# Comparative Analysis of The Performance of CCTV Camera Transmission Media Using UTP Cable and Optical Fiber

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***Abstract***— **CCTV is an important part of maintaining security in the State Polytechnic of Malang, especially the Telecommunications Lab. In the installation of CCTV, the transmission media plays an important role. In this context, UTP cable and optical fiber are commonly used. The purpose of this research is to compare CCTV camera transmission using UTP cable and optical fiber using quantitative research methods with 3 kinds of tests. QoS parameter testing with TIPHON version standardization, network speed testing, and video quality testing using SSIM and PSNR parameters. Optical fiber delay testing gets an average value of 4.28976 ms and UTP cable of 4.44135 ms. The average jitter of optical fiber is 0.0017 ms and UTP cable is 0.2066 ms. In addition, the packet loss value shows that optical fiber has an average percentage of 8% while UTP cable is 11%. Speed testing shows that optical fiber has an upload speed of 987.52 Mbps and a download of 990.34 Mbps, UTP cable shows an upload of 978.98 Mbps and a download of 978.8 Mbps. While video quality testing shows UTP average PSNR value 30.480694 dB and SSIM 0.9158403 dB, and optical fiber with PSNR value 28.443975 dB, SSIM 0.8897703 dB.**

***Keywords— CCTV, EPON, Fiber Optic, UTP Cable, Quality of Service (QoS).***

## I. INTRODUCTION

Have become an important part of maintaining security and surveillance in various environments [1], This is no exception in the State Polytechnic of Malang campus environment, especially the AI Building Telecommunications Lab. There are 8 CCTV cameras in the POLINEMA AI Building which are connected to the POLINEMA PUSKOM intranet network. Where each camera produces a continuous stream of data which is then transmitted via the intranet network to the Network Video Recorder (NVR) device) [2]. Of the 8 CCTV cameras, 4 of them are decentralized IP cameras so that they can record directly to storage media such as SD cards, while the rest are connected to the NVR.

The design of a CCTV camera system using UTP cable transmission media has been carried out by Achmad Hizam. The research was tested to prove the use of UTP cable as an alternative to the use of optical fiber in RT CCTV networks. Testing is focused on measuring latency at different distances, as well as the amount of packet loss resulting from the use of different transmission media [3]. The comparison between UTP cable and optical fiber has also been previously discussed by Eka Setya Wijaya in his research. The test focused on the comparison of latency and throughput measurements [4].

In the installation of CCTV, video transmission from the camera to the central monitoring or receiving device must be carried out efficiently and guaranteed quality. Determination of CCTV quality can be done by testing QOS parameters, namely packet loss, delay and jitter. QoS parameter testing has been carried out previously by Ahmad Basri, in this study using TIPHON standardization, where according to Telecommunications and Internet Protocol Harmonization Over Network (TIPHON), good QoS has packet loss which is categorized as Very Good (0 to 3%), delay which can be categorized as Good (150 to 300 ms) and jitter which is categorized as Good (between 0 - 75ms) [5][6]. According to Arif Rahmatulloh in his journal explained that the high speed and low signal attenuation in optical fiber can contribute to the delivery of high-quality and real-time video data. [7]. In addition, the transmission media used as a link between the router and CCTV also plays an important role in determining the performance of CCTV video transmission. In this context, UTP cable and Optical fiber are two types of transmission media that are commonly used.

UTP cables, which are also often used in computer networks, offer more affordable costs and easier installation. However, the transmission speed and transmission distance of UTP cables can be limited. The types of UTP cables commonly used for CCTV installations are CAT5e and CAT6e UTP cables, where according to the Cisco team all cables in this category have the same maximum cable length of 100 meters. [8]. This shows the weakness of UTP cables when the distance required is getting farther. On the other hand, optical fiber offers very high transmission speeds and long transmission distances of up to 200 km, this is explained by Ummi Hafidhotunnisa in her research [9]. However, according to Maslan M. Patty in his research, the cost of fiber optic installation and equipment is

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still expensive, and maintenance and toughness will be a consideration. [10]. This research aims to conduct a comparative analysis between CCTV camera transmission using UTP cable and optical fiber.

Optical fiber is also a transmission medium that can be used in CCTV. Yamato explained in his research that fiber optic networks are widely used because of the basic properties of Optical Fiber which are resistant to electromagnetic interference, safe from atmospheric influences, have light weight, and have a wide bandwidth as a transmission medium [11].

