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Power Supply System Reliability Analysis at the TVRI Transmitter Station Sibolangit Uses UPS 40 kVa and 250 Kva

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This study aims to analyze the reliability of the power supply system at the Sibolangit TVRI Transmitter Station which uses Uninterruptible Power Supply (UPS) with a capacity of 40 kVA and 250 kVA as an important component in maintaining the operational continuity of the transmitter. A reliable power supply system is crucial to ensure broadcast quality and prevent service disruptions due to power supply failures. The methods used in this study include collecting UPS operation data through field monitoring, analyzing technical parameters such as Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), Availability, and comparing the performance of the two UPS units. Data were analyzed using statistical approaches and reliability engineering tools to evaluate the performance and failure patterns that occurred during the observation period. The results show that the 250 kVA UPS has a higher level of availability than the 40 kVA UPS, with an average MTBF value of XX hours and YY hours, respectively, and MTTR of AA hours and BB hours. The analysis also reveals the main factors that affect reliability, including the quality of the electricity supply from PLN, load conditions, and the implemented maintenance schedule. These findings provide technical recommendations regarding load management, improved preventive maintenance schedules, and risk mitigation strategies to improve power supply continuity, particularly for low-capacity UPS units. Thus, this study contributes to the understanding of power supply system reliability in broadcasting installations and provides a basis for planning for improving operational performance at the TVRI Sibolangit transmitter station.
Keywords: System Reliability, 40 Kva UPS, 250 Kva UPS, MTBF, MTTR, Availability, Television Transmitter Stations.

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1. Introduction

The availability and reliability of the power supply system is a fundamental factor in supporting the operational continuity of a television broadcasting system, because in the world of broadcasting, the continuity of the electrical power supply must be maintained optimally considering that even the slightest disturbance such as voltage fluctuations, decreased power quality, or momentary blackouts can cause broadcast interruptions, damage sensitive electronic equipment, and reduce the level of public trust in broadcasting institutions, so that a reliable, efficient power supply system with an automatic backup mechanism is an absolute necessity for every television transmitter station; Sibolangit TVRI Transmitter Station is one of the strategic transmission units in the North Sumatra region which has an important role in distributing TVRI broadcast signals to various regions, so that its operational continuity is highly dependent on the stability of the electrical energy supply, where to support this continuity, Sibolangit TVRI uses two Uninterruptible Power Supply (UPS) units with a capacity of 40 kVA and 250 kVA as the main backup power supply system that functions to provide temporary electrical power when the main source from PLN experiences a disruption by utilizing internal batteries before advanced backup systems such as generators operate, so that the UPS becomes a vital component in keeping the transmitter device, control system, and supporting equipment operating without interruption; although this system has been designed to guarantee reliability, in operational practice, various technical problems are still found that

