COMPUTERIZED IRRIGATION SCHEDULING AND RADIO CONTROL FOR CENTER PIVOTS

Gerald W. Buchleiter
USDA-ARS
AERC CSU Foothills Campus
Fort Collins, CO 80523

Kenneth Goeglein
Farmer
33199 County Road "C"
Yuma, CO 80759

INTRODUCTION

Using radio telemetry technology to remotely control center pivot sprinkler systems is a relatively recent development in irrigation system management. Although this technology is not new, the application for improved management can be viewed as a new tool capable of reducing the time and effort involved in managing multiple center pivot machines within a single farming operation. These systems which utilize microcomputer technology, have the capability for continuously monitoring the operation and position, for remotely starting or stopping, and for changing the speed or direction of each pivot.

Another tool for improving on-farm water management is irrigation scheduling. Computerized irrigation scheduling which has been available for a number of years, can be very helpful in deciding the time and amount of water to apply during the growing season. Although the radio control system and the irrigation scheduling program are separate entities capable of operating independently, there are several significant benefits to the user when they are integrated into a single system. The automatic collection of data with the monitor system reduces the uncertainty in recording when irrigations occurred and the time required to enter the data for the scheduling program. The remote control capabilities make it much easier to implement the scheduling recommendations since the center pivot machine can be commanded to change speeds or turn off at specific locations in the field.

DESCRIPTION OF EQUIPMENT

The radio control system includes both hardware and software. Figure 1 is a schematic of the hardware which consists of remote terminal units (RTUs) mounted at each pivot, a base station with keyboard and a microcomputer. The RTUs are linked to the base station via UHF 2-way radio communication. The base station is connected to the microcomputer via hardwire. Each RTU contains a radio and the necessary electronic circuitry to collect, store and transmit the data from the connected sensors as well as switch several relays connected to the pivot and pump control circuits.

Software is the programming code which instructs the various pieces of equipment to do the required tasks. The base station unit is programmed with the necessary logic to continually poll all of the RTUs. When a change in condition is noted, blinking lights warn the user that the requested status has changed and the 'before' and 'after' conditions are recorded on the data file. The microcomputer communicates with the base control unit and maintains a log of the system changes for each pivot.

The monitoring software operates unattended unless interrupted by the user. All the RTUs on the pivots are assigned unique addresses. When the microcomputer initiates a

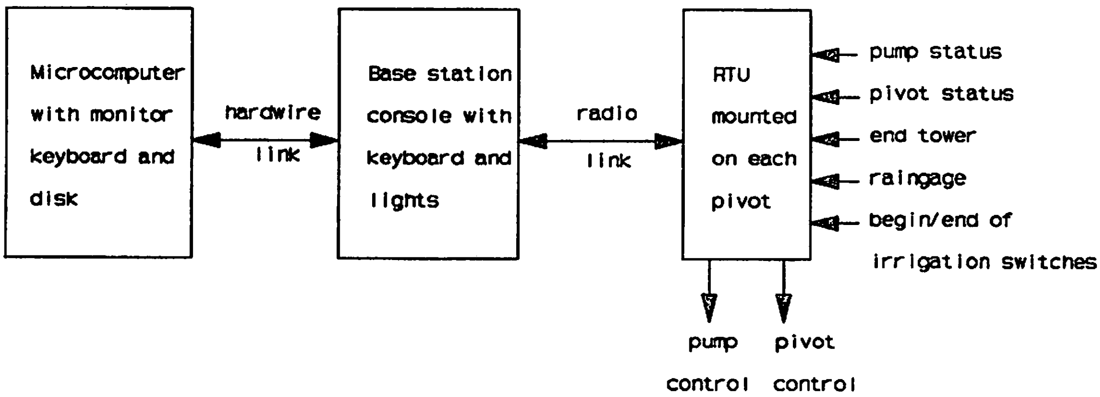

Figure 1 Schematic of radio control system

poll, each pivot is interrogated and must respond before going on to the next pivot. After the response from the pivot is decoded, the operating status and position of the system are displayed on the control console as well as the computer screen. The system position is calculated in software from the measured operating time of the outer tower and the position of several known points around the pivot. If a pivot fails to respond to repeated requests from the base station, the base station displays a no response message and continues polling the next pivot.

If the user wants additional information or wishes to control any pivot, the appropriate choices are selected from the menu. The continuous update of pivots is interrupted and the program transfers to the control portion of the software. The user may interrupt the automatic polling of all pivots to poll a single pivot continuously. Commands may be entered from the keyboard to do the necessary control on the selected pivot. The control software allows turning the pivot ON or OFF, changing the direction of movement or the speed of the center pivot either at the current time or at some future time or position in the field. The commands from the keyboard are maintained at the base station until the appropriate time for transmission to the RTUs at the pivots.

The scheduling program is a separate software package called from the main control menu. Upon selection of this option, the scheduling program is loaded into memory, while all monitor and control functions are suspended. The scheduling program is based on a soil water budget at two points in a field. The first point is near the beginning of the irrigation and the second point is near the end of an irrigation. An application depth is computed from the speed, discharge, minimum time to complete an irrigation and application efficiency. The scheduling program updates and then projects depletion levels at these two points in the future to recommend a range of dates for the next irrigation. The 'no earlier than' date to irrigate is when the soil water depletion at the first point exceeds the applied depth. Irrigating before that date could cause some of the applied water to percolate below the root zone and unavailable to the crop. The 'no later than' date is when the irrigation must begin so the entire field is irrigated before the soil water depletion at the second point exceeds the management allowable depletion.