Meanwhile, according to Lararenjana Edelweis, UTP cable is a type of cable that is often used in the computer and telecommunications industries to provide connectivity between devices [12]. UTP cable types can be distinguished by function and category. UTP cables are commonly used in CCTV installations as an alternative to coaxial cables. The main advantage of using UTP cable in CCTV installation is its affordable price and ease of installation. For CCTV installations, the recommended UTP cable is CAT5e, which is the most commonly used type of UTP cable and has sufficient bandwidth for most IP security cameras available on the market, this is in accordance with what Chen Claire explained in her research. [13]. The maximum recommended distance for UTP cables in CCTV installations depends on the application and type of cable used.

## II. METHOD

### *A. System Methodology*

The design of the process will be explained as shown in Figure 1.

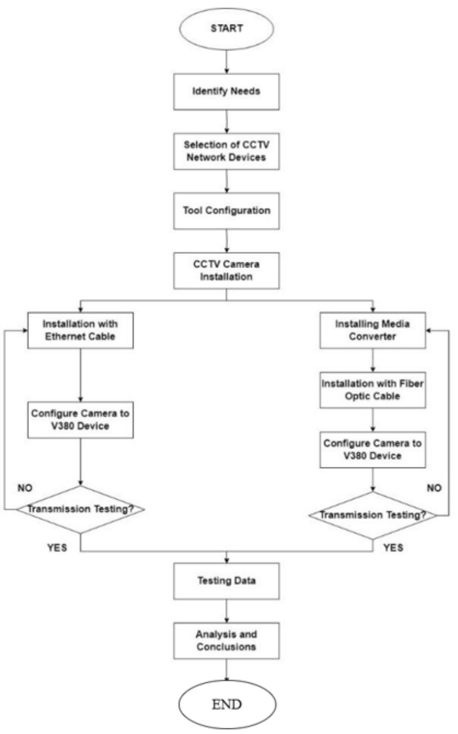


Figure 1. System flowchart

In the research system flow chart, the first step is the identification of needs, which includes determining the monitoring area, surveillance objectives, and required features. The next step is the selection of CCTV network devices, including switches, media converters, and other devices. The configuration process involves setting up the OLT and ONT to enable internet access and CCTV networks. Installation using UTP cable involves connecting the CCTV camera to the ONT via Cat-5e UTP cable, followed by configuration of the camera to the V380 device and transmission testing to ensure CCTV connection and function. For installation using optical fiber, a media converter is installed to convert the optical signal, and a fiber optic cable is used to connect the CCTV camera to the network device. Transmission testing involves checking the video quality, jitter, delay, and reception speed of the CCTV. The test results are then comprehensively analyzed to compare the transmission quality using fiber optic cables.

### *B. System Description*

The research method used is quantitative research method. Where in Figure 2 is shown the CCTV network design system diagram using fiber optic installation.

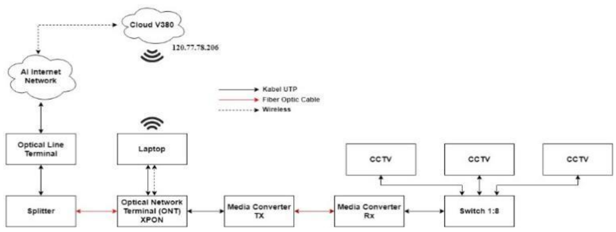


Figure 2. CCTV installation diagram using optical fiber

Figure 2 shows the CCTV network design using optical fiber. The cable line starts from the AI building's internet network and connects to the Optical Line Terminal (OLT), the center of the network. The OLT is connected to the ONT through a splitter that splits the optical signal. The ONT connects the network with CCTV cameras through devices such as Media converter TX, Media converter Rx, and Switch 1:8. ONT plays a role in converting optical signals into electronic signals that can be received by CCTV devices. Media converter Tx and Rx function as adjusters between fiber optic cables and CCTV devices, while Switch 1:8 multiplies the output ports of Media converter Rx according to the number of CCTVs. Users can connect to CCTV cameras wirelessly or with cables to access and monitor video footage.

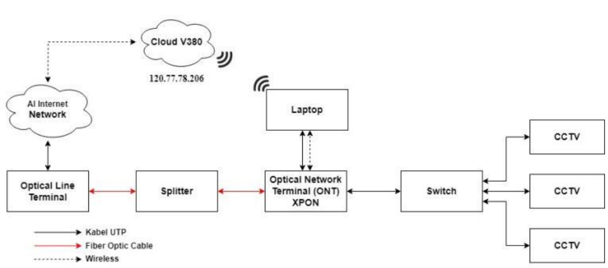


Figure 3. CCTV installation diagram using UTP cable

Meanwhile, Figure 3 shows the installation of the UTP CCTV network connected to the network. The network starts from the AI Building internet which is connected to the Optical Line Terminal (OLT), the central device in the network. Three CCTV cameras are connected to the ONT through Switch 1:8. The OLT is connected to the ONT through a splitter to split the optical signal. The ONT converts the fiber optic signal into a format that can be received by the CCTV devices. Users can connect wirelessly or by cable to the network to monitor the CCTV. This configuration provides the infrastructure to wirelessly monitor CCTV cameras and connect them to the data transmission network.

