Contemporary Journal of Applied Sciences (CJAS)
Vol. 4, No. 5 April 2026: 427-438

CCTV control system utilizing communication technology and sourced by solar panels

I Made Sajayasa[1], I Gede Suputra Widharma[2], I Gde Nyoman Sangka[3], I Nengah Sunaya[4], I Ketut Sumadi[5], I Made Sukma Manggala[6]
[1234]Politeknik Negeri Bali
[56]UHN IGB Sugriwa Denpasar
Corresponding Author: I Gede Suputra Widharma: suputra@pnb.ac.id

A R T I C L E I N F O
Keywords: Solar Panels, Communication Technology, Control System, CCTV

Received: 7, February
Revised: 28, March
Accepted: 20, April

©2026 Sanjayasa, Widharma, Sangka, Sunaya, Sumadi, Manggala (s): This is an open-access article distributed under the terms of the Creative Commons Atribusi 4.0 Internasional.

A B S T R A C T
This study design and implementation of a CCTV control system utilizing communication technology and powered by solar panels as a sustainable energy source. The research aims to develop an integrated system capable of remotely controlling and monitoring CCTV cameras through a web-based platform, while ensuring energy efficiency in off-grid conditions. The system architecture consists of a microcontroller unit, a solar panel energy system with battery storage, and a communication module that connects the hardware to a web server for real-time access.

The methodology involves system design, hardware-software integration, and performance evaluation, including control accuracy on the X and Y axes, communication latency, and energy consumption. Experimental results indicate that the system successfully enables remote camera control and live monitoring via a web interface. The average delay observed in video streaming is approximately 10 seconds, influenced by network conditions and communication protocols. The findings demonstrate that integrating communication technology with solar-powered systems provides a viable solution for CCTV deployment in remote or energy-limited areas. Future improvements should focus on optimizing mechanical design and reducing communication latency to enhance system responsiveness and reliability.

INTRODUCTION

The need for energy as electrical energy is becoming increasingly significant, one of the basic needs of the community is electrical energy and along with the increase in population and economy, it triggers the need for energy. This pattern is also reinforced by the inaccessibility of environmentally friendly resources (solar, wind, geothermal, atomic, and so on) with cheap manufacturing costs [1]. Of the several existing resources, the sun is a very possible competitor as an alternative energy, especially in Indonesia which is located on the equator, which receives very high radiation. To be able to utilize solar energy to become a source of electrical energy, a solar panel is needed.

Solar panels are excellent for supplying electricity to areas remote from electricity lines, such as plantations. They can also be used as a power source for electronic equipment. Some electronic devices, which must operate optimally, require a continuous power supply due to their specialized nature. This equipment is typically used in healthcare, security, government, and other systems. Therefore, a dedicated power generator is essential to keep these devices operating under any circumstances. There are numerous types of specialized equipment that require continuous power outages, including Closed Circuit Television (CCTV).

CCTV cameras play a significant role in security. They are installed in strategic locations to monitor potential criminal activity. Monitoring using CCTV cameras can replace the manual work of monitoring activities or events that have already occurred [3]. Security systems using CCTV are now increasingly being used. The goal is to facilitate direct monitoring. Currently, CCTV is widely used to ensure security in homes and public places. CCTV still relies on electricity from the state electricity company (PLN), which can experience interruptions, resulting in power outages and ultimately cause the CCTV to malfunction. CCTV camera monitoring is often carried out using a personal computer (PC) or television connected to a local network. This is certainly less effective if the CCTV control room is unattended. Therefore, a system is needed that can control and monitor CCTV remotely and utilizes solar energy as a power source for the CCTV cameras, ensuring the system remains operational in any situation. Based on these issues, the author is interested in conducting research on a CCTV control system via a website that utilizes solar energy as a power source.

LITERATURE REVIEW

Solar Panel System

The use of renewable energy, particularly solar power through the installation of solar panels, has become a primary focus of various research and implementations in Indonesia. Solar panels are semiconductor devices that directly convert sunlight into electrical energy. They consist of photovoltaic cells that generate electricity when exposed to sunlight. The average daily sunlight intensity in Indonesia ranges from 4.5 to 4.8 kWh/m²/day, demonstrating the significant potential for developing solar energy as a renewable energy source.

