Design and Development of Digital Gentanik System Based on PLC Outseal

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Abstract. The operation of the railway system on Java is divided into 9 Operational Areas (abbreviated as DAOP). One of the DAOP on Java is DAOP 8, which is based in Surabaya. DAOP 8 covers the area from Surabaya Station to Mojokerto Station. There are two different railway signaling systems and the boundary lies between Mojokerto Station and Tarik Station. At the Tarik Station, the signaling system still uses an analog communication system and one of the subsystems is a gentanik system. Meanwhile, at Mojokerto Station, the gentanik system uses a factory-made digital gentanik system. The analog gentanik system requires a lot of manpower. In addition, due to the age of the equipment, it causes a lot of problems and spare parts are difficult to obtain. Because many things cause disrupted activity, an alternative digital gentanik is proposed. This digital gentanik system is made by utilizing the internet network as a support for long-distance communication. MQTT Explorer is used as the command exchange center and PLC outseal as the control center of the digital gentanik system that has been created. The result in this research is a tool that can replace the existing analog gentanik system because the sound produced by the digital gentanik has an average sound level that is closer to the standard published by the Directorate General of Land Transportation than the analog gentanik system, which is 104.8 dB. In addition, the digital gentanik is made more efficient and effective in operating the system.

Keywords: Digital Gentanik · MQTT Explorer · PLC Outseal

1 Introduction

Railway operations in Java are divided into 9 regions or operation areas [1, 2], in Indonesian, they are called Daerah Operasi (abbreviated as DAOP). One of the train operation areas is DAOP 8, which is centered in Surabaya. DAOP 8 covers railway operations for both stations in Surabaya itself and stations in several nearby cities that are still included in its operational area, which are stations located between Surabaya and Mojokerto Station for the north line, and between Surabaya and Blitar Station for the south line [3]. Mojokerto Station is a type C station with large classes [4] and passengers crossing the Wonokromo - Mojokerto line stop at this station. This line has a fairly heavy rail traffic frequency because it is a link to the south line. On the Wonokromo – Mojokerto line, it

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serves various classes of executive, business, economy, and local trains. Based on data from the Central Statistics Agency, in 2017, the number of passengers getting on and off Mojokerto Station reached 572,845 people [5]. On the east side of Mojokerto Station, there is Tarik Station. Although Mojokerto Station and Tarik Station are next to each other, Tarik Station and Mojokerto Station have different systems, both in terms of routes and operational facilities used.

As stated in the regulation of the minister of transportation of Indonesia number PM 22 of 2021 [6], which is a revision of the regulation of the minister of transportation number PM 66 of 2013 [7], railway infrastructure is railroad tracks, train stations, and train operating facilities so that trains can be operated. Meanwhile, according to PM 45 of 2018, operational facilities are all facilities needed for the train to be operated [8]. Operational facilities are divided into three, namely signaling, telecommunications, and electricity [8]. In the regulation of the minister of transportation number 44 of 2018, railway signaling equipment is a train operating facility that has the function of giving instructions or signals in the form of color, light, or other information with a certain meaning [9]. One of the railway signaling equipment that has an important function is the gentanik system [9]. In the gentanik system, there are two subsystem components, namely inductor and bell [9]. The gentanik system is used to warn signalman at the next station and level crossing man that the train is about to depart. Basically, the gentanik system have a fusnction as a safety device for train travel when the train passes through level crossings. Thus, there is an uninterrupted communication link between one station and another.

The warning is given in the form of a bell code. Based on railway regulations in Indonesia [9, 10], the bell code that is sounded is called the bell code 55A1, 55A2, 55B, 55C, 55D, and 56. Certain bell code will be sent by the the inductor to the bell. To convey a certain bell code, the bell is rung in a certain way. At Mojokerto Station to Tarik Station, the gentanik system used is the analog gentanik. It is one of the Dutch heritage equipment that is still used today. Meanwhile, from Mojokerto Station to Sumobito Station, the gentanik system uses the digital gentanik. Because the analog gentanik at Mojokerto Station to Tarik Station is old, many problems occur and require special maintenance. In addition, the operation of old equipment is also less efficient because it requires a lot of manpower. In terms of maintenance, spare parts are also no longer available. Some problems that often arise are the key of the gentanik bell is difficult to close so the bell continues to ring until the pendulum is at the lower end, the voltage does not reach the bell because the coil in the induction motor is weak, as happens in the transmission system, where the cable is worn out, so the cable is often break up, etc. Based on the problems that have been described, an alternative gentanik in the form of digital gentanik is proposed.