Some of the tools and terms used include:

1. Optical line Terminal

The OLT is the starting point in a passive optical network that is connected to the core switch via a UTP cable [14]. In this research, HA7302CST OLT is used to build a new EPON network in POLINEMA telecommunication lab. This network will later be used for the installation of CCTV devices.

2. Optical Network Terminal

The ONT is responsible for converting optical signals sent through optical fibers into electrical signals which are then forwarded to individual users. Optical Network Terminal (ONT) type HG6821M is used in this research. Its function is to transmit data in the form of voice, packet data (internet) and multimedia [15].

3. Media converter

In this study, a single Gigabit GS 03 media converter is used, which is a transceiver that converts electrical signals used in UTP cables into light waves used in fiber optic cables [16].

4. MSU VQMT

MSU VQMT (Moscow State University Video Quality Measurement Tool) is used to measure the quality of CCTV footage using different transmission media. MSU VQMT is a video quality measurement program. It allows objective comparison between video codecs and analysis of video processing filters [17].

5. PSNR

PSNR (Peak Signal-to-Noise Ratio) is the ratio between the maximum value of the measured bit depth (8bit images have a maximum value of 255) to the amount of noise that affects the signal. Common value range: 20-40. The larger the value, the better the image processing result or the closer to the original image.

6. SSIM

Structural Similarity Index (SSIM), is a highly used method for image quality assessment based on human perception SSIM is built based on three main factors, namely luminance, contrast, and structure. These three factors replace the summation method used as the basis for PSNR calculation [18]. Common value range: 0-1. The larger the value, the better the video quality.

## III. RESULTS AND DISCUSSION

### *A. Testing Packet Loss, Jitter and Delay on CCTV Camera Transmission Using UTP Cable*

Testing and calculating Jitter, delay, and Packet Loss using proxy aims to measure variations in the arrival delay of data packets as well as evaluate the length of time required by data packets to reach their destination via UTP cable. This test circuit is shown in Figure 4.

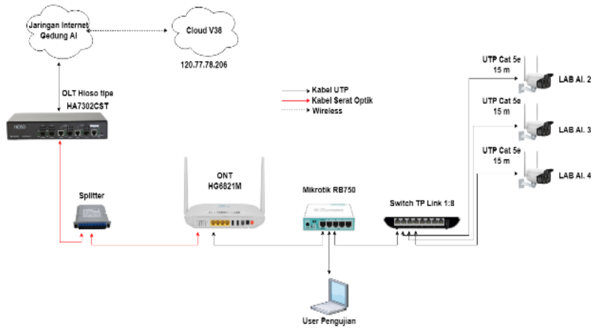


Figure 4. UTP cable QoS testing

The first step is to connect the laptop to the ONT using a LAN cable and check the IP address obtained. Next, the Wireshark software starts the data capture process for 2 minutes, and is repeated 5 times. The data was then filtered using the IP address obtained from the ONT, using the filter "ip.dst == 192.168.x.x". After that, the total packets and time span were recorded to perform the delay calculation. To calculate jitter, the file was exported into CSV. The test results using UTP cable are shown in Table 1.

TABLE I
JITTER TESTING RESULTS USING UTP CABLE

| No. | Testing | Packets | Delay Variation (s) | Jitter (ms) |
|---|---|---|---|---|
| 1. | 1 | 1662 | 0,00188 | 0,001134 |
| 2. | 2 | 1264 | 0,01185 | 0,009375 |
| 3. | 3 | 1379 | 0,00023 | 0,000164 |
| 4. | 4 | 1431 | 0,0332 | 0,023202 |
| 5. | 5 | 1352 | 0,0128 | 0,009464 |
| Average Jitter | | | | 0,008668 |

Table 1 shows the results of CCTV transmission jitter testing using UTP cable. The test was conducted in five experiments with each experiment sending a number of data packets through the UTP cable for 2 minutes. The results of the experiment show that the number of packets successfully transmitted varies between 1352 to 1662 packets in each test. The value calculation was carried out 5 times with an average result of 0.008668 ms.

