Reduction of energy consumption using remote Variable Frequency Drive (VFD)

Redução do consumo de energia com o uso da unidade remota de Frequência Variável (VFD)

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ABSTRACT

The use of technology in irrigation is a parameter to be considered when there is a need for energy savings and greater process control. In several situations, it is necessary to adjust the characteristics of the hydraulic system during operation of the motor shaft in the irrigation system. The use of a Variable Frequency Drive (VFD) changes the frequency of the motor pump to allow the rotation of the motor shaft to suit the needs of the hydraulic system. With a change in the amount of water in the catchment tank, it becomes necessary to adjust the rotation of the motor shaft to a new head. The objective of this study was to develop a system capable of allowing remote control of a Variable Frequency Drive that controls a motor pump that feeds the central pivot. The system was developed from a microcomputer board Raspberry model and an Arduino microcontroller board controlling a potentiometer of 200kΩ and it was observed that three motor-pump-inverter assemblies presented differences in the significance level between the data of the system and the obtained data. The data showed a strong positive correlation. This system can be an alternative when it is not possible to change the inverter parameters in the field.

Keywords: raspberry pi, arduino, frequency control.
RESUMO
O uso de tecnologia na irrigação é um parâmetro a ser considerado quando houver necessidade de economia de energia e maior controle do processo. Em várias situações, é necessário ajustar as características do sistema hidráulico durante a operação do eixo do motor no sistema de irrigação. O uso de um Inversor de Frequência que muda a frequência da bomba do motor para permitir a rotação do eixo do motor para atender às necessidades do sistema hidráulico. Com uma mudança na quantidade de água no tanque de captação, torna-se necessário ajustar a rotação do eixo do motor para uma nova pressão. O objetivo deste estudo foi desenvolver um sistema capaz de permitir o controle remoto de um Inversor de Frequência que controla um moto bomba que alimenta o pivô central. O sistema foi desenvolvido a partir de um modelo de placa Raspberry pi de microcomputador e uma placa de microcontrolador Arduino controlando um potenciômetro de 200kΩ e foi observado que três conjuntos motor-bomba-inversor apresentaram diferenças no nível de significância entre os dados do sistema e os dados obtidos. Os dados mostraram forte correlação positiva. Esse sistema pode ser uma alternativa quando não é possível alterar os parâmetros do inversor no campo.

Palavras-chave: raspberry pi, arduino, controle de frequência.

1 INTRODUCTION
Several resources have been used for the modernization and cost reduction of pumping. In Brazil, one of the major challenges encountered is related to the use of skilled labor and knowledge for the adoption of technological equipment, which often makes the adoption of automation and irrigation control methods unfeasible.

Various studies in the field of technology have contributed to reducing the energy consumption in irrigation. Daccache et al. (2014) developed algorithms to analyze the relationship between the uniformity of application and the pressure level in hydrants, which is an important parameter as it describes strategies for reducing energy consumption with uniform application associated with harvesting and production.

Moreno et al. (2012) developed software capable of correlating the ideal design of the central pivot and the movement of its lateral while considering a theoretical relationship between the characteristics and efficiency of pump curve.

Carrión et al. (2013, 2014) developed a decision-making tool that considers the size of the sprinkler set with the minimum total cost per unit of irrigated area.
An alternative method for reducing the energy costs of irrigation is automation using Arduino. Based on the study by Susmethaa et al. (2015), Arduino is an open-source data acquisition board that is easy to use and uses an ATmega 316 microcontroller. It can be connected to a soil moisture sensor or a water level sensor, among the various available connections.

Automation with the use of information and feedback about what happens on farms contributes to reducing energy, water, and fertilizer consumption and reduces the impact of irrigation on the environment (TARJUELO et al., 2015).

The use of the pump motor rotor at its maximum rotation results in a higher energy consumption during irrigation. At various points in an irrigated area, the rotor assembly may not require maximum rotation. Thus, the use of an inverter allows the adjustment of the rotation to meet hydraulic needs, thereby reducing energy costs.

