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ELECTRICAL NETWORK PROTECTION SYSTEM ON THE CILEGON-CIBINONG CONDUCTOR USING A DEFENSE SCHEME WITH OVER GENERATION SHEDDING (OGS) AT PT PLN (PERSERO) UIP2B JAMALI

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Abstract
A Defense Scheme is a protection mechanism designed to normalize the frequency by reducing load or generation. It serves as a safeguard for electrical facilities, access control for system management, routine maintenance to ensure the security and reliability of power system operations, and even as a pre-planned crisis management tool to address emergencies and disturbances in the electrical system. Several types of defense schemes are employed to address or prevent overload shedding (OLS) and Oover generation shedding (OGS). With the rapid advancements in technology, particularly in the industrial sector, innovative solutions have become increasingly sophisticated. One example is the maintenance system for power plants, which can be optimized through the creation of an operational plan (RENOP) aimed at enhancing efficiency and performance. This includes analyzing the design of electrical network protection systems using the Defense Scheme for over generation shedding (OGS).

Keywords:
Force measurement; uncertainty; weighted least squares (WLS); biomimetics; robotics

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1. Introduction

With the rapid advancements in future technologies, the role of higher education institutions in Indonesia becomes increasingly significant. The Electrical Engineering Study Program at Universitas Pertamina plays a critical role in contributing to technological progress by equipping students with both theoretical knowledge and practical skills. These competencies are fundamental for students as they prepare for the demands of the professional world. To this end, the program emphasizes the importance of practical training, where students gain real-world work experience, reinforce their skills and knowledge in areas relevant to their field of study, expand professional networks, and prepare themselves to enter the workforce after graduation.

The current technological advancements, particularly in the industrial sector, have reached unprecedented levels of sophistication. As one of the key players in the energy industry, PT PLN (Persero) Unit Induk Pusat Pengatur Beban Jawa, Madura, Bali (UIP2B JAMALI) is pivotal in the operation and maintenance of power plants and load control systems. These systems are essential for supporting industrial activities and ensuring the reliability of energy supply. One of the strategic approaches to optimizing the maintenance and performance of power plants is through the development of an Operational Plan (RENOP). This plan aims to enhance efficiency and performance by analyzing the design of electrical network protection systems, specifically employing the Defense Scheme Over Generation Shedding (OGS).

A Defense Scheme is a protection mechanism activated during abnormal operating conditions in the power system that can lead to frequency deviations. This scheme is designed to restore frequency stability by either reducing load or generation. It serves multiple functions, including safeguarding electrical facilities, controlling system access, ensuring operational security through routine maintenance, and implementing pre-planned crisis management to handle emergencies and disturbances in the power system.

Defense Schemes are tailored to the specific topology and conditions of the power system. Two notable types are Overload Shedding (OLS) and Over Generation Shedding (OGS). OLS is utilized to alleviate excessive load conditions, while OGS addresses scenarios where generation surpasses demand. By employing these schemes, power system operators can ensure the stability and reliability of the grid, which is essential for the smooth operation of modern industries.

In the context of the industrial revolution and the growing reliance on renewable energy, the application of Defense Schemes is increasingly critical. Research has shown that adopting advanced defense mechanisms significantly enhances grid resilience and minimizes the risk of outages during abnormal conditions. For instance, a study by Chen et al. (2023) highlights the effectiveness of OGS in managing renewable energy intermittency. Similarly, Smith et al. (2022) emphasize the role of RENOP in improving power plant efficiency and reliability. These findings underscore the importance of integrating advanced protection schemes, such as OGS, into the operation and maintenance of power systems.

Through practical training opportunities at institutions like PT PLN (Persero) UIP2B JAMALI, students at Universitas Pertamina are exposed to real-world challenges and solutions in the field of electrical engineering. This experience not only enhances their technical skills but also prepares them to contribute meaningfully to the development and implementation of cutting-edge technologies in the energy sector.

