Development of a Standards-Based Electrical Design Tool for Resource-Constrained Engineering Practice: A Philippine Case Study

Alwin M. Lunas, Marites E. Olesco, and Pee Jay N. Gealone*
**pjngealone@bicol-u.edu.ph*

Department of Electrical Engineering
Bicol University College of Engineering
Legazpi City, Albay, Philippines

***Abstract*—Proprietary electrical design software remains financially inaccessible or challenging for many engineering practitioners and academic institutions in developing regions. This work attempts to address this by presenting an alternative tool: an integrated electrical system design tool that implements the Philippine Electrical Code (PEC) 2017 and IEEE 1584-2018 (IEEE Guide for Performing Arc-Flash Hazard Calculations) within a unified computational framework. The tool consolidates five core design functions: load calculation, short-circuit analysis, voltage-drop calculation, arc-flash hazard evaluation, and conductor and overcurrent-protection sizing. A three-stage methodology guided development, which includes: (1) needs analysis survey among practitioners and educators in Albay, Philippines; (2) construction of a computational framework; and (3) dual-path validation combining manual calculation verification with focus group user acceptance testing. Validation results demonstrate strong accuracy across all five functions, with less than 1% deviation from manual reference values. User acceptance ratings were 4.929/5.000 for accuracy and 4.786/5.000 for ease of use. This paper demonstrated that the tool provides a viable, standards-compliant alternative to expensive proprietary software for both professional practice and engineering education in resource-constrained contexts.**

***Index Terms*—electrical design tool, Philippine Electrical Code, arc-flash hazard calculation, electrical design analysis, engineering education.**

I. INTRODUCTION

Access to reliable, standards-compliant design tools is a foundational requirement for competent electrical engineering practice. In developed economies, practitioners routinely employ commercial software such as SKM PowerTools, ETAP, or EasyPower to perform integrated load calculations, short-circuit analysis, and arc-flash evaluations within a single environment. However, enterprise licensing costs (generally through annual subscriptions) for these platforms render them effectively inaccessible to individual practitioners and academic institutions in developing regions [1].

In the Philippine context, as confirmed through focus-group discussions, this cost barrier produces two distinct but related problems. First, electrical engineering students learn theoretical design principles without or with very limited exposure to integrated, standards-based workflows. Graduates consequently enter professional practice with limited experience in the computational methods that industry expects them to apply from their first day of employment. Second, practicing engineers who cannot justify commercial software expenditures resort to fragmented workflows combining manual calculations, reference tables, and custom spreadsheets. Such approaches are not only time-consuming but also susceptible to transcription errors, inconsistent application of standards, and the absence of cross-functional checks that integrated tools provide automatically.

The Philippine Electrical Code (PEC) 2017 [2] governs all electrical system design in the Philippines and draws substantially from the National Electrical Code (NEC) [3], introducing locally adapted provisions for climate, construction practice, and infrastructure context. Arc-flash hazard analysis, an increasingly mandatory element of electrical safety programs in industrial facilities, is governed by IEEE 1584-2018 [4]. Implementing both standards simultaneously within a manual or spreadsheet-based workflow is particularly demanding, as the calculations are interdependent and iterative.

This paper presents the development and validation of an accessible, integrated electrical system design tool that addresses this gap. The tool implements PEC 2017 and IEEE 1584-2018 in a unified computational framework covering five interdependent design functions: load calculation, short-circuit analysis, voltage drop assessment, arc-flash hazard evaluation, and conductor and protection sizing. Its primary contribution lies in integrating these standards and functions into a single, accessible platform tailored to Philippine engineering practice.

