

	<b>The Board of Audit and Inspection of Korea</b>	
	<b>Fair Audit Fair Society</b>	

## Audit Report on Safety Management of Power Supply Facilities

Disclosed on January 9, 2020

### I. Audit Background

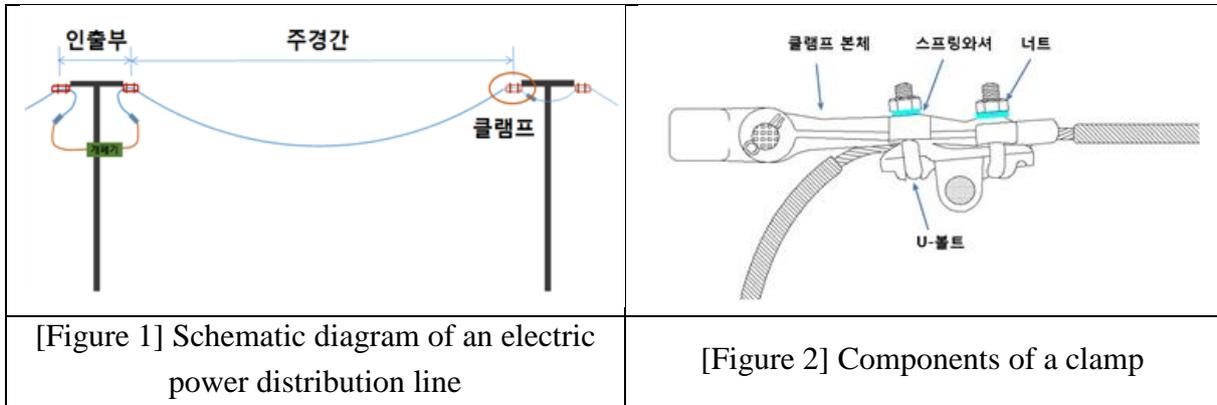
- The Board of Audit and Inspection (BAI) conducted audit on three agencies, including Korea Electric Power Corporation (hereafter referred to as “KEPCO”) from June 17 to July 26, 2019, and enforced the audit findings of 53 cases.
- Electric utilities of Korea achieves a high-level of power supply efficiency. They distribute the electricity generated in large-scale power generation facilities to major cities or metropolitan areas and ensure a high quality of power delivery to end-users (homes, factories, etc.) at cheap rates.
- However, as power supply facilities become larger and more complex, the possibilities of people and property incurring severe damages from massive fires or large-scale power outages also increases.
  - Therefore, it is necessary to detect and improve vulnerabilities, not only in core power facilities, but in power facilities that have been disregarded or deemed less important, as well.
- The BAI conducted this audit in order to address factors threatening the safety of people and to search for improvements by inspecting the current status of safety management at power supply facilities.

## II. Major Audit Findings

### ■ Safety of Power Supply Facilities

#### ① Improper Construction, Maintenance, and Management of Distribution Lines

- From 1972 to present day, KEPCO has been using bolted type dead-end tension clamps (hereafter referred to as “clamps”) for installing wires on electric poles.



인출부: Electrical power-takeoff    주경간: Span length    클램프: Clamp

클램프 본체: Clamp body    스프링와셔: Spring washers    너트: Nuts    U-볼트: U-bolts

- A clamp equipped with two U-bolts and four nuts enables a presser foot to securely hold the wire.
  - Spring washers should be installed between the bolt and the nut to prevent the nuts from loosening over time.
  - Installing a clamp without the necessary nuts or spring washers can reduce its retention force, disabling the clamp from isolating the transmitted vibration to it and, in the long run, causing the wires to break.
- Though KEPCO stated in its guidelines ("Distribution Line Inspection Guidelines") that defective clamps should be inspected, it has not included any details on how to inspect and check the overall condition of the clamps.
  - It was found that KEPCO workers failed to properly check to see if the clamps had been correctly installed.
- During the audit period, the BAI analyzed photos taken by KEPCO Sokcho

branch during the Distribution Line Special Inspection conducted from April to May 2019.

