Electrical Assessment of Bicol University - Legazpi East Campus, Philippines

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Abstract*—Electricity is a critical component of modern society, powering various processes including academic institutions. Fueled by the necessity of advancement, the Bicol University - Legazpi East Campus has undergone significant infrastructure improvements in the past decade, leading to a higher demand for electricity. This increase in electricity demand, however, has a negative impact on the electrical system reliability within the campus as evident in frequent and unwarranted power interruptions that sometimes happen twice a week. Because of the challenge, this research is conducted to assess and prepare proposed improvements on the electrical distribution system of Bicol University-Legazpi East Campus. The campus covers the College of Engineering, College of Industrial Technology, Institute of Design and Architecture, and the Research Development and Extension Centers. The research consists of three (3) parts: (i) inventory of the existing system; (ii) technical analysis involving short circuit and voltage drop calculations; and (iii) development of an improved distribution system. The inventory of the existing system involves the calculation of current and future electrical loads based on the approved Comprehensive Land Use Plan (CLUP) of the campus, as well as the identification of transformers and distribution lines, which are then used to create the Single Line Diagram (SLD) of the campus. A thorough technical analysis is conducted to evaluate the system's compliance with the Philippine Electrical Code (PEC), specifically in terms of short-circuit analysis and voltage drop calculation results. Based on the findings of the first two parts, a proposed new electrical distribution system for the campus is developed and subjected to the same technical analysis (short-circuit and voltage drop calculation) to determine its compliance with the PEC. The analysis revealed that the current electrical distribution system of the campus does not meet PEC requirements for maintaining proper voltage levels in the buildings it serves and cannot effectively support existing and future loads with the existing transformers. As a result, a proposed new distribution system has been developed, which includes several strategically located energy centers (transformer banks) to ensure consistent voltage levels for current and future buildings identified in the CLUP. Extensive technical analysis of the proposed system confirmed that it complies with PEC regulations, ensuring the safety and reliability of the system.

I. Introduction

The Bicol University (BU), a state university in Bicol Region, Philippines, was established on June 21, 1969, through the passage of Republic Act 5521. The major campuses, namely Main Campus and East Campus of the university are in Legazpi City, the capital of the Province of Albay. The BU Legazpi East Campus, which formerly housed the Bicol Regional School of Arts and Trades (BRSAT), was converted to the College of Engineering and the School of Arts and Trades (now named as College of Industrial Technology). BRSAT already existed for decades before it was converted to become these colleges. Since then, the campus has experienced massive improvements and development that include rehabilitation of old facilities as well as construction of new buildings.

At present, the campus houses three (3) academic units namely the Colleges of Engineering (CENG) and Industrial Technology (CIT) and the Institute of Design and Architecture (IDeA). It is also the home of key university offices and facilities such as the Research Development and Extension (RDE) Building, the Food Innovation and Commercialization Center (FICC), the Multi-Tech Facility, and the BUCENG Gymnasium. These developments warrant improvements in the already aging electrical system of the campus, to serve the growing power needs of the campus.

A poorly designed and/or constructed electrical system will mean a poor level of reliability (i.e., frequent power failure or interruption in the system). This will entail productivity losses, inconvenient learning spaces (due to lighting and ventilation issues) and even loss of moral of the population. Thus, any goals for a sustainable growth and development of a university should include a good, reliable, and efficient electrical system. This is why an efficient and reliable power system study including proper protection coordination study and settings must be considered and must be implemented to have a continuous and efficient operation. For this to happen, the power system must ensure that personnel and equipment are protected during abnormal conditions by establishing proper interrupting ratings of protective devices.

Aside from inconveniences brought by poor electrical system, there are also hazards that come with it. According to the IEEE Standard 551-2006, should short circuit occur in electric power system, it may result to any of the following:

1. At fault location, arcing and burning can occur damaging adjacent equipment and also possibly resulting in an arc flash burn hazard to personnel working on the equipment;

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2. High fault currents may cause severe damages to rotating machines;
3. All components carrying the short-circuit currents will be subjected to thermal and mechanical stress that may lead to equipment damages; and
4. System voltage levels drop in proportion to the magnitude of the short-circuit currents flowing through the system elements.

