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Performance Analysis and Protection of Submersible Motor for Unbalance Condition in Dewatering

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Abstract: This study discusses the safety of submersible motors in dewatering under current unbalanced conditions. Submersible motors are commonly employed in artificial lifting systems used in dewatering conditions. The submersible motor is vulnerable to hazards that might cause injury during the current imbalance state in dewatering. The researcher offers a basic protection mechanism that he has devised and a performance study of the submersible motor. Work on dewatering difficulties was finished in this study, and the suggested solution sought to safeguard the submersible motor. The protective strategy is effectively realized by utilizing three temperature sensors based on submersible motor coils by transmitting the signal to the microcontroller, which identifies the defective phases and sends the tripping signal to the AC drives (inverter) and sensors (water), submersible motor probe with ceramic measuring cell, and submersible motor inverter. In addition, the simulation and experimental results for various operating locations are shown in this study. The outcomes are in line with the goals that were set. This study provides guidelines for high-performance submersible motors in wells due to groundwater conditions. These guidelines are based on several failures discovered during an examination. Furthermore, this report suggests many techniques for preventing these failures. These suggestions are based on the investigation of numerous submersible motor pumps from various manufacturers in various wells in Egypt with short-term operations induced by various situations encountered while working on the site.

Keywords: Submersible Motor, Protection, Current Unbalance Condition, Dewatering.

1 Introduction

Submersible motors were introduced and used in Egypt for groundwater drainage [1], with one of the first operators being the Arab Contractors' Company. Groundwater issues have been addressed using ditch-sump and well-point systems [2]. In early 1978, it made headlines for its deep-sea engineering [3]. Submersible engines were employed in 1985 to lower the required water level in deep drainage scenarios [4]. The submersible motor pump (SMP) is a vertical induction motor [5]. All submersible pumps are mainly composed of the motor, bearings, seals, casing, and impeller [6]. In B. oil wells and geothermal wells, SMP combinations are often seen [7,8]. The pipe string drives the submersible motor unit. Both the SMP and the tubing are completely immersed. The technology for submersible motor protection has advanced significantly in recent years. Submersible motors power Egypt's nearly 4,000 water treatment facilities and irrigation and agriculture. The system may stop working if the submersible motor fails. Therefore, submersible motors must be safeguarded against unexpected failures using stringent methods [9].

The Arab Contractors Company has specialized in dewatering for sanitation projects throughout the researcher's time at the dewatering unit. Throughout the work, various issues arose in the continuous execution of these submersible motors' jobs of draining groundwater during the drilling process. This creates an imbalance in the currents of these submersible motors and faults and disturbances that impact how they perform. The researcher conducted the research process to identify these issues and their causes and presented a solution during the current unbalanced condition in dewatering via performance analysis and protection of the submersible motor's current balance and unbalanced conditions.

Submersible motors are vital and can be used in various applications [10], such as large-scale water conservancy projects [11], urban water supply [12], drainage systems [13], mine drainage [14], emergency disaster relief [15], and other occasions. Adequate protection of induction motors is routinely achieved *via* locked-rotor, phase unbalance, and overload protection [16]. It is confirmed

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that the possible causes of insulation failures in electric submersible motors are corrosion of the outer cable surface, mechanical damage, and insulation deterioration due to thermal or electrical stress [17,18]. This paper presents relevant research on the protection of submersible motors from over-temperature damage to the motor winding. Simulation and experimental results for different conditions are displayed. These simulation results agree with those measured experimentally for the submersible motor [19], 11 kW, 22 A, 380 V, and power factor (P.F) = 0.9.

2 Performance Analysis and Protection of Submersible Motor

2.1 Electrical Properties of Submersible Motor Dewatering and Groundwater Control

Many defects in submersible motors cause over-current and other over-temperatures [20]. When the motor is reversed, the water level increases to the point where the SMP's potential energy is exceeded, the impeller drag groove becomes clogged with pollutants and salt, and the pump shuts down without warning. During SMP valves and connections, there are electrical disruptions. As illustrated in **Table 1**, such errors cause high temperatures within the submersible motor. The main goal for researchers is to figure out why the same submersible motor does not have the same stability and asymmetry as shown in **Figure 1**.