- KEPCO failed to recognize that there were at least 16 electric poles with clamps that were defective due to missing spring washers or nuts, and as such, the clamps were neglected and left unfixed.
- In September 2019, the BAI conducted an additional inspection on eight out of 16 randomly selected electric poles. All eight electric poles were found to have problems with faulty clamp installation.

A case where a clamp was left unattended with a nut and two spring washers missing (found during the inspection conducted in May 2019)

	
<p>Special inspection conducted by KEPCO (May 15, 2019)</p>	<p>Audit conducted by BAI (September 9, 2019)</p>

- The BAI gathered nine randomly selected clamps that have been used for cable installation and requested a retention force (a cable holding force) measurement test<sup>1</sup> from the Korea Electrotechnology Research Institute (KERI).
- KEPCO was not aware of the defective clamps, where their clamping force falls significantly short of the fiducial value. The retentive force of a seemingly normal clamp equipped with spring washers and nuts was at a mere 35.5 to 79.6% of the fiducial value, while that of a clamp missing one spring washer was at only 31.8% of the fiducial value.
- The BAI requested an analysis from the Korean Society of Steel Construction (KSSC) on the effects that insufficient retention force of a clamp can have on

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<sup>1</sup> KERI could not measure the retention force of five out of nine clamps, as the cables near a locking device of a testing machine were broken during the test. The following are the results of the remaining four clamps.

the safety of distribution lines.

- The KSSC suggested<sup>2</sup> that if the retention force is lower than a certain level (due to incorrect installation or poor maintenance/management), this will result in the delivery of unexpected forces and vibrations, which will lead to wires breaking from fretting fatigue.

**Audit Result: Request for Warning**

The BAI recommended the CEO of KEPCO to inspect the retention force of the installed bolted type dead-end tension clamps and their fastening condition, and to replace or repair clamps that are faulty. For the distribution lines, the BAI requested KEPCO to pay meticulous attention to their construction, maintenance, and management in the future.

**② Inadequate Preventive Measures for Distribution Line-related Accidents During Forest Fire Danger Period**

- KEPCO established and operated reclosing devices (hereafter referred to as “reclosers”) to prevent temporary faults caused by bird contact with power lines from resulting in unnecessary power outages.
- If a fault on a distribution line blocks the flow of electricity, a recloser repeats the reclosing cycle up to three times at a fixed time interval, regardless of the cause of the fault.
- In the case of temporary faults caused by contact with foreign objects (birds, vegetation, etc.), reclosers help to avoid preventable power outages and increase power supply stability.
- If a recloser operates when a permanent fault (such as broken wire) occurs, this may cause an additional arc flash<sup>3</sup>, which can start fires or electric shock

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<sup>2</sup> In Korea, the domestic electric power distribution facilities are designed and constructed to withstand wind speeds of between 32-47 m/s. In this regard, the KSSC proposed the possibility of consequent fatigue damage upon the exposure of the clamps (whose retention force is less than 43% of the fiducial value) to strong winds of 32 m/s and above.

<sup>3</sup> Electric arc: an intense flash of light and heat produced by an electric discharge between two air-exposed electrodes.

accidents.

- The electric utility of Australia and the United States are preparing and implementing measures, such as halting the operation of reclosers during the dry season, as they experienced great forest fires caused by failures from power facilities.
- o KEPCO also prepared and implemented measures for forest fire prevention, such as disabling reclosers, in the wake of the fire on Cheongdae Mountain in Sokcho, which was caused by broken high-tension electrical power wires in March 2004.
- Since 2005, KEPCO ordered its regional headquarters to disable reclosing devices when the Forest Fire Danger Index (FFDI) issued by Korea Forest Service exceeds 81.
- o In the past three years, from January 2016 to December 2018, the FFDI of 37,657 cases of KEPCO's regional offices nationwide recorded 81 or higher. However, only 1,143 (3%) among these cases were reported to halt their reclosing operations.
- Since even these cases were for the purposes of power distribution construction, it is difficult to deem that the deactivation of these reclosers were a part of the measures to prevent wildfires.
- The regional headquarters of KEPCO were operating reclosers at all times on the grounds that disabling them would increase the risk of power outages.
- o In February 2018, the power distribution management department of KEPCO headquarters discarded the FFDI-based standards on the operation of distribution lines, which have been applied since 2005, stating that the workers had difficulty keeping to the standards and that the standards have become obsolete. In this process, the department did not discuss nor report on the need, the possibilities for on-site applicability, or the supplementary measures for the standards.
- In discarding the FFDI-based standards, KEPCO headquarters strictly prohibited forced line charging (manually operating power transmission after the recloser exhausts its retries).
- The BAI found that, from 2018 to June 2019, operators of KEPCO failed to conform to the standards for recloser operations even when the standards for