II. RELATED WORK

Commercial platforms such as ETAP [5] and SKM PowerTools [6] provide comprehensive multi-function analysis but require annual licensing agreements that are prohibitive for the target user base. In terms of open-source alternatives, they address part of the gap but are not tailored to the target audience and applications, i.e., electrical system design for commercial and residential systems. OpenDSS [7] offers strong power flow and fault analysis capability but is primarily designed for electric utility distribution systems, distributed energy resource (DER) grid integration, and grid modernization. It also lacks a design-oriented interface needed in typical system designs and does not implement PEC 2017 or IEEE 1584-2018 arc-flash analysis. Pandapower [8] targets research and planning contexts rather than practitioner design workflows. Excel-based templates and manual PEC-based workflows are the most common current approach in Philippine engineering offices and institutions [9]. This method addresses one or two functions in isolation and requires manual result transfer between workbooks, which introduces transcription errors.

The tool presented here occupies the gap between these options. Its distinguishing characteristics are: (1) integration of five interdependent design functions in a single interface; (2) explicit PEC 2017 compliance; (3) IEEE 1584-2018 arc-flash calculation; and (4) a practitioner-centered interface developed from requirements gathering rather than adapted from a research context. The contribution is primarily one of integration, localization, and accessibility rather than algorithmic novelty.

III. METHODOLOGY

The development followed a three-stage design methodology adapted from established practice in the development of engineering tools [10], as illustrated in Fig. 1.

A. Stage 1: Needs Analysis Survey

A structured survey was administered to the electrical design professionals and instructors in Albay Province, Philippines, comprising three sections: (a) response profile and current tooling practices; (b) Likert-scale importance ratings for candidate design functions; and (c) open-ended questions to determine the workflow pain points. The respondents ($N = 38$: 24 licensed design practitioners, 14 faculty) were recruited through the IIEE local chapter and local building officials of the local government units (LGUs), reporting a mean professional experience of 11.39 years ($SD = 6.73$).

For section b of the survey, the data were analyzed using descriptive statistics and frequency distributions. The mean importance score, $\bar{I}_f$, for each candidate function f was computed using (1), where r_{fj} is the rating assigned by respondent j. Functions were ranked in descending order of $\bar{I}_f$ within each sub-group to identify shared priorities. The five implemented functions reflect the top-ranked items in both sub-groups.

$$\bar{I}_f = \frac{1}{N}\sum_{j=1}^{N} r_{fj} \tag{1}$$

The results of the open-ended questions were thematically analyzed and incorporated into the proposed design tool's calculation framework.

B. Stage 2: Computational Framework Development

The tool was developed in Python 3.12 with a Tkinter graphical user interface (GUI) for cross-platform compatibility. Each design function is an independent module sharing a common data model, so results from one function (e.g., conductor sizing) propagate automatically as inputs to dependent functions (e.g., voltage drop, arc-flash), eliminating the manual transfer steps practitioners identified as their primary error source. PEC 2017 tabulated values are encoded as structured data tables; IEEE 1584-2018 equations are implemented with intermediate results exposed for step-by-step user verification.

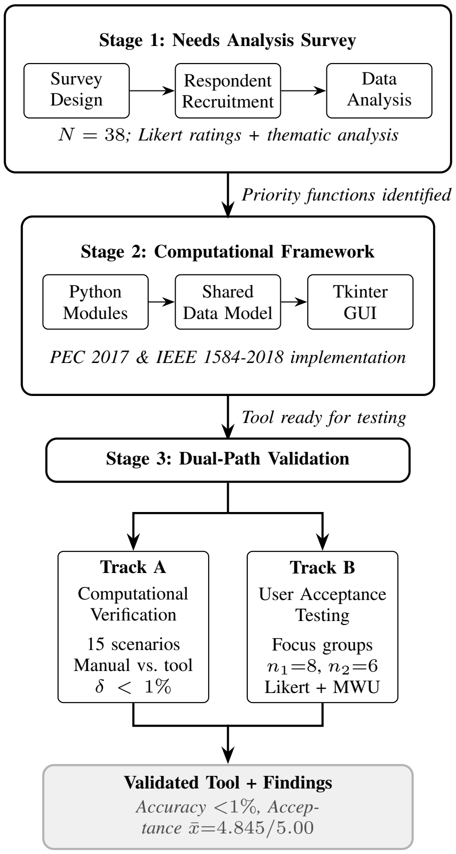

Fig. 1. Three-stage development methodology.