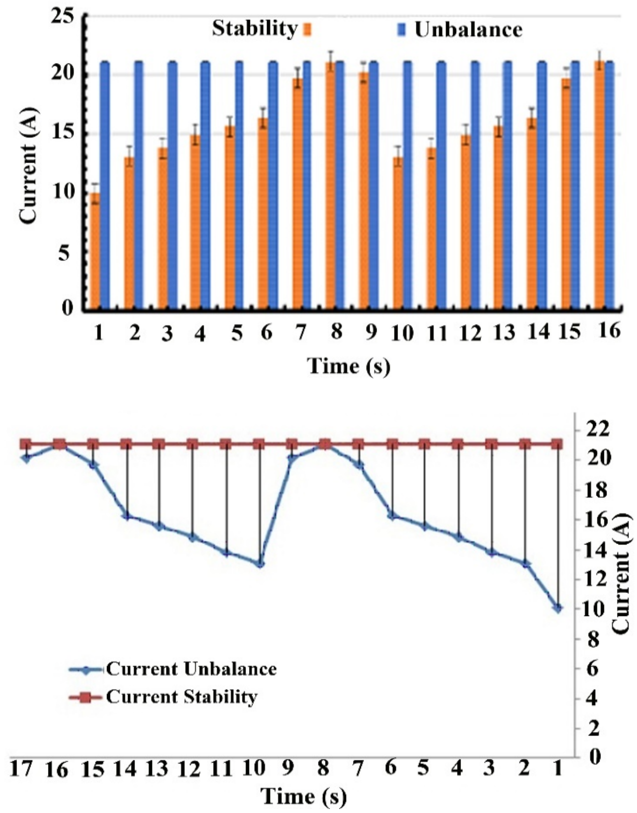


Figure 1. The submersible motor difference between current stability and current unbalance.

Table 1. the difference between current stability and current unbalance for the submersible motor

Time (sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Current Stability (A)	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	20.1
Current Unbalance (A)	10	13.1	13.8	14.9	15.6	16.3	19.7	21.1	20.2	13.1	13.8	14.9	15.6	16.3	19.7	21.2	20.2

2.2 Water Properties of the Submersible Motor

2.2.1 Submersible Motor Installation

Installation of the submersible motor inside the well 87 $m^3 h^{-1}$ as shown in **Figure 2**.

1. Do not keep the motor's bottom end in a mud or dirt area. This may block the diaphragm opening.
2. Check the freeness of the motor shaft and free endplay.
3. Fill the motor with clean, cold drinking water through the water-filling plug.
4. Check the motor for any water leakage. If noticed, tighten all water filling plugs, and drain plugs.
5. Measuring the insulation resistance of the motor, and resistance value should not be less than 20 MΩ.
6. A proper waterproof cable splice must be made between the motor lead and drop cable.
7. Connect the pump and motor until it butts completely to the motor's top surface. Then tighten the nuts in a cross pattern uniformly.
8. Check the axial movement of the pump shaft assembly by lifting it vertically. A minimum lift of 1–1.5 mm will indicate that the coupling is done properly.
9. Position the motor cable on the pump and fix it with a cable guard. Then fasten the suction strainer. Set the pump set inside the borehole above the main point of water inflow (yield point). If the yield point is not ascertainable, use the flow inducer sleeve along with it.

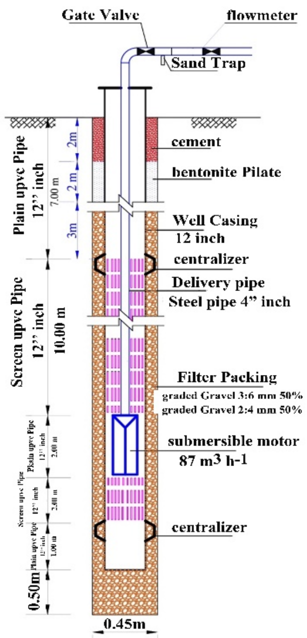


Figure 2. The Submersible Motor inside the well Flow (Q), 87 m^3 h^{-1}.

