Surface irrigation with a variable inflow hydrograph

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Abstract

Surface irrigation is one of the most common methods of irrigation in which its hydraulic behaviour is influenced by the inflow hydrograph. The use of electronic devices in surface irrigation to manage water delivery to the field is important because the water losses can be decreased which results in higher application efficiency. Previous studies have shown that the efficiency of surface irrigation is influenced by the inflow hydrograph shape. In this study, an electronic device has being designed and constructed that is able to regulate the irrigation pump outflow to produce different furrow or border inflow hydrographs including constant inflow, cut-back inflow, gradual reducing inflow, modified cut-back inflow, modified gradual reducing inflow and surge inflow for actual field conditions. The device is controlled by computer and can be programmed for actual field conditions data for any desired inflow rate, inflow variations and irrigation time in order to increase water application efficiency. Based on information given, the device can control deep percolation along the field and runoff at the lower end. The system can also be programmed to account for infiltration characteristics changes along the irrigation season to reduce losses.
Keywords: surface irrigation, inflow hydrograph, automation.

1 Introduction

Surface irrigation is one of the oldest methods of irrigation in which soil surface is used to convey and infiltrate water [8]. This method of irrigation as compared with sprinkler or trickle methods is inexpensive. Therefore, more attention is being paid to improve the efficiency of surface irrigation. For instance runoff

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recovery, cutback technology, variable inflow hydrograph and surge flow irrigation have been studied to reduce losses [2, 9, 3, 6]. Previous studies have shown that the proper selection of inflow hydrograph shape for surface irrigation can reduce runoff and deep percolation which the result is higher application efficiency [1, 2, 5]. The use of non-constant inflow rate (surge flow) for automatic furrow irrigation was first suggested by Stringham and Keller [4] as an improved method of automating cutback furrow irrigation. Since most simple automatic irrigation valves can only turn water on and off, they concluded that it would be simpler to cycle valves to reduce the flow rate on a time basis than to partially close the valves to achieve the cutback stream. The efficient application and distribution of water by surface irrigation is highly dependent on parameters such as inflow rate and shape, advance time, soil texture, soil infiltration, plant coverage, roughness coefficient, field shape, irrigation management and ect. A number of mathematical models of surface irrigation have been developed to simulate irrigation phases such as advance, recession, infiltration, runoff and deep percolation. For instance the Sirmod model can be used to evaluate, simulate and design surface irrigation for constant inflow hydrograph and for limited variable inflow hydrographs such as cut-back inflow hydrograph or surge inflow hydrograph for furrow or border irrigation [7].

To use water and energy most efficiently, and to save labour, it is important to use automatic devices for surface irrigation. However, to date little or no research has being done to design and construct an electronic device controlled by computer which can regulates the pump outflow to provide different or desired furrow or border inflow hydrographs for actual field conditions. This operation is much simpler as compared to the control and automation of individual valve to regulate water delivery to each furrow or border.

The objective of this study is to design and construct a computer control system which can regulates the irrigation pump outflow to produce any desired inflow hydrograph for border or furrow irrigation for actual field conditions.

2 Materials and methods

In this study attempts have being made to design and manufacture a device to achieve the indicated objectives. The device that can be controlled automatically has two mechanical and electronically sections and can be programmed by user based on constant or variable inflow rate for different time periods from beginning to the end of irrigation. The written software for the device which has the graphical capability can be used in windows 98/2000/XP. The menu to create inflow hydrograph is new project from file menu (Figure 1). The new project includes points, functions, combination of points and functions and surge option. Using function it allows the user to develop inflow hydrograph according to a function or combination of different functions provided by the software. The software also has the capability to develop and use other functions based on information given by user. Using points it allows the user to use points to develop inflow hydrograph. Each point has the scale of time and discharge. Using combination it allows the user to use the combination of points and function to develop inflow hydrograph. Using surge it allows the user to simulate surge inflow hydrograph. The user can select surge option to produce surge inflow hydrograph for any desired cycle time or cycle ratio during irrigation time. In this way the automatic operation are simple and the need for surge valve to regulate inflow to the furrows or borders will be eliminated which the results are simplicity and lower operational cost. So, any desired inflow hydrograph including constant inflow, cut-back inflow, gradual reducing inflow, modified cut-back inflow, modified gradual reducing inflow and surge inflow can be obtained with high accuracy for actual field conditions. The obtained hydrograph can be observed using trace window. The inflow rate can starts from a maximum value, remain constant, change gradually, reach zero, remain zero or change according to user demand during irrigation time. The soil infiltration characteristics changes along the irrigation season can also be accounted for by changing the form of inflow hydrograph from irrigation to irrigation. In other word the management of inflow water delivery to the furrows or borders can be achieved easily to reduce losses.