2 Research Methodology

The research process is shown as in Fig. 1. The problems identified were taken from DAOP 8, precisely on the Mojokerto Station and Tarik Station lines. The operation of the analog gentanik which still uses manpower and the maintenance of the analog gentanik which is quite difficult because spare parts are no longer available are the problems that have been identified in this study.

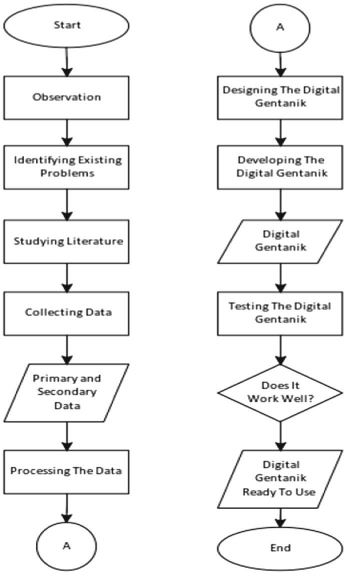

Fig. 1. Flowchart of research

(a) (b)

Fig. 2. Analog gentanik system: (a) The inductor, (b) The bell

Primary data were collected by conducting interviews with gentanik maintenance officers and taking several analog gentanik photos. Primary data that has been collected includes data on the components of the analog gentanik system, how the gentanik system works, and the distance between Mojokerto Station and Tarik Station. From the interviews, it is known that the analog gentanik system consists of two equipments, namely the inductor and the bell Fig. 2.

The inductor is an electric voltage generator that is used to send signals to the bell. The lever to the right of the inductor is rotated to create a magnetic field that produces an electric voltage. At the time of rotating it, the officer must also press the button in front of him as a command to send a certain bell code to the bell. The analog gentanik is a warning bell to inform that the train will depart from the nearest station. The bell will sound if the inductor at the station sends a signal in the form of an electric voltage then the key or relay on the bell is pulled by the magnetic field generated. Figure 3(a) is an activity carried out by officers to raise the pendulum of gentanik because the pendulum

(a)

(b)

Fig. 3. (a) The process of raising the pendulum of gentanik, (b) Tebeng

is already at the bottom. The pendulum moves downwards because the bell bat is pulled to make a sound. This is routinely done after 50 times the bell sounds. In addition to being calculated based on the number of working gentanik, the position of the pendulum that has been below can also be seen based on the outer 'tebeng'. If the tebeng is facing up, it means that the pendulum is already at the bottom.

Second, the primary data in this research collected through interviews is data about how the analog gentanik system works. To be able to design alternative gentanik, it is necessary to know the working principle of the current analog gentanik system. The existing analog gentanik works by using a lot of manpower, where the officer has to turn the induction motor to generate an electric voltage and then press the button on the inductor. One sound series requires 10–15 times to rotate the induction motor. So, for example, if the officer wants to ring the bell code 55A2, the officer must rotate the induction motor approximately 20–30 times [9]. When the induction motor is turned and the button is pressed, the sound will be sent to the level crossing officer and the nearest station in the direction of delivery via a copper cable that runs along the railroad track. When the voltage has been sent to the bell, the bell lock will release the pendulum and the bell will be pulled so that it can make a sound. At that time, the pendulum will automatically continue to descend until it locks again. One time, the pendulum will be in the lowest position and cannot pull the bell, as a result, the bell cannot sound and the pendulum must be raised again by turning the drive until the pendulum is in the top position.

The last primary data is the distance between Tarik Station and the 41 Mojokerto level crossing. The distance between the Tarik Station and the 41 Mojokerto level crossing is obtained through the Google Maps. The results are the distance between the Tarik Station and the 41 Mojokerto level crossing is 7 km, if the selected route follows the rail road, and 6.77 km, if the route is measured by drawing a straight line between the two places.

Secondary data were obtained from literature studies, previous research, and related agencies. Secondary data obtained from the literature study are data on railway regulations and data on certain electronic components needed in designing and building digital gentanik. Secondary data related to railway regulations that support this research are, first, the Regulation of the Minister of Transportation of the Republic of Indonesia

