The Evaluation of Twisted Pair Cable Performance in Circuits with DS18B20 Temperature Sensors

Édipo Sabião Sanches
Civil Engineer. Masters Student in Agricultural Engineering at the Federal University of Grande Dourados, FCA - UFGD, Dourados, MS, Brazil.
ORCID: https://orcid.org/0000-0003-0783-772X
Email: ediposabiao@hotmail.com

Ítalo Sabião Sanches
Civil Engineer. Masters Student in Agricultural Engineering at the Federal University of Grande Dourados, FCA - UFGD, Dourados, MS, Brazil.
ORCID: https://orcid.org/0000-0002-3212-6199
Email: italosabiao@hotmail.com

Guilherme Marcelo de Souza Mariano
Scholarship holder of the Institutional Scientific Initiation Scholarship Program for High School Students (PIBIC-EM) in Civil Engineering at Federal University of Grande Dourados (UFGD) as a High School student at Floriana Lopes State School - Dourados, MS, Brazil.
ORCID: https://orcid.org/0000-0001-7100-1519
Email: gmarcelo260703@gmail.com

Christian Souza Barboza
PhD in Civil Engineering. Professor at the Federal University of Grande Dourados, FAEN - UFGD, Dourados, MS, Brazil.
ORCID: https://orcid.org/0000-0003-0316-7626
Email: christianbarboza@ufgd.edu.br

Agleison Ramos Omido
PhD in Electrical Engineering. Professor at the Federal University of Grande Dourados, FAEN - UFGD, Dourados, MS, Brazil.
ORCID: https://orcid.org/0000-0002-0014-8537
Email: agleisonomido@ufgd.edu.br

Abstract

The transmission of data and energy has been widely used over the past few centuries, but in a complex manner and at high cost. Gradually in order to simplify this process and reduce costs, important network cables have appeared, namely: twisted pair cables, coaxial cables, and fiberoptic cables. Thus, instead of *various wires, a single cable has become necessary. Within this context, this study seeks to evaluate data transmission performance using two types of Ethernet cables, CAT E5 and CAT E6, in circuits with DS18B20 temperature sensors. The evaluation of the two cables was made by reducing their lengths by 10 meters every two weeks to find the length of cable which would ensure a reliable reading of the sensors for use in the research project entitled "The Evaluation of the Potential Use of Surface Geothermal Energy in the City of Dourados, MS". The obtained data indicates that CAT E5 cables with lengths less than 70 meters ensure reliable readings close to the real value, while for CAT E6 Ethernet cables this takes place at lengths of less than 80 meters.*

Keywords: Data Transmission; Twisted Pair Cables; Temperature.

1. Introduction

This article was born from concern regarding our great dependence on non-renewable sources of energy, given that in the development of the research project "The Evaluation of the Potential Use of Surface Geothermal Energy in the City of Dourados, MS," it was necessary to develop a system to make and store underground temperature readings at various depths in the region. In the conception of the system, the distance between the sensor and the data storage module can vary by tens of meters in some units depending on the locations used in the experiment. Thus, it was necessary to establish the best type of cable to transmit this data, given that a positive relationship between the sensors and the data storage module should not interfere with the obtained measurements.

World population growth is a subject of great concern, given that the demand for energy consumption has increased in keeping with this growth, but at a much more accelerated rate. This scenario in turn reflects the excessive use of non-renewable sources of energy, which as a result has led to the emission of high levels of pollutants into the atmosphere.

Of these emissions, carbon dioxide (CO_2) is the main gas responsible for global warming, because it is released with the burning of fossil fuels to produce heat and electricity (ANDRADE, 2012). Energy production using non-renewable sources of energy, such as the burning of coal, natural gas and oil, in addition to endangering the environment due to the emission of these polluting gases, will only be possible for a limited time before these sources are exhausted (OMIDO; BARBOZA; JÚNIOR, 2017).

Thus, it is essential to use clean sources of energy in the climatization of buildings, given that this consumes the greatest amount of energy in a building (CRUZ, 2013).

The growth in demand that resulted from population growth led to the first oil crisis in the 1970s, which naturally became a time to think of alternative renewable sources of energy in an effort to rein in energy consumption (MINISTÉRIO DO MEIO AMBIENTE, 2014). Another relevant event was the Brazilian energy crisis of 2001, which demonstrated the imbalance between electricity generation and consumption.

The future is uncertain, but we do know that a scarcity of non-renewable energy sources is getting closer and closer, which makes the search for energy efficiency in our buildings that much more necessary (OMIDO et. al, 2018).

This panorama indicates the need to minimize the consumption of energy from non-renewable sources, and the use of renewable energy sources is a promising solution for sustainability and energy efficiency (OMIDO et. al, 2019).

Within this context, Geothermal Energy presents itself as an important source of clean, renewable energy, which has been shown to be promising for use in the near future, given that it is environmentally sustainable and available year-round independent of the seasons.

Geothermal Energy is energy which is stored in the form of heat below the ground's surface that comes from solar radiation, the flow of groundwater, and thermal energy stored underground (MINISTÉRIO DO MEIO AMBIENTE, 2014).