A disposition device was used to take readings, as shown in **Table 2**. It was found that there is a difference comparing the behavior of submersible motors under normal and abnormal conditions, as shown in **Figures 3** and **4**.

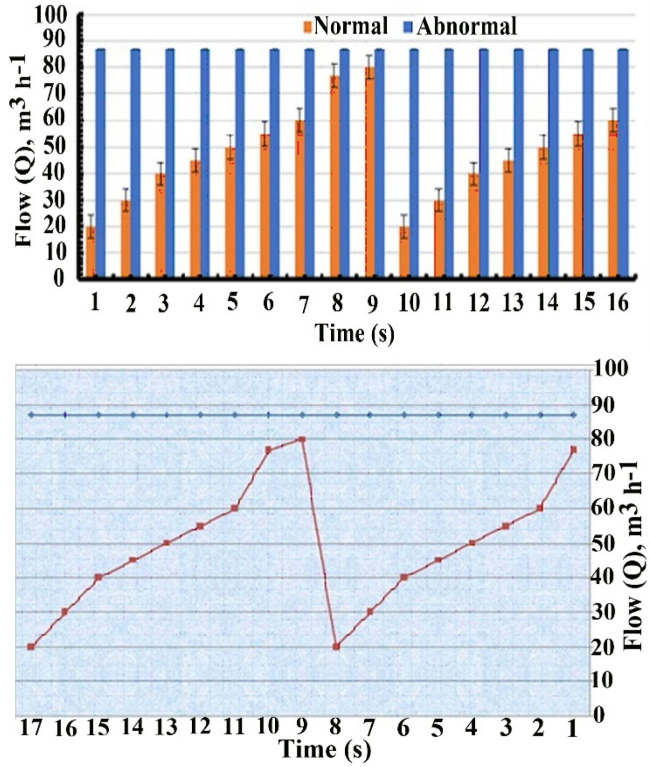


Figure 3. Submersible motors in the normal and abnormal Q (m^3 h^{-1}).

Table 2. Comparison between normal and abnormal Q conditions

Time (sec)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Q m^3 h^{-1} Normal	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87	87
Q m^3 h^{-1} Abnormal	20	30	40	45	50	55	60	77	80	20	30	40	45	50	55	60	77

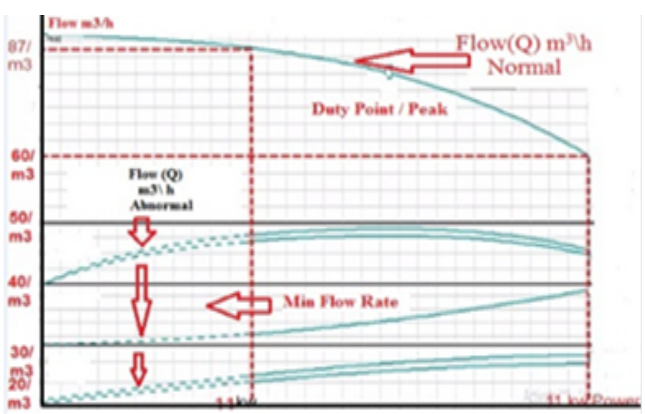


Figure 4. Curve Submersible motors in the normal and abnormal Q (m^3 h^{-1}).

2.2.2 Water Sensors (OPTIBAR LC 1010C)

Figure 5 depicts a submersible level probe with a ceramic measuring cell.

1. Level probe with a 22 mm diameter robust and resistant to high loads.
2. The pressure ranges from 100 mbar (1 mH_2O) to 250 mbar (100 mH_2O).
3. Waterproof TPE cable is also suitable for wastewater.

A- OPTIBAR differential pressure transmitter

The OPTIBAR LC 1010 is a submersible level probe used to measure the level of liquids in the water and wastewater industry.

The high-overload-resistant ceramic-capacitive measuring diaphragm is safe to install and easy to clean during operation. With the robust 316L housing and the highly corrosion-resistant TPE cable, this level probe can be used in various ways.

