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전류검출 방식의 심정 펌프 센서리스형 다기능 컨트롤러 개발

Development of a Sensorless Deep Well Pump Multi-function Controller using Current Detection Method

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Abstract - In this paper, we propose a sensorless multi-function controller applicable for deep well water pumps using current detection method. The proposed system overcomes various drawbacks of existing sensored system and additional features like Over current protection function due to overload, Under current protection function for idling at low water level and Relay function for starting single phase motors and acts as a level indicator to detect water lever in real time by the current detection method. A prototype of the multi-function controller system is designed and all of its functions are tested in the laboratory. The application of the proposed controller ensures reduction in the power consumption and maintenance cost in the facilities like water and septic tanks, drainage and waste water system, oil and chemical tanks where deep well pumps are used.

Key Words : Deep well pump, Water level monitoring sensor, Current measurement, Multi-function Controller

1. Introduction

Deep well pumps are generally used in the facilities like water and septic tanks, drainage and waste water system, oil and chemical tanks where liquid has to be drawn from the reservoir and pumped to the receiving tank. Basically, these pumps use water sensors where water level of the reservoir and the receiving tank is constantly sensed and the controller send signals and drives motors as per the feedback of the sensors. However, over the period of time, the precision of these sensors are deteriorated due to various environmental reasons and are prone to give wrong information to the controller. Also if the signal cables connecting sensors and controller is broken, then the motor might get damaged by over operation. Practically its very difficult and costly to replace those motors or pumps since they are installed in very deep places.

To overcome these practical difficulties sensorless pump system are developed [1-10]. Traditional pumping system incorporating constant-speed pumps waste energy through crude flow control via throttling valves. Lifetime cost analysis shows that the capital cost of a constant-speed pump is typically only 5% of the life time cost. Maintenance and energy consumption make up most of the remaining 95% of the cost [2]. In other words most of these products are expensive and demands high maintenance cost. In this paper, we have proposed and designed a sensorless deep well pump multi-function controller using current detection method. This method checks the amount of current and operates motor according to various level of currents. It overcomes various drawbacks of the existing system by removing sensors and providing several functions like Over current protection function due to overload, Under current protection function for idling at low water level, Relay function for starting single phase motors and acts as a level indicator to detect water lever in real time. A prototype of the multi-function controller system is designed and all of its functions are tested in the laboratory. The application of the proposed controller ensures reduction in the power consumption and maintenance cost in the facilities like water & septic tanks, drainage & waste water system, oil & chemical tanks where deep well pumps are used.

2. Deep well water pump control system

Water is pumped from the reservoir into a receiving tank. This kind of arrangement is used to lift water from a

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reservoir into a water treatment works for treatment before the water goes into the supply network. The water level in the reservoir varies but the discharge level in the receiving tanks remains constant as the water is discharged from a point above the water level. Fig.1 represents the conceptual diagram of a Deep well water system. The operating pressure of a pumped system is calculated in the SI unit of meters (m).

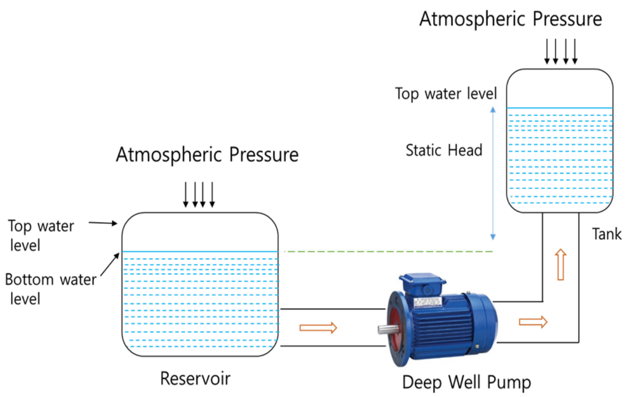

Fig. 1 Conceptual diagram of a deep well water system

For the above system, the operating pressure or the total system head, H_{Total} , is defined as:

$$H_{Total} = H_S + H_D + (P_{RT} - P_{RES}) \quad (1)$$

where

H_s = Static head (m)

H_D = Dynamic head (m)

P_{RT} = Pressure on the surface of the water in the receiving tank (m)

P_{RES} = Pressure on the surface of the water in the reservoir (m)