them had been eased. Eleven regional headquarters of KEPCO conducted forced line charging a total of 339 times, with 101 of the cases being conducted by Gwangju-Jeonnam headquarters.

- As part of its forest fire prevention measures after the Goseong Fire of 2019, KEPCO ordered its regional headquarters to maintain their halt on reclosers located in mountain ranges and to disable the reclosing function of reclosers located near mountain ranges that are under drought advisory or high wind warnings. However, in practice, the judgment for determining whether to stop reclosers was left to each of the regional headquarters with no differentiation or regard for the power lines going through mountains.
- Regional headquarters did not include certain power line reclosers that go through the mountains into the list of those that should be halted, citing reasons of “high number of power outage-sensitive customers,” “recreational use of land,” etc.
- Regional headquarters continued not to fully comply with safety management guidelines even for their own self-selected power line reclosers that go through mountains, showing only a 55.9% implementation rate in maintaining the halt.
- As such, the BAI could infer that the following are the reasons why the regional offices of KEPCO did not stop the operation of reclosers during the days that were at high risk for forest fires:
  - From 2016 to 2018, there were only 2.3 days a year (on average) when the FFDI exceeded 81, and even if the operators stopped the reclosing devices during this period, the increased number of power outages would be at a mere 44.6 per year, which is 2.7% of the annual average number of power outages. It implies that the risk of power outages was not a decisive factor in the failure to observe the prescribed order.
  - KEPCO’s workers not disabling the reclosers in operation seemed to be affected by KEPCO’s annual goal being the reduction in the duration of power outages, and evaluation points<sup>4</sup> being given to each regional office based on

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<sup>4</sup> Performance indicators for distribution area: power outage prevention (7 points), facility management (6 points), construction and management of distribution (8 points), and management of distribution information (6 points)

the length of power outages of each region.<sup>5</sup>

### **Audit Result: Request for Warning**

The BAI requested the CEO of KEPCO to promote the quick establishment of recloser operation guidelines for high-risk days for wildfires and to ensure smooth implementation of the guidelines by delivering specific, effective and detailed operational plans. The BAI also notified the CEO to prepare an evaluation system to strengthen the safety management of power supply facilities and requested warnings for the operators who exercised discretion in discarding the FFDI-based standards for operation of distribution lines.

## **■ Stability of Power Supply Facilities**

### **① Inadequate Preventive Measures for Large-scale Power Outages in a Wide-ranging Area**

- To enhance the stability of the electric power system, the Korea Power Exchange (hereafter referred to as “KPX”) operates and manages electric power systems, in accordance with the “Electric Utility Act,” using the Energy Management System (hereafter referred to as “EMS”<sup>6</sup>), which is equipped with functions of remote monitoring, stability analysis, and automatic generation control.
- The “Regulations on the Management of Electricity Market” announced by the Ministry of Trade and Industry prescribes the responsibilities of the KPX. The KPX should operate electric power systems and protect facilities from overcurrents using the EMS even during contingencies, such as various possible failures of power system facilities (e.g. a transmission line, generator,

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<sup>5</sup> After the fire in Goseong in April 2019, KEPCO headquarters announced to its regional headquarters that temporary power outages occurring in mountainous areas due to the disabling of reclosers will not be reflected in the management evaluation. Afterward, the regional headquarters partially restricted the operation of the distribution line reclosers from going through certain mountainous areas.