TABLE II
DELAY TESTING RESULTS USING UTP CABLE

| No. | Testing | Packet | Delay (ms) |
|---|---|---|---|
| 1 | 1 | 1662 | 16,26821 |
| 2 | 2 | 1264 | 6,482354 |
| 3 | 3 | 1379 | 7,776488 |
| 4 | 4 | 1431 | 6,351689 |
| 5 | 5 | 1352 | 6,870178 |
| Average Delay | | | 8,749784 |

The test results of CCTV transmission delay with UTP cable in Table 2 show varying values. The delay value is obtained based on calculations and from 5 tests conducted, the average total delay is 8.749784 ms.

TABLE III
PACKET LOSS TESTING RESULTS USING UTP CABLE

| No. | Testing | Source | Destination | *Packet loss* |
|---|---|---|---|---|
| 1. | 1 | 1664 | 1494 | 10% |
| 2. | 2 | 1266 | 1172 | 7% |
| 3. | 3 | 1381 | 1214 | 12% |
| 4. | 4 | 1433 | 1266 | 12% |
| 5. | 5 | 1354 | 1199 | 11% |
| Average Packet loss | | | | 11% |

In Table 3, the test results show the variation of data packet loss rate in the five tests conducted. There is a fluctuation in the packet loss rate between 7% and 12% in each test. By calculating the average of the five tests, an average packet loss rate of 11% was obtained.

*B. Testing Packet Loss, Jitter, and Delay on CCTV Camera Transmission Using Fiber Optic Cable*

Just like in the previous test, testing and calculating Packet Loss, Jitter, and Delay using proxy aims to measure variations in the arrival delay of data packets as well as evaluate the length of time required by data packets to reach their destination via fiber optic cable. The test circuit using optical fiber is shown in Figure 5.

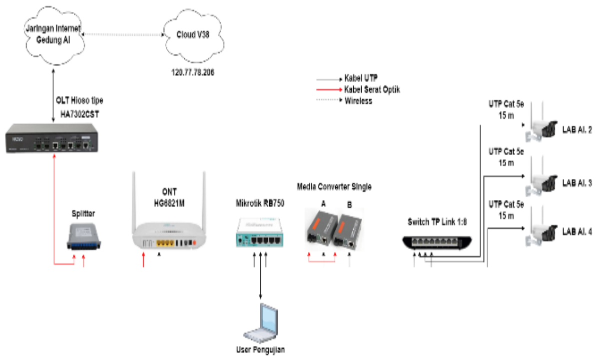


Figure 5. QoS Testing Using Optical Fiber

The process of QoS parameters using optical fiber has similar steps to testing using UTP cable.

TABLE IV
JITTER TESTING RESULTS USING OPTICAL FIBER

| No. | Testing | Packets | Delay Variation (s) | Jitter (ms) |
|---|---|---|---|---|
| 1. | 1 | 1299 | 0,00184 | 0,00142 |
| 2. | 2 | 1338 | 0,03605 | 0,026945 |
| 3. | 3 | 1345 | 0,00679 | 0,005045 |
| 4. | 4 | 1355 | 0,00395 | 0,002916 |
| 5. | 5 | 1352 | 0,0128 | 0,009464 |
| Average Jitter | | | | 0,009158 |

Table 4 shows the results of jitter testing on the CCTV camera transmission network using optical fiber. Just like the previous test, this test was also carried out in five experiments with each experiment sending a number of data packets through the fiber optic cable. The results obtained the number of packets successfully transmitted varies between 20 to 24 packets. While the jitter value in each experiment is obtained through calculation with equation 2.1 where the average result obtained from 5 trials is 0.001173 ms.

TABLE V
DELAY TESTING RESULTS USING OPTICAL FIBER

| No. | Testing | Packet | Delay (ms) |
|---|---|---|---|
| 1. | 1 | 1299 | 5,986672 |
| 2. | 2 | 1338 | 5,965225 |
| 3. | 3 | 1345 | 5,998364 |
| 4. | 4 | 1355 | 5,998634 |
| 5. | 5 | 1352 | 6,870178 |
| Average Delay | | | 6,163815 |

Table 5 shows the results of delay testing on the CCTV camera transmission network using optical fiber. The value obtained from the calculation using equation 2.2 varies greatly. The total average delay from five trials is 4.28976 ms.

TABLE VI
PACKET LOSS TESTING RESULTS USING OPTICAL FIBER

| No. | Testing | Source | Destination | Packet loss |
|---|---|---|---|---|
| 1 | 1 | 1405 | 1301 | 7% |
| 2 | 2 | 1464 | 1340 | 8% |
| 3 | 3 | 1485 | 1347 | 9% |
| 4 | 4 | 1514 | 1357 | 10% |
| 5 | 5 | 1810 | 1709 | 6% |
| Average Packet Loss | | | | 8% |

Table 6 shows the results of packet loss testing of transmission media using optical fiber, showing varying levels of data packet loss during the five tests conducted. The tests involved sending data packets from source to destination, with packetloss rates ranging from 6% to 10%. The average packet loss was 8%, indicating a fairly good rate but still requires further evaluation to understand the potential causes of packet loss.

