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Designing of Automated Controlled Irrigation System for Domestic Application

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Abstract

Water is a vital necessity in industrial and domestic application and water is a scarce resource recent year and its optimal management is challenging. In this paper, an automated irrigation system was designed reduce water utilization in agriculture by using Pipe-Flo Professional and optimization tools. The designed automated irrigation system uses HC controller and sensors to sense variables of flow rate during operation. The optimization model was used to compute the optimal irrigation rate during operation with the help of internet connectivity. The design system was theoretically test for optimal operation and the best controlling possibility during irrigation was revealed. The system was reported to operate with an increase of flow rate and pressure during operation. The design system in the current study was model and simulated for optimal control during irrigation. The best pump for the irrigation system was revealed after series of test and the pump efficiency and stability was more acceptable. Pump 2 was also revealed to have a smaller size which impacts the residential applications and boost the pump performance during operation. It was also shown that varying variable speed during operating pump impacts the system stability and efficiency of system during operation

Keywords: Automated, Irrigation, designed, HC controller and optimization.

INTRODUCTION

To sustain the agricultural sector in a country like South Africa the irrigation system must be optimal and efficient during operation. A proper irrigation system improve productivity, guaranteeing food security in the local economy, and at the same time enhancing economic growth especially in challenging period like climate change, low labor force, and poor soil conditions which needs more innovation in agricultural sector. It should be noted that the South Africa, agricultural sector contributes about 20% of the country's Gross Domestic Product (GDP) and employs more than 30% of the population [1-3]. The agricultural sector is under stress due to the rapid change in climate change that impacts the sector. Recent economic survey revealed the government has suggested the need to grow the agriculture sector and boast food production. This indicates exploiting of the relevant technology and the application of good practices to enhance crops productivity per drop of water in the sector. This is greatly dependent on the design of the irrigation system. Most recent developed technology are being design and test for efficient operation [2-4].

The developed technology is impacted by physical variables or parameters such as atmospheric temperature, humidity, soil moisture and cropping cycles etc. These parameters must be optimized for efficient and stable irrigation system by taken into consideration the relevant sensitive information for automated operation of the irrigation system. In most cases internet connectivity is paramount for an automated operation [3-6]. The internet system provides the relevant network, sensing and computing the system performance. Several approaches have been used to study an efficient automated system such as energy savings techniques and nonlinear model prediction controller system. In most of these studies the controlling functionality are limited with operating parameters and control functions and most studies only focus on water consumption [1-12]. Several irrigation systems have been developed with wireless sensor networking system and the system are currently being used farms. Most system are based on system interaction and data communication network between the sensor nodes and the workstation and most of these systems are inefficient during operation. the major problem being reported ae poor cloud computational techniques not fully explored in the technology. In recent years more research efforts have been geared towards enhancing the combination of cloud computation and internet interaction during irrigation with little success being recorded. However, the role of cloud-based internet computation approach has been investigated for precision in the agriculture sector [1-8]. The main problem observed was the poor automated control during irrigation which needs further investigation. It should be noted that an optimization models for efficient irrigation system design was studied with limited success [12] which did not focus on monitoring and control of the system during irrigation. There is limited literature on control optimization process during irrigation and therefore vital information for model extension are lacking. In this paper, an approach to study and choose the right control system that is efficient and stable during operation. The design system was model and simulated for optimal control during irrigation.

METHODOLOGY

An irrigation system controller is a device that reduces the use of outdoor water through monitoring and the use of location or

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site conditions such as rain, wind, moisture, the type of plants, soil, slope, or weather forecast and then apply the right amount of water based on the mentioned factors. An irrigation Electronic timer Controller can improve the irrigation system efficiency during operation.