C. Stage 3: Validation

The goal of this work is to ensure that the results provided by the tool are comparable to validated manual calculation and the tool is easy to use and acceptable for both academic and professional use. Therefore, the validation followed two parallel tracks discussed herein.

Computational verification was conducted by the development team using a set of 15 representative design scenarios spanning residential (single-phase, 230 V), commercial and industrial (three-phase, 400 V) system types. For each scenario, reference values were computed independently using manual calculation following the procedure prescribed in PEC 2017 and IEEE 1584-2018. Tool outputs were then compared against these reference values. The percentage deviation δ for each computed parameter was evaluated as:

$$\delta = \left| \frac{V_{\text{tool}} - V_{\text{ref}}}{V_{\text{ref}}} \right| \times 100\% \tag{2}$$

where V_{tool} is the value produced by the tool and V_{ref} is the corresponding manual reference value. A result was considered accurate if $\delta < 1\%$, consistent with the precision of tabulated values in PEC 2017 and IEEE 1584-2018 [4].

User acceptance testing was conducted through structured focus group discussions with a subset of survey respondents. Two focus groups were formed: one comprising eight practitioners and one comprising six respondents from the academe. Participants were given a sample standardized design problem and asked to complete it using the tool, then completed a rating instrument covering accuracy, ease of use, interface clarity, standards compliance confidence, and instructional utility. Ratings used a five-point Likert scale. Qualitative observations were recorded by a facilitator and reviewed thematically.

D. Statistical Analysis

Two levels of statistical analysis were applied to the user acceptance data.

Descriptive statistics. Mean ratings and standard deviations were computed for each dimension within each respondent group (practitioners and academics) and for the combined sample. Because the rating instrument used a five-point Likert scale, responses are treated as ordinal data throughout. The group mean $\bar{x}$ and sample standard deviation s for a given dimension are:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i \tag{3}$$

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \tag{4}$$

where x_i is the rating given by respondent i and n is the group size. Group means are reported to three decimal places to preserve precision given the small sample sizes ($n_1 = 8$, $n_2 = 6$), where rounding to two decimal places would mask meaningful differences between group responses.

Normality testing. Prior to inferential analysis, the Shapiro-Wilk test [16] was applied to the pooled score distributions of each group to assess whether the normality assumption for parametric testing was satisfied. The Shapiro-Wilk statistic W is defined as:

$$W = \frac{\left(\sum_{i=1}^{n} a_i \, x_{(i)} \right)^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \tag{5}$$

where $x_{(i)}$ are the order statistics of the sample and a_i are constants derived from the expected values of standard normal order statistics. Values of W close to 1 indicate normality; small values indicate departure from normality. Results confirmed significant departures from normality in both groups ($p < 0.001$), making parametric inference inappropriate.

Inferential comparison. To test whether acceptance ratings differed significantly between the two respondent groups, the Mann-Whitney U test [13] was selected as the primary inferential procedure. This non-parametric test was chosen because Likert-scale responses are ordinal rather than continuous, and because normality was rejected by the Shapiro-Wilk test above. The Mann-Whitney U statistic is computed as:

$$U_k = n_1 n_2 + \frac{n_k(n_k+1)}{2} - R_k, \quad k \in \{1, 2\} \tag{6}$$

where n_1 and n_2 are the two group sizes, R_k is the sum of ranks assigned to group k in the combined ranking of all observations, and the reported test statistic is $U = \min(U_1, U_2)$. The test evaluates whether one group's ratings tend to be systematically higher than the other's by comparing rank sums, and makes no distributional assumption beyond ordinal measurement. All tests were two-tailed with a significance threshold of $\alpha = 0.05$. Effect size was not computed separately given the small and unequal group sizes, for which rank-biserial correlation would be unreliable [13].