Globally, the use of renewable energy has become a key agenda for achieving energy security and environmental sustainability. Indonesia, with its wealth of natural resources, has great potential to develop various types of

renewable energy, including solar power, to meet national energy needs and support environmentally friendly economic growth [3].

Figure 1. Solar panel system

Solar panels, also known as photovoltaic cells, are devices that convert sunlight energy into electrical energy through the photovoltaic effect. These devices consist of semiconductor materials that, when exposed to sunlight, produce direct current (DC). The resulting electrical energy can be used immediately or stored for future electricity needs. Solar Panel Direction and Tilt Angle: In the discussion of shadow analysis, we briefly explained the changing position of the sun relative to the observer's position on Earth. Besides being related to the shadow effect, this also affects the optimization of sunlight absorption for conversion into electrical energy. Solar panels operate on the principle of a p-n junction, a junction between a p-type semiconductor and an n-type semiconductor. This semiconductor consists of atomic bonds containing electrons as its basic constituent. The advantage of an n-type semiconductor is that it has an excess of electrons, or a negative charge, while a p-type semiconductor has an excess of holes, or a positive charge, in its atomic structure. This excess of electrons and holes can be created by doping the material with dopant atoms. For example, to obtain p-type silicon material, silicon is doped with boron atoms, while to obtain n-type silicon material, silicon is doped with phosphorus atoms. The illustration below depicts a p-type and n-type semiconductor junction.

The role of a p-n junction is to create an electric field so that electrons and holes can be extracted by the contact material to generate electricity. When p-type and n-type semiconductors come into contact, excess electrons will move from the n-type semiconductor to the p-type semiconductor, forming a positive pole in the n-type semiconductor and a negative pole in the p-type semiconductor. As a result of the flow of electrons and holes, an electric field is formed, where when sunlight hits the p-n junction arrangement, it will push electrons to move from the semiconductor towards the negative contact, which is then used as electricity, and conversely, holes move towards the positive contact waiting for electrons to come [12].

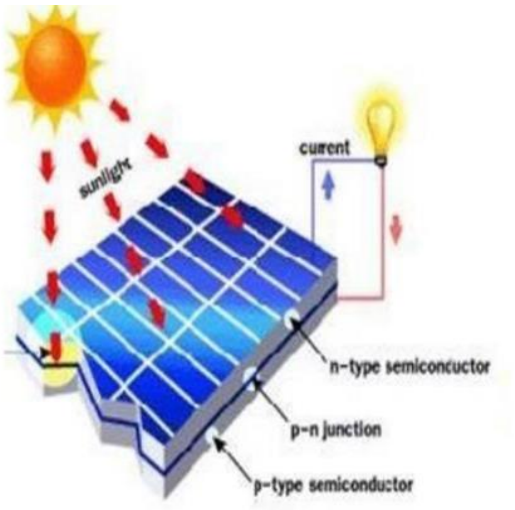

Figure 2. Solar panel system diagram

A solar charge controller is a control device that regulates the voltage and current output from solar modules, prevents overcharging of batteries, and controls the discharge process. When using a charge controller, it is important to consider the voltage and power output of the solar module and the amount received by the battery. A solar charge controller, or charge regulator, is the most important component in a solar cell circuit because the primary function of the charge controller is to maintain or secure the battery, a vital component in a solar cell [14].

Closed Circuit Television (CCTV)

Closed Circuit Television (CCTV) is a monitoring device based on a digital video camera that is used to send signals to a monitor screen in a certain room or place. The purpose of this is to be able to be used as evidence of a crime that has occurred. In general, CCTV is often used to monitor public areas, such as: Banks, Hotels, Airports, Military Warehouses, Factories and Warehouses. In conventional systems using a VCR (Video Cassette Recorder), first the image from the CCTV camera is only sent via cable to a certain monitor room which still requires direct supervision by an operator or security officer with a low image resolution of 1 image per 12.8 seconds. Along with the rapid development of the times, the use of CCTV cameras has also experienced developments. The current digital CCTV camera system can be run or controlled via a personal computer or mobile phone, and can be monitored anywhere and anytime as long as an internet network is available [10].

