Journal of Applied Engineering and Technological Science
Vol 4(1) 2022 : 405-414

DEVELOPMENT OF MONITORING TOWER USING GYROSCOPE SENSOR BASED ON ESP32 MICROCONTROLLER

Al Imran[1*], Muliaty Yantahin[2], Abd Muis Mappalotteng[3], Muh Arham[4]
Electrical Engineering Department, Universitas Negeri Makassar, Indonesia[1234]
alimran@unm.ac.id

Received : 15 November 2022, Revised: 06 December 2022, Accepted : 06 December 2022
**Corresponding Author*

ABSTRACT
This research is a research and development research that aims to find out the results of the development of tower slope monitoring tools using the ESP32 Microcontroller-Based Sensor Gyroscope and find out the test results of the tool tower tilt monitoring using the ESP32 Microcontroller-Based Gyroscope Sensor. The development model used in this study is a prototyping model with stages of collecting needs, building prototypes, evaluating prototypes, coding, testing, evaluation, uses of system. The data used are interviews, questionnaires, observations and measurements. The data were analyzed using descriptive statistical analysis techniques. Based on the results of this study is a prototype of a tower slope monitoring tool was produced that was used to monitor the slope of the tower remotely through the telegram application. From the test results of the tower tilt monitoring tool using the MPU6050 gyroscope sensor based on the ESP32 microcontroller, it was found that the average time it takes to receive notifications if they occur the slope is 3.21 seconds. The results of the pecan test n there is a difference in the angle read at a height of 1 meter is 0.3 degrees, a height of 2 meters 0.2 degrees, a height of 3 meters 0.22 degrees, and a height of 4 meters 0.18 degrees. The results of the functional suitability test show that the tool functions as designed. The usability characteristic of the tower slope monitoring tool gets an average score of being included in the excellent category.

Keywords: *Monitoring, Tower, Gyroscope Sensor, Microcontroller*

1. Introduction

The development of the times has affected technological advances, which currently appear various objects and electrical devices (Rymarczyk, 2020). One of the applications of technological developments in the modernization era that is becoming a current trend is remote monitoring technology. Various aspects try to take advantage of rapidly developing technology as much as possible in its use in everyday life, from simple problems to problems that are far more complex. Remote monitoring technology really needs its role to facilitate a job with monitoring that can be done remotely and can facilitate its use, one of which is monitoring the slope of the tower (Feng et al., 2021; Zhang et al., 2018).

The main parts of the transmission are towers, insulation, conductors, and grounding wires. The reliability of the transmission system is very dependent on the condition of the equipment which is highly correlated to the resistance of the equipment to disturbances. Steel construction is the most widely used high voltage overhead line tower construction. This construction is one of the main parts that also often experience interference. The communication system in Indonesia is channeled through communication devices that can transmit signals. This tool is supported by a steel pole called a telecommunication tower. Telecommunication tower is a telecommunication building structure that uses a combination of steel frames as its construction material (Seran, 2017; Malviya & Jamle, 2019; Tsavdaridis et al., 2020).

The tower is a major component of the transmission and telecommunication lines so that the collapse of the tower greatly affects the power transmission and telecommunication system (Idris, et al., 2021). There are cases of tower collapses in several regions in Indonesia which impede the distribution of electricity and telecommunication energy to be one of the problems that need to be addressed.

The case of tower collapse is not only influenced by the age of the construction, but also can be influenced by various things, such as natural conditions (Abdelwahed, 2019). Strong winds and heavy rain around the tower resulted in changes in conditions and soil structure that could affect the slope level of a tower, in this case the High Voltage Air Line (SUTT) tower. The collapse of the tower can disrupt the distribution of electric power and can cause casualties. However, this risk can be reduced if the slope of the tower can be known earlier, so that corrective action can be taken quickly for towers that have the potential to collapse. Therefore, it is necessary to monitor the slope of the tower in real time utilizing the Internet of Things to facilitate the tower monitoring process. Syufrijal S. (Syufrijal, 2018) has previously developed a prototype for an automatic distance and slope measurement system using an Internet of Things (IoT)-based microcontroller, but has not yet been used to detect tower tilt.

