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MONITORING IRRIGATION WATER APPLICATION WITH COMPUTERIZED CONTROLLERS

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INTRODUCTION

In the Central Plains area of Colorado, Kansas and Nebraska, approximately 9 million acres of cropland are irrigated by center pivot irrigation systems (2003 Census of Agriculture). Existing systems span the generations of center pivot technology evolution from water to electric and hydraulically driven machines. Due to their design, center pivots are operating on varying topography, and often have a range in soil textures present under a single machine. Perched water tables challenge managers of standard machines with the need to provide little or no irrigation water to some areas while fully irrigating others. Each of these factors represents a reason for using some sort of monitor/controller to manage water applications based upon need. In the process, altering machine speed of travel and irrigation cycles is the first step in site specific irrigation. Precision application and site specific irrigation are techniques to maximize the value of the water applied via a center pivot.

On a more basic front, farming operations often include an average of 3 center pivot systems with some operations including 15 or more. Without a programmable controller, the producer must physically being on site to determine the status of the center pivot. With new technology, producers can now obtain knowledge of whether the system is operating on a real-time basis by communicating with the machine to determine operating status. The same technology provides to change operation settings from a remote location. The purpose of this article is to present some of the research that has been conducted to evaluate system controllers for use in monitoring and controlling center pivots and discuss how these systems could be used in a site-specific irrigation system.

SITE SPECIFIC IRRIGATION

Over the last two decades research has been conducted by public and private groups seeking to development methodology and decision making tools necessary for application of water and plant nutrients based upon the physical limitations of a tract of land. In essence this work was adding center pivot irrigation systems to the list of variables that can be considered on a site-specific basis. As the technology has evolved so has the list of terminology used to help lay claim to unique ways standard center pivot controls are replaced and/or enhanced to allow variation in the center pivot's application depth and water application rate.

Initial steps to define decision making tools used for site-specific irrigation began in the early 1980's. Technologies such as Low Energy Precision Application (LEPA) were developed based on the early efforts to define optimum flow rates for sprinkler heads operating within inches of the soil surface (Lyle and Bordovsky, 1981). A series of control manifolds were used deliver different flow rates. Later work by Roth and Gardner (1989) sought to use the irrigation system to apply different amounts of nitrogen fertilizer with irrigation water.

Fully site-specific irrigation research was initiated in earnest in the early 1990's at four locations across the US. Reports of this work were published beginning in 1992 based upon work conducted the USDA-ARS researchers located in Fort Collins, CO (Fraisse, et al., 1992), Moscow, ID (McCann and Stark, 1993), Florence, SC (Camp and Sadler, 1994), and Pullman, WA (Evans et al., 1996). These efforts have helped to shape the technologies used to control moving sprinkler systems and individual sprinklers.

Individual sprinkler control of water application depth can be accomplished by using a series of on-off time cycles or as it has become known as 'pulsing' the sprinkler (Karmeli and Peri, 1974). Reducing the on time is effective and reducing both the application depth and the water application rate. This is accomplished using either direct-acting or pilot-operated solenoid valves. Direct acting valves have a linkage between the plunger and the valve disc while the pilot-operated solenoid uses irrigation pipeline pressure to activate the valve.

A second method for controlling irrigation water application was developed by King and Kincaid (2004) at Kimberly, ID. The variable flow sprinkler uses a mechanically-activated needle to alter the nozzle outlet area which lowers the sprinkler flow rate over the range of 35 to 100% of its rated flow rate based upon operating pressure. The needle can be controlled using electrical and hydraulic actuators. The main issue is that the wetted pattern and water droplet size distribution of the sprinkler changes with flow rate which creates water application uniformity issues due to a change in sprinkler pattern overlap.

A third method of controlling irrigation water application is to include multiple manifolds with different sized sprinkler nozzles. In this case, activation of more than one sprinkler manifold can serve to increase the water application rate and depth above that for a single sprinkler package. Control of each manifold is accomplished using solenoid valves similar to those described for the pulsing sprinkler option above.

As with any new technology, there are positives and negatives associated with each of these three methods of controlling sprinkler flow rates. Certainly long term maintenance is an issue. However, the biggest factor limiting their use is installation cost that ranges from around $2000 for a system monitor to over $20,000 for control of individual sprinklers.