Surface Geothermal Energy is based on the principle that the ground at shallow depths is thermically stationary, which makes it possible to use it to dissipate heat in the summer and to provide heat in winter, given that during the summer it has a lower temperature than the external environment, and in winter it has a higher temperature than the external environment (WEBB; FREITAS, 2012). Thus, at a depth of approximately 6 meters, the ground presents a constant temperature close to the yearly average temperature in this region, while below 6 meters, the temperature increases 2º to 3º C every 100 meters in depth (RIO, 2011).

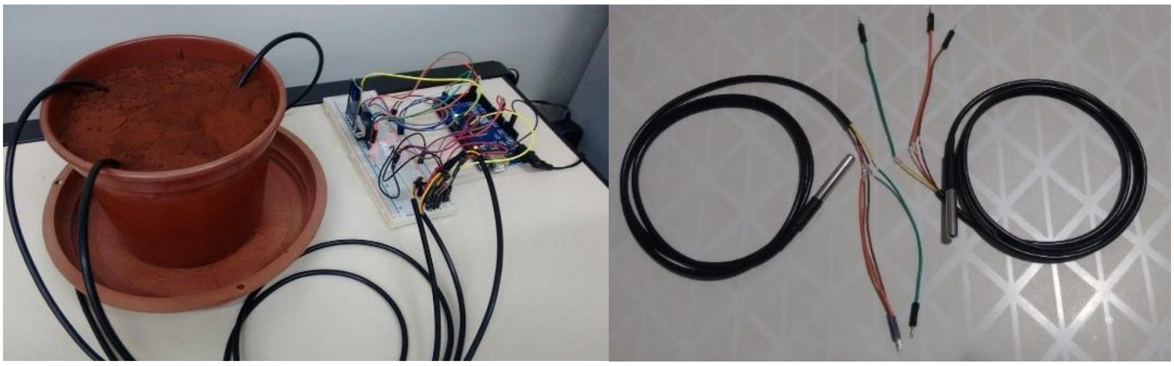
Thus, this energy is available during every season of the year, independent of climatic changes (VOSGUERITCHIAN, 2006), giving it a clean and renewable character. This renewal occurs through the effects of the sun, rain and the internal heat of the Earth's crust (RIO, 2011). Thus, Geothermal Energy can be considered fundamental to fighting the consumption of fossil fuels and reducing the amount of carbon dioxide released into the atmosphere (RABELO, 2002).

The transmission of data and energy has been widely studied over the past few centuries, but it has been performed in a more complex manner and at a high cost. Gradually, in order to simplify these processes and reduce these costs, important types of cables have appeared, namely: twisted pair cables (CAT E5, CAT E6), coaxial cables and fiber-optic cables. Thus, instead of various wires, it has become necessary to use a single cable to transmit data and energy in an efficient and reliable manner (GRIPA, 2015).

In order to establish the best type of cable to make this connection between the temperature sensors installed underground and the data storage module, this work evaluates the efficiency of this data transmission using two types of Ethernet cables: CAT E5 and CAT E6.

2. Methodology

Initially we developed a prototype (Figure 1-a) to test the efficiency of the DS18B20 temperature sensors (Figure 1-b) which we were going to use to measure the underground temperature at various depths. In the prototype, three DS18B20 sensors were buried in a small pot and connected to an Arduino Mega 2560 R3 (a free electronic prototype hardware platform with a single board), to collect and store the temperature data.



(a) (b)

Figure 1 - (a) Prototype Installation, (b) DS18B20 Temperature Sensors.
Source: The Author, (2021).

A protoboard with 830 holes was responsible for the connection between the system elements, which consisted of the Arduino board, a DHT22 temperature and humidity sensor, an RTC DS1307 digital clock module and a Micro SD Card (Figure 2).

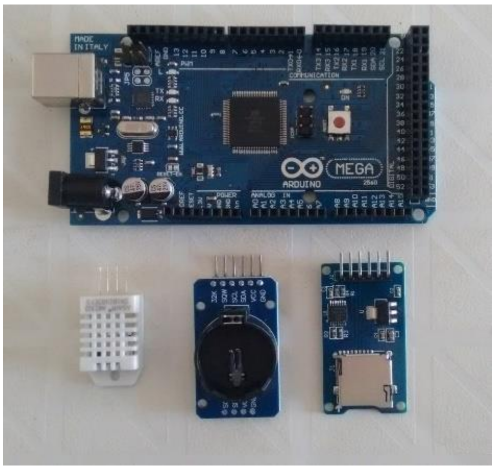


Figure 2 - The Arduino, DHT22, and RTC DS1307 Modules and the Micro SD Card respectively.
Source: The Author, (2021).