Based on the problems above, it is necessary to develop a tower tilt monitoring tool using a gyroscope sensor with an ESP32 microcontroller with remote control that can be accessed via telegram (Setiawan et al., 2020). This was done because there were several cases of tower collapse due to the changing conditions of the tower construction and it was too late to get handling from the officers so that with the tower tilt monitoring tool it can automatically detect the condition of the tower by sending a signal to the officer. In addition, of course, it will cause various impacts that can affect the distribution of electricity.

2. Research Methods

This research is research and development or Research and Development (R&D). R&D is research that aims to develop new products or improve existing products and validate those products. The product referred to in this study is a microcontroller-based tower tilt monitoring prototype via telegram. A prototyping model was used in the development used in this study. Model Prototyping is a simple modeling process that allows the user to have a basic picture of the system and to do initial testing (Pressman, 2012). This development model was chosen because it is most suitable for developing product prototypes. This development model is very flexible because changes can occur at each stage of development, or if there is a stage that is not perfect, the developer can return to the next stage. The prototyping model consists of 7 stages, namely collecting requirements for building prototypes, evaluating prototypes, coding systems, testing systems, evaluating systems, and using systems.

Development Procedure

The procedure or development stages in this study based on the prototyping *model* are shown in the following figure.

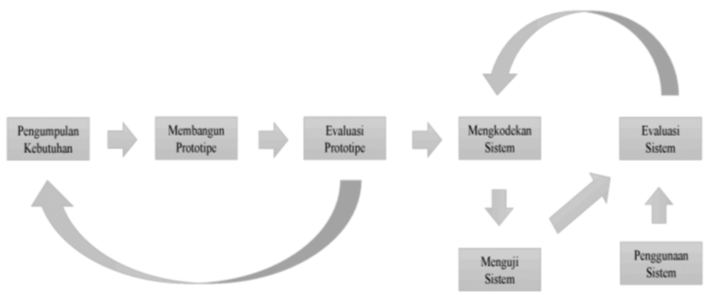

Fig. 1. Development Procedure

1. Collection of Needs

   In order to carry out system development, an initial needs assessment and analysis of ideas or ideas to build or develop the system is required. Analysis is used to find out what components are in the running system. It can be in the form of hardware, software, network, and system users as the end user level of the system. The next step is to collect the information needed by end users which includes the costs and benefits of the system being built or developed.
2. Build a Prototype

   Build prototypes by designing tools and systems. This stage aims to produce a system design that will be developed. The design is based on a needs analysis that has been completed previously.
3. Prototype Evaluation

This evaluation is carried out by the researcher concerned whether the prototype that has been built is appropriate. If it is appropriate then step 4 will be taken. If not the prototype is revised by repeating steps 1,2 and 3.

4. Coding the System

   In the prototyping stage, what has been agreed is translated into a programming language. The programming language used is the C programming language, using the Arduino IDE and to process commands using the Telegram BOT.

5. System Testing

   At this stage the researcher tested the prototype components, tested the slope at height, tested the distance, and tested ISO 25010 (Made et al., 2021) for functional suitability and usability

6. System Evaluation

   The validator evaluates whether the prototype of the tower tilt monitoring tool that has been developed is as expected. If not, then the researcher will repeat steps 4 and 5. But if it is appropriate, then step 7 can be done.

7. System Usage

   The prototype of the tower slope monitoring tool that has been tested and accepted by the validator is ready to be used.

In this study, the data analysis technique used was descriptive statistical analysis technique. Descriptive statistical analysis is a data analysis technique used to analyze data by describing or describing data that has been collected soberly without any intention of making generalizations from the research results. The analysis was carried out based on existing characteristics and sub-characteristics. Data analysis techniques in this study are divided into several analyzes as follows:

Analysis of testing the accuracy of the slope at a height using an artificial pole which serves to determine the comparison of the tool to detect the slope if it is at a different altitude. A distance testing analysis was carried out to see whether all commands could be sent properly based on the distance of the surrounding complex area, up to the furthest distance of around 1300 km. Functional suitability testing is carried out as follows:

Functional suitability testing uses test cases that are assessed on the Guttman scale. The test results are calculated using the formula from the Feature Completeness matrix. The formula for calculating Feature Completeness is (Dako & Ridwan., 2021):

$$X = \frac{I}{P}$$

Information :
I = Number of features that have been successfully implemented
P = Number of features designed

The result of the Feature Completeness calculation, namely the value of X which is close to 1, indicates that almost all of the designed features have been successfully implemented. So that the Functional Suitability characteristics are declared acceptable if X approaches ($0 \leq X \leq 1$).