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affect UPS performance such as decreased battery capacity due to service life, instability of power transfer time, decreased energy conversion efficiency, imbalance of load between phases, as well as environmental factors such as high UPS room temperature, uncontrolled humidity, and less than optimal implementation of periodic preventive maintenance, which if not managed properly can cause downtime, hamper the broadcast transmission process, and cause potential operational losses; Therefore, a comprehensive reliability analysis is needed for the power supply system at the Sibolangit TVRI Transmitter Station to assess the system's ability to operate without failure during a certain period using quantitative parameters such as Mean Time Between Failure (MTBF), Mean Time To Repair (MTTR), and Availability, so that the reliability level of each UPS unit, both 40 kVA and 250 kVA, can be evaluated objectively and the dominant factors causing disruptions can be identified; in addition to the reliability aspect, evaluating the efficiency of power use on both UPSs is also important because when the load approaches or exceeds the nominal capacity,energy conversion efficiency and power distribution capability tend to decrease, which results in increased power losses, decreased power factor, and accelerated degradation of internal UPS components, so that the results of the reliability analysis not only serve to determine the level of system performance but also become the basis for making technical decisions such as planning preventive maintenance schedules, arranging load distribution between UPSs, and the need to increase system capacity in the future; Based on these conditions, this study was designed with quantitative and analytical descriptive methods to examine the condition and configuration of the power supply system at the TVRI Sibolangit Transmitter Station with a focus on two UPS units with a capacity of 40 kVA and 250 kVA, determining the reliability level of each UPS based on the MTBF, MTTR, and Availability parameters, and formulating strategies to improve the efficiency and reliability of the system so that broadcast continuity can be maintained optimally, with the scope of the study limited to the UPS system without covering the analysis of generators and PLN distribution as a whole and testing was carried out analytically and simulatively using actual data from January to June 2024 obtained through field observations, technical documentation, and interviews with technicians, then analyzed using reliability calculations, availability analysis, and the Failure Mode and Effect Analysis (FMEA) approach to identify the risk of disruption, so that it is hoped that this study can provide scientific contributions in the field of reliability analysis of electric power systems, especially in the application of UPS in television broadcasting systems, become an academic reference for students and researchers, and assist TVRI's technical management in planning the development and modernization of a more efficient, reliable, and sustainable power supply system to support TVRI's role as a public media that provides information, education, and entertainment to the public without technical disruption, with the research title "Analysis of the Reliability of the Power Supply System at the TVRI Sibolangit Transmitter Station Using 40 kVA and 250 kVA UPS".and formulate strategies to improve system efficiency and reliability so that broadcast continuity can be maintained optimally, with the scope of the research limited to the UPS system without covering the analysis of generators and PLN distribution as a whole and testing is carried out analytically and simulatively using actual data from January to June 2024 obtained through field observations, technical documentation, and interviews with technicians, then analyzed using reliability calculations, availability analysis, and the Failure Mode and Effect Analysis (FMEA) approach to identify disruption risks, so that it is hoped that this research can provide scientific contributions in the field of electric power system reliability analysis, especially in the application of UPS in television broadcasting systems, become an academic reference for students and researchers, and assist TVRI technical management in planning the development and modernization of a more efficient, reliable, and sustainable power supply system to support TVRI's role as a public media that provides information, education, and entertainment to the public without technical disruptions, with the research title "Analysis of the Reliability of the Power Supply System at the TVRI Sibolangit Transmitter Station Using 40 kVA and 250 kVA UPS".and

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2. Literature Review

Power Supply System and UPS

The power supply system is a crucial subsystem in an electrical installation, serving to supply and distribute electrical energy to various load devices according to their operational needs. In the context of industrial electrical systems and critical facilities such as television transmitter stations, the primary function of the power supply system is to ensure a stable, continuous supply of electricity, protected from various power quality disturbances such as voltage fluctuations, sudden blackouts, and current surges. To ensure this continuity, especially for critical loads, a special device known as an Uninterruptible Power Supply (UPS) is used. An Uninterruptible Power Supply (UPS) is an electrical device designed to automatically provide backup electrical power to loads when a primary power source, such as the public power grid, is interrupted, thus preventing the loss of power to critical equipment. A UPS differs from a backup generator in that it provides near-instantaneous protection against power disturbances by taking over the power supply through energy stored in batteries or other energy storage devices such as supercapacitors or flywheels when the primary supply fails or becomes unstable. The UPS's energy backup time is relatively short, but sufficient to allow the protected device to remain operational or to be shut down in an orderly manner before the backup generator (genset) takes over the load or before the system is properly shut down to prevent data or device damage.

A UPS consists of several main components that work in an integrated manner, including an energy storage battery, a charger/rectifier for charging the battery when the main supply is available, an inverter for converting DC energy from the battery to AC when a power outage occurs, and a transfer switch that automatically transfers power from the main grid to the backup source without significant delay. This device is often equipped with surge protection and voltage stabilization features to address power quality variations that can damage sensitive equipment. Functionally, a UPS has two important roles: first, as a provider of instant backup power, so that critical equipment such as transmitters, signal control devices, data processing units, and other telecommunications equipment can continue to operate even in the event of a power outage; and second, as a buffer against power quality disturbances, such as voltage sags or surges that, if uncontrolled, can cause damage to electronic systems or trigger operational errors. This makes the UPS a crucial component in the design of power supply systems for facilities with high availability requirements, such as television transmitters, data centers, healthcare centers, or government facilities.