Figure 5. Sensor's water (OPTIBAR LC 1010C).

B-Highlights

• High-overload-resistant ceramic measuring cell for uninterrupted measuring operations.

• The outer diameter of 22 mm allows for simple installation in 1 pipe and confined spaces

• The flush ceramic measuring diaphragm allows for easy and safe cleaning.

• High quality, corrosion-resistant cable made of TPE guarantees versatility in application.

• Simple parameterization through optional HART communication or in a fixed measuring range.

C-Industries: water, wastewater, plant engineering and environmental technology.

D-Applications

Level measurement in an oil tank and gauge measurement in a deep well.

3. Submersible Motor Faults When Stopping Work While Drilling

The submersible motor is affected by many faults, which cause decreased water inside the well, over current and so on, over-temperature, such as reverse motor movement, and increases the level of water to be greater than the potential energy of the SMP. **Figure 6** displays the clogging of the drag slot of the impeller by impurities and salt, closing the pump SMP valve without notice and an electrical fault during connection. Such faults lead to excessive temperatures inside the engine. In this case, the sensors detect an increase in temperature and send the temperature values to the microcontroller. Then the microcontroller disconnects the panel.

Figure 6. Increasing the level of water in the well.

4. The Proposed Scheme System

The proposed technique consists of a rectifier, sensors, microcontroller, and output circuit consecutively connected with AC drives (inverter ABB). 11kw submersible motor is used, as shown in **Figure 7**. (The block diagram of the proposed technique, and the whole circuit of the proposed technique).

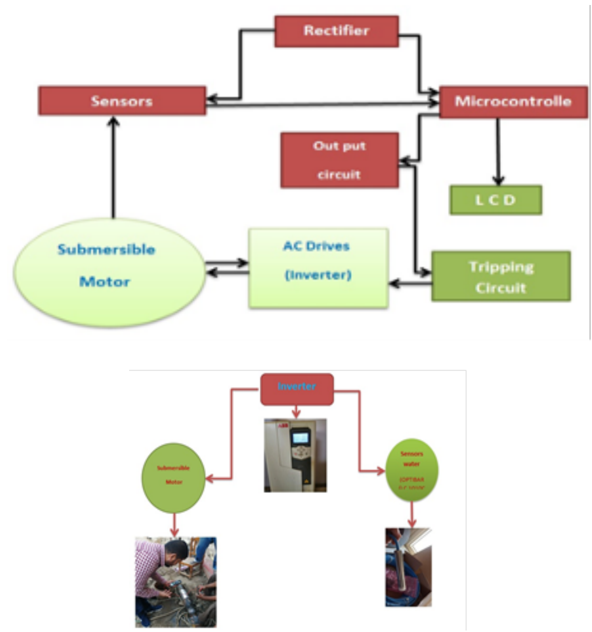


Figure 7. System block diagram of the proposed technique.

4.1 Schematic Diagram of the Proposed Technique to the Whole System

Three temperature sensors based on microcontrollers are used to build this protection strategy. This temperature accurately represents the temperature of the three-phase submersible motor windings. In the case of water, the temperature sensor sends a signal to the microcontroller to detect the wrong phase, and the frequency converter (inverter) and the water sensor (OPTIBAR LC 1010C) get a trip signal. **Figure 8** shows a submersible motor with ceramic measuring cell probes and converters based on submersible motors.

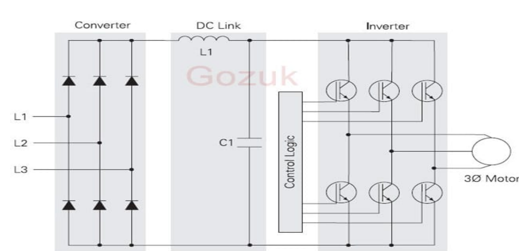


Figure 8. Diagram of the proposed technique for whole system.