Analog CCTV cameras are a type of conventional camera that are the first generation of CCTV cameras. These CCTV cameras are connected to a DVR (Digital Video Recorder) using a coaxial cable. Recordings from the CCTV camera are stored on the DVR. To view the recordings, you can use a PC monitor connected to a local network [11].

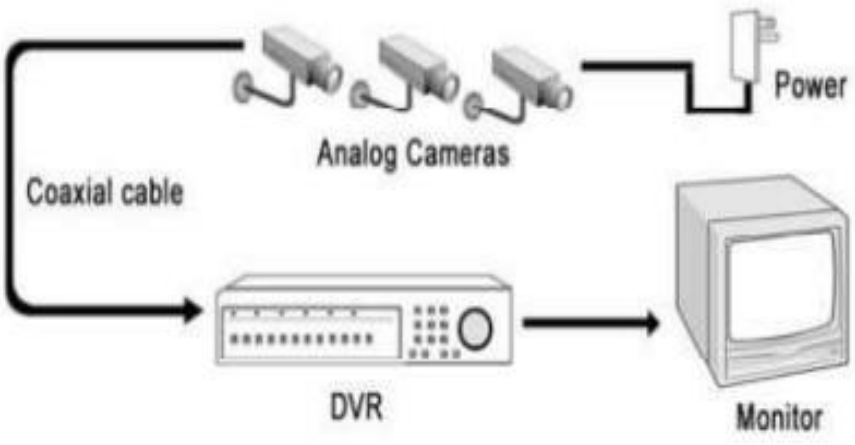

Figure 3. Analog CCTV system

IP cameras are a further development of analog CCTV cameras, offering superior functionality and operation. IP cameras are capable of automatically transferring data or converting recorded video files into digital files that can be viewed online via the internet using a designated IP address. These cameras are capable of processing images or recordings and then sending information via a computer connection, accessible to users using web browsers such as Mozilla Firefox, Internet Explorer, Chrome, and others [11].

Figure 4. IP Camera CCTV system

METHODOLOGY

There are three methods in this research to solving the problem in designing a rooftop simulation based on PVSyst software.

1. Literature Study Method

In writing this thesis, the author studied references from various sources such as books, journals, articles related to the research that the author is researching. The various references used by the author to create this final assignment and other references related to the research.

2. Discussion or Interview Method

Collecting data by conducting direct discussions with expert

3. Observation Method

The author obtains data by coming directly to the field to observe and record the data needed to complete the thesis.

The research method used in this study is a research and development method because this method contains designing, determining, measuring, and analysis of numerical data related to the performance of the solar panel system, CCTV control system, and communication technology.

This system design is made to control CCTV cameras through communication technology that uses solar panels as an energy source to power the CCTV cameras and control the movement of the CCTV cameras by creating a stand that is moved using a stepper motor.