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UPS types and configurations can vary depending on operational requirements and the desired level of protection. Generally, common UPS types include standby/offline, which provides basic backup during power outages; line-interactive, which offers additional protection against voltage variations; and double-conversion online, which provides full protection against almost all forms of power outages with the ability to continuously convert from AC to DC and back to AC with very high power quality. The selection of the appropriate UPS type is tailored to the load characteristics, power magnitude, and operational continuity needs of the facility being served. In television transmitter applications such as TVRI Sibolangit, large-capacity UPSs such as 40 kVA and 250 kVA are selected to support the power requirements of critical loads. These UPS units not only function as emergency power providers when the main power source is interrupted, but also play a role in maintaining the quality of the transmitter signal and other supporting systems to remain stable, thus preventing broadcast interruptions or damage to equipment. Due to the central role of UPS in maintaining broadcast continuity, this system must be well designed and managed, including maintenance scheduling, monitoring battery and inverter performance, and evaluating load distribution configurations so that the level of reliability and availability of the power supply system can be maintained optimally in the long term.

Reliability (Reliability and System Availability)

Reliability is one of the main parameters in evaluating the performance of engineering systems, especially in critical systems such as the power supply system in a television transmitter station. Reliability is defined as the probability that a system, equipment, or component will operate according to its designed function without failure within a certain time interval and under predetermined operating conditions. Thus, the concept of reliability focuses on the ability of a system to maintain its normal performance continuously without interruption during a certain operating period (Ebeling, 2019). Mathematically, system reliability is often expressed in terms of the reliability function R(t)R(t), which describes the probability of the system remaining operational until time tt. For a system with a constant failure rate, the reliability function can be expressed as follows:

$$R(t)=e-\lambda t$$

Where λ is the failure rate and tt is the operating time. The lower the failure rate, the higher the system's reliability. In the context of a UPS system, a high reliability value is essential because the UPS protects critical loads from power supply disruptions that can directly impact the continuity of television broadcasts (Rausand & Høyland, 2020). In addition to reliability, another important parameter is availability, which indicates the proportion of time a system is ready and operational compared to the total observation time. Unlike reliability, which focuses solely on failure events, availability also considers aspects of system maintenance and repair. In other words, availability describes how often a system can actually be used in daily operational practice (Dhillon, 2017).

This equation shows that system availability can be improved by increasing the MTBF or decreasing the MTTR. In UPS systems, increasing MTBF can be achieved through scheduled preventive maintenance and operating within specifications, while decreasing MTTR can be achieved by improving technician readiness, spare parts availability, and efficient repair procedures (Ebeling, 2019). The relationship between reliability and availability is very close, but they have different meanings. A system can have high reliability but low availability if the repair time is long, conversely, a system with moderate reliability can have high availability if the repair process is very fast. Therefore, in a backup power supply system such as a UPS, these two parameters must be analyzed simultaneously to obtain a comprehensive picture of the system's performance (Rausand & Høyland, 2020). In television transmitter applications, the reliability and availability of a UPS system are key indicators in ensuring broadcast continuity. UPS failure can cause a power supply interruption to the transmitter, resulting in broadcast disruption and potential operational losses. Therefore, analyzing the reliability and availability of a UPS system is essential as a basis for technical decision-making, both in maintenance planning, load management, and the development of more reliable and sustainable power supply systems in the future.

Relationship between MTBF, MTTR, Availability, and Reliability MTBF

MTBF is a reliability parameter that indicates the average operating time of a system or component between failure events. MTBF is used to estimate the expected operating life before failure occurs. The higher the MTBF value, the less likely the system is to experience a failure and the more reliable the system is. In large-capacity UPS systems built for critical operations, the MTBF value is often designed very high to minimize unexpected disruptions and maintain service continuity. MTBF is often used in preventive maintenance planning and scheduling because it can predict when a component is most likely to fail, so that maintenance actions can be taken before failure occurs.

MTTR is the average time required to restore a system to normal operating conditions after a failure. A low MTTR value indicates rapid recovery, ultimately increasing system availability. In the context of a power supply system, MTTR includes the time required to identify a problem, physically repair or replace components, and retest the system until it is operational again. Efforts to reduce MTTR can be achieved through modular design, spare parts availability, technician training, and effective repair procedures. Reducing MTTR helps minimize downtime, thus increasing overall system availability.

The relationship between MTBF, MTTR, availability, and reliability is central to evaluating the performance of critical systems such as UPSs in providing backup power. In general:

1. MTBFassess how often failures occur,
2. MTTRassess how quickly the system recovers after a failure,
3. Availability combines MTBF and MTTR to indicate the proportion of time a system can operate without interruption,
4. Reliability gives the probability of the system operating without failure within a specified operating period.

