the pulses for the Commonwealth Edison power meter.

2. Energy counts from each of the three Fermilab transformers. These pulses are generated for every 6 KWHR of energy consumption.

3. Two timing pulses.

   a. One pulse is sent at the beginning of every Commonwealth Edison half hour. This is a Commonwealth Edison generated pulse.

   b. One pulse is sent every Main Ring reset.

Calculation of Power

It is felt that the site power should be calculated once per minute with an accuracy of better than 2%. This would provide the operations staff sufficient accuracy and updating to respond to changes in site power while running very near the limit. At the Commonwealth Edison limit of 60 MWHR/HR the Commonwealth Edison 100 KWHR pulses provide us no better than 10% accuracy over a 1 minute period. Fermilab personnel have outfitted the Laboratory's three primary transformers with watt-hour meters that produce pulses at 6 KWHR increments. Using these pulses for the site power calculation yields a result accurate to 0.6% over one minute at 60 MW. To ensure this accuracy, the calculation is always done over an integral number of Main Ring cycles. One of these three transformers is used solely for the Main Ring ramp. Therefore, the system can calculate the Main Ring power and display this number separately. (See Figure 2 for display).

These 6 KWHR pulses are integrated over the half hour period, and the energy is displayed along with the energy derived from Commonwealth Edison's 100 KWHR pulses. This serves as a self check on both sets of counters.

One situation which is not covered by this scheme of power calculations is beam storage. While beam is being stored, the Main Ring reset pulse which normally triggers the calculation is absent. In this case an internal software timer will time out and the system will recognize that a store is underway. Power calculations continue with a slightly longer time base until the Main Ring reset pulse returns.

Keeping Fermilab Under the Limit

The primary function of the power monitor system is to free operations from the concern to keep the Laboratory under the 30 MWHR per half hour limit. The specifications in regard to this were twofold. First, it should be very easy to ascertain at a glance what the energy consumption has been with respect to the limit. Second, with no operator intervention at all the system must make sure the limit is not exceeded.

To accomplish this overall objective the system must always be aware of what the limit is. For each calendar year a PROM is burned which contains an entry for each day. The National Bureau of Standards clock transmits a day of the year number (1-366) which is

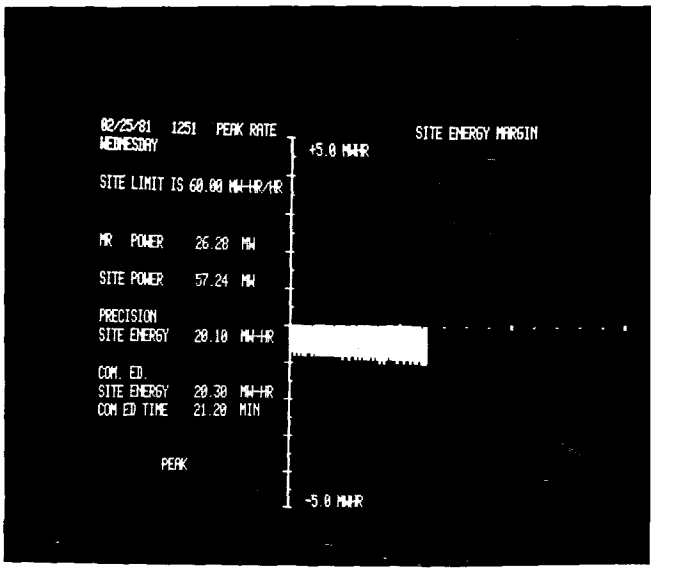

Figure 3

used to index the PROM table. The table contains the month, day of the month, day of the week and most importantly whether peak billing rates are to be imposed on that day. Each time a "beginning of half hour" pulse is received this table is consulted. If the day is one during which peak rates will be imposed, then the time of day is interrogated to determine if the half hour will fall between 0900 and 2200 hours. If so, the system will set the site limit to 60 MWHR/HR. Otherwise an arbitrary chosen limit of 90 MWHR/HR (an energy rate greater than any in Fermilab's history) will be used. If the Laboratory desires to self impose a limit which is less than either 60 MWHR/HR or 90 MWHR/HR, this limit may be dialed in on thumbwheel switches. The monitor will then note the Fermilab override.

In all plotting and limit checking routines the monitor uses the Commonwealth Edison 100 KWHR pulses to maintain consistency with the Commonwealth Edison power meter. The display indicates the energy and shows the time into each half hour. At the beginning of each half hour a plot is begun which is shown in Figure 2. This histogram is plotted as the 100 KWHR pulses are received. The height of the lines indicates the total energy used to that point in the half hour, while the X coordinate is minutes into the half hour. The slope of the dotted line is power at the limit rate. This display is very useful in showing trends, but it lacks resolution, particularly when near the limit. For this reason a second plot is available. At fifteen minutes into the half hour a check is made to see if the Laboratory is close to (∿3 MWHR) or above the limit rate. If so, a second plot will replace the first one. In this case the histogram indicates the difference between the limit line and the actual energy used. (See Figure 3).

Alarming and Tripping

At anytime during the last fifteen minutes of the half hour that the site energy is greater than the limit rate, a message will be posted on the Main Control Room annuciator system indicating that the Main Ring cycle time must be increased. If this message is not heeded the system must take action itself. The only means the monitor has to control site power is to shut off the Main Ring ramp. Of course the rest of the site continues to draw power with the ramp off, so that the

energy level at which the ramp will be tripped is determined by the following equation:

Trip Level (MWHR) = Half Hour Limit (MWHR) - (Site Base Load (MW) x Time Left in Half Hour (HR))

It is possible to have the power monitor regularly calculate the site base load. It is the difference between site power and Main Ring power as displayed on the monitor. However, since the power monitor system has no control over what may be turned on it was felt that a site base load greater than any recorded should be used. This will make the system safe under all conditions.

The microprocessor regularly sends a stay alive pulse to a one shot. If the processor fails to do this the ramp will be tripped, thus preventing a system failure from allowing a power overrun.

Acknowledgement

The authors wish to thank Hugh Christ for support in building the hardware.