Testing of Usability Characteristics was carried out using a questionnaire which was distributed to 30 respondents to assess the prototype of the tower tilt monitoring tool being developed. Each statement/question in the questionnaire has 5 answer choices with an assessment based on a Likert scale (Sugiyono., 2013). After obtaining the average value of the questionnaire data collected, it will be concluded that the quality level of the tool is based on the category in Table 1.

Table 1 - Usability Characteristics Assessment Category

Category	Interval
Very Good	4,2 - 5,0
Good	3,4 - 4,1
Pretty Good	2,6 – 3,3
Not Good	1,8 – 2,5
Very Less Good	1,0 – 1,7

3. Results And Discussion

A. Results

1. Results of Needs Analysis

This needs analysis is to find out what components are in the running system, which can be in the form of hardware, software, network, and system users as the end user level of the system. The needs regarding the tower slope monitoring tool prototype developed are:

a. Tower tilt monitoring tool with the command feature to send tower slope data on a telegram.
b. Tower tilt monitoring tool with command feature sends tower tilt warning on telegram.
c. Tower tilt monitoring tool with a sound warning feature on the buzzer.
d. Tower tilt monitoring tool with a feature to read slope data on the LCD.

2. Build a Prototype

Based on the results of the needs analysis, the prototype will be built at this stage to produce the following design:

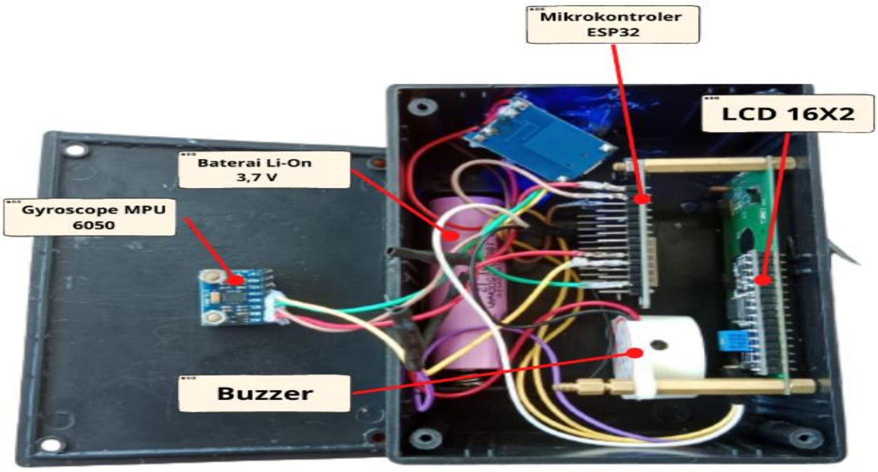

Fig. 2. Prototype Series

The electronic circuit design includes the electrical circuit design *consisting* of ESP32 microcontroller components, gyroscope sensors, buzzers, LCDs, batteries and solar panels.

3. Prototype Evaluation

This evaluation is carried out to find out to what extent the results of the prototype design for the tower tilt monitoring tool that have been developed are in accordance with the needs or not. Based on the results of the evaluation of the prototype design of the tower slope monitoring tool, the design was declared in accordance with the needs to be developed (Keshari et al., 2021).

4. Coding System

At this stage, in accordance with the agreement regarding the design translated into the C programming language using the Arduino Integrated Development Environment (IDE) software used by the author is version 1.8.19. The programming contained in the Arduino IDE software has 3 main parts, namely structure, values, and functions. Before coding the tower tilt monitoring tool, first create a bot father token on Telegram. Making telegram bots is important for connecting telegram messages that will be used to carry out commands on the Arduino IDE according to system requirements. The bot on Telegram will display tower tilt data and tower tilt warnings remotely.