<sup>6</sup> It refers to a system managing generation and provision of electricity, also in the presence of unexpected failures, to secure the stability of an electric power system by monitoring and controlling the real-time status of power plants and substations nationwide.

or transformer).

- When a contingency occurs, and the load on a transmission line exceeds 150% of the allowable current, this can initiate cascading failures in the power system and cause massive power outages across a wide range of areas.
- o The KPX learned through testing operations in 2016 that, even with the EMS, they were only able to resolve 15 (18.5%) out of a total of 81 contingency-induced overcurrents (a current flowing in excess of 150% of the allowable value in the transmission line).
- The KPX did not apply the results in improving the function of the EMS (Security Constrained Economic Dispatch<sup>7</sup>) or in developing the operational standards for the EMS.
- o The BAI, during the audit period, examined the EMS log data for contingency analysis and confirmed that, from June 3 to July 2, 2019, 398 transmission lines were overloaded (for a cumulative total of 1,220 minutes) under the hypothetical situations of power system failures.
- Using the EMS, the KPX attempted to reduce the overloads of 79 (20%) out of 398 failures on transmission lines, but only solved 23 of them.
- As for the transmission lines in operation without using EMS, the KPX controlled the electric power system to alleviate the overloads of 184 out of 319 transmission lines, but left the remaining 135 lines unattended.
- If power system contingencies occur under these conditions, they can lead to transmission line failures caused by excess current. There also exists the hazard of cascading failures in transmission networks and of large-scale power outages if the contingencies occur during the peak periods of electricity demand.

Total number of overloaded transmission lines	Use of the EMS function (SCED)		Non-use of the EMS function (SCED)	
	Overload resolved	Overload unresolved	Power system control	Power system control not

<sup>7</sup> Security Constrained Economic Dispatch (SCED) plays the role of responding to contingencies and establishing plans for real-time dispatch. In doing so, it contributes to retaining a steady level of current flowing in a transmission line.

			implemented	implemented
398 (100%)	23 (6%)	56 (14%)	184 (46%)	135 (34%)

- The KPX has not reported to KEPCO on the facilities having load management problems, such as the 398 transmission lines being overloaded under contingency conditions. The KPX, thereby, deprived KEPCO of the chance to review and formulate measures (such as enhancing transmission facilities) to manage the power systems.
- The BAI articulated concerns that certain failures in a power system during the peak periods of demand can undermine the stability of the system, causing cascading failures in the transmission system and result in massive power outages.

#### **Audit Result: Notification**

The BAI requested the CEO of KPX to establish measures regarding contingency-driven overload that occurred in transmission/substation facilities. The BAI underlined the need for developing measures to operate power systems, such as provision of real-time solutions to alleviate overload in the transmission or substation facilities. Also, the BAI recommended KPX to prepare measures to reduce the risk of large-scale power outages (caused by power overloads) in a wide area. The BAI suggested the KPX communicate the contingencies that occurred at the transmission/substation facilities to the facility owners, so the owners can reflect the contingencies into their plans for expanding the transmission network.

### **■ General Safety Management of Power Supply Facilities**

#### **① Inadequate Quality Inspection: Approval for Purchasing Defective Transformers**

- KEPCO approved and purchased transformers, which should have proven faulty in the quality inspection.
- A top-pole transformer is an electrical apparatus that reduces the high voltage to a level suitable for household use (220V).

- KEPCO checks whether the temperature of the insulating liquids (oil used for insulating and cooling electrical equipment) remain under the limit during the temperature rise test, and only approves the transformers that meet the criteria.
  - o From March to May 2019, KEPCO, concluded that 145 top-pole transformers satisfied the product requirements, even though the inner temperature of these transformers rose beyond acceptable levels, as these transformers contained less than the standard amount of insulating liquid.
  - This problem possibly stemmed from the inattentiveness of the KEPCO worker who oversaw and checked the test results submitted by the manufacturer of the transformers. The BAI stated that the KEPCO worker may have failed to notice that the manufacturer, conscious or otherwise, listed the temperature rising limit as being 10°C higher than the standard in the test report. For some of the transformers, KEPCO failed to notice that the manufacturer used an incorrect formula for the temperature rise test.
- During this audit period, KEPCO requested KERI for a temperature rise test of five randomly selected transformers of those delivered to KEPCO. The result showed that all of them exceeded the temperature rise limit.
- o The BAI expressed concern over the faulty transformers, such as their inadequate quality reducing their life expectancy.