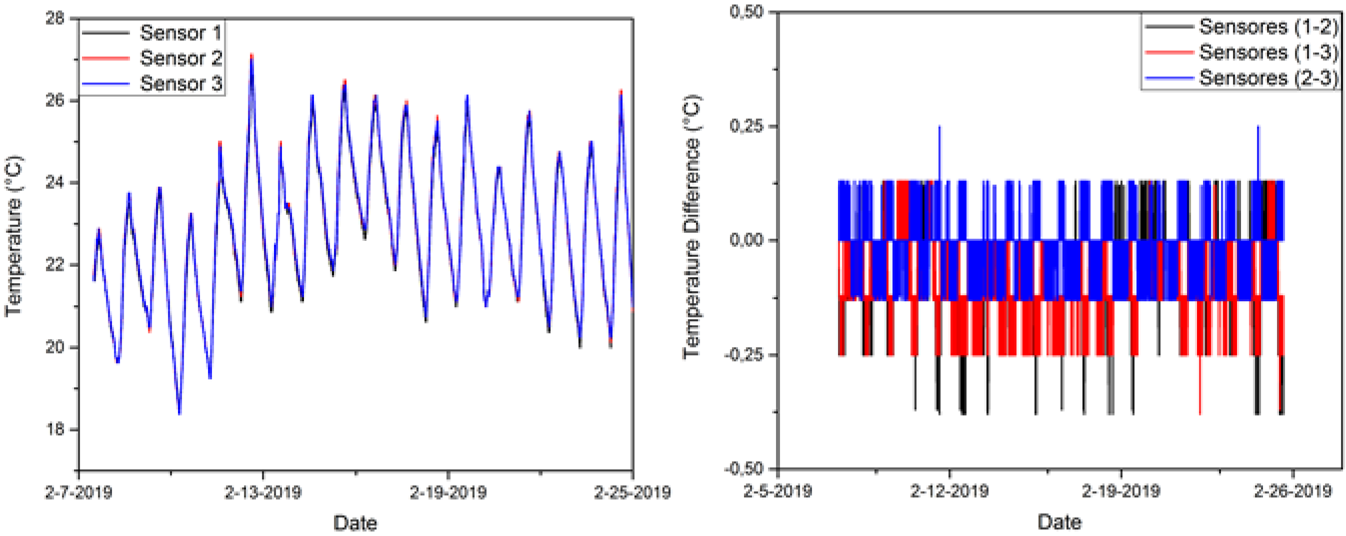
The DHT22 sensor is responsible for collecting the temperature and humidity data where the sensor is installed. The RTC DS1307 digital clock module controls the time intervals between the temperature readings, which in this case were performed every five minutes. The Micro SD Card stores the information necessary for the project: values, date and time of the temperature readings from the DS18B20 sensors and the environment's humidity readings, in the form of a text file (Figure 3).

```
15:33:15 - 08.02.19   Sensor[ 1 ]: 27.38   Sensor[ 2 ]: 27.38   Sensor[ 3 ]: 27.38   Sensor DHT22 -> Temperatura: 28.10 - Umidade: 73.30
15:38:16 - 08.02.19   Sensor[ 1 ]: 27.38   Sensor[ 2 ]: 27.38   Sensor[ 3 ]: 27.38   Sensor DHT22 -> Temperatura: 28.00 - Umidade: 73.80
15:41:16 - 08.02.19   Sensor[ 1 ]: 27.25   Sensor[ 2 ]: 27.25   Sensor[ 3 ]: 27.38   Sensor DHT22 -> Temperatura: 27.70 - Umidade: 73.40
15:46:17 - 08.02.19   Sensor[ 1 ]: 27.25   Sensor[ 2 ]: 27.25   Sensor[ 3 ]: 27.25   Sensor DHT22 -> Temperatura: 27.70 - Umidade: 74.00
15:51:18 - 08.02.19   Sensor[ 1 ]: 27.13   Sensor[ 2 ]: 27.13   Sensor[ 3 ]: 27.25   Sensor DHT22 -> Temperatura: 27.60 - Umidade: 74.20
15:56:20 - 08.02.19   Sensor[ 1 ]: 27.13   Sensor[ 2 ]: 27.13   Sensor[ 3 ]: 27.13   Sensor DHT22 -> Temperatura: 27.50 - Umidade: 73.80
16:01:21 - 08.02.19   Sensor[ 1 ]: 27.13   Sensor[ 2 ]: 27.13   Sensor[ 3 ]: 27.13   Sensor DHT22 -> Temperatura: 27.50 - Umidade: 73.90
16:06:22 - 08.02.19   Sensor[ 1 ]: 27.00   Sensor[ 2 ]: 27.13   Sensor[ 3 ]: 27.13   Sensor DHT22 -> Temperatura: 27.40 - Umidade: 73.30
16:11:24 - 08.02.19   Sensor[ 1 ]: 27.00   Sensor[ 2 ]: 27.00   Sensor[ 3 ]: 27.00   Sensor DHT22 -> Temperatura: 27.40 - Umidade: 74.40
16:16:25 - 08.02.19   Sensor[ 1 ]: 26.88   Sensor[ 2 ]: 26.88   Sensor[ 3 ]: 27.00   Sensor DHT22 -> Temperatura: 27.30 - Umidade: 74.70
16:21:26 - 08.02.19   Sensor[ 1 ]: 26.75   Sensor[ 2 ]: 26.75   Sensor[ 3 ]: 26.88   Sensor DHT22 -> Temperatura: 27.30 - Umidade: 74.60
16:26:28 - 08.02.19   Sensor[ 1 ]: 26.75   Sensor[ 2 ]: 26.75   Sensor[ 3 ]: 26.75   Sensor DHT22 -> Temperatura: 27.20 - Umidade: 75.40
16:31:29 - 08.02.19   Sensor[ 1 ]: 26.75   Sensor[ 2 ]: 26.63   Sensor[ 3 ]: 26.75   Sensor DHT22 -> Temperatura: 27.10 - Umidade: 76.80
16:36:30 - 08.02.19   Sensor[ 1 ]: 26.63   Sensor[ 2 ]: 26.63   Sensor[ 3 ]: 26.63   Sensor DHT22 -> Temperatura: 26.90 - Umidade: 77.60
16:41:32 - 08.02.19   Sensor[ 1 ]: 26.63   Sensor[ 2 ]: 26.50   Sensor[ 3 ]: 26.50   Sensor DHT22 -> Temperatura: 26.90 - Umidade: 79.00
16:46:33 - 08.02.19   Sensor[ 1 ]: 26.50   Sensor[ 2 ]: 26.50   Sensor[ 3 ]: 26.50   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 79.40
16:51:34 - 08.02.19   Sensor[ 1 ]: 26.50   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 79.70
16:56:36 - 08.02.19   Sensor[ 1 ]: 26.50   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.60 - Umidade: 80.10
17:01:37 - 08.02.19   Sensor[ 1 ]: 26.38   Sensor[ 2 ]: 26.25   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.60 - Umidade: 80.30
17:06:38 - 08.02.19   Sensor[ 1 ]: 26.38   Sensor[ 2 ]: 26.25   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.60 - Umidade: 80.20
17:11:40 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.25   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.60 - Umidade: 80.00
17:16:41 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 79.50
17:21:43 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 78.70
17:26:44 - 08.02.19   Sensor[ 1 ]: 26.38   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 78.00
17:31:45 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 77.30
17:36:47 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.90
17:41:48 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.70
17:46:49 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.50
17:51:51 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.40
17:56:52 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.40
18:01:53 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.38   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.30
18:06:55 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.80 - Umidade: 76.30
18:11:56 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 76.10
18:16:57 - 08.02.19   Sensor[ 1 ]: 26.25   Sensor[ 2 ]: 26.38   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 76.00
18:21:59 - 08.02.19   Sensor[ 1 ]: 26.13   Sensor[ 2 ]: 26.25   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 75.90
18:27:00 - 08.02.19   Sensor[ 1 ]: 26.13   Sensor[ 2 ]: 26.25   Sensor[ 3 ]: 26.25   Sensor DHT22 -> Temperatura: 26.70 - Umidade: 75.90
```