CONTROLLERS

Center pivot manufacturers have developed proprietary means of monitoring and controlling center pivots using a variety of technologies under the trade names:, OnTrac IPAC, Tracker, and Grow Smart. The computerized control panels provide center pivot operators with the potential to monitor and control center pivots using telephones, radio telemetry, internet connections and satellite communication. In addition, there are a few private venture monitors and/or controllers that are available under the trade names: Farmscan, AgSense, and Pivotrac. Farmscan is the only company providing equipment for total VRI at this time.

The first requirement is to know the system position. If a producer queries the control panel during the course of an irrigation event, knowledge of where the system is lets the producer determine if problems have occurred and also how soon the system will reach stop-in-slot (SIS) positions. Standard machines utilize a resolver located at the pivot point to report the position of the first tower. In nearly all cases, the main component of new controllers is a Wide Area Augmentation System (WAAS) enabled GPS unit that is mounted near the last tower of the center pivot. The WAAS is a publicly available system that provides a differentially corrected signal to increase the accuracy of the unit at a relatively low cost.

Part two includes monitoring the center pivot control circuitry. This is accomplished directly at the main pivot panel. But can also be done using a Programmable Logic Controller (PLC) device. The main panel houses control circuitry for the end gun, system speed of travel and direction, and on/off controls. Since most of this circuitry terminates at the end tower, center pivot monitors and controllers also can be mounted near the last tower control box.

At the pivot point additional components can be monitored and/or controlled such as auxiliary chemical pumps, system operating pressure and flow rate. Likewise, weather sensors can be monitored to provide wind speed and direction, temperature and rainfall information if desired. Options also exist to continuously monitor soil water content in the field. Current research is aimed at developing decision support tools for using a center pivot mounted infrared thermometer (IRT) to help manage irrigation water applications.

Part three of the system includes a communication link between the controller and the end user whether that be cell phone, land line phone, radio or internet connection. Cell phone links are accomplished using an on-board modem. This arrangement requires cell phone service from the pivot location and from the user location. However, there are few locations in the Central Plains where communications are not possible.

Some systems transmit GPS coordinates and system monitor information via satellite radio to a satellite which is transmitted back to a ground-based facility where it is distributed via the internet and made accessible by phone using IVR solutions developed specifically for center pivot controls.

Radio telemetry is another means of transmitting information from the field to the office or phone. However, radios are line of site communication devices so buildings, trees, and hills can impede communications over long distances. Most radio communication links employ radios operating in the 900 MHz range to communicate over distance less than 15 miles. For longer distances, a bridge or repeater is positioned on a tower to communicate over longer distances.

SYSTEM REQUIREMENTS

Selecting the method of sprinkler control may be the easiest decision to make since the main factor of concern is: Will it pay to install the controls? However, once the decision is made to use a variable rate sprinkler application system-based upon some predetermined management zone size, design of the remaining portions of the irrigation system become interdependent.

How will the pumping plant respond to changes is system flow rate requirements? As sprinklers turn on and off, the flow rate required by the system varies. The response of a standard system is that the pump output will follow the pump curve to the right or left depending on whether more or less sprinklers are operating. More significant is that sprinklers near the end gun have flow rates that are significantly greater than sprinklers near the pivot point. Consequently, turning off sprinklers on the first 200 feet of the system will have much less effect than turning off a 200 foot section near the end gun. The correct design response is to install a pumping plant with variable revolutions per minute (RPM) so that as more sprinklers are added, the pumping RPM is increased and visa versa. In this way the pumping plant can supply water at the design pressure regardless whether 50 or 150 sprinklers are in operation.

The difficulty arises when the motor used to supply power the pump is the same one used to supply power to the center pivot. Changes is pump RPM require changes in engine RPM. So a separate energy supply may be required for the center pivot.

How do I adjust the chemical injection system to apply different chemical amounts (fertilizer or pesticides)? Application of variable chemical rates can be achieved by simply maintaining a design injection rate and let the difference in water application depth control the chemical application rate. However, what if our management decisions require high application of a plant nutrient to an area that is to receive little or no water? A second factor is that the time of travel for chemicals to be transported from the pivot point to a position on the pivot lateral varies with the velocity of water in the pipeline. As the number of sprinklers in operation changes so does the water flow velocity. Thus, chemical could enter the system with a velocity of 6 feet per second when all sprinklers are on and 3 feet per second when a large number are turned off. This factor will determine when a change in injection rate should start.