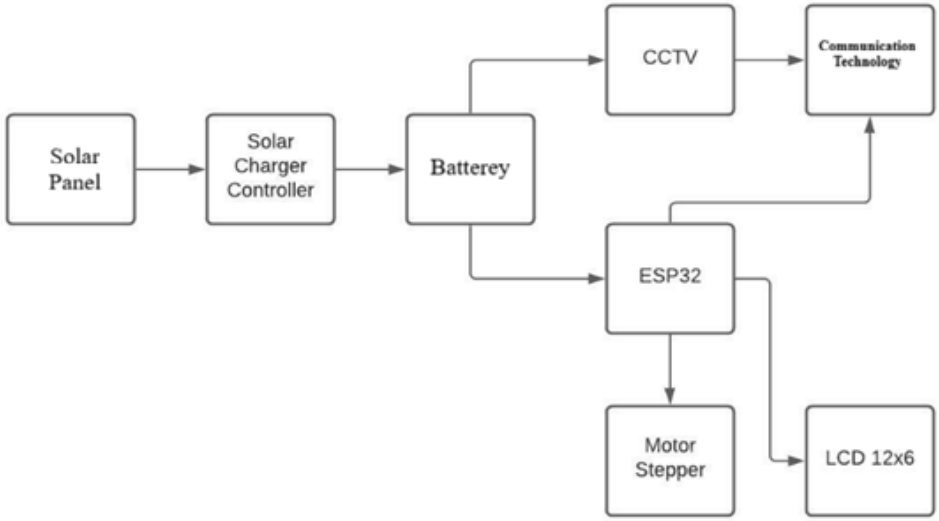

Figure 5. Research Diagram

The design of utilizing solar panels as an energy source in a CCTV control system through this communication technology. Solar panels will absorb sunlight to become electrical energy which is then channeled to a solar charger controller that functions to regulate the voltage and current released from the solar panels and also to control battery charging. If the battery is fully charged, the solar charger controller will stop charging the battery. Meanwhile, if the battery is not full, the solar charger controller will continue charging. Then the battery will provide a supply to power the CCTV camera and power the ESP32 microcontroller. The ESP32 microcontroller which controls the stepper motor will move the stepper motor used as the movement controller of the CCTV camera. Then after the ESP32 microcontroller is connected to the internet network, the LCD will display the connected CCTV control system. Then on the gadget, buttons will appear to control the movement of the CCTV camera and there is also a live display of the CCTV camera.

RESEARCH RESULT

Designing hardware and software system

The system creation process begins with the purchase of the necessary tools and materials for the CCTV control system. After all components are collected, the components are assembled. Programming is then carried out using the Arduino IDE software, then connecting the microcontroller and stepper motor circuits. After that, connecting to the database will be displayed on the dashboard of the communication technology used. Once the program is running properly, a place is created to place the programmed circuit into a panel box to make it look neat. After that, the system is tested, including testing the stepper motor and CCTV camera to ensure they function properly and can be controlled and monitored through the display on the communication technology used by the user.

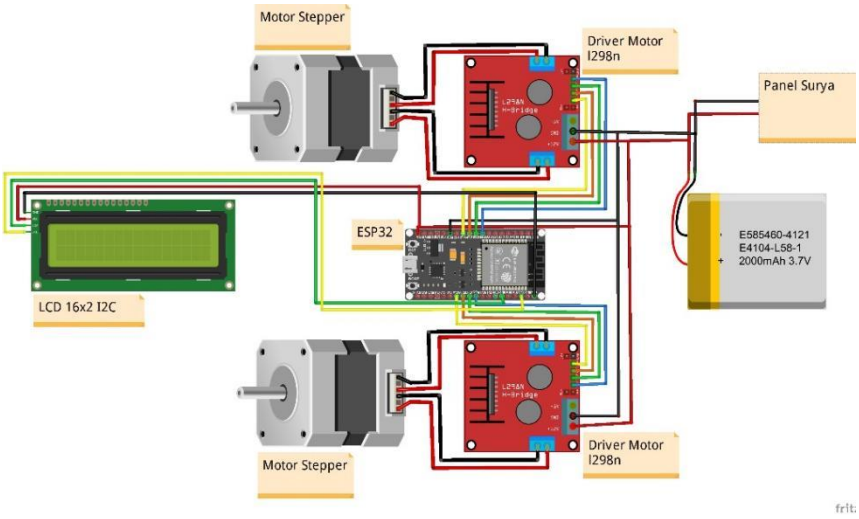

Figure 6. Designing hardware system

Figure 5 shows the CCTV control system circuit. It includes an ESP32 microcontroller, an L298N motor driver, a 16x2 I2C LCD, an LM2596 step-down module, and an L7812 regulator. The ESP32 microcontroller controls a series of other electronic modules connected to the microcontroller's GPIO pins. The hardware design for the CCTV control system is shown in Figure 6.