Figure 1. Electronic timer Controller

Electronic timer controller uses a time clock to program a schedule for irrigation. The controller cannot be programmed off site, it requires an operator to make changes to the system. The controller will not use the internet to obtain site data any change in irrigation operation. However, a sensor can be added to the controller to improve irrigation accuracy. The controller works by indicating the day of the week it is going to irrigate, the time of the day and run time for the irrigation. Electronic Timer controller cannot monitor valve conditions and cannot also provide real time feedback to the irrigation system of the conditions such as notification of whether irrigation is taking place or not. Since the main purpose of this study is to improve the efficiency of the irrigation system, it is important to focus on the irrigation controller system for optimal irrigation during operation. An irrigation system smart controller uses on site data that is obtained via onsite sensors that are connected to the controller, local weather stations and plant information entered the controller. The controller also uses Wi-Fi to connect to the internet to obtain weather forecast information. It also can be controlled via a smartphone mobile App from any part of the world using the internet. The mobile App can also send feedback notifications to the irrigation system owner such as solenoid valve faults and other operation notifications. The App also allows you to activate and deactivate the irrigation system and change controller settings. By making use of site data the irrigation system smart controller can adjust the watering volumes and schedules accordingly depending on the weather forecast, moisture, and plant types.

The irrigation system smart controller is connected to solenoid valves which in turn controls a certain area or zone of the garden independently. Since the garden will be divided into zones which are usually created according to the plant types, this makes it possible for zones to have different run times and makes it possible to provide the right volumes of water according to the plant types. This helps save water and eliminates the need for human physical interaction with the irrigation system as opposed to the current manually operated system. The irrigation system smart controller will allow for a complete automation of the whole irrigation system, it will also eliminate the need for human physical interaction and help save water since the irrigation system uses plant water requirements to irrigate the garden which eliminates over watering. The figure below shows how an irrigation controller system.

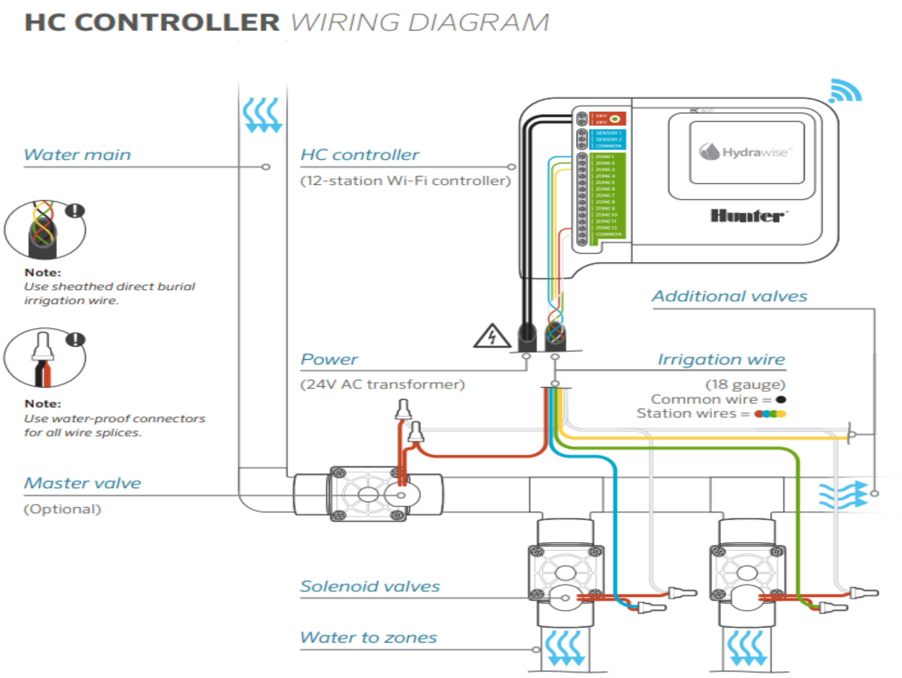

Figure 2. HC Irrigation controller wiring during operation

The irrigation smart controller is the latest technology of all irrigation controllers available on the market. It is very accurate and can be operated from anywhere in the world if there is internet connection and can adjust irrigation conditions independently compared to the electronic timer controller. It is also the best controller for our irrigation system since it is the one that possess the required features that are needed to achieve the design goals for our irrigation system. The pump selection is also vital for efficient controlling of the system during operation. One of the major problems is the very low pressures of water during operation. The available pressure on the sight is not enough to operate a sprinkler irrigation system. Therefore, a booster pump is required to provide the required pressure to operate the residential irrigation system during operation. A booster pump is designed to increase the flow and pressure of water that comes out of home appliances or garden and taps. The booster pump can be connected to municipal main water supply or to a tank that will be situated next to the house. Booster pumps are recommended where there is a low water pressure from mains or if the water pressure is too low for the function of household sprinkler systems and this can affect several factors such as net positive suction head of the pump system during operation and this is given as.