2. Method

A. Planning and Implementation of the Defense Scheme

The steps involved in the planning and implementation of the Defense Scheme are as follows:

a. **Proposal and Review of Defense Scheme Scenarios**
The operational system function proposes new Defense Scheme scenarios or reviews existing scenarios due to changes in system parameters, the addition of new installations, or unanticipated disturbances that are not covered by the existing Defense Scheme.

b. **Coordination with UP2B**
The operational system function at the central unit coordinates with UP2B to conduct a study of the Defense Scheme. The output of this process is a recommendation for the Defense Scheme scenario.

c. **Discussion and Consensus Building**
Discussions are held with the operational system function, transmission, distribution, generation, regional, and project functions regarding the recommended Defense Scheme scenario. The output is a meeting record containing the agreed-upon Defense Scheme scenario for implementation.

d. **Engineering Design**
The operational system function designs the engineering aspects of system protection equipment for the Defense Scheme in coordination with the installation owners (transmission/distribution/generation). The output is an approval drawing document from the installation owner.

e. **Protection System Coordination**
Settings and coordination of system protection equipment are discussed among the operational system function and installation owners.

f. **Installation and Commissioning**
The operational system function installs and commissions the Defense Scheme with assistance from the installation owner.

g. **Documentation and Reporting**
The operational system function issues a report on the installation and commissioning of the Defense Scheme scenario, signed by both the operational system function and the installation owner. The implemented Defense Scheme is documented in a Defense Scheme manual.

B. Evaluation of Defense Scheme Performance

The steps for evaluating the Defense Scheme performance are as follows:

a. **Detection of System Disturbances**
The operational system function detects system disturbances that activate the Defense Scheme.

b. **Performance Records and Reports**
The operational system function at the central unit and UP2B records the Defense Scheme performance during disturbances. UP2B submits disturbance and performance reports to the central unit.

c. **Performance Evaluation**

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The central unit evaluates the Defense Scheme performance to ensure 100% effectiveness. If the Defense Scheme operates successfully, an assessment is conducted to verify alignment with targets or load quota realization.

d. Investigation of Malfunctions

If the Defense Scheme does not achieve 100% effectiveness, the operational system function and the installation owner jointly investigate malfunctioning equipment.

e. Recommissioning

Post-investigation, the malfunctioning Defense Scheme equipment undergoes recommissioning and reevaluation to ensure performance.

f. Final Reporting

The operational system function issues a recommissioning report for the Defense Scheme scenario, signed by the operational system function and the installation owner.

C. Over Generation Shedding (OGS)

Over Generation Shedding (OGS) is a generation-limiting scheme implemented through relays to manage or secure current flow into equipment, ensuring it does not exceed line protection limits by tripping generators or opening circuit breakers (PMTs). Power systems often face unavoidable disturbances, such as sudden trips on feeders due to overloading or natural disruptions causing conductor breaks. The input for OGS activation is typically the current [7]. OGS aims to reduce power flow in overloaded transmission lines, inter-bus transformers (IBTs), or transformers by tripping generators. It is a type of Defense Scheme designed to prevent overloads or blackouts in electrical systems. In recent studies, OGS has proven effective in mitigating the risks of overloads and blackouts in power systems. According to Chen et al. (2023), implementing advanced Defense Schemes like OGS enhances grid stability and reduces operational risks. Furthermore, Smith et al. (2022) emphasized the importance of coordination among operational functions to ensure the effective deployment of OGS in modern power systems. The integration of OGS also aligns with the increasing complexity of renewable energy systems. For example, Zhang et al. (2021) demonstrated that OGS significantly improves the reliability of transmission networks under high renewable penetration. These findings underscore the importance of adopting systematic approaches to Defense Scheme planning and evaluation.

3. Result and Discussion

A. Power System

In general, an electrical power system consists of three main components: power generation, power transmission, and power distribution. A modern power system is a complex network comprising power generation plants, transmission lines, and distribution networks. These components work together to deliver electricity from generation centers to load centers [1]. To achieve the operational objectives of an electrical power system, the generation, transmission, and distribution components must function as an integrated unit, as illustrated in Figure 2 below.