Figure 3 - The Data Storage on the Micro SD Card.

Source: The Author, (2021).

The three DS18B20 sensors used in the prototype provided reliable temperature readings, given that all of the sensors measured practically the same ambient temperature, as can be seen in Figure 3. This fact can also be noted in Figure 4-a, in which we can verify the overlapping measurements from the three sensors. The efficiency of the three sensors used becomes even more evident when we plot the temperature differences among the sensors (Figure 4-b), given that the value does not surpass ±0.5°C, which is within the sensitivity limits of these sensors according to the manufacturer.



(a) (b)

Figure 4 - (a) Temperatures Registered by the Three Sensors. (b) Differences between the Readings (Between all of the Two Sensor Pairs).

Source: The Author, (2021).

With the efficiency of the sensors confirmed, we proceeded to the project's next step: establishing the best type of Ethernet cable to measure ground temperatures at various depths, related to the research project "The Evaluation of the Potential Use of Surface Geothermal Energy in the City of Dourados, MS". In the conception of the system, the distance between the sensor and the data storage module can vary by tens of meters in some units depending on the locations used in the experiment. Thus, it was necessary to establish the best type of cable to transmit this data, given that a positive relationship between the sensors and the data storage module should not interfere with the obtained measurements.

The installed system consisted of four DS18B20 sensors, with one of them being connected to 100 meters of CAT E5 cable (Figure 5-a). The sensors collected the ambient temperature data, with three of them transmitting data directly from the Arduino (Figure 5-b) and the fourth transmitting data via a 100-meter-long cable.

(a) (b)

Figure 5 - Installed System. (a) Configuration with 100 meters of CAT E5 Cable, (b) Arduino Platform. Source: The Author, (2021).

We defined a time interval of 15 days for the data collection to verify the reliability of the measurements obtained with the configuration based on Graphic Origin software. At the end of each period, the length of the cable was reduced by 10 meters until the difference between the measurements was close to the sensor's sensitivity limit. We then followed the same procedure with the CAT E6 cable (Figure 6).

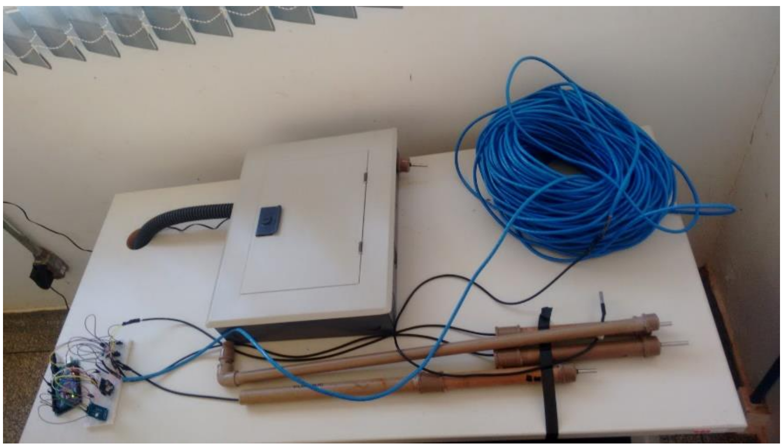


Figure 6 - Installed System with 100 Meters of CAT E6 Cable.
Source: The Author, (2021).