5. Testing

a. Testing the ESP32 microcontroller connection

Testing the connectivity of the ESP32 microcontroller to WiFi is carried out using a smartphone hotspot so that the network connection is faster for distance testing. For remote testing, the smartphone hotspot WiFi is placed around the ESP32, if the ESP32 is connected, it will appear on the Arduino IDE serial monitor. The test on ESP32 can be seen in the image below.

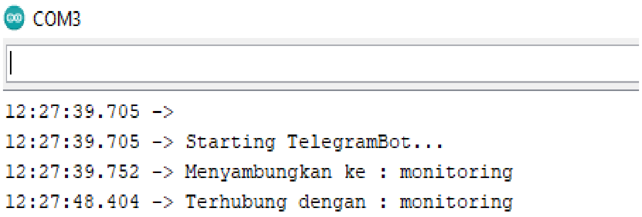

Fig. 3. ESP32 Microcontroller Testing

Based on the results of testing the connectivity of the ESP32 microcontroller, it can be concluded that the ESP32 microcontroller can function properly.

b. *Gyroscope* Sensor Testing

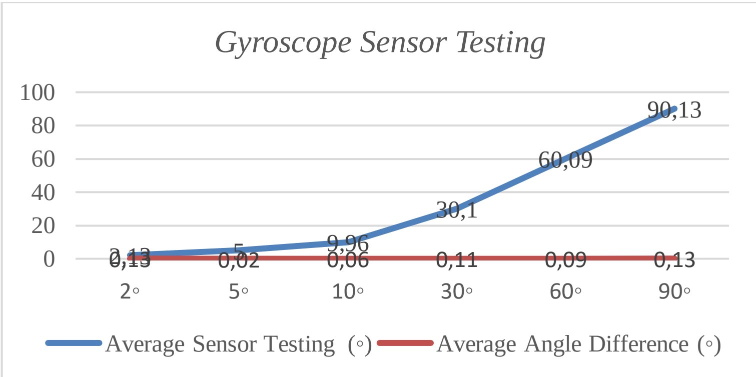

Fig. 4. Gyroscope Sensor Testing

Based on the data above, it can be concluded that the Gyroscope sensor is able to detect tilt and there are no problems when configuring data .