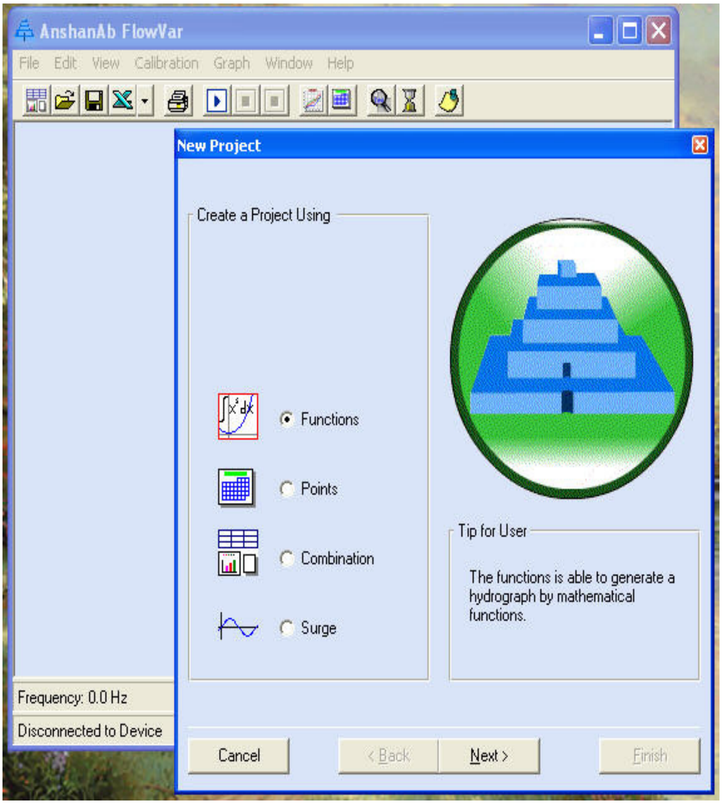

Figure 1: New project from the file menu.

Most electro pumps used for irrigation are operated by motors which have constant rotation. However, using the Squirrel-cage induction motors including rotation control device (variable frequency drive, VFD, Fig. 2), the rotation of the motors can be controlled which the result is the variable pump outflow. Based on this fact the hardware section of the proposed system was designed.

The electronic section of the device receives information (frequency) from computer and sends appropriate signal to the variable frequency drive to adjust the output frequency (voltage) of the VFD connected to the electro motor to regulate the rotation of the pump. Therefore, the rotation of the electro motor controls the pump outflow to the water delivery system to furrows or borders based on desired inflow hydrograph selected by user. The selected irrigation pump for the field depends on the required flow rate.

The electronics has an on board LCD monitor to see the operation and a keypad to input the basic parameters. The device is relatively inexpensive and its energy is supplied by one or three phase power electrical lines depending on the motor or VFD type.

3 Results and discussion

Figure 3 shows an example of a developed constant inflow hydrograph. The flow rate is 2 lps and irrigation time is 160 minutes. Under this condition, to have complete irrigation at lower end of the field, the tail water runoff will be unavoidable. Figure 4 shows an example of a linear gradual reducing inflow hydrograph. As compared to Figure 3 the flow rate and irrigation time are the same but the tail water runoff can be reduced. Figure 5 shows an example of a modified gradual reducing inflow hydrograph. This form of inflow hydrograph can be used to avoid deficit irrigation at the lower end. Figure 6 shows an example of another form of a modified gradual reducing inflow hydrograph. Depends on field conditions, this form of inflow hydrograph can be used to have better distribution of water along the field. Figure 7 shows an example of input data to develop a surge inflow hydrograph for different cycle times of 20 and 40 minutes and cycle ratio of one half. Figure 8 shows the developed surge inflow hydrograph for the data given in Figure 7. Figure 9 shows an example of non-linear gradual reducing inflow hydrograph. Depends on field conditions, this form of inflow hydrograph can be used to reduce losses. All the above inflow hydrographs have the same initial inflow rate of 2 lps and irrigation time of 160 minutes. Based on field conditions, the right inflow hydrograph can be selected to reduce deep percolation at upper end of the field and to reduce runoff at the lower end of the field which the result is better distribution of water along the field and consequently higher application efficiency.

The proposed system as compared to other automatic water delivery systems to the field is simple to use, the irrigation management can easily be done and the need for using the complicated water delivery devices to control and change the inflow rate will be eliminated.

The system can be used as a management tool to apply the desired inflow hydrograph to surface irrigation field in order to reduce losses and have better distribution of water along the field.

Figure 2: Variable frequency drive.