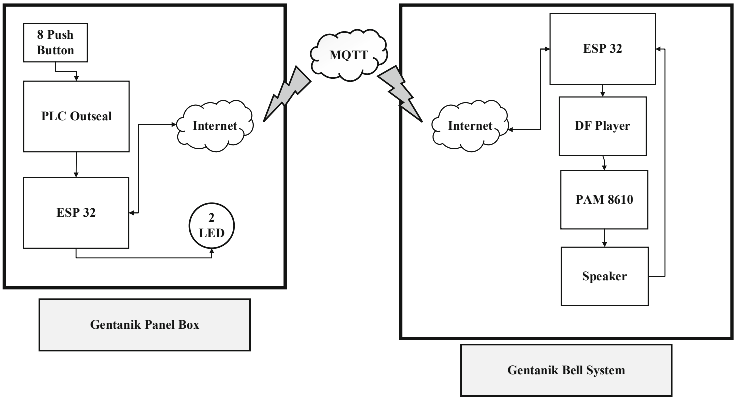

Fig. 4. Communication block diagram between the gentanik inductor panel and digital gentanik

Number PM. 44 of 2018 concerning the Technical Requirements of the Railway Signaling System [9]. The regulation explains in detail what requirements must be met in the installation of gentanik and a series of sounds that have been determined as a bell code. Second, the author uses data from the Decree of the Director General of Land Transportation No. 770 of 2005 [11], which explains the quality standard for the sound of bells at crossing gates, which is 115 dB. Third, the author also uses official regulation 3 (PD 3) published by PT Kereta Api Indonesia and PM 44 of 2018, which discusses the bell code 55–56. Based on the two regulations [9, 10], each set of bells has 5 chimes. The bell code 55A1 means that the train is heading downstream, signaled by 1 set of bells. The bell code 55A2 means that the train is heading towards the village or upstream, signaled by 2 sets of bells. Then, the bell code 55B is the cancellation bell code, signaled with 4 sets of bells. Furthermore, the bell code 55C is a signaled hazard bell code with 8 sets of bells. The last is the bell code 56 which is an experimental bell code which consists of 5 sets of bells Fig. 4.

After collecting data, the next research method is data processing. Data processing is done by determining the important points of the collected data. These important points become a reference in designing the system and testing the performance of the created digital gentanik system. The design of the digital gentanik system made in this research is the design of the gentanik panel box to replace the gentanik inductor and the use of speaker that can produce audio recordings of the bell to replace the analog bell. In using the gentanik panel box, the officer does not need to turn the induction motor as was previously done on the gentanik inductor, but the officer only needs to press one of the buttons provided on the panel. On the front panel box, there is an explanation of the bell code that makes it easier for officers to choose the push button. When the button is pressed, PLC outseal will read the command and process it. The command will continue to ESP 32, where ESP32 is used as a bridge for data communication over the internet network. Then the ESP32 connects to the internet with the help of WiFi. For 2-way communication the author uses the MQTT broker as a medium for exchanging orders [12]. The quality of MQTT Broker as server has been compared and evaluated in studies [13]. Because the quality is quite good, the MQTT server was chosen in this study [13].

After the command is entered into MQTT, the ESP32 on gentanik digital will take the command with the help of portable WiFi. After the command is obtained, the DF player will play the audio recording of the gentanik bell according to the command received. To play sound, the DF player is assisted by PAM 8610, where PAM 8610 is an amplifier that produces sound through speakers [14]. If the sound can be produced, the voltage signal will be sent back to the ESP32. ESP32 will forward the voltage signal to the ESP32 which is in the gentanik panel box as a feedback. When the gentanik panel box gets feedback from the digital gentanik, the ESP 32 in the gentanik panel box lights up the LED as a feedback indicator, which indicates whether the sound can be played and whether the quality of sounds is good or not. Communication is done using the internet network. So, it does not require a physical connection between the two devices. There is no need for extra cables [15] to follow train lines to level crossings and nearby stations. Then, speakers that are placed on a level crossing as a substitute for analog gentanik do not require special treatment, such as in analog gentanik which must raise the pendulum every time the gentanik has sounded 50 times.

3 Results and Discussion

3.1 Function Test of Digital Gentanik

Figure 5 is a created digital gentanik. On the front panel box, there are seven buttons and two indicator lights. The meaning of each abbreviation above the button is explained in Table 1. Meanwhile, two indicator lights, from left to right, indicate the power status (on or off) and the gentanik system status (standby or working). Digital gentanik performance is tested in two ways. The first test is the function test. The second test is the sound loud test of the gentanik bell.

The first function test aims to find out whether both the gentanik panel box and the gentanik bell can work properly. To find out these results, each button on the front panel box is tested whether it is able to send the appropriate signal to the gentanik bell or not so that the gentanik produces the expected bell sound. The second function test aims to test the feedback provided by the bell system to the gentanik panel box system. The second function test is said to be successful if the indicator light on the panel box changes color from red to green when receiving feedback from the gentanik bell system and the indicator light turns red again if the gentanik digital system is in standby.