IV. COMPUTATIONAL FRAMEWORK

A. Load Calculation

The load calculation module implements the demand factor and load classification procedures of PEC 2017 Article 2.20. Connected loads are entered by type (lighting, receptacle, motor, HVAC, special) and the module applies the appropriate demand factors to compute the total demand load in kilowatts and kilovolt-amperes, accounting for power factor. The governing equation for total demand load P_D is:

$$P_D = \sum_{i=1}^{n} P_i \cdot DF_i \tag{7}$$

where P_i is the connected load of load group i in watts and DF_i is the applicable demand factor from PEC 2017 Table 2.20.

B. Conductor and Protection Sizing

Conductor sizing follows PEC 2017 Table 3.10.16, which tabulates allowable ampacities for copper and aluminum conductors by size, insulation type, and installation condition. The module applies temperature correction factors (PEC 2017 Table 3.10.16.A) and conduit fill adjustment factors (PEC 2017 Table 3.10.16.B) automatically based on user-specified installation parameters. The minimum required conductor ampacity I_{min} is computed as:

$$I_{min} = \frac{I_{load}}{CF_T \cdot CF_F} \tag{8}$$

where I_{load} is the design load current, CF_T is the temperature correction factor, and CF_F is the conduit fill adjustment factor. Overcurrent protection device ratings are selected from the standard sizes enumerated in PEC 2017 Section 2.10.20.

C. Voltage Drop Analysis

Voltage drop is computed using the exact formula for single-phase and three-phase circuits respectively:

$$VD_{1\phi} = 2 \cdot I \cdot L \cdot (R\cos\theta + X\sin\theta) \tag{9}$$

$$VD_{3\phi} = \sqrt{3} \cdot I \cdot L \cdot (R\cos\theta + X\sin\theta) \tag{10}$$

where I is the load current in amperes, L is the one-way circuit length in meters, R is the conductor AC resistance in ohms per meter at operating temperature, X is the conductor reactance in ohms per meter, and θ is the load power factor angle. Percentage voltage drop is computed relative to the nominal system voltage and compared against the PEC 2017 recommended limits of 3% for branch circuits and 5% for combined feeder and branch circuits.

D. Short-Circuit Analysis

The short-circuit analysis module computes available fault current at any point in the distribution system using the impedance method. The available three-phase symmetrical fault current I_{sc} is:

$$I_{sc} = \frac{V_{LL}}{\sqrt{3} \cdot Z_{total}} \tag{11}$$

where V_{LL} is the line-to-line voltage and Z_{total} is the total system impedance from the utility source to the point of fault, computed as the complex sum of utility, transformer, and conductor impedances. Single-phase line-to-ground fault currents are computed using the method of symmetrical components as prescribed in IEEE Std 141-1993 [11]. Results are used to verify that selected protective devices have adequate interrupting ratings.

E. Arc-Flash Hazard Analysis

Arc-flash calculations follow the IEEE 1584-2018 empirical model [4]. The model computes arc fault current, incident energy, and arc-flash boundary as functions of system voltage, available bolted fault current, gap between conductors, working distance, and enclosure type.

The required personal protective equipment (PPE) category is determined from the computed incident energy per NFPA 70E [12].

V. RESULTS

A. Computational Accuracy

Table I summarizes percentage deviations between tool outputs and manual reference calculations across the 15 validation scenarios for each of the five design functions. The result shows that all deviations fall within 1.0% of reference values. The largest observed deviation (0.87%) occurred in arc-flash incident energy calculations for a medium-voltage industrial scenario, this is attributable to rounding in intermediate IEEE 1584-2018 interpolation steps. Load calculation and conductor sizing results matched reference values exactly in all scenarios, as these computations involve table lookups and direct arithmetic calculations.