*C. CCTV Network Transmission Speed Measurement*

Speed measurements are carried out to identify the efficiency of UTP and Fiber optic cables in transmitting data from CCTV cameras using OpenSpeedtest software. Speed testing is carried out in upload and download conditions, which are carried out for 5 repetitions. The speed testing circuit using UTP cable and optical fiber is shown in Figure 6 and Figure 7.

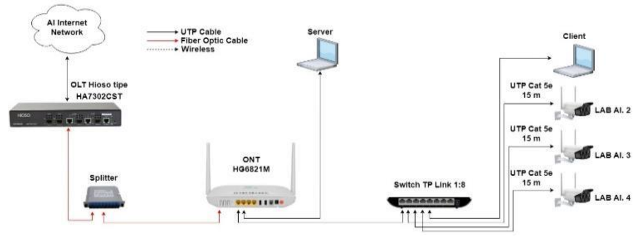


Figure 6. Speed Testing Using UTP Cable

Figure 6 shows the CCTV transmission speed testing circuit, starting with connecting the CCTV to the router via switch port 1:8. The process continues with transmission speed testing, where data is sent from the server (laptop) to the client (another laptop). The server laptop is connected to the ONT port using an ethernet cable, while the client laptop is connected to the switch port via an ethernet cable. Before starting the test, Windows Defender Firewall on the laptop is disabled. The openspeedtest software was run on the server laptop after confirming the connection from the ONT, and the IP address of the test results was recorded. On the client laptop, a browser was opened to access the IP address logged earlier, and openspeedtest was run to measure the transmission speed. This process was repeated 5 times to obtain consistent results.

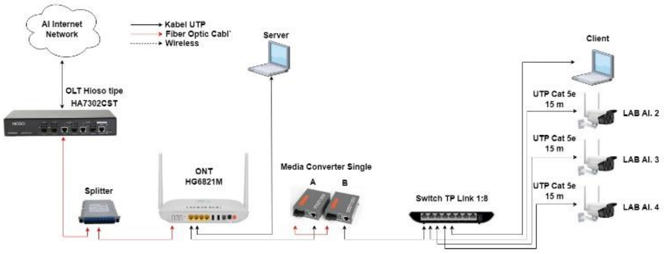


Figure 7. Speed Testing Using Optical Fiber

Figure 7 shows the speed testing circuit using optical fiber. The speed process using optical fiber has similar steps to testing using UTP cable.

TABLE VII
UPLOAD AND DOWNLOAD SPEED TESTING

| No | Testing | Optical Fiber | | UTP | |
|---|---|---|---|---|---|
| | | ***Download* (Mbps)** | ***Upload* (Mbps)** | ***Download* (Mbps)** | ***Upload* (Mbps)** |
| 1. | 1 | 986,6 | 981,1 | 980,6 | 979,7 |
| 2. | 2 | 987,5 | 980,6 | 975,3 | 981,3 |
| 3. | 3 | 989,9 | 984 | 977,7 | 976,4 |
| 4. | 4 | 985,7 | 995,2 | 978,7 | 975,4 |
| 5. | 5 | 987,5 | 984,7 | 979,9 | 977,7 |
| Average | | 987,44 | 985,12 | 978,44 | 978,1 |

Table 7 shows the results of testing the speed of the CCTV camera transmission network with two types of cables measured using openspeedtest software. The speed measured is the upload speed and download speed for each transmission. Testing was carried out in five trials with varying results. The average upload speed obtained from transmission using UTP cable is 978.1 Mbps with a download speed of 978.44 Mbps. While in transmission using optical fiber the average upload speed obtained is 985,12 Mbps and the download speed is 987,44 Mbps.

## *D. Video Quality Testing*

Testing the quality of CCTV videos obtained from both types of transmission by comparing the quality of CCTV videos with different installations using MSU VQMT Software. The parameters used are PSNR and SSIM. The video quality testing scheme is shown in Figure 8.