c. Solar Panel Testing

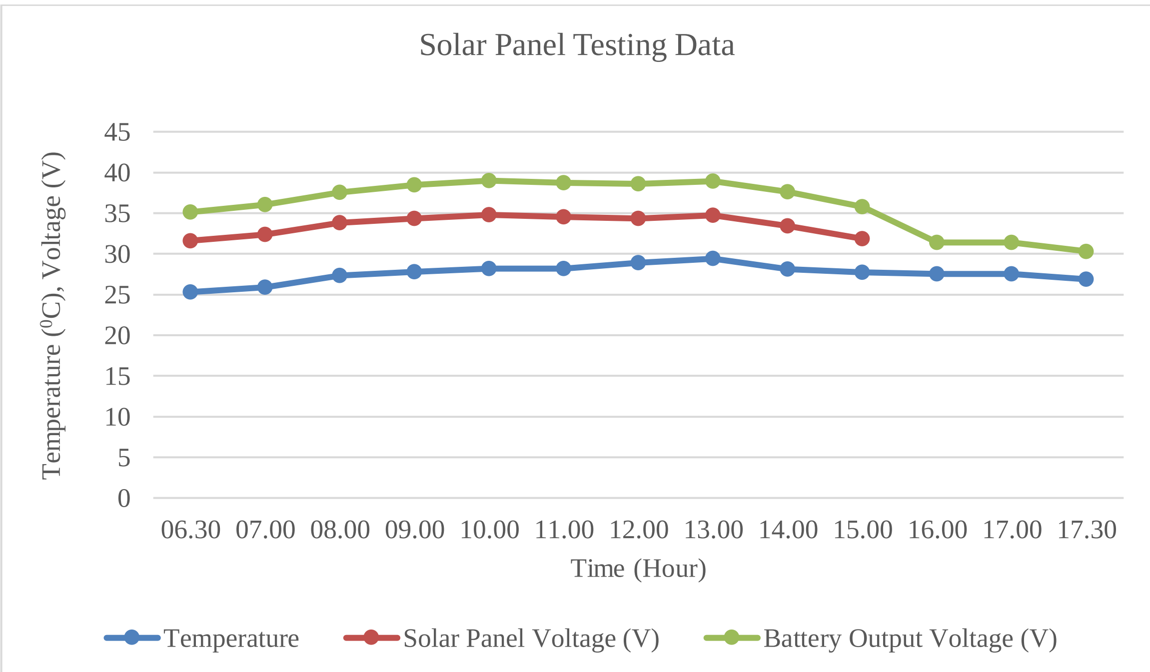

Fig. 5. Solar Panel Testing

Based on the data above, it can be explained that the higher the temperature, the better the performance of solar panels, but the temperature is excessive. But continue the performance of solar panels. The most effective time for solar panels to have good performance is at 09.00-14.00.

d. Slope Test Results at Height

1) Testing the slope at a height of 1 meter

Table 2 - Meter Height Slope Data

No	Tower Tilt Angle (degrees)	Tilt Angle on The Tool Display (degrees)	Telegram Status	Buzzer Status	difference (degrees)
1	2	2,2	Alert	Beeps	0,2
2	5	5,3	Alert	Beeps	0,3
3	10	10,2	Alert	Beeps	0,2
4	20	20,5	Alert	Beeps	0,5
5	30	30,3	Alert	Beeps	0,3
		Average			0,3

2) Testing the slope at a height of 2 meters

Table 3 - Meter Height Slope Data

No	Tower Tilt Angle (degrees)	Tilt Angle on The Tool Display (degrees)	Telegram Status	Buzzer Status	difference (degrees)
1	2	2,2	Alert	Beeps	0,2
2	5	5,2	Alert	Beeps	0,2
3	10	10,1	Alert	Beeps	0,1
4	20	20,1	Alert	Beeps	0,1
5	30	30,4	Alert	Beeps	0,4
		Average			0,2

3) Testing the slope at a height of 3 meters

Table 4 - Meter Height Slope Data

No	Tower Tilt Angle (degrees)	Tilt Angle on The Tool Display (degrees)	Telegram Status	Buzzer Status	difference (degrees)
1	2	2,2	Alert	Beeps	0,2
2	5	5,2	Alert	Beeps	0,2
3	10	10,2	Alert	Beeps	0,2
4	20	20,1	Alert	Beeps	0,1
5	30	30,4	Alert	Beeps	0,4
		Average			0,22

4) Testing the slope at a height of 4 meters

Table 5 - Meters Height Slope Data

No	Tower Tilt Angle (degrees)	Tilt Angle on The Tool Display (degrees)	Telegram Status	Buzzer Status	difference (degrees)
1	2	2,1	Alert	Beeps	0,1
2	5	5,1	Alert	Beeps	0,1
3	10	10,2	Alert	Beeps	0,2
4	20	20,2	Alert	Beeps	0,2
5	30	30,3	Alert	Beeps	0,3
		Average			0,18