The software design for this CCTV control system uses the Arduino IDE. Figure 7 shows that the program code created in the Arduino IDE does not display any error messages after compiling the program. The program code is then uploaded to the ESP32 microcontroller, enabling it to access the website and display CCTV camera recordings and buttons to adjust the direction of the CCTV camera.

Figure 6. Designing software system

DISCUSSION

This system is designed using solar panels as the primary source of environmentally friendly and efficient electrical energy. The solar panels capture sunlight and convert it into direct current (DC) electricity. It then flows to the Solar Charge Controller (SCC), which plays a crucial role in optimally regulating the battery charging process. The SCC also protects the battery from overcharging or over discharging, thus extending battery life and increasing system reliability. The electricity generated by the panels is then stored in batteries, which serve as a backup energy source when sunlight is unavailable, such as at night or on cloudy days. The installed load must have a capacity appropriate to the device's intended use, but the load capacity must be supported by a maximum power supply. Using solar energy as a power source to power a CCTV control system, with a total load of 12 W and a 24-hour power supply, the battery capacity required to supply a 12 W load is a 24 Ah battery.

Table 1. Solar Modul Measurements

SOLAR MODULE	
Max. Power (Pmax)	100 Wp
Max. Power Voltage (Vmp)	17,8 V
Max. Power Current (Imp)	5,62 A
Open Circuit Voltage (Voc)	22,4 V
Short Circuit Current (Isc)	5,95 A
Power Tolerance (Pmax)	0~ +3%
Modul Dimension	1000x670x30mm
Max. Series Fuse Rating	10 A
All Technical Data at Standard Test Condition AM=1,5 E=1000w/m2 TC=25°C	

To control the CCTV camera's movement, a stand was created for the camera that can move left and right, up and down. The stand uses two stepper motors to control the camera's movement. The stepper motor consists of eight coils. When current flows through one coil, a magnetic field is generated, activating the rotor. When the current moves to the next coil, a magnetic field is generated, causing the rotor to move. The rotor's movement angle is 1.8°, or one step.

Table 2. CCTV Moving Measurements

CCTV Moving	Trial	Target (°)	Result (°)	Error (%)
Up/Left	1x	9	5,7	3,3
	2x	18	11,1	6,9
	3x	27	16,5	10,5
	4x	36	21,9	14,1
	5x	45	27,3	17,7
Down/Right	1x	9	5,7	3,3
	2x	18	11,1	6,9
	3x	27	16,5	10,5
	4x	36	21,9	14,1
	5x	45	27,3	17,7

In this study, the stepper motor's movement is controlled using buttons on the website. There are four buttons to control the CCTV camera's movement: left, right, up, and down. When the button is pressed, the stepper motor rotates 9° per rotation. This button receives data from the database, which is then retrieved by the microcontroller to drive the stepper motor. When a button is pressed on the website, the database stores data 1, and the microcontroller then retrieves the data from the database.

The program sets the stepper motor to rotate at a rate of 9 degrees per rotation. The total angular movement of the stepper motor is 1.8 degrees. Based on the results of this study, there was a discrepancy in the test results, with differences in the results between pressing the up and down buttons. This was due to the poor construction of the camera mount. As the motor rotated on the camera mount axis, there was slight slippage, causing the rotation to not match the specified results.

CONCLUSION

Based on the research and discussion on the CCTV control system via a communication technology utilizing solar energy as a power source, the following conclusions can be drawn:

1. The CCTV control system was designed by designing hardware in the form of a CCTV camera mount to allow it to move left, right, and up and down. The CCTV camera's movement is controlled via the website.
2. When viewing CCTV camera footage via YouTube live streaming on the webpage, there is a delay of approximately 10 seconds. This is because the

Frames Per Second (FPS) value is sometimes below 30 FPS and also depends on the internet connection during streaming.

3. Based on the calculations, with a 24 Ah battery capacity, the operating time to power a 12 W load is 24 hours. Therefore, the power stored in the battery is sufficient to meet the load's needs without recharging for one day.