3. Results and discussion

Our analyses began with the CAT E5 Ethernet cable which was 100 meters long. The four sensors were connected to the Arduino and collected the detected ambient temperatures for at least two weeks, without any intervention in the system. The comparison between the values detected by the sensors directly connected to the Arduino and the sensor linked to the 100-meter-long CAT E5 cable made it possible to verify any possible interference by the cable in the sensor's measurements.

Figure 7-a shows the temperatures collected by the four sensors, with the curves of the three sensors connected directly to the Arduino appearing on top of each other, or in other words, they collected the same temperature values. On the other hand, the curve which shows the temperatures collected by the 100-meter-long cable do not agree with the other readings, which demonstrates the interference of the cable's length in the obtained temperature values.

Observing the differences in the readings caused by the connection cable's length, we reduced its length by 10 meters thus connecting the Arduino to a CAT E5 cable 90 meters in length, and new temperatures were measured with the system continuing to function for two more weeks. The temperature measurements during this period are displayed in Figure 7-b.

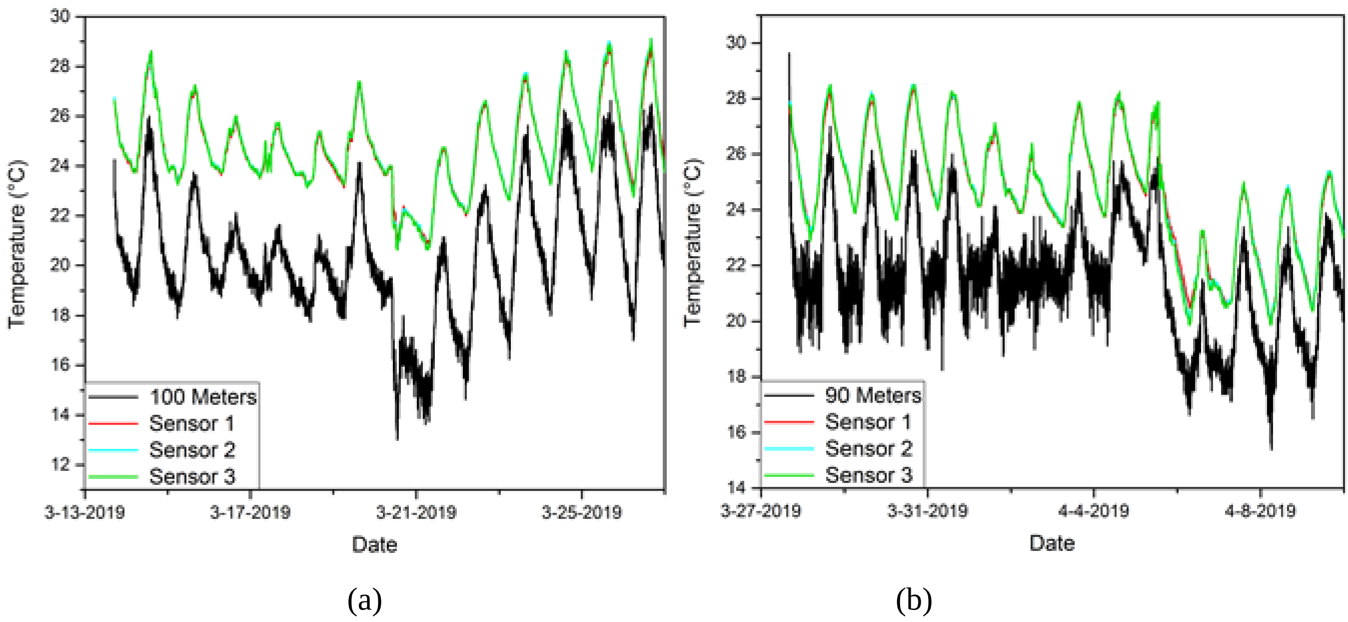
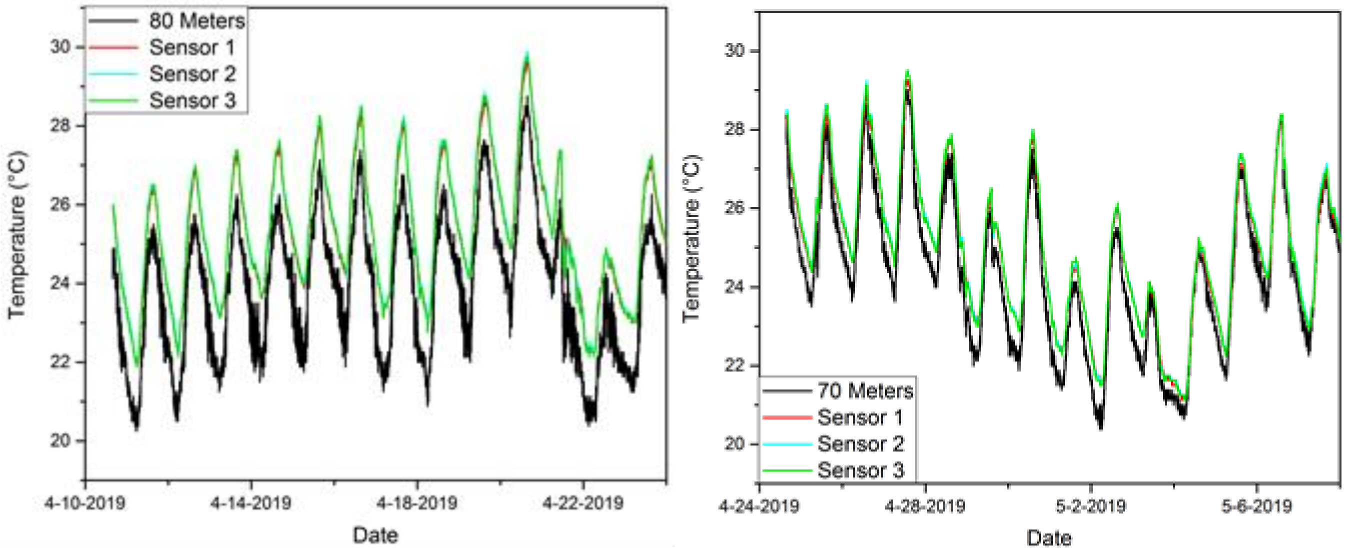