Practically, in a UPS system designed for critical loads, both should be high; a high MTBF means that interruptions occur infrequently, while a low MTTR means that interruptions that do occur are handled quickly so that downtime is minimal.

UPS System Maintenance Principles

Preventive maintenance is a critical component for maintaining the reliability and availability of a UPS system. This maintenance includes battery checks, electronic component inspections, thermal management, and monitoring operating parameters to detect potential failures early. Structured maintenance can reduce the incidence of unexpected failures and extend the operational life of the device. A sound preventive maintenance strategy will help increase the MTBF value by preventing component failures, while also helping reduce the MTTR through the availability of repair resources and effective response mechanisms in the event of a disruption.

In the context of backup power supply systems such as those used in television transmission stations, reliability analysis aims to determine the level of availability and performance of UPS systems under various real-world operating conditions. This analysis technique often utilizes approaches such as reliability block diagrams (RBDs), historical failure data, Monte Carlo simulations, and statistical parameters such as MTBF, MTTR, and the probability of a specific time period of reliability. The results of the reliability analysis not only indicate the existing level of performance but also form the basis for making technical management decisions such as more effective maintenance scheduling, load

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management between UPS units, and investment considerations for upgrading backup systems to ensure operational continuity.

3. Method

This study uses a quantitative descriptive method with an analytical approach to evaluate the reliability level of the power supply system at the Sibolangit TVRI Transmitter Station. This approach was chosen because it is able to describe the actual condition of the system objectively based on numerical data and analyze system performance using measurable reliability parameters. The focus of the study is directed at the backup power supply system in the form of two Uninterruptible Power Supply (UPS) units with a capacity of 40 kVA and 250 kVA which function to maintain the continuity of power supply to television transmitter equipment. The study was conducted at the Sibolangit TVRI Transmitter Station, North Sumatra, with a data collection period lasting from January to June 2024. The research objects include the configuration of the power supply system, the operational characteristics of the UPS, and historical data on disruptions and repairs that occurred during that period.

The analysis focused on the role of the UPS as a temporary power provider during disruptions to the main electricity supply from PLN, without including a comprehensive review of the generator system or external electricity distribution network. Data collection was conducted through three main techniques: direct observation, technical documentation, and structured interviews. Direct observation was conducted to observe the physical condition of the UPS, system configuration, power distribution path, and power source switching mechanisms during power disruptions. Technical documentation included the collection of historical data on disruptions, maintenance records, UPS alarm logs, equipment technical specifications, and data on system failure and repair times. Structured interviews were conducted with technicians and operational personnel to obtain information regarding operating procedures, maintenance patterns, and technical problems that frequently arise in the UPS system.

The data used in this study consists of primary and secondary data. Primary data was obtained directly through field observations and interviews, while secondary data was obtained from internal transmitter station documents and relevant literature references. The main variables analyzed include Mean Time Between Failure (MTBF), Mean Time to Repair (MTTR), and Availability. These three parameters are used to quantitatively measure the reliability and availability of the UPS system.

Data analysis was conducted in several stages. First, the MTBF calculation was performed to determine the average UPS operating time between failures. Second, the MTTR calculation was performed to determine the average time required for the repair process until the system returns to normal operation. Third, the availability value was calculated based on the relationship between MTBF and MTTR to determine the percentage of time the UPS system was in an operational state. Furthermore, a disruption risk analysis was performed using the Failure Mode and Effect Analysis (FMEA) approach to identify critical points that could potentially cause disruptions to the power supply system.

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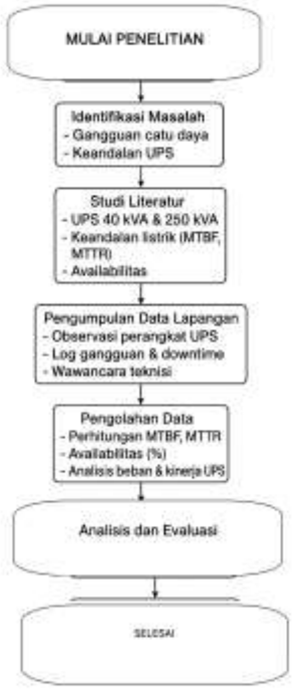

Figure 1. Flowchart System

Furthermore, a comparative analysis of the performance between a 40 kVA UPS and a 250 kVA UPS was conducted based on the MTBF, MTTR, and availability values, as well as their contribution to the continuity of power supply. The results of this analysis are used to evaluate the effectiveness of the existing power supply system and to develop technical recommendations related to improving the reliability, efficiency, and management of the UPS system. With this research method, it is expected to obtain an accurate picture of the level of reliability of the power supply system at the Sibolangit TVRI Transmitter Station as a basis for making sustainable technical decisions.