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Fig. 5. Digital gentanik panel box

Table 1. Meaning of the bell code

Acronym	Stand for (in Indonesian)	Meaning of The Bell Code
TSBR	Tombol Semboyan Berita	Code to inform that the train will be departing
TR	Tombol Reset	Code to command gentanik system to return to standby state
TSBH	Tombol Semboyan Bahaya	Code to inform that travel condition is in a dangerous situation and urgent action is needed
TC	Tombol Percobaan	Code to inform that the gentanik is in trial or testing sound and function
TSB	Tombol Semboyan Pembatalan	Code to inform that the message that has been sent cannot be continued as an order or canceled

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Figure 6 is an example of sending a 55A1 bell code or a bell code that informs that the train is heading upstream, so that the expected sound of the bell recording is the sound of 1 set of bells. To send the bell code 55A1, the TSBR button is pressed simultaneously with the left directional button. When the bell code is received by the gentanik bell system, the gentanik bell system will play the sound of 1 series of bells and the indicator light on the panel box turns green due to feedback sent by the gentanik bell system. When the audio bell has finished playing, the officer needs to press the reset button together with the direction button to return the system status to standby.

3.2 Sound Loud Test of Digital Gentanik

Based on the Decree of the Directorate General of Land Transportation Number 770 of 2005 concerning technical guidelines for level crossing between roads and railways, the requirement for the sound power of the gentanik bell must be 115 dB from a distance of 1 m. Thus, the authors conducted testing based on existing guidelines to obtain test results.

The Table 2 shows the results of measuring the sound of the gentanik bell in the field and the measurement of the digital gentanik bell. From 46 measurements, the gentanik bell in the field has an average sound strength of 87.5 dB. While the digital gentanik bell has a sound strength of 104.8 dB. This means that the bell designed and built in this research is close to the standard in the existing regulations. Then, the sound of the chime has not reached the standard limit because the volume of the sound player, namely the DF player, is not optimally adjusted by considering the loudspeaker reliability.

(a)

(b)

(c)

(d)

Fig. 6. Function test of digital gentanik: (a) Standby system, (b) Sending a 55A1 bell code to the gentanik bell system, (c) System is working, (d) Pressing reset button to return status

Table 2. Sound meter level test data

No.	Bell Testing at Tarik Station	Gentanik Digital Testing	No.	Bell Testing at Tarik Station	Gentanik Digital Testing	No.	Bell Testing at Tarik Station	Gentanik Digital Testing
1	91.6	106	17	91.9	101.1	33	88.8	102.2
2	87.7	107.2	18	88.9	105.4	34	89.5	107
3	91.2	106.1	19	88.2	105.2	35	84.6	105.7
4	91.2	104.9	20	84.1	104.1	36	86.5	104.9
5	83.5	106.4	21	91.5	105.2	37	88.4	105.4
6	89.3	99.2	22	88.5	106.2	38	82.1	107.5
7	87.3	105.5	23	84.2	107.7	39	88.9	103.4
8	80.7	104.9	24	86.4	106.5	40	85.2	106.9
9	85.1	106.1	25	89.8	104.1	41	87.2	104.8
10	89.5	104.3	26	81.7	105.5	42	85.5	101.9
11	91.4	103.6	27	86.3	106.3	43	86.5	103.7
12	82.7	104.3	28	83.4	106.3	44	87.9	107.7
13	88.4	101.8	29	86.8	105.7	45	90.2	107.5
14	89.9	103.8	30	89.2	103.5	46	91.2	106.8
15	89.9	102.4	31	86.2	104.3			
16	91.1	101.7	32	87	103.8			

4 Conclusion

From the research that has been done, several conclusions obtained are:

1. The design of the digital gentanik consists of a gentanik panel box and a gentanik bell system. PLC Outseal is used as controller in this device, ESP32 as interface between equipment and internet network of portable model, and DFPlayer for storing and playing gentanic bell recordings.
2. The working principle of the digital gentanik system is to press the button on the gentanic box panel at the station to send a bell code signal to the gentanic bell system at level crossings. The gentanic bell system at the level crossing will select and play the bell audio recording according to the received bell code input. At the same time, the gentanik bell system also sends feedback to the gentanik panel box system to notify that the gentanik bell system is executing the given command.
3. From the results of the test for the sound level of the digital gentanic bell, the sound of the digital gentanic sound is close to the sound level standard stipulated in the Decree of the Director General of the Republic of Indonesia No. 770 Year 2005, which has an average value of 104.8 dB.

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