Figure 7 - Behavior of the CAT E5 Cable. (a) Cable with a Length of 100 Meters, (b) Cable with a Length of 90 Meters.

Source: The Author, (2021).

The new results reveal a greater approximation between the sensor with the 90-meter cable and the temperature registered by the other sensors connected directly to the Arduino, but there is still a considerable difference. We thus reduced the cable's length to 80 meters and the temperatures obtained still remained a certain distance from the results of the other sensors (Figure 8-a), which led us to reduce the cable's length even further to 70 meters. Figure 8-b shows that at this length the measurements from the four sensors presented differences close to the sensitivity limits of these units.



(a) (b)

Figure 8 - Behavior of the CAT E5 Cable. (a) Cable with a Length of 80 Meters, (b) Cable with a Length of 70 Meters.

Source: The Author, (2021).

The obtained data makes it possible to affirm that a CAT E5 cable can be used to acquire and transmit temperature data obtained from the DS18B20 sensor as long as the distance between the sensors and the data storage equipment is less than 70 meters, because using longer cables results in interference in the collected values.

The procedure performed with the CAT E5 cable was repeated for the CAT E6 Ethernet cable. During the first two weeks, the temperature measurements were obtained using a 100-meter-long cable connecting one of the sensors to the Arduino. Again, our intent was to verify the behavior of the DS18B20 temperature sensor coupled with a 100-meter-long CAT E6 cable and three more temperature sensors connected directly to the board.

Figure 9 shows the differences between the temperatures provided by the three sensors and the temperature provided by the sensor coupled with the CAT E6 cable. The curves of the sensor readings linked directly to the platform are practically on top of each other, while the curve for the 100-meter-long cable presents data which differs from the data measured by the other sensors, registering values above the sensitivity of the sensor unit, which thus indicates interference in the measurements due to the cable's length.

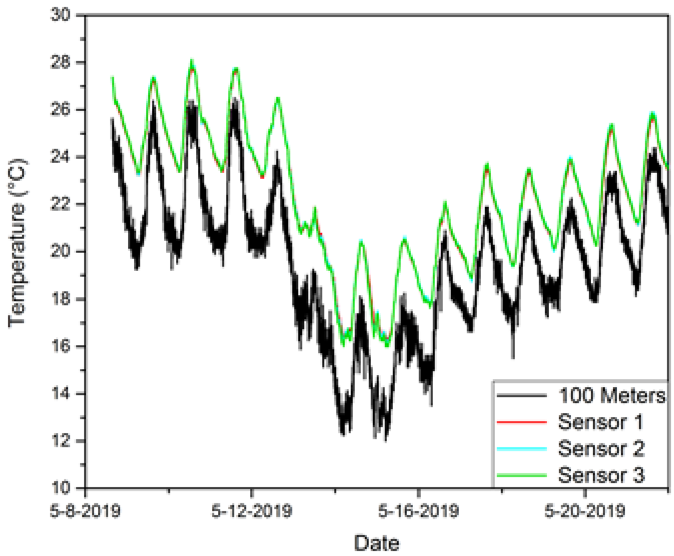
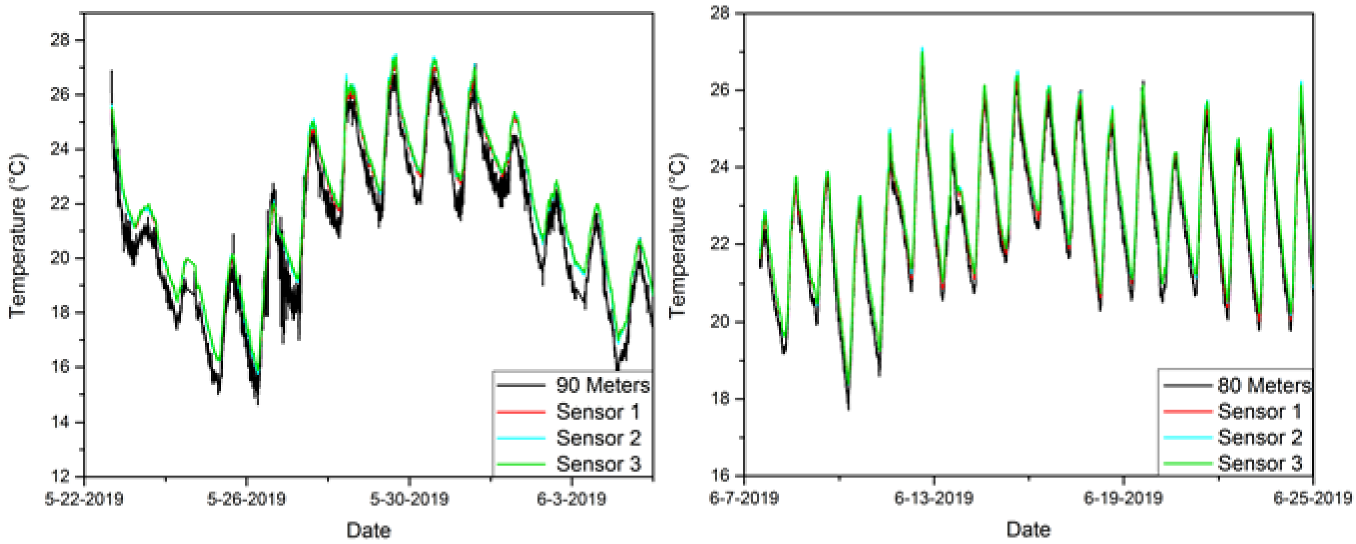