How accurately can I determine system position if application rate changes are desired? Center pivot position on most systems (without special equipment) is determined by the resolver that is located at the pivot point. Alignment systems typically have an accuracy of $\pm 1.5^{o}$ of where the first tower is located. Thus, at a distance of 1320 feet from the pivot point, the position of the last sprinkler could be off by 34 feet or more. Research conducted by Peters and Evett (2005) found that resolver determined position errors could be up to 5 degrees or over 100 feet on a 1320 foot long center pivot. Installation of a WAAS enabled digital GPS system can increase the accuracy of determining the location of the pivot lateral to errors of less than 10 feet. The net effect of being able to accurately determine the pivot lateral location is that management zone size can be reduced without increasing the potential for a misapplication.

From an engineering perspective these are not trivial questions particularly if changes in water, nutrient and energy use efficiency are to be accomplished simultaneously. In the end it is the accuracy of the data we use to make decisions that is critical. And so another question must be answered: *Will the increase in water application to management Zone 25 yield enough forage or grain to pay for the application?*

Information Requirements

To make full use of site specific irrigation techniques, geo-referenced field information is needed for variables that will be used in making irrigation management decisions. Field soil texture and fertility will be needed to help isolate field areas where plant available water is indeed the single most important factor. Yield maps could show areas with reduced yields that are due more to soil nutrient levels than plant available water or a combination of the two. The difficult factor is to have production functions that give accurate information about what will happen to yield if water or plant nutrients are altered. Acquiring this information may require a few years of in-field testing while harvesting with a yield monitor.

Field maps of each of these variables (field slope and soil texture, fertility level, grain or forage yield) represent information that make up levels in a Graphic Information System (GIS) analysis. It is important that these maps provide information on a management zone size basis. Limitations in the ability to collect point measurements due to cost or response time of sensors all impact the spatial resolution of the application map. For example, an 8-row combine operating at 6 mph and collecting yield estimates every 3-seconds provides a different spatial picture than a center pivot with control of banks of 5 sprinkler heads. Consequently, variable rate irrigation controls will typically be at less resolution than any of the other crop production inputs.

SUMMARY

Center pivot controllers and monitors are available to help producers manage water application on a whole or part of field basis. The combination of knowledge of current system status and location in the field help ascertain if the irrigation application is proceeding as planned. By recording other field based information water applications can be adjusted due to different crops, field topography, soils and productivity levels. Ultimately, the complete control of crop water inputs on a IMZ basis could save between 10-20% of the water applied per season. Lowe installation costs and further development of decision support systems for use by producers are needed before variable rate technology will receive widespread use by row crop producers in the Central Plains area.

TERMINOLOGY

Listed below are general definitions for the acronyms that are used in the discussion of center pivot monitors and controls.

GIS Geographic Information Systems is a system that allows for sets of geo-referenced variables (layers) to be analyzed, managed, displayed, and used to developed site-specific maps for the application of water, pesticides, or plant nutrients.

GPS Global Position Systems is a satellite system means of determining field positions, speed of travel, and time with sufficient precision to allow site specific application of irrigation water, pesticides, or plant nutrients in response to productivity indices.

IMZ Individual Management Zone is an individual area of an irrigated field for which the technology exists to alter the application of water, pesticides, or plant nutrients in response to productivity indices.

IRT Infra-Red Thermometry is the use of an infrared thermometer to record plant leaf temperature as an indicator of plant stress.

IVR Interactive Voice Response is technology that enables users to retrieve or deliver information on time critical events and activities from any telephone.

LEPA Low Energy Precision Application is a water, soil, and plant management system for uniformly applying small frequent irrigations near the soil surface to field areas planted in a circular fashion and accompanied by soil-tillage to increase soil surface water storage.

PA Precision Agriculture, or site-specific farming is the precise delivery of water, pesticides and plant nutrients based upon suspected deficiencies in or need for water, pesticides, or plant nutrients.

PLC Programmable Logic Controller is a digital computer used for automation of electromechanical processes and is designed for multiple inputs and outputs, and is not affected by temperature, electrical noise, or vibration.

VRI Variable Rate Irrigation is the delivery of irrigation water to match the needs of individual management zones within an irrigated field.

VRT Variable Rate Technology is the process of applying irrigation water, pesticides, or plant nutrients at rates which are based on defined crop production indices.

WAAS Wide Area Augmentation System is a navigation aid developed by the Federal Aviation Administration to augment the accuracy, integrity and availability of the GPS for use in aircraft flight monitoring and control.

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