**Audit Result: Request for Reprimand**

The BAI demanded that the CEO of KEPCO reprimand the two officials in charge for their failures related to the transformer acceptance test.

**Audit Result: Request for Correction**

The BAI ordered the manufacturer, who produced 145 units of the top-pole transformer that did not meet the temperature rise requirements, to provide KEPCO with better quality products. The BAI also stated that all the equipment delivered should be subject to rigorous scrutiny by KEPCO.

## ② Negligent Handling of a Construction Site Accident

- In terms of electrical accidents on a construction site, such as electrical shock or electrical burns, the internal regulations of KEPCO (the “Electrical Safety and Health Management Regulations”) stipulated the procedures as follows.
  - The regional office should investigate after reporting the accident to both the regional headquarters and the safety management department of the corporate headquarters. If an accident arises from any reason attributed to the construction company, KEPCO imposes penalties or sanctions on the company, such as termination of contract and suspension of construction.
- In April 2018, an accident<sup>8</sup> occurred during power distribution construction. Though regional office 'A' of KEPCO was aware of the accident, they did not follow procedures regarding accidents: investigation and report to upper-level management.
  - KEPCO did not enforce a suspension of construction (for 30 days for an accident sustaining serious injuries) nor impose a penalty (KRW 3 million) on the construction company, even when the accident has compromised the health and safety of a construction worker.

### **Audit Result: Request for Reprimand**

The BAI demanded that the CEO of KEPCO reprimand the four officials in charge for their negligence (not duly investigating the accident on the construction site). The BAI also requested to impose, according to the related regulations, penalties to the construction company responsible for the safety accident involving a serious injury of a worker on site.

### **Audit Result: Request for Warning**

The BAI demanded that the employees of KEPCO fully comply with the related regulations (such as the "Electrical Safety and Health Management Regulations") and initiate immediate reporting and follow-up action after an accident occurs.

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<sup>8</sup> The injured worker was hospitalized for six months and treated for third-degree burns on his shoulder, chest, and arms (over 35% of the total body surface area).

### ③ Inadequate Management of Subcontracts for Electrical Construction

- According to the "Electrical Construction Business Act," if a constructor (who entered a contract with KEPCO) plans to work on a subcontract or re-subcontract with another company, they would need to seek approval from KEPCO. The contractor should then report the status of the construction to KEPCO, allowing them to check the progress of the construction work.
- The "Electrical Construction Business Act" prohibits non-registered electrical contractors from undertaking any electrical construction. Subcontracting is contingent upon approval from the client who awarded the original contract for the electrical construction.
- The BAI detected the wrongdoings of the construction companies (which could lead to shoddy construction), such as proceeding with subcontracting without seeking KEPCO's approval and pursuing illegal re-subcontracting.
  - Company B subcontracted a part of the construction for power distribution conduits (contract price of KRW 145.55 million), which was awarded by KEPCO in November 2017, to an individual who was not registered as an electrical constructor.
  - Amid the construction of distributing main lines in August 2016, Company C, the prime contractor, awarded a subcontract (contract price of KRW 257.89 million) to another contractor without gaining approval from KEPCO.
  - The BAI identified another problem of Company C: illegal re-subcontracting. Company C carried out the construction of distributing main lines through a subcontract with another company, paying an estimated KRW 128.32 million. However, this construction work was awarded by KEPCO in May 2016, and as such, re-subcontracting was not permitted.
- Apart from these examples, the BAI found five more cases in violation of the "Electric Construct Act." Some entities, including Company D, were suspected of illegal subcontracting transactions.