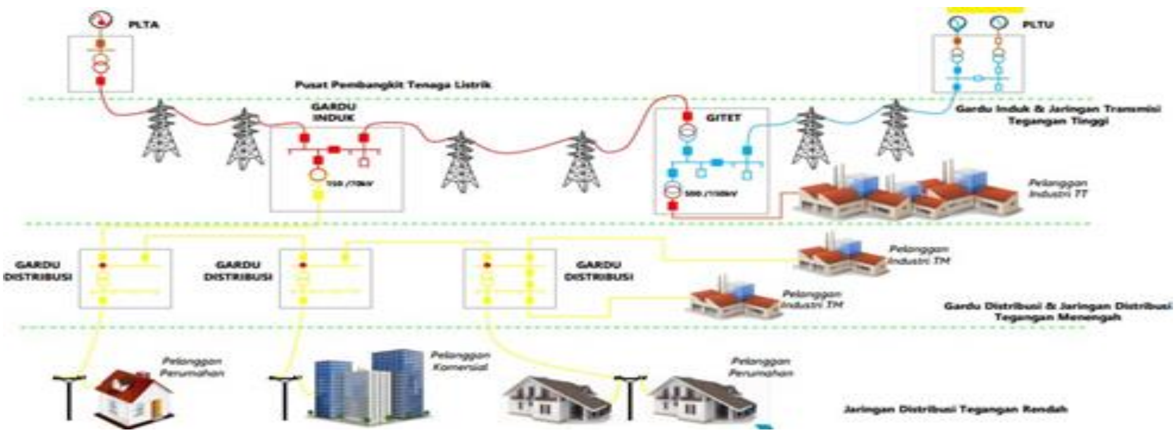

Figure 1. Power System Grid

Electrical power systems are critical for ensuring the reliable and efficient delivery of electricity to meet societal demands. The three primary components are interconnected and must work seamlessly to achieve optimal performance:

a. **Power Generation**
The generation component is responsible for producing electricity. This is typically achieved using various energy sources, such as fossil fuels, nuclear energy, or renewable resources like wind, solar, and hydropower. Power plants are strategically located based on resource availability, economic considerations, and proximity to major load centers.
b. **Power Transmission**
Transmission systems transport electricity over long distances from power generation plants to substations near load centers. This is achieved using high-voltage transmission lines to minimize power losses. Transmission networks often include interconnected systems that enhance reliability and enable efficient energy exchange between regions.
c. **Power Distribution**
The distribution system delivers electricity from substations to end users. This component involves medium- and low-voltage networks designed to meet the specific requirements of residential, commercial, and industrial customers. Distribution systems often employ smart technologies to enhance monitoring, control, and reliability.

B. Modern Power System Challenges

Modern electrical power systems face several challenges due to increasing demand, the integration of renewable energy sources, and the complexity of maintaining stability and reliability. Some of these challenges include:

1. **Renewable Energy Integration**: The variability of renewable energy sources such as wind and solar requires advanced grid management techniques to ensure consistent power delivery [2].
2. **Grid Stability**: Maintaining frequency and voltage stability is critical, especially with the increasing use of distributed energy resources (DERs) [3].
3. **Aging Infrastructure**: Many power systems operate with aging equipment, which necessitates upgrades to maintain efficiency and reliability [4].

C. Importance of Integration

The seamless integration of generation, transmission, and distribution is essential for a resilient and sustainable power system. For example, advancements in smart grid technology allow for real-time monitoring and control, enabling better coordination across all components. Additionally, the adoption of advanced protection schemes, such as Defense Schemes discussed earlier, further enhances system reliability by mitigating risks associated with overloads and faults.

To achieve the objectives of electrical power system operations, three main aspects must be considered: economics, reliability, and quality. However, the prioritization of these aspects can vary depending on real-time conditins. In the event of disturbances, security becomes the primary priority, while quality and economic factors take a backseat. When security and quality are stable (normal conditions), economic considerations should take precedence. This dynamic prioritization ensures the effective and reliable operation of the power system under varying circumstances.

D. Key Operational Conditions

The operation of a power system involves different states, which are categorized as follows:

1. **Normal Condition**
   - All consumers are served without interruptions.
   - Operational constraints are resolved.
   - System security requirements are met.
2. **Alert Condition (Siaga)**
   - All consumers are still served without interruptions.
   - Operational constraints are managed, but system security is compromised.
   - This condition may indicate the system is at risk, requiring immediate attention to avoid further degradation.
3. **Emergency Condition**

- Some or all consumers cannot be served due to system failures.
- Operational constraints are not met, leading to a potential risk of blackouts or cascading failures.
- Emergency actions, such as load shedding or isolating faulted sections, are necessary to prevent total system collapse.