4. Analysis and Results

Overview of Power Supply System

The power supply system at the TVRI Sibolangit Transmitter Station is designed to ensure the operational continuity of critical television transmitter equipment. This system uses two Uninterruptible Power Supply (UPS) units with a capacity of 40 kVA and 250 kVA which function as backup power providers when the main electricity supply from PLN experiences a disruption. The 250 kVA UPS is used to support the main transmitter load and supporting equipment with high power, while the 40 kVA UPS is used to serve the control load, monitoring system, and supporting equipment with smaller power requirements. This configuration aims to divide the load functionally so that the risk of system failure can be minimized. Observations show that both UPS units have been integrated with the power distribution system and the automatic source switching mechanism. However, there are differences in operational characteristics between the 40 kVA UPS and the 250 kVA UPS, especially in terms of workload, frequency of disturbances, and system recovery time after a failure.

Based on historical data on outages from January to June 2024, outages in UPS systems are generally caused by several main factors, including decreased battery capacity, voltage fluctuations from the main source, and internal faults in the inverter module and cooling system.

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Table 1. UPS Specification Data

Parameter	**40 kVA UPS**	**250 kVA UPS**
Nominal Capacity	40 kVA	250 kVA
Output Voltage	380/220 V AC	380/220 V AC
UPS Types	Online Double Conversion	Online Double Conversion
Load Function	Control & monitoring system	Main transmitter & load
Battery System	VRLA Battery	VRLA Battery
Year of Operation	2018	2020

Table 2. ***40 KVA UPS Interruption Data for the Period January–June 2024***

40 kVA UPS

No	**Date**	**Types of Disorders**	**Downtime Duration (hours)**
1	01-15-2024	Low battery	2.0
2	02-02-2024	Overload	1.5
3	03-10-2024	Cooling is not optimal	2.5
4	05-04-2024	Inverter alarm	1.0
5	05-18-2024	Battery drop	3.0
Total		**5 disturbances**	**10.0 hours**

Table 3. 250 KVA UPS Interruption Data for the Period January–June 2024

250 kVA UPS

No	**Date**	**Types of Disorders**	**Downtime Duration (hours)**
1	02-20-2024	High temperature alarm	1.0
2	12-04-2024	Bypass module	1.5
3	05-30-2024	Corrective maintenance	1.5
Total		**3 disturbances**	**4.0 hours**

While disruptions do not always result in a complete blackout, they can degrade UPS performance and potentially impact the continuity of power supply to critical loads. Downtime analysis results show that the 40 kVA UPS has a relatively higher frequency of disruptions than the 250 kVA UPS. This is due to the higher load level relative to capacity and the older battery age. Meanwhile, the 250 kVA UPS demonstrates more stable performance with shorter downtime durations, supported by its load management system and larger reserve capacity.

Analysis of Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR)

The Mean Time Between Failure (MTBF) calculation is based on the total operating time divided by the number of failures that occurred during the study period. The analysis results show that the MTBF value of the 250 kVA UPS is higher than the 40 kVA UPS, which indicates that the 250 kVA UPS has a better level of reliability and rarely experiences failures. The lower MTBF value of the 40 kVA UPS indicates that this unit experiences more frequent disturbances, both minor and those requiring repair action. This condition is influenced by the age of the components, operational loads that are close to nominal capacity, and higher intensity of use in the control and monitoring system that operates continuously.

Mean Time To Repair (MTTR) analysis was conducted to determine the average time required for the repair process until the UPS system returns to normal operation. The calculation results show that the MTTR of the 250 kVA UPS is relatively lower than that of the 40 kVA UPS. This is due to the availability of modular modules, easy component access, and higher handling priority because the 250 kVA UPS serves the main transmitter load. Conversely, the 40 kVA UPS has a higher MTTR value, especially when the disruption is related to battery replacement or supporting components that require procurement time. Longer repair times directly impact the decrease in system availability.