$$\text{NPSH(ha)} = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{{v_2}^2 - {v_1}^2}{2g} + h_L \qquad [1]$$

where ha – total head on pump being impacted by pressure and velocity during operation. the available power delivered by the pump to the fluid and available net positive suction head is given as

$$P_A = h_a \gamma Q \qquad [2]$$

$$\text{NPSH}_A = \frac{P_o - P_v}{\gamma} + \Delta z - h_L \qquad [3]$$

where Po – Static pressure (absolute) above the fluid in the reservoir, Pv - Vapor pressure head of the liquid, Total head losses in the irrigation system = $h_{L\,main\,pipe}$ + $h_{L\,Zone\,B}$ = 1.179 + 4.868 = 6.047m

The sprinklers require 2 Bar for them to function, 2Bar = 2×105 Pa

$h = \frac{P}{\gamma}$ $\qquad$ $\boldsymbol{\gamma}$ = 9.79×103N/m3 for water at 20°C

$$h\ \text{sprinkler} = \frac{2\times10^5}{9.79\times10^3} = 20.429\text{m}$$

Therefore, the total head required by the system:

H = h sprinklers

= 20.429m

Q-total for zone A and D = 4.5 m3/hr

Theoretical simulation was performed for pump selection by using the tool of Pipe-Flo Professional and different results are revealed below.

Pump 1 Results

Manufacturer: AnsiPro Pump Company.50

Type: AP96-ANSI End Suction

Speed (rpm): 2950

Head (m): 22.6

Efficiency: 32.3%

Q(m3/hr): 4.7

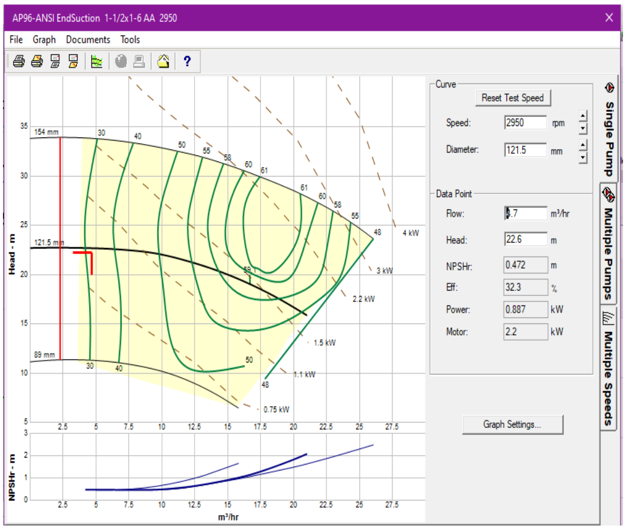

Figure 3: Simulated results of pump 1 during operation

The results of Figure 3 were obtained using Ansi-Pro Pump Company.50 tool type AP96-ANSI End Suction

Speed (rpm): 2950, Head (m): 22.6,

Efficiency: 32.3%, Q(m3/hr): 4.7.

The first automated controlled design system was tested as shown in Fig.3. The automated controlled designed revealed different discharge and different heads during operation. The obtained results shown in Fig.3 revealed the performance of three pumps system in the controlled automated system. It is shown from Fig. 3 that the higher the head the greater the power being needed to run the pump during operation during the operation of the control automated system design in the current study. Interestingly, different flow rate is revealed by the different design control automated head during operation. It is also shown that the higher the head, the greater the discharge of the irrigation system during operation. head system is also revealed for the different pump system during operation and it is shown that the pump with the higher head has the highest head system and the pump with the lowest head has the lowest head system. The flow system of the design controlled automated pump system is shown in Fig.4 below.