Although the atmospheric pressure changes with height, the change in pressure that occurs over the pumping height is often so small that it can be considered negligible. In this example, the change in pressure over the elevation from the reservoir to the receiving tank is not significant and hence is negligible, i.e., $P_{RT} - P_{RES} \approx 0$. Therefore, equation (1) becomes:

$$H_{Total} = H_S + H_D + ... \quad (2)$$

The static head H_S is the physical change in elevation between the surface of the reservoir and the point of discharge into the receiving tank. As the water level in the reservoir can vary, the static head for the system will vary between a maximum and a minimum value:

$$H_{Smin} = \text{Discharge level} - \text{Reservoir Top water level} \quad (3)$$

$$H_{Smax} = \text{Discharge level} - \text{Reservoir Bottom water level} \quad (4)$$

2.1 Sensored deep well water pump control system

This type of method completely relies on the measurements of sensors located at the underground reservoir and the water tank. The controller receives signals from the sensors and runs motor if water is below the threshold in the water tank and stop the pump if the water level in the underground reservoir goes below the threshold or water in the tank goes above the threshold. Fig. 2 shows a typical sensored deep well water pump control system.

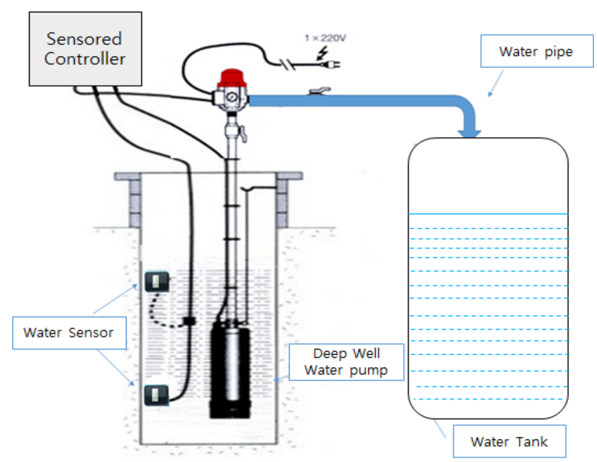

Fig. 2 Sensored deep well water pump system

The main drawback of this system would be the possibility of running the pump even there is no water in the reservoir and damage the motor. Over the period of time, the precision of sensors inside the reservoir or tank may be deteriorated from the things like algae and it can give wrong measurements. Also, in case the sensor wires connecting to the controller gets disconnected by any means, the motor may either be running constantly or not run at all. Since everything is located at the deep underground, practically it would be very hard or expensive to find the source of error and troubleshoot or do maintenance work incase the motor is damaged.

2.2 Proposed sensorless multi-function control system

The proposed system is a sensorless control system where the level of water is detected by the level of current in the motor. In case there is no water in the reservoir then the current decreases 90% below the standard current. The controller detects the current and stops the motor immediately. The motor will start again after the water level rises in the reservoir (automatic refilling time) and pumps to the tank.

The proposed system overcomes the drawbacks of the sensored system since the controller does not work with the values measured by sensor anymore. Besides that, it gives the additional features of Over current protection function due to overload, Under current protection function for idling at low water level, Relay function for starting single phase motors and acts as a level indicator to detect water lever in real time by the current detection method.

Fig. 3 and Fig. 4 represent proposed sensorless multi-function control system and main program flowchart of the system.