a. Test Results Based on Distance

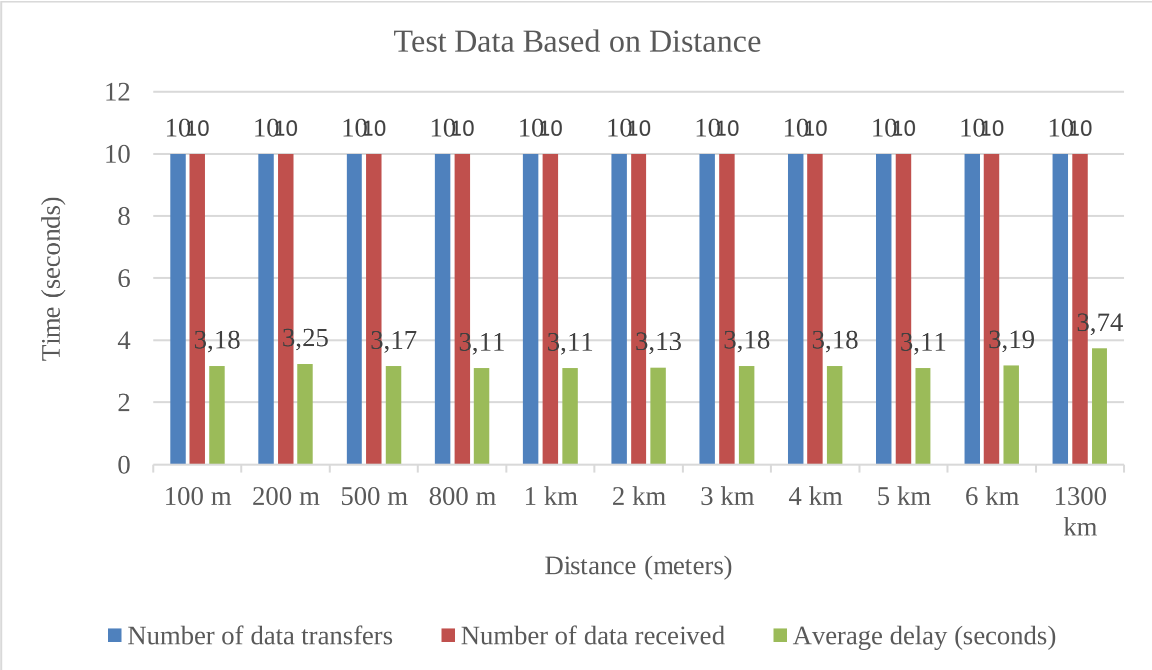

Fig. 6. Testing Based on Distance

Based on the test results for the shortest distance of 100 m and the farthest distance of 1300 km, it is known that all command messages and warning notifications can be monitored properly. The average time required for sending data is 3.21 seconds.

b. Test Results ISO 25010 Characteristics of Functional Suitability.

Table 6 - Functional Suitability Testing

Validator	I	P	X=I/P
Dr. Haripuddin, S.T., M.T.	7	7	1
Zulhajji, S.T., M.T.	7	7	1

Based on the calculation of the Feature Completeness, the value of X is 1 which indicates that all the command and sensor detection features designed previously have been successfully implemented, so it can be concluded that the Feature Completeness of the prototype tower tilt monitoring tool is accepted.

c. ISO 25010 Test Results for Usability Characteristics

Table 7 - *Usability* Testing

Interval	Category	Respondent	Percentage (%)
4,2 - 5,0	Very Good	20	80%
3,4 - 4,1	Good	5	20%
2,6 - 3,3	Pretty Good	0	0
1,8 - 2,5	Not Good	0	0
1,0 - 1,7	Very Less Good	0	0
Total		25	100%

Based on the results of testing the usability characteristics of the tower tilt monitoring tool prototype, the average value was 4.34, so the test was included in the very good category.

6. Evaluation

The prototype evaluation stage in this study was carried out to improve the application based on comments and suggestions that had been submitted in the functional suitability and usability testing. After the application is adjusted to the wishes of the user and the media expert validator, the next step can be carried out. The results of the final calculation of the usability test obtained an average value of 4.34 and the functional suitability test obtained a value of 1. If the value is converted based on a Likert scale assessment, the final value is included in the very good category. These results indicate that the tool developed is appropriate and can be continued to the next stage.

7. Use of Prototypes

A prototype tower tilt monitoring tool using a Gyroscope sensor based on an ESP32 microcontroller via telegram is used as a reference for a remote tower tilt monitoring system. It is hoped that with the trial use of the tower tilt monitoring tool prototype, officers can remotely monitor or monitor the tower slope in real time.

B. Discussion

A tower tilt monitoring tool using a Gyroscope sensor based on an ESP32 microcontroller via telegram is a prototype to determine the tower tilt status and provide a warning if a slope occurs above the tower tilt tolerance value. This tower monitoring tool is monitored via telegram messages on smartphones, laptops, or computer devices that have been installed with the Telegram application to make it easier for tower officers to monitor the slope of the tower remotely, anytime, and anywhere. a tower tilt monitoring tool using a Gyroscope sensor based on an ESP32 microcontroller was developed in the C programming language through the Arduino Integrated Development Environment (IDE) and telegram data processing using the telegram BOT. This aims to facilitate the development of tower slope monitoring tools via telegram messages (Muslih et al., 2018).