4.2. Pre-installation Protection of the Submersible Motor

1. Check the inside diameter of the well [21].
2. The borehole must be flushed well to free it from sand, silt, and other foreign particles.
3. The submersible motor must never run dry and ensure the pump set is always submerged in water.
4. The submersible motor assembly must handle clean, cool, fresh water without abrasives.
5. Make sure that the voltage fluctuations lie within +10% of the motor's rated voltage.
6. It is mandatory to install a genvik motor with a complete protection control system for both 1ph and 3ph. Preventor, dry run prevention, phase failure, phase reversal, and lightning protection.
7. It is recommended to use a flow inducer sleeve over the submersible motor to give better cooling effects to the motor if the submersible motor is installed in a larger diameter well. As shown in **Table 3**, a schematic diagram of the proposed technique for the whole system is shown.

5. Experimental Results

The proposed protection scheme is designed to protect the windings of submersible motors from overheating. The recommended protocol thresholds are 40 ºC and 2 sec. The submersible motor for this study is 11 kW, 22 A, 380 V and P.F. = 0.9 (Figure 9).

Figure 9. Motor winding temperature protection is the proposed technique.

5.1 Performance Analysis and Protection of the Submersible Motor During the Current Unbalance Condition in Deep-well Dewatering

Main parts of a well: As shown in **Figure 10**, the main components of a deep well are solid pipes (casing), screen, filter, sand trap, discharge pipe, submersible motor, flow meter, and gate valve.

Uses of wells in dewatering:

1. Dewatering of deep excavation in unconfined aquifers.
2. Relief of uplift pressure in confined aquifers.

Favorable conditions for using deep wells submersible motor:

1. Clean sands and gravels-high permeability.
2. Dewatering to unlimited depths.
3. Pressure relief on the clay layer below excavation.
4. Good access to the excavation.

Unfavorable conditions for using deep wells Submersible Motor:

1. Silty soils-low permeability.
2. Satisfied soils.
3. Wells are slow to drain soil-it not good for achieving rapid drawdown.
4. If drawdown to an impermeable layer is required.

Dewatering the appearance of these faults on the worksite:-

Case 1: Reverse the direction of motor rotation.

Case 2: Groundwater rises in a well.

Case 3: Reverse motor motion.

Case 4: Raising the water level above the SMP potential.

Case 5: Impeller chute clogged with dirt and salt.
Case 6: Shut off the pump SMP valve without notice.

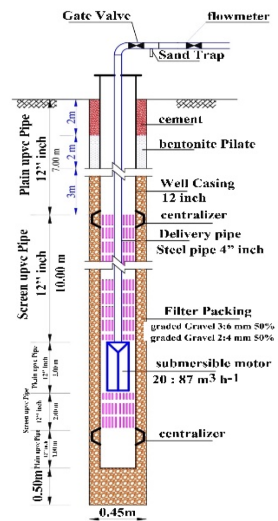


Figure 10. The Submersible Motor inside the well Q, 20:87 m^3 h^{-1}.

If the water level is greater than the potential energy of the SMP, the motor's temperature will increase. One such case was investigated. The SMP is immersed deeper than usual in the well, which causes an overload of the motor. As shown in **Table 4**, the measured temperature for Coil 2 was recorded as 40.63ºC. As can be seen, the red light-emitting diode (LED) will light up, indicating that the submersible motor has warmed up. Therefore, the trip signal is sent through the output circuit, and the LCDs "Coil 2 Overheat." The following table shows the behavior of the schema before and during operation.

A piece of impurity (gravel and grit) has been placed at the entrance to the impeller to prevent water from entering and stopping its circulation. It does stop the impeller. The engine is trying to spin, and this leads to pulling the current higher because of the engine's high temperature, which represents an overloaded motor. The proposed circle is set at a separation temperature of 40ºC and a separation time of 2 sec. The following table shows temperature values before and during operation on each winding. Table 4 shows that the over-temperature and over-current were released on winding 2 and were 40.63ºC. As seen, the red LED is operating, which indicates an increase in the temperature of the submersible motor. Consequently, the output circuit sends the tripping signal, and the LCDs "Coil 2 Overheat." The following table shows the scheme's response before and during the operation.