In anticipation to above mentioned resulting effects of short circuit occurrence, proper sizing of protection based on the computed fault current must be observed to trigger the protection during abnormal condition. In this way, electrical equipment failure and hazard to personnel will be controlled if not prevented.

Since the BU Legazpi East Campus has existed for almost a century now (including its existence as BRSAT), its electrical system is already old, and some parts are likewise outdated. Its existing plan was also found to be lacking with important specifications and design analyses as required by the Philippine Electrical Code (PEC). Assuming that important design analyses were not conducted as bases for the design specifications of protective devices and other equipment, it will be hazardous under abnormal conditions.

Furthermore, according to IEEE standards, power systems should be designed so that protective relays operate to sense and to cause the quick isolation of faults in the end view limiting the extent and duration of service interruptions. Subsequently, the existing equipment installed was not specified as efficient during abnormal conditions, the need for upgrading is therefore necessary.

The main objective of the research project is to assess the campus' electrical system and prepare a comprehensive plan in its upgrade by reviewing the original design and improving it into a safety compliant design supported by analyses such as voltage drop calculations, fault calculations, protection coordination analysis, arc hazard and grounding calculations as required by the Philippine Electrical Code 2017 (Article 1.3.2.1 (f)) [1].

In accomplishing the above stated objective of this research project, the research aims to establish the several technical objectives. First, is to identify major gaps or defiance of the existing plan and installed equipment from PEC. Second, improved Single Line Diagram (SLD) of the electrical system based on the major gaps and defiance found in the existing plan and installed equipment. Third, appropriate interrupting capacity of protective devices of the system based on the results of fault calculation. And lastly, appropriate safety guidelines such as arc flash boundaries, PPE and labeling for electrical equipment and personnel.

II. Methodology

The conduct of electrical assessment is divided into three categories of activities: (1) on-site inspection and inventory of electrical system and equipment, (2) development of single-line diagram of the system, and (3) analytical assessment of reliability and compliance to relevant codes and standards [2] [3].

A. Data Source

Inspection and inventory are carried out across the entire campus. The result of actual inspection and inventory served as the primary data alongside the available as-built plans, and equipment specifications from purchase orders [4]. Key Informant Interview is used to bridge the gaps in the primary data [5].

B. Data Tabulation and Presentation

The data gathered are presented in tabular form using spreadsheets for easy visualization and analysis. Single-line diagram is developed to be the reference in the conduct of analysis for the following: (a) transformer sizing, (b) sizing of over-current protection device, (c) conductor sizing, and (d) voltage drop calculation [6].

C. Analytical Assessment

In the conduct of this electrical assessment, the following are the key areas of concern: (1) Transformer, (2) Emergency Generator, (3) Overcurrent protection, (4) and Size of Conductor [7]. The inspection and inventory conducted are focused on these areas, except for the emergency generator because it was not existent at the time of study. The properties of existing equipment and components of the system in these areas are tabulated and presented to be assessed its compliance to existing standards [8].

Voltage reliability is one of the key measures of the electrical system's reliability and compliance to existing standards. Literatures pointed out the importance of consistent voltage level within the acceptable range in a locality [9][10][11]. Hence, this study used the result of voltage drop calculation as the primary benchmark in the conduct of assessment. Based on the PEC 2017, the percent voltage drop from the transformer to the farthest point in the circuit shall not be more than five (5) percent. Equations (1) and (2) are used in the said calculations for three-phase and single-phase systems, respectively [1][13].

$$VD = 1.732\ IZ \quad (1)$$

$$VD = 2IZ \quad (2)$$

where, VD = voltage drop
I = line current
Z = total impedance of the line

D. Results of Analysis

The results of voltage drop calculation, visual inspections, and physical evaluation of equipment and electrical system are compared to the existing standards of the code and compliance to laws and regulation related to climate change adaptation and disaster risk reduction. After identifying the weak points of the system, recommendations are given to ensure compliance and improve reliability.

III. Results and Discussion

A. Existing Electrical Loads in BU East Campus

As previously mentioned, campus is composed of three (3) academic units, and several key university offices and facilities. This translated into 25 buildings situated in the campus. The buildings in the campus are primarily for instruction and research-related activities; hence the loads are generally lighting, small appliance loads, electronic equipment/devices, and air-conditioning units.