Prior to scheduling at the beginning of the season, crop, soil and irrigation system data for each field must be collected and entered in a data file. Information about the weather station and the units of measurement for the individual parameters must be entered in the weather file. Details of the required information are explained in the irrigation scheduling program documentation. Although these data are entered once during 'startup', the depletions and cumulative amounts for water application and crop water use are updated with each run of the scheduling program. Evapotranspiration data can be entered either as a single ET number that is calculated external to the program or as values of several climatic parameters used in the Penman or Jensen-Haise equations to calculate daily ET values. Choice of which option to use depends on user preference and the availability of the necessary data. Field measurements of depletions on specific dates can also be entered from the keyboard. This information is used to verify that computed depletions agree with actual depletions and to adjust computed depletions if necessary.

An irrigation is considered to be one complete revolution of the pivot machine. The start and stop of an irrigation are recorded by the monitor system. Microswitches mounted on the pivot are activated by the lateral pipe as it makes a revolution. These microswitches are adjusted to switch when an irrigation begins and ends. Changes in the status of these microswitches are sensed by the monitor system and logged in a data file. Prior to scheduling, the data file containing all of the changes in pivot operation is processed and times are assigned for the start and stop of each irrigation.

Rain is measured with a tipping bucket rain gauge mounted on the pivot above the sprinkler nozzles. The data stored in accumulating registers at the RTU are transmitted back to the base station at each poll. The difference between the beginning and ending reading for each register is calculated while processing the daily log of pivot operations prior to scheduling.

DESCRIPTION OF SITE

On the Goeglein farm, 5 pivots are monitored and controlled with the radio telemetry system. Irrigations for these 5 fields plus an additional 4 fields are scheduled weekly using the irrigation scheduling program. While the radio telemetry system is not essential for using irrigation scheduling, it does make it easier to keep track of irrigations and make the necessary changes for scheduling irrigations.

The irrigation scheduling program is run once a week on the day the crop consulting service probes the fields to determine depletion levels. This makes it very easy to compare calculated depletions with actual depletions and make any adjustments to the calculated depletions in the data files. Prior to scheduling, the irrigations from the previous week are updated into the scheduling format from the daily operation files of the monitor system. Because of distrust in the reliability of the tipping bucket rain gauges, rainfall amounts are entered manually from the keyboard. Since there is no weather station on the farm and reference Et amounts are available from the Soil Conservation Service, daily reference Et amounts are also entered manually from the keyboard.

The monitor and control system coupled with irrigation scheduling is useful when the water supply is adequate as well as when it is marginal. When the pump capacity is greater than the peak crop water use, following the scheduling recommendations reduces overwatering and the associated energy costs. The potential for leaching valuable nitrogen fertilizer is also reduced which may either reduce fertilizer costs if more than the crop requirement for nitrogen is applied or reduce yield losses due to nitrogen deficiency if excessive amounts of nitrogen fertilizer are leached below the root zone. One field with a pump capacity of 8.5 gpm/ac., had a 3 year average corn yield of 206 bu./ac. even though it was fertilized for a maximum yield of 175 bu./ac. Following the irrigation scheduling recommendations reduced pumping and fertilizer costs while achieving better than expected yields.

For fields where the pump capacity is less than the peak crop water use, the value of the monitor system is the increased ability for checking irrigation systems and responding quickly to equipment malfunctions. Down time due to equipment malfunctions can cause significant yield reductions especially during peak use periods. Prior to the installation of the radio telemetry system, one field with a pump capacity of 5.1 gpm/ac. and a water holding capacity of about .8 in./ft., had a maximum yield of 150 bu./ac. With the telemetry system, the pivot was programmed to omit irrigating some of the less productive hills and was more carefully monitored to reduce down time, so the average corn yield increased to 165 bu./ac.

EXPERIENCES

There have been few problems with the monitor and control hardware. The reported system position is sometimes in error because of the method of determining the center pivot position. A method which reliably measures the pivot movement physically rather than calculating the position, would eliminate some of the problems which occur because of erroneously reported positions. Some unexplained variability in rainfall data between several pivots cast some doubt on the best way to mount the rain gauges to the center pivot machine. Vibrations from wind during thunderstorms caused additional tips in the tipping bucket rain gauge to be counted and caused erroneous rain gauge readings. The reliability of reporting the current status of each pivot has been very good. After 3 years of use, there have been no component failures which caused erroneous reporting of current operating statuses. There have been no equipment failures from lightning damaging the equipment.

Use of the radio control system and the irrigation scheduling program has changed the style of management somewhat. Many times, and especially during peak use periods, the current statuses of pivots are observed at the base station rather than driving to each pivot and making visual observations. The savings in time and labor due to the radio control system, the savings in pumping costs and the increased yields due to irrigation scheduling have been significant. Although unbiased comparisons of management before and after installation of the monitor and control system are difficult to make, the annual savings for labor and vehicle costs are approximately $3.50 /acre. Twice daily trips to check sprinklers 20 miles away were reduced to once or twice a month. Assuming a modest 10% reduction in water use from irrigation scheduling, the savings in energy costs are about $5.00/acre. In several fields where the pump capacity is marginal for supplying peak water use, the additional income from increased yields of 15 bu./ac. is significant.

The benefits and costs on a per acre basis vary depending on the farm size, travel distance and time to check all the pivots, current level of management, water availability and pumping costs. For Ken Goeglein, investing in this integrated system was a good financial decision and has improved his level of management.