In various situations, it is necessary to change the rotation parameters via a Variable Frequency Drive in the field. In some situations, altering the inverter parameters may be impractical because of the difficulty in going to the field at a given moment.

Based on this, the aim of this study is to develop a system capable of enabling remote control of the Variable Frequency Drive to reduce energy consumption. The system was powered by frequency data from seven sets of motor pumps that fed on seven central pivots.

The data entered into the system were compared to the data provided by the Variable Frequency Drive using an F-test at a significance level of 5% and Pearson correlation coefficient. The sets showed a strong positive correlation between the pump rotation curve data and data obtained from the remote control. The system can be an important tool for controlling and assisting the reduction of pumping energy consumption.
2 MATERIALS AND METHODS

This work was carried out in the Water and Soil Engineering Department of the Engineering Department at the Federal University of Lavras. This involved developing a device that allowed for the alteration of the pump's rotation by sending voltage signals ranging from 0 to 10V to a WEG inverter model CFW-05 and using the data collection software provided by the manufacturer, SuperDrive v.5.70.

2.1 DEVELOPMENT OF THE HARDWARE AND SOFTWARE OF THE SYSTEM

The system is composed of an Arduino model Uno rev.3 connected and controlling by a TG9E tuning servo motor coupled with a logarithmic potentiometer with a resistance of 200kΩ. Raspberry Pi 3 model B was configured with XRDP software to act as a remote server.

For the network connection, a portable TP-Link 3G router model MR3020 and a D-Link 3G modem were used, with a DDNS server configured through the weaved website.

The communication between the user and the system was structured in two aspects: communication developed to work on the Raspberry Pi and communicate with the user, and firmware developed to control the servo motor from the Arduino.

User communication was developed in Python and firmware programming was performed in Arduino. User communication is based on the input of 36 frequency values, which can be saved as .txt file for later loading if required.

2.2 SYSTEM COMMUNICATION WITH THE VARIABLE FREQUENCY DRIVE

For connection to the inverter, a Keystone RJ-11 model and a Cat5e network cable with RJ-45 connectors were connected to the inverter via analog ports 19, 20, and 22. Ports 19 and 22 are supplied with voltages of +5V and -5V. Port 20 is the voltage reception port from the potentiometer, with a range of 0–10V (FIGURE 1).

Figure 1 – Demonstration of analog ports 19, 20, and 22 on the WEG CFW-05 inverter.
The frequency readings and control voltage supplied by the Variable Frequency Drive were verified using the Super Drive program with the aim of associating the rotation angle of the servo motor with the voltage provided by the potentiometer.

The Variable Frequency Drive operated within the minimum and maximum frequency ranges. With the direct current voltage supplied by the inverter, it is possible, based on Equation 1, to determine the parameters that link the inverter's analog control voltage to its operating frequency (WEG, 2017).

In this study, the minimum frequency was set at 3 Hz and the maximum at 60 Hz, and the parameters of Equation 2 were determined.

\[
F = \left\{ \left[ (F_{\text{max}} - F_{\text{min}}) \times v_{\text{max}}^{-1} \right] \times v \right\} + F_{\text{min}}
\]  

(1)

Where:

- \(F_{\text{max}}\): maximum frequency set in the Variable Frequency Drive (Hz)
- \(F_{\text{min}}\): minimum frequency set in the Variable Frequency Drive (Hz)
- \(v_{\text{max}}\): voltage supplied to the potentiometer (V)
- \(v\): voltage provided by the potentiometer after the current passes through the resistance (V)

As the values of \(F_{\text{min}} = 3\) Hz, \(F_{\text{max}} = 60\) Hz were determined before the tests, and the value of \(v_{\text{max}}\) was provided by default by the inverter, equal to 10V, the following equation was determined (Equation 2) (WEG, 2017):

\[
F = 5.7 \times v + 3
\]  

(2)
2.3 CHARACTERIZATION OF DATA USED IN THE SYSTEM SIMULATION

The frequency data for simulating the system were obtained from the values of seven motor-pump-inverter (MBI) sets. Each set of frequencies contained 37 frequency values, except for MBI7, which contained 27 frequency values.