TABLE I
COMPUTATIONAL ACCURACY: MAXIMUM PERCENTAGE DEVIATION FROM MANUAL REFERENCE CALCULATIONS

Design Function	**Max. Deviation (%)**	**Scenarios Tested**
Load Calculation	0.00	15
Conductor Sizing	0.00	15
Voltage Drop Analysis	0.12	15
Short-Circuit Analysis	0.34	15
Arc-Flash Analysis	0.87	15

B. User Acceptance

Table II presents mean user acceptance ratings from the focus group instrument. Ratings are reported separately for practitioner and academic respondents and as a combined mean. Overall ratings were high across all dimensions for both groups. Academic respondents gave slightly higher ratings on the instructional utility dimension, consistent with their expressed interest in the tool as a pedagogical aid for bridging hand calculations and professional practice. Practitioners gave marginally higher ratings on workflow integration, reflecting their appreciation of the consolidation of previously fragmented multi-step workflows into a single interface.

TABLE II
USER ACCEPTANCE RATINGS (5-POINT LIKERT SCALE, $n = 14$)

Dimension	**Practitioners** ($n = 8$)	**Academic** ($n = 6$)	**Combined** ($n = 14$)
Accuracy	4.875	5.000	4.929
Ease of Use	4.750	4.833	4.786
Interface Clarity	4.750	4.833	4.786
Standards Confidence	4.875	4.833	4.857
Workflow Integration	4.875	4.833	4.857
Instructional Utility	4.750	5.000	4.857
Overall	**4.813**	**4.889**	**4.845**

C. Inferential Statistical Analysis

To determine whether user acceptance ratings differed significantly between practitioner and academic respondents, a Mann-Whitney U test was applied to each of the six rating dimensions. The Mann-Whitney U test was selected over an independent-samples t-test for two reasons: (1) the rating data are ordinal in nature, as responses were recorded on a five-point Likert scale; and (2) Shapiro-Wilk normality tests confirmed that the score distributions of both groups deviated significantly from normality ($W = 0.476$, $p < 0.001$ for practitioners; $W = 0.366$, $p < 0.001$ for academic respondents), violating the distributional assumption of parametric tests. The Mann-Whitney U test makes no normality assumption and is well suited to small-sample ordinal data [13].

Table III presents the results of the two-tailed Mann-Whitney U test for each dimension, reporting group means, the U statistic, and the exact p-value.

The Mann-Whitney U test returned no statistically significant difference between practitioner and academic respondents on any of the six rating dimensions (all $p \geq 0.05$). The largest observed difference was on the Instructional Utility dimension

TABLE III
MANN-WHITNEY U TEST RESULTS: PRACTITIONERS VS. ACADEMIC RESPONDENTS ($n_1 = 8, n_2 = 6$, TWO-TAILED, $\alpha = 0.05$)

Dimension	**P Mean**	**A Mean**	U	p	**Sig.**
Accuracy	4.875	5.000	21.0	0.471	ns
Ease of Use	4.750	4.833	22.0	0.786	ns
Interface Clarity	4.750	4.833	22.0	0.786	ns
Standards Confidence	4.875	4.833	25.0	0.915	ns
Workflow Integration	4.875	4.833	25.0	0.915	ns
Instructional Utility	4.750	5.000	18.0	0.243	ns

P = Practitioners; A = Academic; ns = not significant ($p \geq 0.05$)

($U = 18.0$, $p = 0.243$), where academic respondents rated the tool more highly (mean = 5.000) than practitioners (mean = 4.750), consistent with the academic group's primary interest in the tool as a teaching and verification aid. However, this difference did not reach statistical significance at the $\alpha = 0.05$ level, most likely due to the small sample sizes. The overall practitioner mean across all dimensions was 4.813 ($SD = 0.394$) and the overall academic mean was 4.889 ($SD = 0.319$).