4. **Recovery Condition**
   - This is a transitional phase from an emergency state back to normal operation.
   - Voltage and frequency are closely monitored and maintained within specified ranges to ensure stability during recovery.
   - The operational conditions of a power system are illustrated in Figure 3, which visually represents the transitions and priorities during these states.

E. Real-Time Prioritization and Challenges

The prioritization of objectives in a power system highlights the complexity of real-time operation and control. These priorities must adapt to changing conditions to maintain system stability and service continuity. Below is a detailed explanation of how each priority functions under specific conditions:

1. **Economics**
   - Economic operation involves optimizing generation and transmission costs while maintaining efficiency.
   - Under normal conditions, operational strategies prioritize minimizing production costs and transmission losses, often using economic dispatch and unit commitment methods.
2. **Reliability**
   - Reliability ensures uninterrupted power supply to consumers.
   - This includes planning for contingencies, maintaining redundancy in transmission paths, and ensuring rapid response to faults or disturbances.
3. **Quality**
   - Power quality pertains to maintaining voltage and frequency within acceptable ranges.
   - Poor power quality can result in equipment damage, reduced efficiency, or consumer dissatisfaction.

F. Practical Considerations in Operational Conditions

a. **In Normal Conditions**
Economic optimization tools, such as optimal power flow (OPF), are employed to achieve cost-effective operation while maintaining quality and reliability.

b. **In Alert Conditions**
Operators must identify risks and take preventive measures, such as reconfiguring the network or redistributing loads, to prevent escalation into an emergency.

c. **In Emergency Conditions**
Immediate corrective actions, including load shedding or activating Defense Schemes (e.g., Over Generation Shedding), are required to stabilize the system and prevent widespread outages.

d. **In Recovery Conditions**
Coordination among generations, transmission, and distribution is critical to restoring normal operation. System operators may prioritize reconnecting critical loads and gradually restoring service to other areas.

e. **Importance of System Security**
System security is a cornerstone of power system operation, especially during disturbances. It involves real-time monitoring, dynamic reconfiguration, and deploying protection mechanisms to mitigate risks. Advanced tools, such as supervisory control and data acquisition (SCADA) systems, enable operators to respond quickly and maintain stability.

G. OGS Scheme on the Cilegon-Cibinong Transmission Line Using DigSilent

The Cilegon-Cibinong Transmission Line is a high-voltage transmission network project connecting Cilegon in Banten with Cibinong in West Java, Indonesia. This project aims to enhance the reliability of electricity supply and strengthen interconnections between electrical systems across Java. Spanning approximately 130 kilometers and operating at 500 kV, this transmission line is a critical component of the region's power infrastructure [3]. Over Generation Shedding (OGS) is an automated regulation system in power networks used to prevent overvoltage and overfrequency conditions caused by excess power generation that surpasses system demand. For high-voltage transmission lines like the Cilegon-Cibinong line, implementing an OGS scheme ensures the stability

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of the power system under varying operational conditions. The OGS scheme for the Cilegon-Cibinong transmission line can be analyzed using DigSilent, a powerful simulation tool for power system analysis. By incorporating the system's parameters and the OGS scheme into the simulation, DigSilent enables the evaluation of OGS performance under various operating conditions. The main objectives of the DigSilent simulation are to assess the effectiveness of the OGS scheme in mitigating overvoltage and over frequency issues, to evaluate the performance of the power system during peak load conditions and disturbances, to identify potential improvements to the system's reliability and security.

The schematic representation of the Cilegon-Cibinong transmission line in DigSilent is illustrated in Figure 4.