Figure 9 - Behavior of the CAT E6 Cable with a Length of 100 Meters.

Source: The Author, (2021).

Following our methodology, we reduced the length of the CAT E6 cable to 90 meters, leaving the other three sensors intact. This system remained the same for two more weeks while temperature data was collected and stored using the Arduino. The obtained results, presented in Figure 10-a, indicate that a cable length of 90 meters interferes with the measurements, which is just what occurred with the CAT E5 cable.

Then the cable length was reduced to 80 meters, given that the difference between the sensor readings was still above the unit's sensitivity limit. Figure 10-b presents the corresponding curves for the new configuration with the new length, and the data does not present values greater than the sensibility limits of the sensors, which indicates that temperature measurements obtained with CAT E6 cables 80 meters in length are reliable.



(a) (b)

Figure 10 - Behavior of CAT E6 Cable. (a) Cable with a Length of 90 Meters, (b) Cable with a Length of 80 Meters.

Source: The Author, (2021).

Here are the average temperatures measured by the sensors with each configuration, referring to the CAT E5 cable system (Table 1) and the CAT E6 cable system (Table 2):

Table 1 - Average Temperatures Obtained with the CAT E5 Cable System.

Configuration	Average temperatures collected (°C)			
	Sensor 1	Sensor 2	Sensor 3	Sensor coupled with E5 cable
100 meters	24.50	24.50	24.50	20.13
90 meters	24.63	24.75	24.63	21.50
80 meters	25.25	25.25	25.25	24.13
70 meters	25.00	25.00	25.00	24.38

Source: The Author, (2021).

Table 2 - Average Temperatures Obtained with the CAT E6 Cable System.

Configuration	Average temperatures collected (°C)			
	Sensor 1	Sensor 2	Sensor 3	Sensor coupled with E6 cable
100 meters	22.63	22.75	22.75	20.13
90 meters	21.75	21.75	21.75	21.00
80 meters	22.75	22.88	22.88	22.50

Source: The Author, (2021).

We obtained the average temperatures for each sensor for each of the utilized configurations. Examining the data, it may be observed that as the Ethernet cable's length decreased, the sensors coupled with the CAT E5 and CAT E6 cables registered temperatures which came closer and closer to those collected by the sensors which were directly connected with the storage system, thus indicating their interference in the data transmission.

It is valid to stress that the differences of around 0.5°C during the experiment in question are sufficient to guarantee that the DS18B20 sensor coupled with the CAT E5 or CAT E6 cables is giving reliable temperature readings, given that the manufacturer lists the unit's sensitivity as ±0.5°C.

With the reduction in the length of both cables, we may note an increase in the reliability of the readings for the CAT E5 cable as well as the CAT E6 cable, since they are approximately equal to the values measured by the sensors connected directly to the board.

That being so, we can affirm that for the CAT E5 Ethernet cable lengths less than 70 meters guarantee reliable measurements which are close to the real value, and for the CAT E6 Ethernet cable lengths less than 80 meters guarantee reliable measurements which are close to the real value.

4. Conclusion

Our findings show that the CAT E5 cable is a reliable transmitter of data between a sensor and a storage system located less than 70 meters away, while for the CAT E6 cable this distance can be up to 80 meters. The analyses performed by the Graphic Origin software demonstrate the reliability of these cables for the used lengths, given that the difference between the readings obtained from the four utilized sensors were close to the sensitivity limits of the DS18B20 sensors stipulated by the manufacturer, namely ±0.5°C.

This study was essential for the research project “The Evaluation of the Potential to Use Surface Geothermal Energy in the City of Dourados, MS”, given that its results make it possible to achieve greater quality and efficiency in temperature measurements at various depths underground, thus making it possible in fact to determine the real geothermal potential of Dourados.