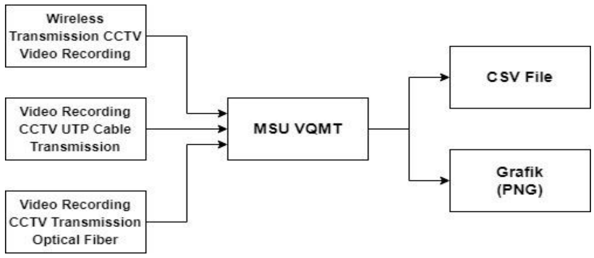


Figure 8. Video quality testing schematic

Figure 9. PSNR testing of lab recording. AI 2

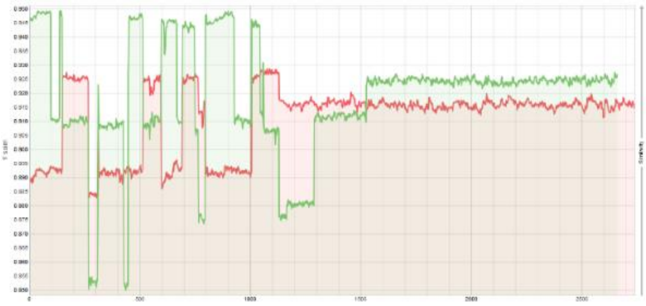

Figure 10. SSIM testing of lab recordings. AI 2

Figure 9 and Figure 10 show two comparison graphs of video quality test results from CCTV camera recordings in the AI Lab 2 POLINEMA using UTP and fiber optic cables. Tests were carried out on camera footage for 2 minutes for both types of cable. The results show that the PSNR value using UTP cable is higher (31.201330 dB) compared to optical fiber (29.972069 dB), although the optical fiber graph shows better stability. Meanwhile, in the SSIM test, the UTP cable graph is also higher than the optical fiber, with a total SSIM value of 0.921130 dB for UTP and 0.911387 dB for optical fiber.

Figure 11. PSNR Testing of Lab Recording. AI 3

Figure 12. SSIM testing of lab recordings. AI 3

Figure 11 and Figure 12 show the results of CCTV camera video quality testing in AI Lab 3 with SSIM and PSNR parameters. In PSNR testing, the UTP value is greater (30.040775 dB) than optical fiber (27.769014 dB), although the UTP graph tends to be unstable and up and down in each frame. SSIM testing also shows a smaller optical fiber value (0.876816 dB) compared to UTP (0.913285 dB).

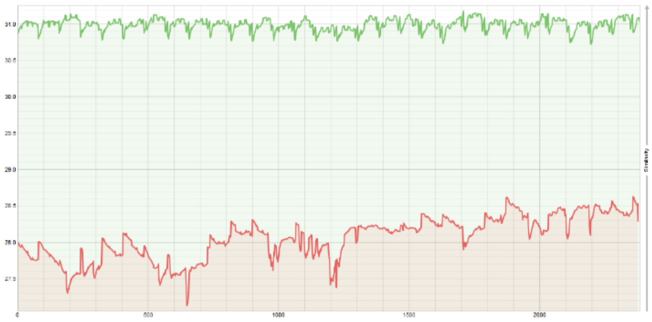

Figure 13. PSNR Testing of lab recording. AI 4

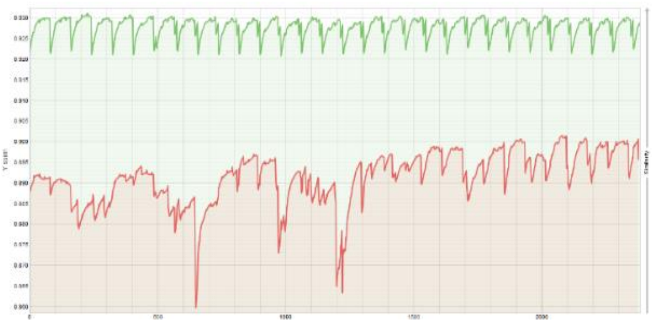

Figure 14. SSIM Testing of lab recordings. AI 4

Figure 13 and Figure 14 show the results of CCTV camera video quality testing in AI Lab 4 with SSIM and PSNR parameters. In the PSNR test, the value of UTP is greater (30.040775 dB) than optical fiber (24.138962 dB). The use of UTP in Lab. AI 4 produces a stable graph, different from the previous test. SSIM test results also show a smaller value of optical fiber (0.880764 dB) compared to UTP (0.919683 dB). For further details, the video quality test results can be seen in Table 8 and Table 9.