The development of the tower slope monitoring tool is carried out by fulfilling user criteria, so that the prototype development process can be accounted for and tested (Zhang et al., 2021). This tool was developed using a prototype development model, which has seven stages, namely needs analysis, building a prototype, evaluating a prototype, coding the system, testing the system, evaluating the system, and using the system. The development of the monitoring tool begins with carrying out the needs analysis stage to identify the need for the tower slope monitoring tool to be developed. The method used to analyze the data is interviews with users. Based on the results of the interviews, a prototype can be built. This stage resulted in the design of a tower tilt monitoring tool including the design of the electronics and the design on the pole. The next stage is the evaluation of the prototype, which aims to find out whether the design results of the tower tilt monitoring tool are in accordance with the needs or not. Based on the evaluation results, the prototype design of the tower tilt monitoring tool is declared to be in accordance with the needs of home users regarding the tower tilt monitoring tool to be developed.

The next stage is coding the tower slope monitoring tool system, in the agreed prototype stage translated into programming language. The programming language used is C language, using the Arduino IDE and to manage commands using the Telegram BOT (Kurniawan, 2020). The system coding stage produces an ESP32 microcontroller-based tower slope monitoring tool that can be controlled via telegram. The tower slope monitoring tool that has been developed will be tested using slope accuracy measurements at height, distance measurements, and ISO 25010 standards. testing 2 characteristics of ISO/IEC 25010 namely functional suitability and usability characteristics.

Based on the results of system expert validation, testing, and user responses to the trial of the tower tilt monitoring tool, the quality of the developed tower tilt monitoring tool prototype was declared valid and included in the very good category. From the monitoring test based on the distance, all command messages and warning notifications can be monitored properly. The average time required for sending data is 3.21 seconds with the closest distance being 100 meters and the farthest distance being 1300 kilometers. The results of testing the slope of the tool with different heights on the pole with the lowest height of 1 meter and the highest of 4 meters. The average difference in slope angle read at a height of 1 meter is 0.3 degrees, a height of 2 meters is 0.2 degrees, a height of 3 meters is 0.22 degrees, and a height of 4 meters is 0.18 degrees. The difference in slope angle between the tool and the pole angle can also be caused by measurement errors made manually.

Testing the functional suitability characteristics of the tower tilt monitoring tool, using the feature completeness formula to get an X value of 1, the tower tilt monitoring tool is stated to be very good. The usability characteristics of the tower tilt monitoring tool get an average value of 4.34 which is included in the very good category. Based on the research results of the tower tilt monitoring tool using a gyroscope sensor based on the ESP32 microcontroller via telegram after being validated and tested on measurement characteristics and ISO 25010 standards, it can be concluded that all the characteristics tested have met the quality standards for the development of a tower tilt monitoring tool. The results of this test can represent that the developed system is actually functioning, so it can be stated that this tower tilt monitoring tool is valid, effective and efficient to implement.

Conclusion

Based on the research data that has been carried out and the discussion that has been put forward, the following conclusions can be drawn. the danger if there is a tilt is sent to the user's telegram and the buzzer sounds at the tower location. Monitoring tower tilt is effective for monitoring tower tilt in real time from a distance, and increasing the efficiency of tower supervision. The tower tilt monitoring tool using a gyroscope sensor based on an ESP32 microcontroller is declared to have fulfilled all aspects of the test based on tilt testing, distance testing and ISO 25010 Standards. Test results based on the distance of all command messages and warning notifications can be monitored properly. The average time required for sending data is 3.21 seconds with the closest distance being 100 meters and the farthest distance being 1300 kilometers. Testing the inclination of the tool with different heights on the pole with the lowest height of 1 meter and the highest of 4 meters. The average difference in slope angle read at a height of 1 meter is 0.3 degrees, a height of 2 meters is 0.2 degrees, a height of 3 meters is 0.22 degrees, and a height of 4 meters is 0.18 degrees. The results of testing the tower tilt monitoring tool on the functional suitability characteristics were declared acceptable, and usability was in the very good category.