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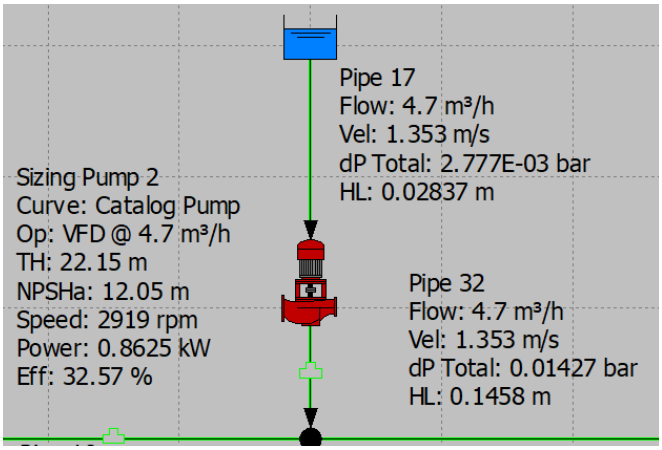

Figure 4: diagram of pump, pipes, and flow during in the automated design system during operation

Pump 2 results

Manufacturer: Dayliff.50

Type: Vertical multistage

Speed (rpm): 2810

Head (m): 24

Efficiency: 60.67%

Q(m3/hr): 4.7

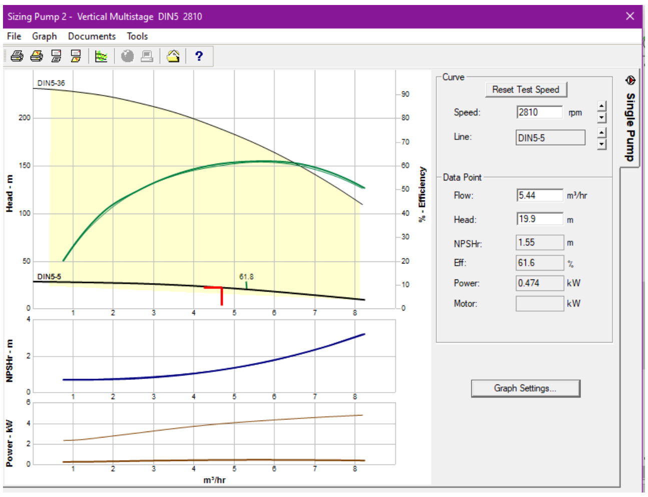

Figure 5: Simulated results of pump 2 during operation

The second automated controlled design system was tested as shown in Fig.5. The results shown in Fig.5 revealed the automated performance for pump design 2 and it is shown that pump DIN5-36 operate with a higher head than pump DIN5-5. It is revealed that their discharge is the same during irrigation for the controlled automated design. The system is more efficient during operation as shown in Fig.5. It is also shown that the power produced by the system is more acceptable during operation and therefore design system 2 is better than design system one. The flow system of the design controlled automated pump system is shown in Fig.6 below

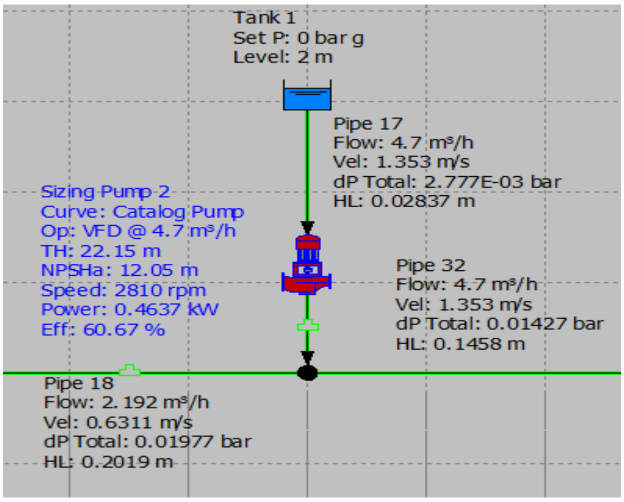

Figure 6: diagram of pump, pipes, and flow during in the automated design system during operation.