Table 3. Schematic diagram of the proposed technique to the whole system

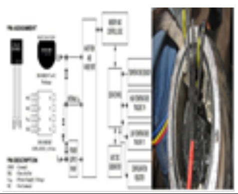
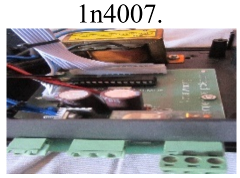
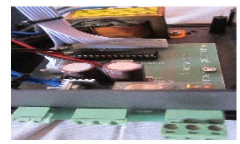
Components	Sensor	Rectifier	Microcontroller	Output Circuit
Type **Specifications** **Figures**	Three sensors DS18B20 	Liquid crystal display (LCD) and sensors feeds by 5V DC. The step-down transformer is to convert 220 V to 12 V (AC). For silicon diodes 1n4007. 	Mega family, atmega328 16 MHZ crystal for its oscillator the one cycle instruction during 0.0625 µsec programmed using C language 	The output circuit consists of BC337 transistor and 12VDC Relay 
Composition	It is installed on the motor winding inside the submersible motor. **1**. Unique 1-Wire interface requires only one port pin for communication **2**. Multidrop capability simplifies distributed temperature sensing applications **3**. Requires no external components **4**. Can be powered from data line. Power supply range is 3.0 V to 5.5 V **5**. Zero standby power required **6**. Measures temperatures from -55ºC to +125ºC. 7. User-definable, nonvolatile temperature alarm settings.	The microcontroller, the LCD and sensors feeds by 5 V DC. So, the Rectifier circuit is implemented in the rectifier circuit and a 5 V DC regulated power supply system. Such DC supply system consists of step down transformer, rectification circuit, smoothing circuit, regulation circuit. The step-down transformer converts 220 V AC to 12 V AC. The rectification circuit is to convert 12 V AC to 12 V DC, 4 silicon diodes 1n4007. Smoothing circuit is to smooth the voltage. The regulation circuit, lm7805, is to regulate the voltage to 5 V DC	So, its time response is very fast in reading. It periodically presents the readings of temperature on the LCD instantaneously. Microcontroller will stop the motor in case of increasing the motor windings temperature than the set point temperature after the estimated time delay. This comes by sending a tripping signal to the output circuit to stop the motor until discovers the reason for increasing the temperature.	The normally closed point is opened to stop the motor if its winding temperature increases than the setpoint temperature shows the output circuit configuration.

Table 4. Comparison between temperature submersible motor normal and abnormal

Time (min) / Temperature	5	10	12	14	15	16
T1/winding 1	29.87ºC	33.81ºC	34.25°C	36.88°C	38.81°C	40.06°C
T2/winding 2	29.94°C	33.81°C	34.38°C	36.81°C	39.56°C	40.63°C
T3/winding3	29.00°C	33.00°C	34.50°C	36.75°C	38.75°C	40.00°C

We are constantly exposed to this issue at the beginning of the processing and operation of the worksites, when the valves are closed without warning, resulting in submersible motor failure due to excessive storage. In this instance, the suggestion was tested. The table below shows how the scheme worked before and during the motor winding temperature protection submersible motor shown in Figure 11. The suggested circle has a separation temperature of 40ºC and a separation period of 2 sec. The temperature values before and during the operation of each winding are shown in the table below. Table 4 reveals that the over-temperature and over-current were discharged on winding 2 and were 40.63ºC. As can be seen, the red LED is on, indicating that the temperature of the submersible motor s rising. As a result, the tripping signal is conveyed through the output circuit, and the LCDs "coil 2 overheat."