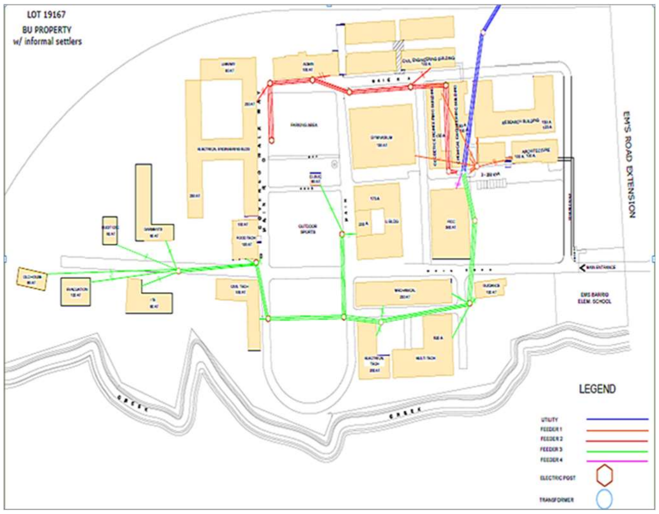

Figure 1. Existing Electrical Distribution Map of BU East Campus

Figure 1 shows the existing overhead electrical distribution system in BU East Campus with four feeders. Also shown in the figure are the distribution lines from Albay Power and Energy Corporation as the distribution utility/service provider in the province.

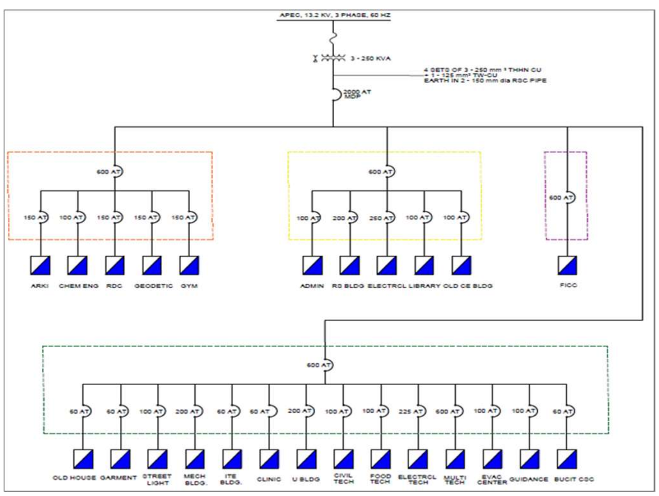

Figure 2. Existing Single Line Diagram of BU East Campus

Figure 2 shows the existing Single-Line Diagram (SLD) of the campus. It is currently connected to the 13.2 kV line of the Albay Power Electric Corporation (APEC), with a 3-250 kVA transformer. The distribution system is composed of four (4) feeders with 600 AT each line for protection.

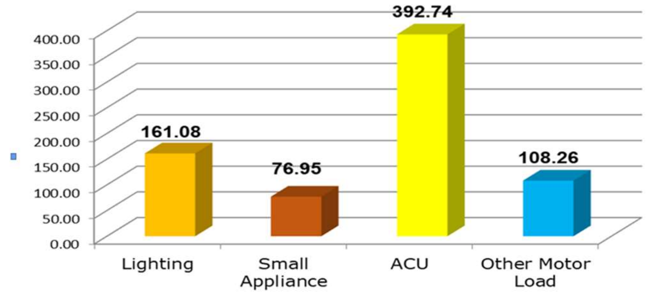

Figure 3. Total Connected Load by Load Type, in KW

B. Total Connected Loads in BU East Campus

The total connected load in the whole system can be calculated. It is noted that the whole system is supplying a total of 739.02 kW.

Figure 3 shows the summary of loads by load type. The ACU system is the biggest load carried by the system with 392.74 kW of calculated load.

C. Status of Utilization of Electrical Loads and Equipment at the BU East Campus

The researchers found out that the current electrical system is underutilized. However, the inventory of load shows that the connected load is approximately 740 kW, the actual load is significantly lower than this.