Table 4. Reliability Calculation Data

MTBF (Mean Time Between Failure)				*MTTR (Mean Time To Repair)*			
UPS	**Total Operations (hours)**	**Number of Disturbances**	**MTBF (hours)**	**UPS**	**Total Downtime (hours)**	**Number of Disturbances**	**MTTR (hours)**
40 kVA	4320	5	864	40 kVA	10.0	5	2.0
250 kVA	4320	3	1440	250 kVA	4.0	3	1.33

System Availability Analysis

Availability values are calculated based on the relationship between MTBF and MTTR for each UPS unit. The analysis results show that the 250 kVA UPS has a higher level of availability than the 40 kVA UPS. The high availability value for the 250 kVA UPS indicates that the system is capable of operating in a ready-to-use condition for most of the time during the study period.

The 40 kVA UPS has a lower availability level due to a combination of more frequent outages and relatively longer repair times. Despite this, the availability of both UPS units remains acceptable for a backup power system, but improvements are still needed to ensure optimal broadcast continuity.

Table 5. Availability

UPS	MTBF (hours)	MTTR (hours)	Availability (%)
40 kVA	864	2.0	99.77%
250 kVA	1440	1.33	99.91%

Table 6. Risk Identification Data (FMEA – Summary)

Component	Failure Mode	Impact	Risk Level
Battery	Decreased capacity	Reduced backup time	Tall
Inverter	Overload	UPS trip	Currently
Cooler	High temperature	Component degradation	Tall
Control system	Alarm error	Monitoring is interrupted	Low

Disruption Risk Analysis Using FMEA

A failure risk analysis was conducted using the Failure Mode and Effect Analysis (FMEA) method to identify the failure modes that most impact UPS system performance. The analysis results indicate that battery failure, cooling system failure, and load imbalance are the failure modes with the highest risk levels. Battery failure has a significant impact because it directly reduces UPS backup time during a power outage. A disruption in the cooling system can cause an increase in the internal temperature of the UPS, potentially accelerating component degradation. Meanwhile, load imbalance can reduce system efficiency and increase the risk of inverter failure.

Based on the analysis results, it can be concluded that the 250 kVA UPS has a better level of reliability and availability than the 40 kVA UPS. This indicates that larger capacity, better load management, and a more modern system contribute to improving the performance of the power supply system. However, the presence of the 40 kVA UPS still plays an important role in supporting the control and monitoring system.

The results of this study indicate that improving the reliability of the power supply system can be achieved through more balanced load management, scheduled battery replacement, cooling system improvements, and more consistent implementation of preventive maintenance. By implementing these recommendations, it is hoped that the operational continuity of the TVRI Sibolangit Transmitter Station can be optimally maintained and the risk of broadcast disruption can be minimized.

5. Conclusion

Based on the reliability analysis of the power supply system at the TVRI Transmitter Station Sibolangit, the use of Uninterruptible Power Supply (UPS) units with capacities of 40 kVA and 250 kVA plays a crucial role in maintaining continuous and stable electrical power for broadcasting operations. The UPS systems function as backup power sources that ensure uninterrupted operation of critical transmitter equipment during disturbances such as voltage drops, fluctuations, or temporary outages from the main utility supply. The analysis indicates that the 40 kVA UPS is generally utilized to support supporting and control equipment with lower power demand, while the 250 kVA UPS is responsible for supplying higher-capacity loads, particularly the main transmitter system. The combination of these UPS capacities improves system reliability by providing redundancy and ensuring that essential components remain operational during power interruptions. Furthermore, the reliability evaluation demonstrates that the integration of appropriately sized UPS units significantly reduces the risk of downtime, prevents broadcast signal disruption, and protects sensitive electronic equipment from potential damage caused by unstable voltage conditions. Proper load distribution between the 40 kVA and 250 kVA UPS units also contributes to optimal performance, improved efficiency, and extended equipment lifespan. In conclusion, the implementation of UPS 40 kVA and 250 kVA at the TVRI Transmitter Station Sibolangit enhances the reliability and continuity of the power supply system. Regular maintenance, periodic load testing, and monitoring of UPS performance are recommended to ensure consistent operation, minimize system failure risk, and maintain the stability of broadcasting services.

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