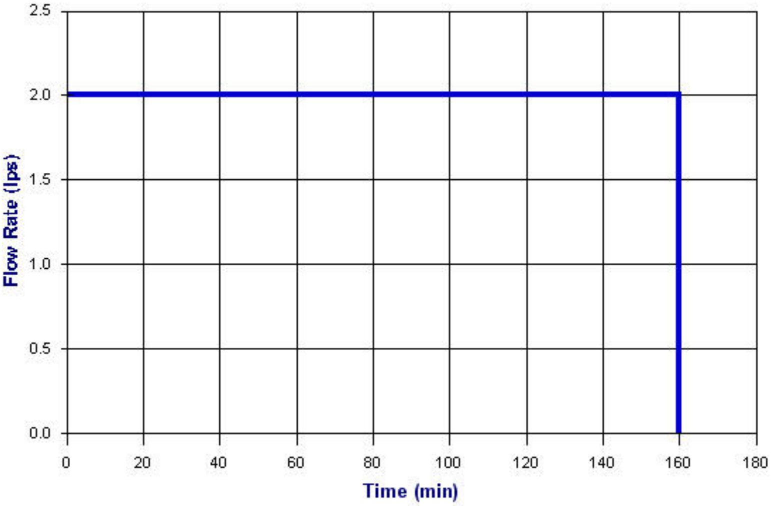

Figure 3: Example of constant inflow hydrograph.

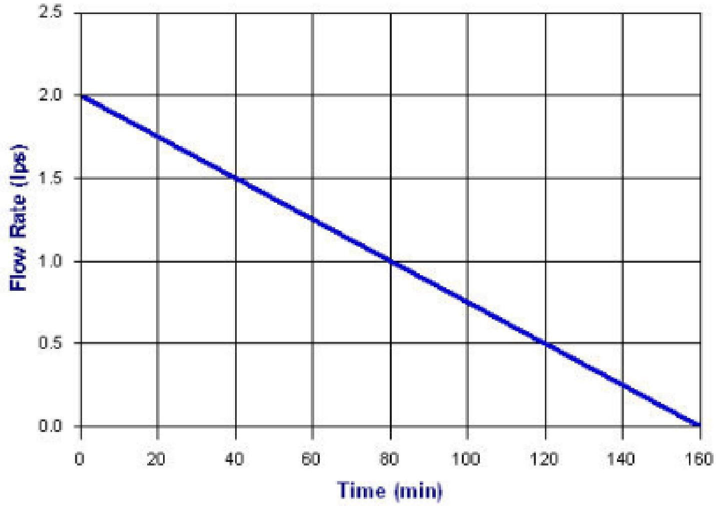

Figure 4: Example of linear gradual reducing inflow hydrograph.

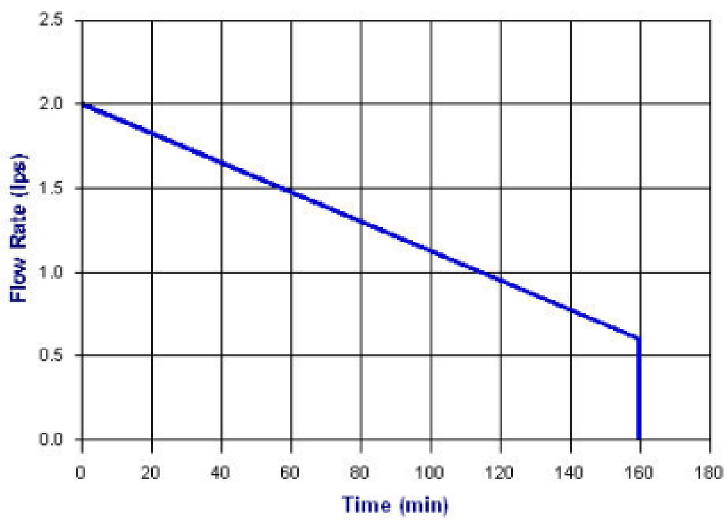

Figure 5: Example of modified gradual reducing inflow hydrograph.

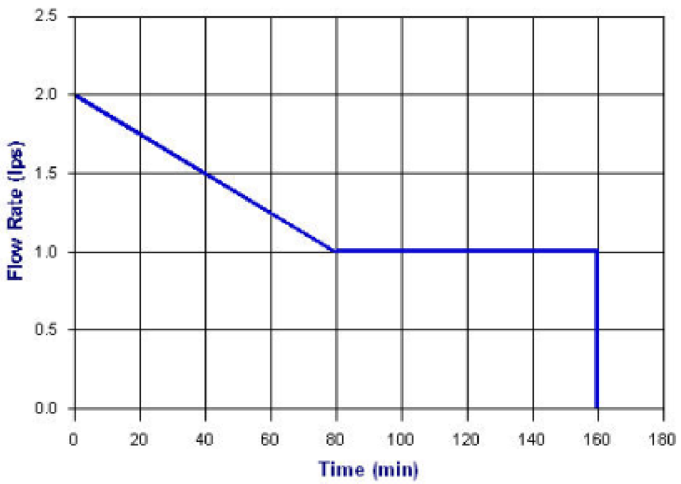

Figure 6: Example of modified gradual reducing inflow hydrograph.