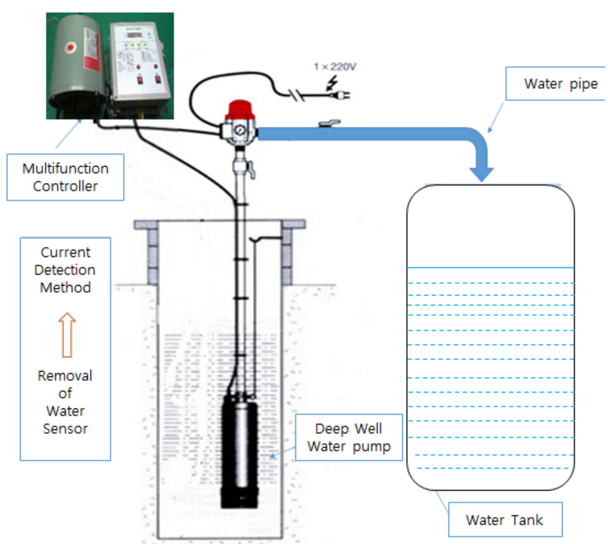

Fig. 3 Proposed sensorless multifunction control system

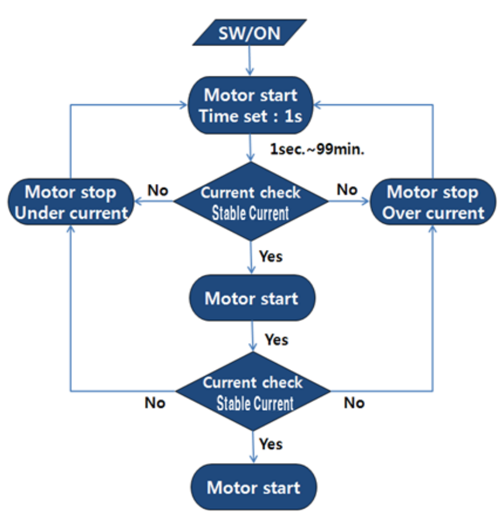

Fig. 4 Main program flowchart of the proposed system

3. Design of the proposed multi-function controller

3.1 Circuit design of the proposed multi-function controller

The internal circuitry of the proposed multi-function controller can be divided into MCU control circuit and Pump control circuit. In MCU control part consists of SET, UP, DN and STORE button for setting, increasing, decreasing or storing current values respectively.

Here, Fig. 5 represents the circuit diagram of the MCU part where SENSOR represents the sensor to measure the water level of the tank. The contact point goes into CLOSE mode if the water level is higher than the threshold and into OPEN mode if the water level is lower than the threshold. CT refers to the current sensor where it measures over-current, under-current and relay function. Also if current gets detected more than 1A the Triac driver Q2 gets activated and pump start to operate through corresponding capacitor.

Fig. 6 represents the pump control circuit where MC acts as a electronic contactor which allows or blocks current flow, checks the over current, under current and the water level of the tank. CAP is an operating capacitor which provides leading current to the operating coil for driving the motor. The current flows from Triac Q1 to CAP to to run the motor and after that Q1 turns OFF.