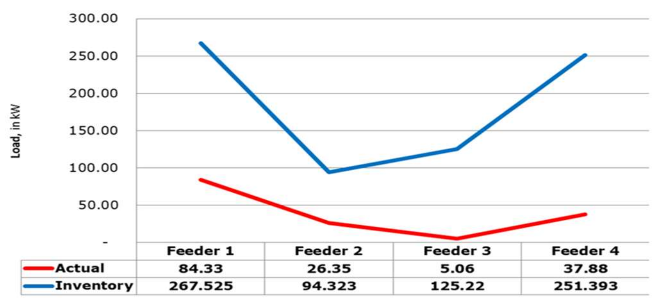

Figure 4. Connected Load VS. Actual Load Consumption

Figure 4 shows that the actual load of the feeders is lower than the calculated load based on the inventory of connected load, hence we can conclude that system is underutilized resulting to a very low utilization factor.

D. Status of Compliance of Electrical System in BU East Campus with PEC

Figure 4 shows that the actual load of the feeders is lower than the calculated load based on the inventory of connected load, hence we can conclude that system is underutilized resulting to a very low utilization factor.

Table 1 shows that in Feeder 1, only LPP 3 Research Development and Extension Building failed to comply with PEC Standard. Hence, this should be rectified.

TABLE I. PERCENT VOLTAGE DROP FOR FEEDER 1

Panel Name	*V at SE*	*%VD*	*Remarks*
LPP 1 Architecture Building	233.08	2.9%	C
LPP 2 Chemical Engineering Building	233.39	2.8%	C
LPP 3 Research Development and Extension Building	224.69	6.4%	NC
LPP 4 Geodetic Engineering Building	233.42	2.7%	C
LPP 5 Gymnasium	232.10	3.3%	C

Note: C – Compliant and NC – Non-compliant

Table 2 shows that in Feeder 2, all branches that failed are not compliant with PEC Standard. Hence, this should be rectified.

Table 3 shows that Feeder 3 is compliant with PEC Standard.

TABLE II. PERCENT VOLTAGE DROP FOR FEEDER 2

Panel Name	*V at SE*	*%VD*	*Remarks*
LPP 1 Administration Building	223.60	6.8%	NC
LPP 2 RS Building	221.00	7.9%	NC
LPP 3 Electrical Engineering Building	221.11	7.9%	NC
LPP 4 East Campus Library	222.29	7.4%	NC
LPP 5 Old Civil Engineering Building	227.39	5.3%	NC

Note: C – Compliant and NC – Non-compliant

TABLE III. PERCENT VOLTAGE DROP FOR FEEDER 3

Panel Name	*V at SE*	*%VD*	*Remarks*
Food Innovation and Commercialization Center (FICC) Building	233.48	2.7%	C

Note: C – Compliant and NC – Non-compliant

TABLE IV. PERCENT VOLTAGE DROP FOR FEEDER 4

Panel Name	*V at SE*	*%VD*	*Remarks*
LPP 1 Old House	223.66	6.8%	NC
LPP 2 Garments Building	223.84	6.7%	NC
LPP 3 Street Lights	224.18	6.6%	NC
LPP 4 Mechanical Technology Building	225.58	6.0%	NC
LPP 5 ITE Building	223.86	6.7%	NC
LPP 6 Clinic	223.36	6.9%	NC
LPP 7 U Building	223.46	6.9%	NC
LPP 8 Civil Technology Building	224.42	6.5%	NC
LPP 9 Food Technology Building	224.28	6.6%	NC
LPP 10 Electrical Technology Building	225.62	6.0%	NC
LPP 11 Multi-Technology Building	229.10	4.5%	C
LPP 12 Evacuation Center	223.77	6.8%	NC
LPP 13 Guidance Office	229.31	4.5%	C
LPP 14 BUCIT CSC Office	223.83	6.7%	NC

Note: C – Compliant and NC – Non-compliant

Table 4 shows that in Feeder 4, 12 out of 14 branches failed to comply with the PEC Standard. Hence, Feeder 3 needs a lot of improvement to comply with standards. The existing electrical system of the campus is already outdated and can no longer sustain the current demand as well as future demand of the campus. The following are the key results of the assessment of the Existing Electrical System:

1. The Main wires used as feeder lines for all feeders (which is 60 mm2) ACSR are all undersized if calculated based on the Total Connected Load.
2. In terms of Voltage Drop, Feeders 1, 2, and 4 have branches that does not comply with PEC standard even with the current load. Hence, it is inferred that with higher utilization factor, the whole system will experience under-voltage.
3. Old Buildings have poor Over-Current Protection Devices (OCPD).