ADVANCED RESEARCH

After designing CCTV control system utilizing a communication technology and sourced by the solar panel system, the author has the following suggestions utilizing batteries as electrical energy storage to store the power generated by the solar power plant system. This way, in the event of a power outage, the energy stored in the batteries can be used as a backup source. And also need to attention to the construction of the CCTV camera mount so that the movement results from the motor used match the desired results.

ACKNOWLEDGMENT

This section we say thanks to our colleagues who provided suggestions for our paper: Electro Engineering Department in Politeknik Negeri Bali (PNB), foundation of Cita Widya Suhita (CWS), Engineering in HEA Ganesha Indonesia, and Communication Studies in UHN IGB Sugriwa Denpasar.

REFERENCES

Arthadi, IP, MD PP, GFS, Dimas, DN, Widharma, IGS. (2017). Paket Program Aplikasi: Analysis and Mapping. Politeknik Negeri Bali.

Widharma, IGS, Lalu, FN. (2022). Buku Ajar Mikrokontroler dan Aplikasi. Penerbit Wawasan Ilmu, Banyumas, Jawa Tengah.

Bialevich, V.; Zachleder, V.; Bišová, K. (2022). The Effect of Variable Light Source and Light Intensity on the Growth of Three Algal Species. Cells

Widharma, IGS, Sunaya, IN; Sajayasa, IM; IGN Sangka; Darminta, IK; Anggreni, AAMD. (2021). Effect of Heating Light on Lamps to the Behaviour of Tilapia Seedlings Sourced from Solar Panels. Proceedings iCAST-ES 2021, pages 1305-1311.

Jatmiko, Hasyim Asy'ari, Mahir Purnama. (2011). Pemanfaatan Sel Surya dan LED untuk Perumahan. Seminar Nasional Teknologi Informasi & Komunikasi Terapan.

Suputra Widharma, IG, Sunaya, IN. (2017). Analisis menentukan keandalan sistem distribusi dengan pemanfaatan aplikasi algoritma genetika berbasiskan pemrograman Matlab, Jurnal Matrix 5 (1)

I Gde Ketut Sri Budarsa, I Ketut Sumadi, IGN. Sangka, IM. Sajayasa, IN. Sunaya, IGS.Widharma, IGK. Abasana. (2024). An evaluation study of service quality on tourist satisfaction at villas through digital communication. Digital Theory, Culture & Society 3(1).

Rochadiani, TH; William, W.; Santoso, H; Natasya, Y; Ariqoh, UDN; Rahayu, RAS. (2022). Penerapan IoT Untuk Pemantauan Kualitas Air Kolam Peternak Ikan Di Kampung Kalipaten. Prosiding PKM-CSR, Vol. 5

Nurjaman, HB; Purnama, T. (2022). Pembangkit Listrik Tenaga Surya (PLTS) Sebagai Solusi Energi Terbarukan Rumah Tangga. Jurnal Edukasi Elektro, Vol. 06 (02).

Suputra Widharma, IG, Sunaya, IN. (2017). Aplikasi Sistem Akuisisi Data Pada Sistem Fire Alarm Berbasis Sistem Mikrokontroller. Jurnal Logic 14 (2).

Supriadi, M, Sunaya, IN, Widharma, IGS. (2019). Simulasi Pengendalian Kecepatan Putar Ceiling Fan Berbasis Arduino. Jurnal Vastuwidya 2 (2)

IGS. Widharma, IN. Sunaya, IGN. Sangka, IP. Sutawinaya, IM. Sajayasa, IGK. Abasana, IGK. Sri Budarsa. (2025). Integrating Digital Technology in the Study of Rooftop Solar Panel Planning for Hospital By Using Software. AJNS 4 (2).

IG.N. Sangka, IG.S. Widharma, and I.G.K. Sri Budarsa, (2026) "MathematicalModeling of an Adaptive Lighting SystemBased on Solar Panels and DigitalCommunication for Microalgae Synthesis",KINETIK, vol. 11, no. 1, Feb. 2026.