TABLE VIII
PSNR TESTING RESULTS OF VIDEO QUALITY IN EACH LAB

| Lab | PSNR UTP (dB) | PSNR Optical Fiber (dB) |
|---|---|---|
| Lab AI 2 | 30,45453 | 29,24899 |
| Lab AI 3 | 30,00069 | 28,03188 |
| Lab AI 4 | 30,98686 | 28,05105 |
| Average | 30,480694 | 28,443975 |

TABLE XI
PSNR TESTING RESULTS OF VIDEO QUALITY IN EACH LAB

| Lab | SSIM UTP (dB) | SSIM Optical Fiber (dB) |
|---|---|---|
| Lab AI 2 | 0,919138 | 0,911078 |
| Lab AI 3 | 0,900582 | 0,866829 |
| Lab AI 4 | 0,927801 | 0,891404 |
| Average | 0,9158403 | 0,8897703 |

### E. *Research Data Analysis*

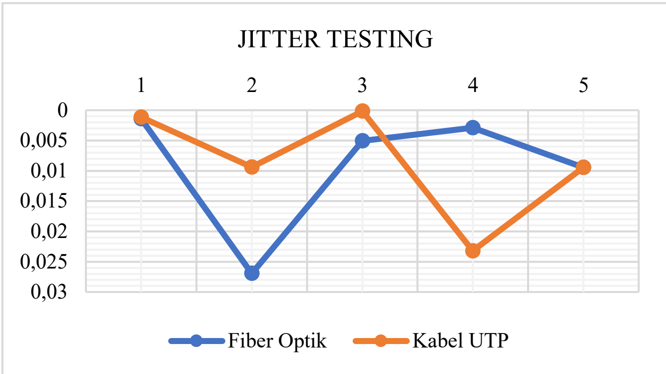


Figure 15. Jitter Testing Comparison Chart

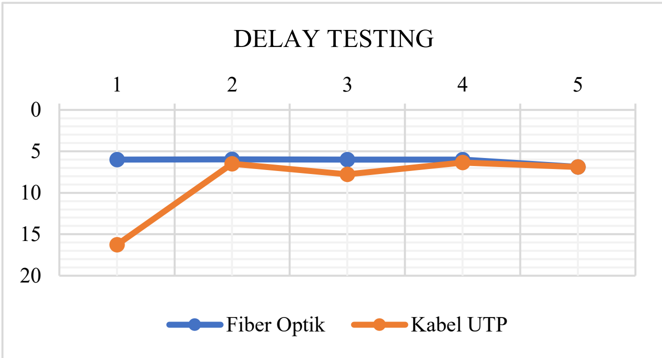


Figure 16. Delay Testing Comparison Chart

Based on Figure 15, there is a significant difference in delay between using UTP cable and optical fiber. The delay graph on the UTP cable shows larger changes, while the optical fiber shows a more stable delay. The average delay for UTP cable is 4.44135 ms, while optical fiber has an average delay of 4.289764 ms. The jitter test comparison graph in Figure 16 also shows a striking difference. UTP cable shows drastic changes from the first experiment to the next, while optical fiber shows more stable changes. The average jitter of UTP cable is

0.206602 ms, while optical fiber has an average jitter of 0.001173 ms. From these results it can be interpreted that optical fiber excels in terms of delay and jitter, offering faster response and better data transmission stability in CCTV applications.

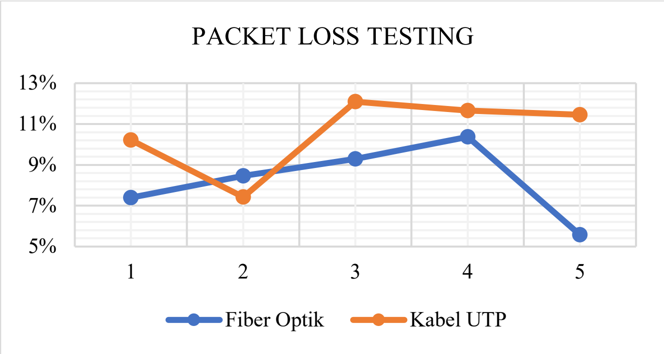


Figure 17. Comparison Chart of Packet Loss Testing

Figure 17 show that the UTP Cable graph shows a packet loss rate between 7% to 12%, while the Optical Fiber graph shows a packet loss rate between 6% to 10%. Based on Table 3 and Table 6, the average UTP cable test is 11% and optical fiber is 8%. This shows that optical fiber shows a slightly lower packet loss rate compared to UTP cable. However, when based on the TIPHON standard, the results of both are in the good category (3 - 15%).