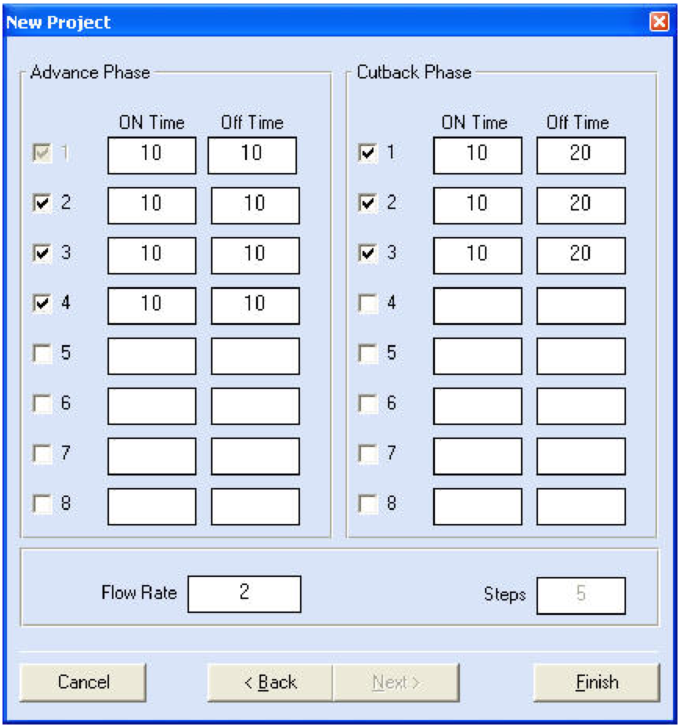

Figure 7: Input data for surge inflow hydrograph.

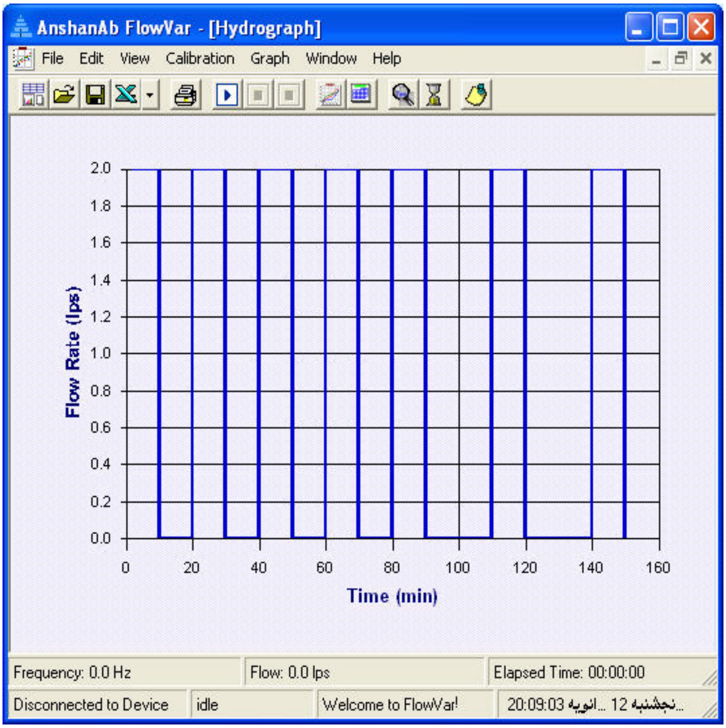

Figure 8: Example of surge inflow hydrograph.

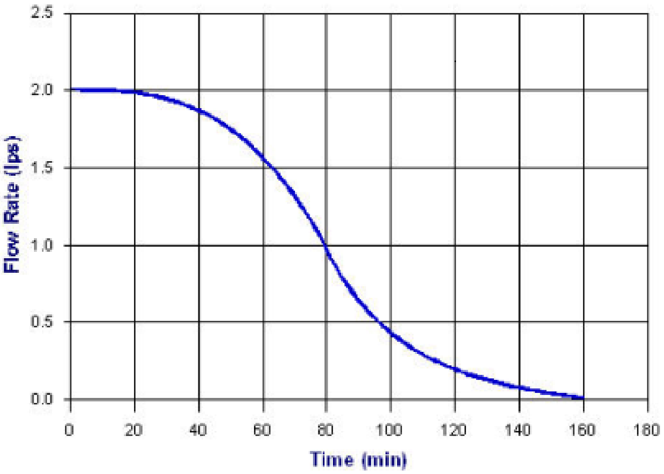

Figure 9: Example of non-linear gradual reducing inflow hydrograph.

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