E. Proposed Electrical Distribution System for BU East Campus

The analysis included all necessary electrical calculations for the proposed electrical system of the campus, including explanations on how the required data, values, sizes, etc. are being derived. In every calculation, respective reference documents and basis of calculation including formulas Calculations are done with the aid of computing tool., i.e., MS Excel®.

The proposed electrical system of this study is based on this CLUP, integrating new buildings that will be constructed as indicated in the plan.

With the implementation of the CLUP, many of the old buildings are demolished and replaced with new buildings as indicated in the figure. Table V shows the list of buildings and its general description and status.

The electrical load for office buildings is primarily composed of lighting loads, small appliance loads, IT equipment (computers, printers, scanners, etc.) and air-conditioning units. For academic buildings which houses classrooms, function rooms, and laboratory rooms, require electrical energy for lighting, small appliance loads, air-conditioning units, and laboratory equipment that may include motor loads. Multi-purpose buildings require a similar load as office buildings but may include specialized equipment to meet the need of the building occupants. The proposed electrical system design is developed to meet the demand of the existing and the proposed buildings included in the CLUP for the campus. The load in the proposed building is estimated based on the general description of the building and its intended use.

The proposed electrical system is composed of four (4) main feeders, with the Gymnasium having its own transformer. The Gymnasium is designed to have its own transformer as well as metering as per the University's development plan.

Figure 5 shows the single line diagram of the proposed electrical system based on the electrical calculations such as

Voltage Drop Computation, Short Circuit Analysis, OCPD calculation, and Arc Flash Analysis.

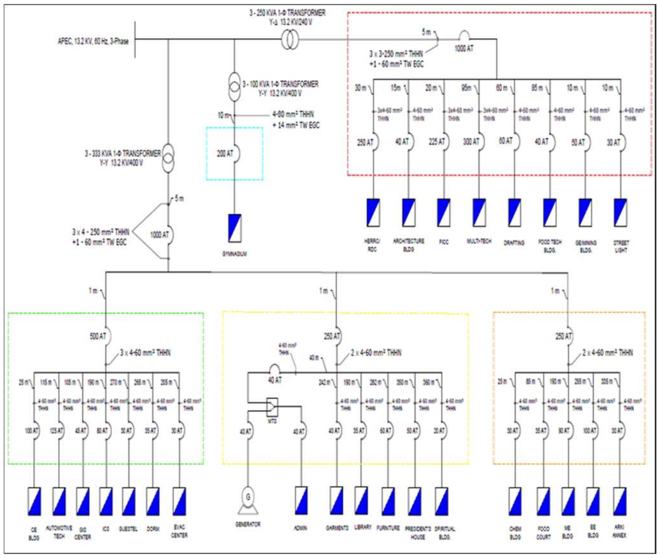

Figure 5. Connected Load VS. Actual Load Consumption

TABLE V. PERCENT VOLTAGE DROP FOR FEEDER 4

Name of Building	*Description*	*Status*
Administration Building	Office Bldg.	Existing
Architecture Bldg.	Office & Academic Bldg.	Existing
Architecture Annex Bldg.	Academic Bldg.	Proposed
Automotive Tech. Building	Academic Bldg.	Proposed
CE building	Office/Academic Bldg.	On-going
ChE Building	Office/Academic Bldg.	Proposed
Dormitory	Residential Bldg.	Proposed
Drafting/ U-Bldg.	Academic Bldg.	Existing
EE Building	Office & Academic Bldg.	On-going
Evacuation Center	Multi-Purpose Bldg.	Proposed
FICC	Multi-Purpose Bldg.	Existing
Food Court	Food & Office Area	Proposed
Food Tech. Bldg.	Office/Academic Bldg.	Proposed
Furniture Building	Office/Academic Bldg.	Proposed
Garments	Office/Academic Bldg.	Proposed
GE/EM Bldg.	Office/Academic Bldg.	Existing
GIS Center	Office/Academic Bldg.	Proposed
Guestel	Residential Bldg.	Proposed
Gymnasium	Sports/Event Center	Existing
HERRC/RDC Bldg.	Office Bldg.	Existing
ICS building	Office/Academic Bldg.	Proposed
Library	Office/Academic Bldg.	Proposed