#### **Audit Result: Notification**

The BAI stressed the need for vigilant monitoring on the construction companies to refrain them from practicing construction works with an

unauthorized construction contractor and illegal re-subcontracting. The BAI urged that the CEO of KEPCO establish measures to impose disciplinary action against companies or individuals who failed to abide by the "Electronic Construction Business Act," such as bringing about charges to those responsible or restricting their eligibility to participate in future bids.

#### ④ **Appointments of Unqualified Employees as Construction Supervisors**

- According to the “Electric Technology Management Act,” KEPCO can assign workers qualified for construction supervision to oversee the construction. Afterward, KEPCO should inform the municipal/provincial governor of the deployment status of the supervisors and provide a supervision report.
- Constructors need to report exact costs to guarantee the presence of the supervisor throughout the construction process, as the deployment length of the supervisor is determined by the cost and type of construction.
- Nevertheless, the KEPCO construction branch in Chungbuk-Gangwon area underreported the overall construction costs (KRW 615 million) of electric transmission and substation facilities by 70% percent.
- From 2014 to May 2019 (for a total of 803 days), KEPCO carried out 21 electrical substation construction projects with an insufficient number of supervisors.
- During that period, the BAI detected 13 additional cases of KEPCO’s poor management of supervisors on transmission facility construction sites. KEPCO did not inform the municipal/provincial governors of how they place supervisors at the construction sites nor submit reports on construction supervision.
- KEPCO assigned six non-qualified personnel to perform supervisory duties for five of their construction projects.
- With the absence of qualified supervisors, workers can be exposed to various types of risks during construction. In the end, substandard buildings, a result of ill-managed construction, can impair the safety of people.

**Audit Result: Request for Warning**

The BAI recommended the CEO of KEPCO to submit reports on the deployment status of construction supervisors and the completion of construction supervision, as well. The BAI prompted KEPCO to place qualified workers to perform supervisory duties and to report on the construction costs with scrupulous care to prevent the absence of construction supervisors. The BAI also demanded KEPCO to provide a warning to its workers regarding proper management of supervisors.

**Audit Result: Notification**

The BAI notified the seven municipal/provincial governors, including the Mayor of Seoul Metropolitan City, to impose appropriate penalties on KEPCO for violating the “Electric Technology Management Act” (such as allowing non-authorized workers to supervise construction projects) in accordance with relevant regulations.

**⑤ Improper Establishment and Operation of Power Distribution Automation System**

- KEPCO established and has been operating the Distribution Automation System (DAS)<sup>9</sup> to take prompt measures after locating faulty areas, such as broken power lines. The system informs KEPCO workers of any faults found in real-time detection via alarms, which allows the workers to better repair them.
- In order to verify the effectiveness of the DAS alarm system, the BAI examined and compared the alarm history and the data on failures that occurred in 2018.
- Out of 17,336 alarms that occurred in 2018, only 123 cases (0.7%) were correct in detection. Further to this, the DAS failed to alert KEPCO on 23 (16%) of the 146 failures on distribution lines.

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<sup>9</sup> The DAS monitors and remotely controls the switches on distribution lines. The system also provides information related to a substation, such as the status of circuit breakers, circuit loads, and fault sections.

- KEPCO identified the cause of the malfunctions (repeated false alarms) in the 4,307 out of 17,213 units of the switch on distribution lines and completed repairing 4,070 units (237 units were under repair).
- However, KEPCO did not make subsequent efforts to secure the reliability of the DAS alarm system. For instance, among the 4,070 repaired switches, 234 units suffered from recurring alarm malfunctioning problems. The cause of false alarms for 12,906 units remains unknown.
- Under these circumstances, in April 2018, the DAS detected a failure on distribution lines and sent the alarm signal to a worker at KEPCO. The worker, though, did not scrutinize the lines where the line failure was reported and regarded it as a false alarm. Consequently, the problem was left unattended for more than 3 hours.
- The BAI voiced concern over the impact of frequent false alarms. These false alarms hamper workers from responding immediately to power facility failures, resulting in fire, electric shock accidents, or damages to facilities.

**Audit Result: Notification**

The BAI notified the CEO of KEPCO to develop measures to ensure that the DAS detects failures (e.g. broken distribution and transmission lines) in a prompt and accurate manner.