These results indicate that the tool achieves equivalently high acceptance across both user populations, suggesting that the design decisions made during development—particularly the integration of step-by-step result transparency and the use of familiar PEC 2017 terminology—served the needs of both groups without requiring trade-offs between professional and educational utility.

VI. DISCUSSION

A. *Interpretation of Results*

Near-zero computational deviations across all five functions confirm that the tool faithfully implements the prescribed PEC 2017 and IEEE 1584-2018 procedures. Zero deviation in load calculation and conductor sizing reflects their deterministic, table-lookup nature. Sub-percent deviations in voltage drop and short-circuit analysis arise from IEEE-prescribed rounding conventions; the largest deviation (0.87% in arc-flash) is consistent with the inherent interpolation uncertainty in empirical arc-flash models [14] and is well within any practically relevant safety margin.

The Mann-Whitney U test confirmed no statistically significant difference between practitioner and academic acceptance ratings (all $p \geq 0.05$), indicating that design decisions made during development served both groups without trade-offs. The overall combined mean of 4.845 out of 5.00 is consistent with high-acceptance outcomes reported in technology acceptance studies across comparable professional and educational user groups [15]. The largest observed group difference (Instructional Utility, $p = 0.243$) reflects the academic group's interest in the tool as a verification and teaching aid, consistent with the qualitative focus group feedback.

Relative to spreadsheet-based workflows, the tool provides three material improvements: (1) automatic inter-function result propagation eliminates manual transfer errors; (2) embedded standard tables are applied consistently across all calculations; and (3) the IEEE 1584-2018 arc-flash module provides compliance that is difficult to implement correctly in spreadsheet form. Relative to OpenDSS and Pandapower, the tool sacrifices analytical depth in favor of a practitioner-oriented design workflow from load data to safety labeling.

B. *Limitations*

The following are the limitations that bound the current implementation.

1) *Graphical Visualization*. The tool operates through a form-based interface without a graphical single-line diagram editor, requiring users to enter each system element sequentially with no interactive canvas to construct or inspect the distribution network visually.
2) *Code currency*. The 2017 PEC edition was current at development. Future revisions will require a structured update process, ideally with a data-driven architecture separating standard tables from the calculation engine.
3) *Interoperability*. No export interface to CAD or BIM platforms currently exists.
4) *Sample size*. Focus group validation involved 14 respondents from a single region; broader multi-regional testing is needed to confirm generalizability.

VII. CONCLUSION

This paper presented the development and validation of an integrated electrical system design tool implementing PEC 2017 and IEEE 1584-2018 in a unified, accessible framework. All five design functions achieved computational accuracy within 1% of manual reference values, and user acceptance testing returned a combined mean of 4.845 out of 5.000 with no statistically significant difference between practitioner and academic respondents ($p \geq 0.05$ on all dimensions). A representative case study demonstrated a ten-fold reduction in design time relative to conventional spreadsheet workflows while preserving full result transparency for instructional use.

The statistical equivalence between practitioner and academic ratings is a meaningful result in itself. It confirms that the design decisions made during development—particularly the exposure of all intermediate results and the adoption of PEC 2017 terminology throughout the interface—served both constituencies simultaneously without requiring trade-offs. This dual-purpose utility is significant for Philippine engineering education, where the gap between classroom instruction and professional practice has historically been widened by the inaccessibility of integrated, standards-compliant tools. A student who verifies a hand calculation using the tool and a practitioner who completes a panel design with it are operating within the same computational environment, reinforcing the same standard and the same workflow discipline.

The findings confirm that locally developed, standards-compliant tools can serve as viable alternatives to expensive proprietary software in resource-constrained markets. The contribution of this work is not primarily algorithmic, but rather it lies in the deliberate integration of regulatory context, user-centered design, and open implementation. The practitioner-centered development model employed here, anchored in a structured needs analysis and validated through dual computational and user-acceptance tracks, may serve as a replicable template for similar tool development efforts addressing other national electrical codes or regional engineering contexts across Southeast Asia and beyond.