Therefore, to install systems that evaluate the potential to use Surface Geothermal Energy, CAT E6 Ethernet cables can be used given that they present greater reliability in their temperature measurements and support longer cable distances efficiently, and they can be installed in systems in which the ground perforation is far from the Arduino responsible for reading and storing the data.

5. Acknowledgements

The authors would like to thank the Federal University of Grande Dourados (UFGD), and especially the Graduate Learning and Research Office (PROPP) and the Scientific Initiation Grant Institutional Program for Secondary Education (PIBIC-EM) - CNPq/UFGD for their support in developing this research.

6. References

ANDRADE, Pedro Brogueira. **Eficiência energética em edifícios: oportunidades e desafios.** 2012. Dissertação de Mestrado (Mestrado Integrado em Engenharia Eletrotécnica e de Computadores Major Energia) - Faculdade de Engenharia da Universidade do Porto (FEUP), 2012.

CRUZ, Ricardo Jorge Lucas Vaz. **Utilização da energia térmica do solo para climatização de edifícios.** 2013. Dissertação de Mestrado (Mestrado em Engenharia Civil) - Universidade de Aveiro, Aveiro, 2013.

MINISTÉRIO DO MEIO AMBIENTE. **Guia prático de eficiência energética: reunindo a experiência prática do projeto de etiquetagem: Ministério do Meio Ambiente e Ministério da Cultura.** Brasília: MMA, 2014. 93 p.

GRIPA, Marcelo. **Entenda como é feita a transmissão de dados e energia por um único cabo.** 2015. Disponível: https://olhardigital.com.br/solucoes_corporativas/noticia/entenda-como-e-feita-a-transmissao-de-dados-e-energia-por-um-unico-cabo/49927. Acesso em: 05 Jul. 2019.

OMIDO, Agleison Ramos; BARBOZA, Christian Souza; JÚNIOR, Orlando Moreira. **Energia Geotérmica: Uma Aliada Na Busca Da Eficiência Energética.** In: VIII Congresso Brasileiro de Gestão

Ambiental - CONGEA. 2017. Campo Grande, MS. Anais (on-line). Disponível em: http://www.ibeas.org.br/congresso/Trabalhos2017/X-005.pdf. Acesso em: 01 Jul. 2019.

OMIDO, Agleison Ramos; BARBOZA, Christian Souza; SANCHES, Édipo Sabião; SANCHES, Ítalo Sabião. **Estudos Iniciais Para Utilização da Energia Geotérmica na Climatização de Edifícios.** In: VIIII Congresso Brasileiro de Gestão Ambiental - CONGEA. 2018. São José dos Campos, SP. Anais (on-line). Disponível em: http://www.ibeas.org.br/congresso/Trabalhos2018/X-007.pdf. Acesso em: 01 Jul. 2019.

OMIDO, Agleison Ramos; BARBOZA, Christian Souza; SANCHES, Édipo Sabião; SANCHES, Ítalo Sabião. **Uso da Energia Geotérmica na Construção Civil: Um Panorama da Sua Aplicação em Edificações Brasileiras.** In: III Encuentro Latinoamericano y Europeo de Edificaciones y Comunidades Sostenibles - EURO ELECS. 2019. Santa Fé - Paraná, Argentina. Libro de Actas (on-line). Disponível em: https://drive.google.com/file/d/1rV4VH7ifSQwS12JYlnNklvhV7OZspwVQ/view?fbclid=IwA1Yog_yH0V1TX13xaUD_gJy4n8bWV-dy9tzhQjIH7XS__tBZcDUNWAvv8U. Acesso em: 25 Jun. 2019.

ORIGIN LAB: Graphig e Analysis. Disponível em: https://www.originlab.com. Acesso em: 14 Jun. 2019.

RABELO, Jorge L. et al. **Aproveitamento da Energia Geotérmica do Sistema Aquífero Guarani - Estudo de Caso.** In: XII Congresso Brasileiro de Águas Subterrâneas. Revista Águas Subterrâneas. 2002. Disponível em: https://aguassubterraneas.abas.org/asubterraneas/article/viewFile/22057/14417. Acesso em: 05 Jul. 2019.

RIO, José Pedro Teixeira Espinheira. **Geotermia e implicações nas tecnologias da construção: estudo de casos.** 2011. Dissertação de Mestrado (Mestrado Integrado em Engenharia Civil - Departamento de Engenharia Civil) - Faculdade de Engenharia da Universidade do Porto, Porto, 2011.

VOSGUERITCHIAN, Andrea Bazarian. **A abordagem dos sistemas de avaliação de sustentabilidade da arquitetura nos quesitos ambientais de energia, materiais e água, e suas associações às inovações tecnológicas.** 2006. Dissertação de Mestrado (Mestrado em Tecnologia da Arquitetura – FAUUSP) - Universidade de São Paulo, São Paulo, 2006.

WEBB, Peter Bourne; FREITAS, Tereza M. Bodas. **Considerações geotécnicas no dimensionamento e exploração de fundações com aproveitamento geotérmico.** In: XIII Congresso Nacional de Geotecnia. 2012. Lisboa, Portugal. Disponível em: https://www.researchgate.net/publication/303340243_Consideracoes_geotecnicas_no_dimensionamento_e_exploracao_de_fundacoes_com_aproveitamento_geotermico_The_geotechnics_of_ground_source_energy_systems. Acesso em: 05 Jul. 2019.