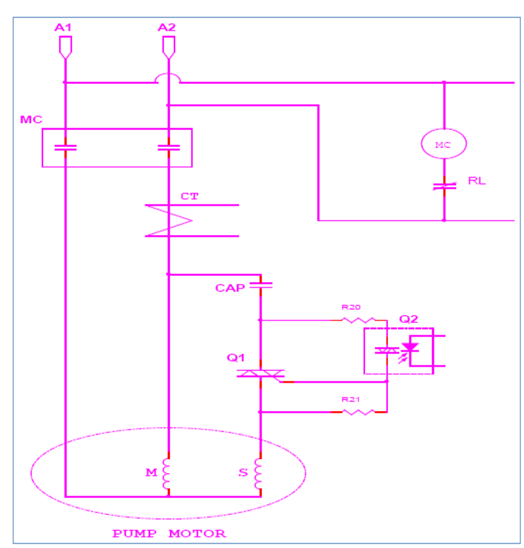

Fig. 5 Circuit diagram of the MCU control part

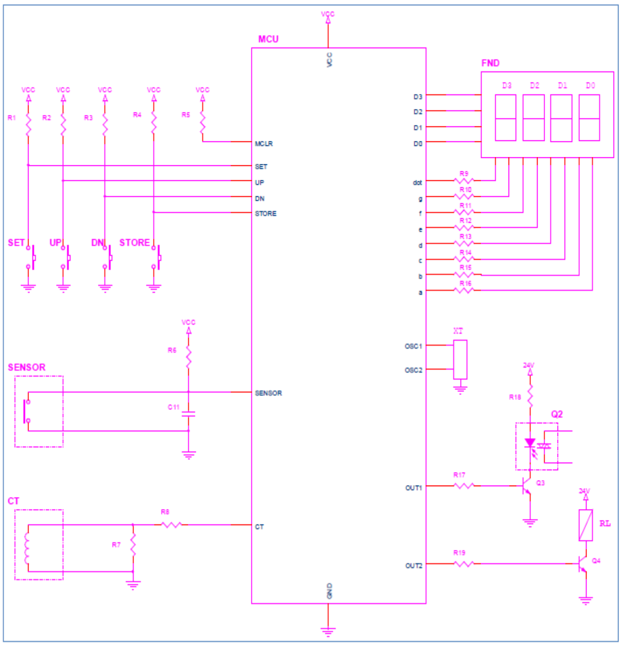

Fig. 6 Circuit diagram of the pump control part

Fig. 7 Test of Current detection function

3.2 Results and discussion

A laboratory prototype of the proposed Multi-function controller was built and each of its function was tested. Fig. 7 shows the test of current detection function of the multi-function controller. Here, load current was compared with the value shown in FND device and the error range was ±0.2 A and ± 10%. Fig. 8 shows the test of over current function. Here, 120%-150% more than normal current was given to test the function. The error range was ± 20%. and ± 0.3 sec. Similarly, Fig. 9 shows the test of under current function of the multi-function controller. Here, the load current was 80% less than normal current and the error range

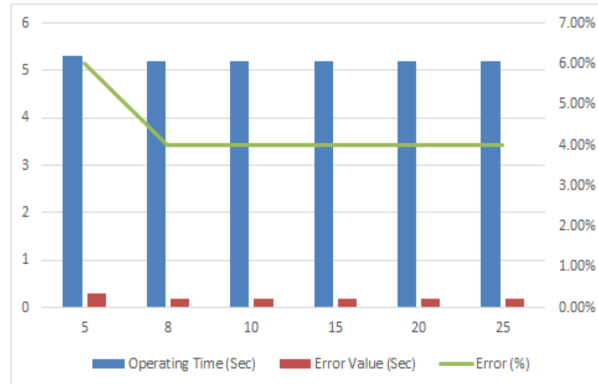

Fig. 8 Test of Over current function

Fig. 9 Test of Under current function

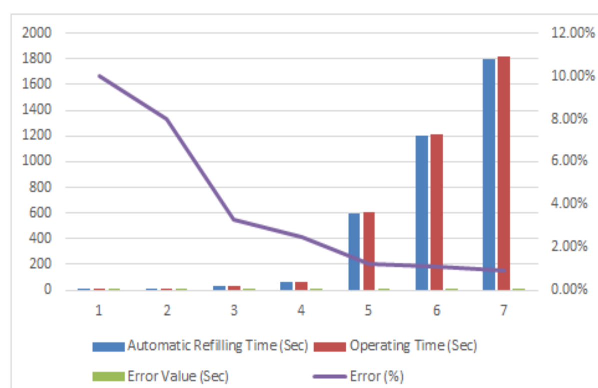

Fig. 10 Test of Automatic refilling time function

was ± 20%. and ± 0.3 sec. Lastly, Fig. 10 shows the test of automatic refilling time function. When the water level goes down below the threshold in the reservoir, under current situation arises, since there is no load. The test checks the operating time of the motor after the automatic refilling of the reservoir. The error range was ± 20%. and ± 0.5 sec.

Fig. 11 Designed prototype of the multi-function controller

Table 1 Comparison of the designed system with existing systems

Category	Existing Systems	Proposed System
Control	Sensors	Current detection
Function	Running or shutting down the pump according to sensed values	Multi-functional Under current protection function, Over current protection function, Automatic relay function and Automatic refill function
Power Consumption	High	Low
Cost	High maintenance cost	Reduced installation and maintenance cost

Fig. 11 shows the designed prototype of the multi-function controller.

Here, Table 1 shows the comparison of the designed sensorless system with sensored system. It show the proposed system is has improved with multifunction feature, low power consumption and low maintenance and installation cost.

4. Conclusion

In this paper we have designed a sensorless multi-functional controller to overcome the disadvantages of the sensored deep well pump system. The multi-functional controller uses current detection method to control the motor and additionally it gives over current protection function, undercurrent protection function, and automatic time refilling function. A real prototype was made and several performance tests were conducted to check its reliability. The main improvement of the designed system is the omission of the sensors and provide a cheap, easy and reliable system. With the use of the proposed controller, we expect the reduction in the installation costs, maintenance costs and power consumption in the deep water pump system or other such facilities.

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