2.4 TEST CHARACTERIZATION

During the tests, the SuperDrive v.5.70 software was used, in which the frequency values were entered into the developed system, and the obtained values were verified.

The parameters and naming in the inverter's programming obtained through SuperDrive 5.70 were, respectively, motor frequency and analog input Al1, respectively. Al1 input is the parameter at which the analog control voltage of the inverter is obtained.

The values obtained from SuperDrive 5.70 software were compared with the input values. For comparison, Snedecor's F-test was conducted at a significance level of 5%.

3 RESULTS AND DISCUSSIONS

3.1 SYSTEM CHARACTERIZATION

The developed system features the capability to input 36 frequency values. The system includes a timer synchronized with the Raspberry Pi clock, which enables the determination of when frequency value changes should occur.

Changes in the frequency values were sent to the Arduino to control the servo motor. The system saves a set of frequency values, and the file is saved with .csv extension. For this functionality, there is a 'Grava csv' button.

Data saved in a CSV file can also be loaded into the system. For this feature, there is a "Lê csv" button (FIGURE 2).
3.2 SYSTEM VALIDATION

Using the frequency dataset fed into the system, a dataset provided by the inverter controlled by the system was obtained. From this, it was possible to plot the curves of each motor-pump-inverter (MBI) set by comparing the input data with the data obtained from the Variable Frequency Drive (FIGURE 3).
From the charts, it is possible to notice a greater difference in the MBI3, MBI4, MBI5, and MBI6 sets. In this regard, an F-test was conducted at a significance level of 5% to compare the data entered into the system with the data...
obtained from the Variable Frequency Drive. Pearson’s correlation coefficients were also obtained (TABLE 1).

Table 1 – Results of the F-test and Pearson correlation coefficient between the data entered into the system and the data obtained from the Variable Frequency Drive.

<table>
<thead>
<tr>
<th>Test F</th>
<th>Set of Data</th>
<th>F-value</th>
<th>5% Signif</th>
<th>Correlation Pearson</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBI1</td>
<td>1.391451</td>
<td>3.854407</td>
<td>NS</td>
<td>0.9953</td>
</tr>
<tr>
<td>MBI2</td>
<td>2.709835</td>
<td>3.8544</td>
<td>NS</td>
<td>0.997</td>
</tr>
<tr>
<td>MBI3</td>
<td>14.8798</td>
<td>3.8544</td>
<td>S</td>
<td>0.9955</td>
</tr>
<tr>
<td>MBI4</td>
<td>44.23</td>
<td>3.8544</td>
<td>S</td>
<td>0.9944</td>
</tr>
<tr>
<td>MBI5</td>
<td>11.58</td>
<td>3.8544</td>
<td>S</td>
<td>0.9948</td>
</tr>
<tr>
<td>MBI6</td>
<td>41.39</td>
<td>3.8544</td>
<td>S</td>
<td>0.9786</td>
</tr>
<tr>
<td>MBI7</td>
<td>1.4627</td>
<td>3.8544</td>
<td>NS</td>
<td>0.9957</td>
</tr>
</tbody>
</table>

S. Significant NS. Not significant

Source: From the author (2017).

Through Snedecor’s F-test at the 5% significance level, it was observed that the MBI3, MBI4, MBI5, and MBI6 sets showed significant differences. However, all sets exhibited a strong positive correlation, indicating that the system responded to the frequency changes requested by the user.

4 CONCLUSION

The development of the system enabled remote access to change the inverter frequency according to the requirements of the hydraulic system. The system exhibited a significant difference in the four evaluated motor-pump-inverter sets; however, all of them showed a strong positive correlation.

As a future development, it is suggested to use an Arduino model that allows for the direct input of voltage into the inverter via the Arduino’s analog output port, eliminating the need for a potentiometer.
REFERENCES