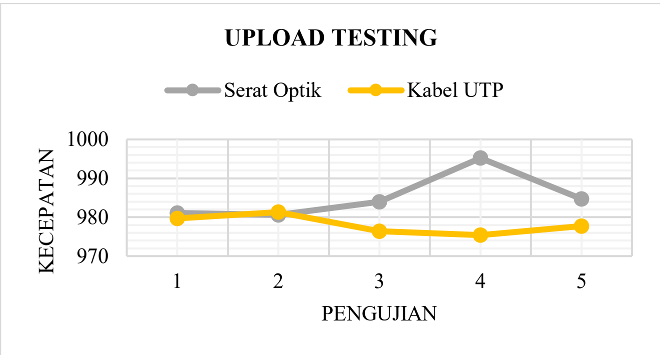


Figure 18. Upload Speed Test Comparison Chart

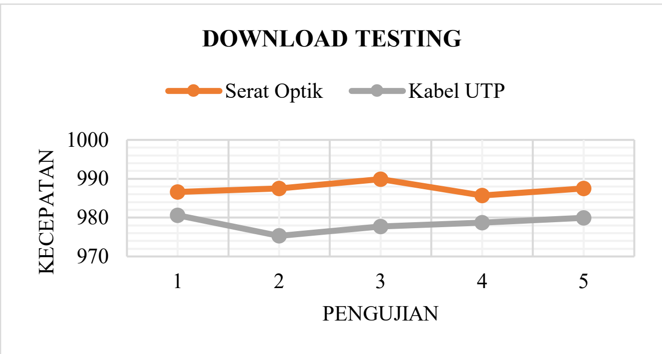


Figure 19. Download Speed Test Comparison Chart

Based on Figure 18 and Figure 19, it can be seen that optical fiber shows better values in terms of upload and download speeds compared to UTP cable. In accordance with the theory that optical fiber will provide better results in data transmission. Based on Table 7, the average upload and download speed of UTP is 978.1 Mbps and 978.44 Mbps. While the average upload and download speed of optical fiber is 985.12 Mbps and 987.44 Mbps. With an upload difference of 7.02 Mbps and a download difference of 9 Mbps.

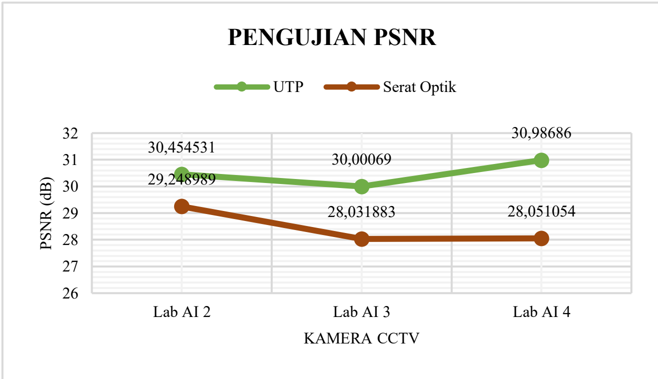


Figure 20. Video Quality Test Comparison Chart PSNR Parameters

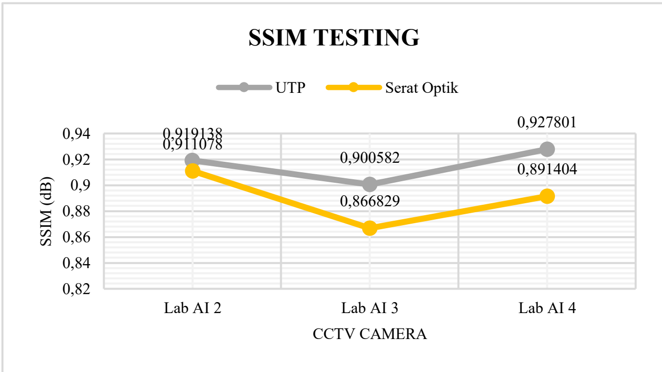


Figure 21. SSIM Parameters Video Quality Test Comparison Chart

Based on Figure 19 and Figure 20, PSNR testing shows the difference in PSNR values in Lab. AI 2 of 1.205542 dB, in Lab. AI 3 of 1.968807 dB, and in Lab. AI 4 of 2.935806 dB. While SSIM testing produces a difference in value in Lab. AI 2 of 0.00806 dB, in Lab. AI 3 of 0.033753 dB, and in Lab. AI 4 of 0.036397 dB. PSNR and SSIM, as image and video quality metrics, were used to evaluate the similarity between the two video recordings. The calculation results show that the video quality of the two-transmission media has a small difference in value.

## IV. CONCLUSION

The simulation results of the hybrid power flow generator consisting of 8 wind power plants and 6 solar power plants with a grid-connected connection to the PLN electricity source show that the voltage value on each bus still meets the input voltage safety tolerance limit of 105% for overvoltage and 95% for

Undervoltage. equipment connected to an energy source supplies active power according to the equipment specifications that have been determined and there is no critical or marginal failure in supplying the existing load. This simulation also shows that there are losses in the system of 190,811 kW so it is necessary to add a capacitor bank component with a capacity of 1 MVAR to improve the power factor in the network.

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