Name of Building	*Description*	*Status*
ME bldg.	Office/Academic Bldg.	Proposed
Multi-Tech Bldg.	Multi-Purpose Bldg.	Existing
President's House	Residential Bldg. & Office Bldg.	Proposed
Spiritual Sanctuary	Religious Area	Proposed
Library	Office/Academic Bldg.	Proposed
ME bldg.	Office/Academic Bldg.	Proposed
Multi-Tech Bldg.	Multi-Purpose Bldg.	Existing
President's House	Residential Bldg. & Office Bldg.	Proposed
Spiritual Sanctuary	Religious Area	Proposed

In the proposed design, the existing 3-250 kVA Transformer, located near the FICC Building, will supply most of the existing load and will have a 13.2/0.240 kV, Y-Δ system since this is the system used by the existing buildings. For the new buildings, the university opts for a 400 V, Wye-Wye, and three-phase electrical system. Hence, the proposed design will also include a system that operates in the said system. The new buildings will be supplied by 3-333 kVA Transformer, 13.2/0.230 kV, Y-Y, through Feeders 1 to 3.

In summary, the four (4) feeders will be operating in two separate systems. Feeders 1 to 3 will be operating at 13.2/0.23 kV, Y-Y system, and will serve most of the new buildings. While Feeder 4 will retain its 13.2/0.24 kV, Y-Δ system, and serve existing buildings.

IV. CONCLUSION

Based on the results of electrical inspection and electrical calculations conducted, the following are the conclusions by the researchers. For the assessment of existing electrical system, the researchers draw the following conclusions:

1. The existing electrical system of BU East Campus is composed of four feeders being supplied by 3-250 kVA transformer, 13.2/0.240 kV, Y-Δ, 60 Hz system. The inventory result of Section 2.1.2 shows that the total connected load is 739.02 kW or approximately 870 kVA at 0.85 pf. With these, the existing transformer is deemed undersized;
2. The utilization factor of the system is very low; this is concluded upon comparing the actual current measured during peak hours versus the total connected load (based on inventory);
3. The existing cable used in Feeders 1 to 4 (currently 60 mm2) is undersized if the load is calculated based on the total connected load. (See 2.60, page 48, for details);
4. Frequent power interruption is experienced due to incidence of under-voltage and over-loading;
5. There are branch circuits that are under-voltage. They failed to comply with the 5% maximum voltage drop required by the PEC 2017; and

6. BU is implementing the approved BU Comprehensive Land Use Plan (CLUP) that will significantly alter the campus. Some buildings are to be demolished and new buildings will be constructed. With these, it is concluded that the proposed electrical system should be based on the electrical plan.

For the proposed electrical system, the researchers draw the following conclusions:

1. Upon completion of the implementation of the BU CLUP, the east campus will have an estimated total connected load of 1,198.36 kVA. With these, a new energy center must be built because the existing 3-250 kVA transformer bank of the campus can no longer supply the said load. But it must still be incorporated to the proposed electrical system;
2. A 13.2/0.400 kV, Wye-wye system is the preferred system of the administrators and users. However, existing three-phase loads operating 230 V should be considered in the proposed system. The gymnasium must also be supplied by a separate transformer bank (in accordance with BU development plan);
3. Incorporating the said considerations, the proposed system is composed of three separate transformer banks connected to the local utility (APEC). Feeders 1 to 3, serving the North Side of the campus composed of the new buildings, are supplied by the proposed 3-333 kVA transformer, 13.2/0.400 kV, Y-Y, 60 Hz system. The existing buildings will form Feeder 4 that is supplied by the existing 3-250 kVA transformer, 13.2/0.240 kV, Y-Δ, 60 Hz system. The Gymnasium (Feeder 5) is served by the proposed 3-100 kVA 13.2/0.400 kV, Y-Y, 60 Hz system;
4. The proposed electrical system is compliant with the 5% maximum voltage drop required by the PEC 2017.
5. The proposed electrical system is compliant with the PEC 2017 with regards to wire size and OCPD.
6. The KAIC rating is properly sized based on the result of Fault Calculation in Section 4.5. Summary of Fault Calculation
7. The Arc Flash Analysis result shows that the Arc Flash Level for Transformer and MSE is Level 1, while Level zero (0) for DP, and corresponding PPE, signage and other actions has been recommended.

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