Future work will pursue the following directions: (1) extending the tool's scope to networked multi-panel systems requiring automated topology management; (2) implementing a data-driven architecture that separates PEC standard tables from the calculation engine to facilitate maintenance across code revision cycles; and (3) developing export interfaces to other design tools and common report formats to improve interoperability with existing professional workflows.

ACKNOWLEDGMENT

The authors thank the College of Engineering and to the Office of the Vice President for Research Development and Extension (OVPRDE) of Bicol University for the support and funding. As well as to the Building Officials of Albay Local Government Units (LGUs) and EE practitioners who participated in this study.

REFERENCES

[1] A. Ali, J. Yin, F. Li, H. Cui *et al.*, "Pathway toward an open source ecosystem in power systems: A blueprint for collaborative innovation and software sustainability," *IEEE Electrif. Mag.*, vol. 13, no. 2, pp. 58–67, Jun. 2025, doi: 10.1109/MELE.2025.3558711.

[2] Philippine Electrical Code (PEC) 2017, Institute of Integrated Electrical Engineers of the Philippines, Manila, Philippines, 2017.

[3] NFPA 70: National Electrical Code, National Fire Protection Association, 2007.

[4] IEEE Std 1584-2018, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, IEEE, New York, NY, USA, 2018.

[5] Operation Technology Inc., "ETAP Electrical Power System Analysis Software," 2023. [Online]. Available: https://etap.com

[6] SKM Systems Analysis Inc., "PowerTools for Windows," 2023. [Online]. Available: https://skm.com

[7] R. C. Dugan and T. E. McDermott, "An open source platform for collaborating on smart grid research," in *Proc. IEEE Power Energy Soc. Gen. Meeting*, Detroit, MI, USA, Jul. 2011, pp. 1–7.

[8] L. Thurner, A. Scheidler, F. Schäfer, J.-H. Menke, J. Dollichon, F. Meier, S. Meinecke, and M. Braun, "Pandapower—An open-source Python tool for convenient modeling, analysis, and optimization of electric power systems," *IEEE Trans. Power Syst.*, vol. 33, no. 6, pp. 6510–6521, Nov. 2018.

[9] G. V. Hilutin, A. M. Lunas, F. D. Dematera, Z. D. Mañago, L. A. D. Ayo, and P. J. N. Gealone, "Electrical assessment of Bicol University–Legazpi East Campus, Philippines," in *Proc. IEEE Syst. Inf. Eng. Des. Symp. (SIEDS)*, Charlottesville, VA, USA, Apr. 2023, pp. 25–30.

[10] D. Hajjar and S. M. AbouRizk, *Application framework for development of simulation tools*, J. Comput. Civ. Eng., vol. 14, no. 3, pp. 160–167, 2000.

[11] IEEE Std 141-1993, *IEEE Recommended Practice for Electric Power Distribution for Industrial Plants* (IEEE Red Book), IEEE, New York, NY, USA, 1993.

[12] NFPA 70E: Standard for Electrical Safety in the Workplace, National Fire Protection Association, Quincy, MA, USA, 2021.

[13] S. Siegel and N. J. Castellan, *Nonparametric Statistics for the Behavioral Sciences*, 2nd ed. New York, NY, USA: McGraw-Hill, 1988.

[14] R. L. Doughty, T. E. Neal, and H. L. Floyd, "Predicting incident energy to better manage the electric arc hazard on 600-V power distribution systems," *IEEE Trans. Ind. Appl.*, vol. 36, no. 1, pp. 257–269, Jan./Feb. 2000.

[15] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Quarterly*, vol. 27, no. 3, pp. 425–478, Sep. 2003.

[16] S. S. Shapiro and M. B. Wilk, "An analysis of variance test for normality (complete samples)," *Biometrika*, vol. 52, no. 3/4, pp. 591–611, Dec. 1965.