Refrences

Abdelwahed, B. (2019). A review on building progressive collapse, survey and discussion. *Case Studies in Construction Materials, 11*, e00264.

Dako, R. D., & Ridwan, W. (2021). Pengujian karakteristik Functional Suitability dan Performance Efficiency tesadaptif. net. *Jambura Journal of Electrical and Electronics Engineering*, *3*(2), 66-71.

Feng, H., Wang, K., Yue, Y., & Hu, P. (2021, May). Analysis of influence of coal mining on stability of tower on Loess Slope and deformation monitoring. In *IOP Conference Series: Earth and Environmental Science* (Vol. 772, No. 1, p. 012098). IOP Publishing.

Idris, A. R., Usman, U., & Suyono, W. (2021). Analisis Pengaruh Pemasangan Counterpoise pada Tower Transmisi Saluran Udara Tegangan Tinggi 70 kV Line Mandai-Pangkep. *Seminar Nasional Teknik Elektro Dan Informatika (SNTEI), September*, 104–109.

Keshari, S. R., Chandramohan, V. P., & Das, P. (2021). A 3D numerical study to evaluate optimum collector inclination angle of Manzanares solar updraft tower power plant. *Solar Energy, 226*, 455-467.

Kurniawan, A. D. (2020). Design and Implementation of Home Security Using Telegram Botfather. *FIDELITY: Jurnal Teknik Elektro, 2*(1), 11-15.

Made Dwi Mulyawan, dkk. (2021). Kualitas Sistem Informasi Berdasarkan ISO/IEC 25010: Literature Review. *Majalah Ilmiah Teknologi Elektro*, Vol. 20, No.1, Januari – Juni 2021, 15-27.

Malviya, S., & Jamle, S. (2019). Determination of Optimum Location of Rooftop Telecommunication Tower over Multistory Building under Seismic Loading. *International Journal of Advanced Engineering Research and Science.*

Muslih, M., Supardi, D., Multipi, E., Nyaman, Y. M., & Rismawan, A. (2018, September). Developing smart workspace based IOT with artificial intelligence using telegram chatbot. In *2018 International Conference on Computing, Engineering, and Design (ICCED)* (pp. 230-234). IEEE.

Pressman, R. S. (2012). *Rekayasa perangkat lunak Pendekatan Praktisi*. Yogyakarta: Penerbit Andi.

Rymarczyk, J. (2020). Technologies, opportunities and challenges of the industrial revolution 4.0: theoretical considerations. *Entrepreneurial business and economics review*, *8*(1), 185-198.

Seran, M. (2017). Analisa Struktur Tower BTS Berdasarkan Hasil Re-Verticality Menggunakan Staad Pro. *Eureka: Jurnal penelitian teknik sipil dan teknik kimia*, *1*(1).

Setiawan, A. W., Muhammad, F., & Hidayat, A. (2020, September). Development of an web-based wearable gait recognition system using gyroscope and accelerometer sensors. In *2020 International Seminar on Application for Technology of Information and Communication (iSemantic)* (pp. 370-373). IEEE.

Sugiyono, D. (2013). Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D.

Syufrijal, S. (2018). Prototipe Sistem Pengukuran Jarak dan Kemiringan Otomatis Menggunakan Mikrokontroler Berbasis Internet of Things (IoT). *Autocracy: Jurnal Otomasi, Kendali, dan Aplikasi Industri*, *5*(02), 68-72.

Tsavdaridis, K. D., Nicolaou, A., Mistry, A. D., & Efthymiou, E. (2020, October). Topology optimisation of lattice telecommunication tower and performance-based design considering wind and ice loads. In *Structures* (Vol. 27, pp. 2379-2399). Elsevier.

Zhang, X., Zhang, Y., Zhang, L., Qiu, G., & Wei, D. (2018). Power transmission tower monitoring with hydrostatic leveling system: measurement refinement and performance evaluation. *Journal of Sensors*, 2018.

Zhang, X., Manogaran, G., & Muthu, B. (2021). IoT enabled integrated system for green energy into smart cities. *Sustainable Energy Technologies and Assessments, 46*, 101208.