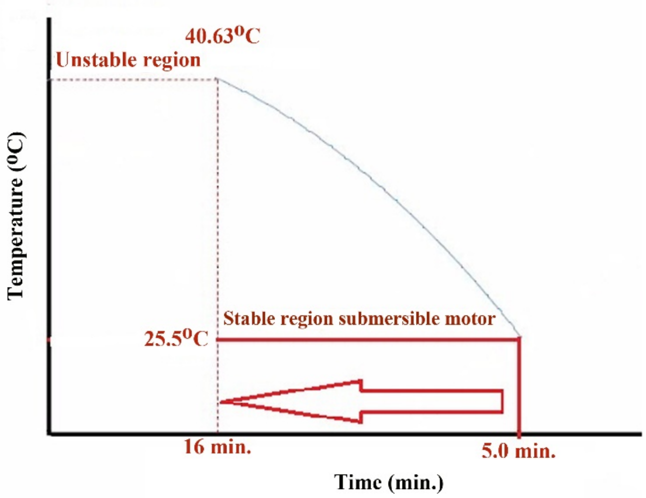


Figure 11. Motor winding temperature protection submersible motor the proposed technique.

In this scenario, the SMP was connected to a single-phase rather than a three-phase power supply, and an over in the current engine was detected in conjunction with an over in temperature. The suggested circle has a separation temperature of 40.00 ºC and a separation period of 2 sec. The temperature readings before and during operation on each winding are shown below. Winding 2 had an over-temperature of 40.63 ºC, whereas winding 1 had a temperature of 40.00 ºC. As can be seen, the red light is on, indicating that the temperature of the submersible motor has risen. As a result, the tripping signal is sent through the output circuit, and the LCDs are labelled "Coil1 Overheat" and "Coil 2 Overheat" in **Figure 12**. The table below depicts the scheme's reaction before and throughout the experiment.

Figure 12. Coil 2 overheat.

6. Simulation Results :-

As shown in **Figure 13**, several simulations of the proposed scenarios are done. The PROTEUS program is used. The whole circuit of the proposed technique is simulated at phase temperature.

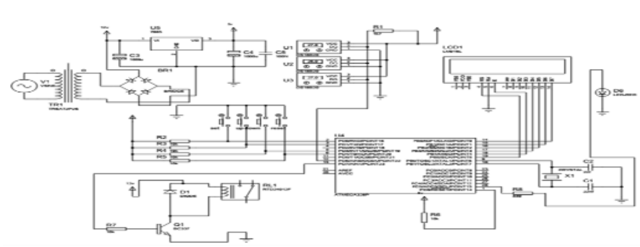


Figure 13. Simulation the proposed.

7. Conclusions

During work, the submersible motor's performance and protection are being checked during the current unbalanced situation in dewatering.

1- When looking at the performance of the submersible motor during dehydration, it was found that most of the submersible motor failures were caused by the motor getting too hot.

2- In the performance analysis, it was also found that some wells lacked water, which affected the working performance of the submersible motor, resulting in an unstable current. The motor was unbalanced, resulting in the electrical display in the table and data, with measurements and symbols in the research work.

3- It was found that there were many drilling and engineering-related problems and shutdowns in the case of a lack of water in the well and a mismatch in the submersible motor speed.

4- When performing performance analysis, it is recommended to organize the well water intake process, which must correspond to the rotational speed of the submersible motor. An inverter must be installed on the submersible motor to control the motor's frequency and speed.

5- Also, a plan includes putting in a temperature sensor, and the DS18B20 inside of the three-phase submersible motor winding detects the temperature.

6- These sensors transmit the natural temperature and monitor any change in temperature inside the submersible motor, transmitting and sending a signal to the microcontroller (Mega family, atmega328). It uses a 16 MHz crystal.

7- A new scheme for performance analysis and protection of submersible motors from overheating has been developed. The presented protection scheme is implemented practically using three thermometer sensors based on the winding motor and sending a single signal to a microcontroller connected in series with the inverter. The simulation results agreed reasonably with those measured experimentally for the motor used in the research. High-precision measuring of the speed of segregation and up to 0.1ºC. Showing degrees for internal submersible motor heat is constantly on your screen; proposed time measuring and monitoring the change in temperature before it arrives in coils. The proposed scheme is simple and inexpensive while highly efficient, giving high precision. We suggest that companies' producers install sensors inside submersible motors to protect against overheating.

8- The proposed scheme controls any increase in temperature and then sends a signal to the inverter to disconnect the submersible motor and stop working as described in the research paper.

Conflict of Interest

All authors declare that there is no conflict of interest regarding the publication of this paper.

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