Pump 3 results

Manufacturer: Crane Barnes.50

Type: Selfprime-Univers-4E TS7 1913

Speed (rpm): 1913

Head (m): 22.2

Efficiency: 32%

Q(m3/hr): 4.72

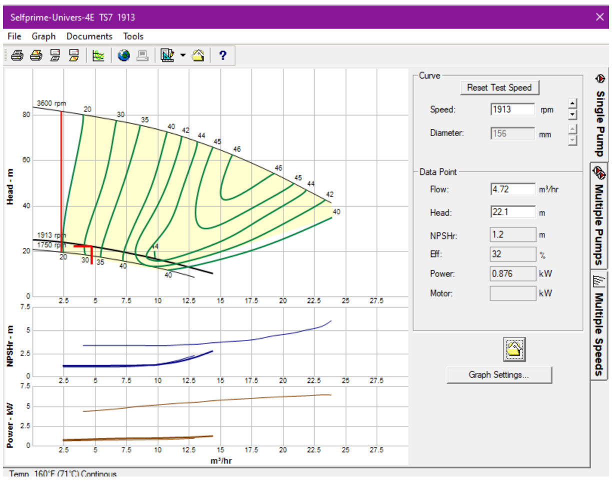

Figure 7: Simulated results of pump 3 during operation.

The third automated controlled design system was tested as shown in Fig.7. The automated controlled designed revealed different discharge and different heads during operation. The obtained results shown in Fig.7 revealed the performance of three pumps system in the controlled automated system. It is shown from Fig. 7 that the higher the head the greater the discharge of the irrigation system during operation and the lower the pump head the lower the discharge produced by the system during operation. It was also shown that the NPSH and the power produced by the system is also low and therefore the system is not efficient. The flow system of the design controlled automated pump system is shown in Fig.8 below

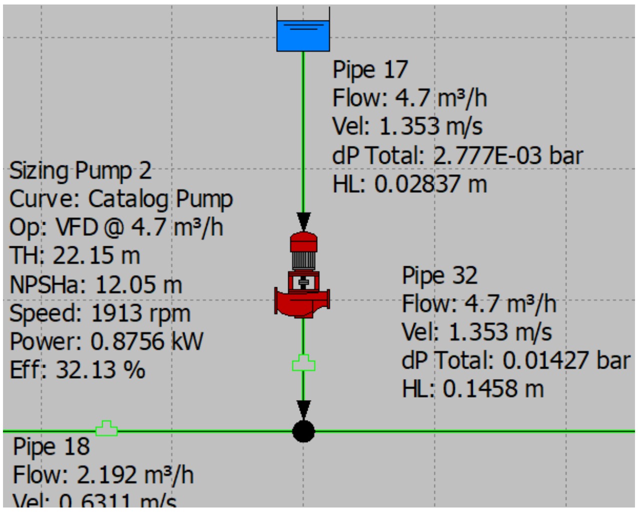

Figure 8: diagram of pump, pipes, and flow during in the automated design system during operation

DISCUSSION OF FINDINGS

Three different pump manufacturers (Dayliff.50, AnsiPro Pump Company.50, Crane Barnes.50) were tested under the same irrigation system. The pumps were simulated under the same irrigation system requirements to determine the best pump for the application. The best pump or the pump with the highest efficiency for each pump manufacturer was selected, and the results for each pump presented. Pump 1 and pump 3 have a very low efficiency and are therefore not suitable for the system. This is since these pumps are heavy duty or industrial pumps. They are also very big in size and often require applications where larger volumes of water needs to be pumped over long distances. These pumps are suitable at municipal water treatment plants and supplying water to residential areas which explains why they underperform in this design because this design is working under very low flow rates. Pump 2 has managed to produce better results, which makes it ideal for the irrigation system because it is significantly lower in size and is suitable for residential applications. Pump 2 has managed to produce the highest efficiency, and this makes it the best pump for the job.

CONCLUSION RECOMMENDATIONS

The aim of the study was to study and choose the right control system that is efficient and stable during operation. The design system was model and simulated for optimal control during irrigation. The best pump for the irrigation system is Pump 2 because it has managed to produce the highest efficiency. Pump 2 is also smaller in size when compared to pump 1 and 3. Another reason why it is also the best pump for the job is that it is designed for residential applications such as booster pump and it is a variable speed operating pump which can be programmed differently when irrigating the different zones. However, when installing the pump, it is of great importance to connect it to the irrigation system controller to obtain optimum results and to insure that the controller has full control of the whole system.

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