Figure 2. Cilegon – Cibinong Feeder Model

From the schematic representation of the Cilegon-Cibinong Extra High Voltage Transmission Line 1 (SUTET Cilegon-Cibinong 1), the results for daytime peak load (BP) during workdays and the secured equipment are summarized as follows:

a. Key Observations from Table 1: Daytime Peak Load Conditions

1. Peak Load Analysis:
    - The daytime peak load represents the maximum electrical demand on the transmission line during regular workday hours.
    - This analysis identifies the stress on the transmission line under typical operational conditions, particularly during high-demand periods.
2. Secured Equipment:
    - Specific equipment along the transmission line is evaluated for its ability to operate within safe limits under peak load conditions.
    - Protective measures, such as Over Generation Shedding (OGS), are implemented to ensure that critical components are safeguarded against potential overloads or failures.

b. Importance of Peak Load Analysis and Equipment Security

Analyzing peak load conditions is critical for understanding the operational performance of high-voltage transmission lines and ensuring the stability and reliability of the power system. Below are the key points elaborated:

1. Peak Load Conditions:
    - During peak load periods, the transmission line is subjected to its highest capacity utilization, making it essential to evaluate its operational performance.
    - Factors such as increased power demand, temperature effects on conductors, and potential bottlenecks in power flow are assessed to ensure the line can handle these conditions.
2. Secured Equipment:

  - Equipment security refers to ensuring that transformers, circuit breakers, protection relays, and other critical components are not exposed to conditions that could lead to failures.
  - The OGS scheme plays a vital role in maintaining equipment security by automatically shedding excess generation or diverting loads to prevent overvoltage and overfrequency conditions.

3. Use of Over Generation Shedding (OGS):
  - OGS is particularly significant during peak load conditions as it helps prevent system instability caused by excess generation.
  - By dynamically balancing the power flow, OGS ensures that all equipment operates within its designed specifications, thereby prolonging the lifespan of system components.

4. Impact on System Reliability:
  - Ensuring the security of equipment under peak load conditions minimizes the risk of cascading failures and outages.
  - A well-functioning OGS scheme improves the overall reliability of the transmission system and supports uninterrupted power delivery to consumers.

c. Application of Data in System Planning and Operations

The results of peak load analysis and equipment security measures serve multiple purposes in system planning and operations:

- Operational Planning: Real-time data on peak load conditions inform operational decisions, such as dispatching generation units or rerouting power flows to avoid overloading specific lines.
- Preventive Maintenance: Identifying equipment at risk during peak load conditions allows for targeted maintenance schedules, reducing the likelihood of unplanned outages.
- System Expansion: Insights from peak load studies guide infrastructure expansion projects, such as upgrading transmission capacity or adding redundancy to improve system resilience.

Future Directions

- Dynamic Load Monitoring: Advanced monitoring tools, such as synchrophasors, can provide real-time insights into load variations and equipment performance under dynamic conditions.
- Integration with Smart Grids: Incorporating smart grid technologies, such as demand response and distributed generation, can alleviate peak load stress on transmission lines.
- Enhanced Simulation Studies: Using sophisticated simulation tools like DigSilent, operators can model various peak load scenarios and their impact on system stability and reliability.

Table 1. Daytime Peak Load Condition of SUTET Cilegon-Cibinong 1

Loading and Voltage							
Normal Condition				N-2 Maintenance Trip of the SUTET Depok-Gandul 2 Circuits			
SUTET	MW	%	kA	SUTET	MW	%	kA
DEPOK-CIBNG 1	729	42	0.840	DEPOK - CIBNG 1	26	4	0.063
DEPOK-CIBNG 2	729	42	0.840	DEPOK - CIBNG 2	26	4	0.063
DEPOK-GNDUL 1	702	41	0.809	DEPOK - GNDUL 1	0	0	0
DEPOK-GNDUL 2	702	41	0.809	DEPOK - GNDUL 2	0	0	0
JAWA7-BLRJA 2A	982	45	1.128	JAWA7 - BLRJA 2A	698	32	0.799
JAWA7-BLRJA 1A	982	45	1.128	JAWA7 - BLRJA 1A	698	32	0.799
SRLYA-BLRJA 1	1129	33	1.298	SRLYA - BLRJA 1	707	20	0.816

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SRLYA-BLRJA 2	1129	33	1.297	SRLYA - BLRJA 2	707	20	0.815
SRLYA-CLBRU 1	937	55	1.087	SRLYA - CLBRU 1	1649	97	1.938
SRLYA-CLBRU 2	937	55	1.087	SRLYA - CLBRU 2	1649	97	1.938
CLBRU-CIBNG	915	44	1.065	CLBRU-CIBNG	2272	114	2.732
CIBNG-TAMBUN 1	872	51	1.005	CIBNG - TAMBUN 1	843	51	1.004
CIBNG-TAMBUN 2	870	51	1.006	CIBNG - TAMBUN 2	841	51	1.006
Loading and Voltage							
Normal Condition				N-2 Maintenance Trip of the SUTET Depok-Gandul 2 Circuits			
Voltage KV	KV	%	kA	Voltage KV	kV	ΔV	kA
LESTARI BANTEN ENERGI7	505			LESTARI BANTEN ENERGI7	505	0	
SURALAYA BARU7	505			SURALAYA BARU7	505	0	
SURALAYA LAMA7	505			SURALAYA LAMA7	505	0	
NEWBALARAJA7	502			NEWBALARAJA7	505	-3	
CILEGONBARU7	503			CILEGONBARU7	501	2	
JAWA7	505			JAWA7	506	-1	
GORDA	145			GORDA	144	1	
PUNCAK ARDI MULYA	145			PUNCAK ARDI MULYA	144	1	
IBT	KV			IBT	kV		
IBT1_1SRLYA75	117			IBT1_1SRLYA75	117		
IBT2_1SRLYA75	111			IBT2_1SRLYA75	112		
IBT1_1CLBRU75	297			IBT1_1CLBRU75	297		
IBT2_1CLBRU75	297			IBT2_1CLBRU75	297		
IBT3_1CLBRU75	349			IBT3_1CLBRU75	349		
IBT1_1BRAJA75	261			IBT1_1BRAJA75	244		
IBT2_1BRAJA75	261			IBT2_1BRAJA75	244		
IBT3_1BRAJA75	193			IBT3_1BRAJA75	180		
IBT4_1BRAJA75	193			IBT4_1BRAJA75	180		
IBT1_1DEPOK75	74			IBT1_1DEPOK75	91		
IBT2_1DEPOK75	49			IBT2_1DEPOK75	62		
Generators	MW	Mvar		Generators	MW	Mvar	
PLTU SURALAYA 1-8	3752	655		PLTU SURALAYA 1-8	3752	780	
PLTU LBE	625	106		PLTU LBE	625	127	
PLTGU CILEGON	196	59		PLTGU CILEGON	196	59	
PLTU LABUAN	227	68		PLTU LABUAN	227	68	
PLTU LONTAR 1,2,3	726	138		PLTU LONTAR 1,2,3	726	136	
PLTU JAWA 7	1982	337		PLTU JAWA 7	1982	403	
Total PLTU Suralaya 1-8+LBE+Jawa 7	6359			Total PLTU Suralaya 1-8+LBE+Jawa 7	6359		

Based on the peak load and voltage data of the SUTET Cilegon-Cibinong 1 during daytime maintenance conditions, when SUTET Depok-Gandul 2 circuits are tripped, the CLBRU-CIBNG generator experiences an overload in both power and current. In normal conditions, the SUTET Cilegon-Cibinong transmission line delivers a power output of 915 MW with a current level of 1.065 kA. While during the maintenance trip of both Depok-Gandul circuits (N-2) on workdays, the load on the Cilegon-Cibinong transmission line increases significantly. The generated power and current rise to 2,272 MW and 2.732 kA, respectively, representing an increase of 114% from the baseline. The generator shifts from operating at 44% of its capacity under normal conditions to handling an additional 114% load, risking thermal stress, reduced efficiency, and potential damage to system components.

4. Conclusion

Over Generation Shedding (OGS) is an automated or manual action (though manual actions are rarely used) to cut the electricity supply from power plants when there is an oversupply in the power system. OGS is typically implemented when the oversupply cannot be managed through other measures, such as increasing electricity demand by adding generation units or enhancing the capacity of the transmission network. OGS is commonly carried out to avoid power outages (total blackout), which can result in significant economic and social losses.

The use of the Defense Scheme Over Generation Shedding (OGS) is one of the options in power system protection that helps prevent system damage that could lead to network disturbances. Additionally, OGS can minimize the impact of damage on the system and accelerate system recovery in the event of a disturbance. However, OGS can also cause inconvenience for customers who experience unexpected power outages due to the sudden interruption of electricity supply.

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