BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Complaint Against Kansas City Power & Light Company by Jamie Littich.	))	Docket No. 16-KCPE-195-COM

KANSAS CITY POWER & LIGHT COMPANY'S REPLY
TO STAFF'S SECOND REPORT AND RECOMMENDATION

Kansas City Power & Light Company ("KCP&L" or "Company"), by and through its counsel, hereby submits its reply ("Reply") to the *Notice of Filing of Staff's Second Report and Recommendation* ("Staff's 2nd Report") of the Staff of the State Corporation Commission of the State of Kansas ("Staff" and "Commission," respectively), filed on March 8, 2017.

In its 2nd Report, Staff continues to recommend that KCP&L be ordered to "'show cause' why it should *not* be required to take the actions outlined in [Staff's] Report."[1] As noted in KCP&L's January 30, 2017, response to Staff's Initial Report[2] ("KCP&L Response" or "Response"), Staff's recommendations are based on a misapplication of the National Electric Safety Code ("NESC") and unfounded conclusions, and as such are inappropriate.

Staff asserts that its interpretation as to the applicability of Part 1 of the NESC is correct, and offers additional support for its position. Below, KCP&L will explain why Staff's interpretation as to the applicability of Part 1 of the NESC is in error, and will respond to the additional comments contained in Staff's 2nd Report. Many of Staff's allegations are a restatement of previous allegations and, to that extent, KCP&L incorporates its previous responses herein by reference.

[1] Staff's 2nd Report, p. 9.
[2] Confidential Notice of Filing of Staff's Report and Recommendation, filed Dec. 15, 2016 ("Staff's Initial Report").

I. PROCEDURAL AND FACTUAL BACKGROUND

1. For the sake of brevity, KCP&L will not recite the entire procedural and factual background, except to the extent a clarification is necessary. Rather, this Reply will focus primarily on Staff's 2nd Report. A recitation of the procedural and factual background can be found in KCP&L's Response.

II. REPLY TO STAFF'S 2nd REPORT

2. In its Initial Report, Staff recommended the Commission require KCP&L to explain either in this proceeding, or in a separate show cause proceeding, why KCP&L should not be required to perform eight (8) specific tasks identified by Staff.[3] Staff's recommendations were based on an analysis involving the application of Part 1 of the NESC.[4] In its 2nd Report, Staff reasserts its recommendations contained in its Initial Report, and also states that "Staff… is not recommending the Commission order KCPL to perform the various tasks outlined in the R&R. Rather, Staff is recommending the Commission order KCPL to show cause as to why it should not be required to take the actions outlined in the Report."[5] As KCP&L explained in its Response to Staff's Initial Report and will further explain in this Reply, Staff's recommendations are founded on a misapplication of the NESC. Furthermore, Staff has provided no new analysis or evidence to support its recommendations, but has merely offered new opinions, assumptions and conjecture in support of initiating an extensive proceeding and requiring undertakings by KCP&L that have not been shown to be either necessary, or proportionately responsive to the incident at issue in this complaint. In fact, Staff is recommending the Commission order KCP&L to undertake actions that no other utility in Kansas is required to undertake. As noted in

[3] Staff's Initial Report, p. 12.
[4] Staff's Initial Report, pp. 9-10.
[5] Staff's 2nd Report, p. 9.

response to KCP&L Data Request No. 1, no other utility has been required to "perform and conduct a failure analysis for each outage occurrence" or "take additional steps prior to restoring service to confirm that service restoration will not cause a safety risk to adjacent customers" or "modify its software programs such that CSRs can search a group of adjacent customers for any unusual activity related to the distribution system." Staff's response is attached hereto as **Attachment A**. KCP&L will now respond to each item identified by Staff and explain why Staff's recommendations remain either unnecessary or unsupported.

A. Staff's assertion that the incident involved a bolted ground fault is unlikely and cannot be substantiated.

3. In the Background section of its 2nd Report, Staff frames its analysis based on the assumption that the fault in question was a bolted ground fault; however, Staff's assumption is unlikely and cannot be substantiated. A bolted ground fault implies a solid connection to the ground. Such a fault would have significant amperage. The short circuit peak secondary fault current, based upon the transformer and secondaries that are the subject of this complaint, is calculated to be approximately 8,569 amps for a line to neutral fault and 9,387 amps for a line to line fault.[6] This would equate to the expected amperage for a bolted ground fault. Staff's analysis, which is at best an approximation, shows a peak secondary current of 950 amps with an average of 300 amps – well below the amperage for a bolted ground fault. This difference would indicate the fault that occurred was not a "bolted ground fault" and most likely a high impedance fault, wherein an obstruction or impedance reduces the fault current, making it look more like load current. This distinction is important because a true bolted ground fault creates a much higher likelihood of fault clearance in a short period of time based on the secondary conductor damage curve. In reality, with the limited data available, there is simply no way to determine for

[6] See **Attachment B** for calculations.

certain if the secondary fault was or was not a "bolted ground fault"; however, Staff's analysis does not support their assertion.

B. KCP&L's interpretation of the NESC code is consistent with that of experts on the code – including the published official handbook written by the code's original authors.

4. As a reminder, Staff argued in its Initial Report that based on its investigation of the instant complaint proceeding, KCP&L was out of compliance with NESC provisions 101, 121A, 153, and 161A.[7] In its 2nd Report, Staff argues that its application of Part 1 of the NESC to the instant complaint is appropriate because it is Staff's belief that the scope of Part 1 of the NESC includes items outside generating and substation facilities. Specifically, Staff states that "[i]n Staff's opinion, the title and scope of Part 1 of the NESC clearly include equipment that is not necessarily within the confines of an Electric Supply Station."[8] However, Staff's position is an incorrect interpretation of the code and is in direct disagreement with the official interpretation of the NESC as expressly stated in the NESC Handbook ("the Handbook"). The Handbook is published by the NESC Committee members who actually wrote the code, in order to provide users with comments on the code and to give guidance as to the intent behind the various provisions. An excerpt from the Handbook pertaining to Rule 101 Scope states: "In all editions, Part 1 only applies where the covered facilities are accessible to qualified persons. ***Where the requirements of Rule 110A (Enclosures of equipment) are not met, the area is considered to be accessible to unqualified personnel and Part 2 applies. Where the requirements of Rule 110A are met, the area is considered to be accessible only to qualified***

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[7] Staff's Initial Report, pp. 9-10.
[8] Staff's 2nd Report, p. 3.

persons and Part 1 applies."[9] (Emphasis added.) Rule 110A provides information about how to keep unqualified personnel from getting near supply station equipment. This includes provisions for fencing, walls, barriers, partitions, etc. In other words, it is clear from the Handbook that Part 2 applies to the overhead facilities in question in this docket and Part 1 is expressly intended to only apply to supply stations. Staff's expansive application of the scope of Part 1 to encompass overhead facilities, like those in question in this docket, is inappropriate and contrary to the NESC drafters' intent.

5. The Handbook also comments on Rule 161 in Part 1 Electrical protection with the following statement: "Rule 161 applies in electric supply stations; ***there is no corresponding rule specifying overcurrent protection for electric supply lines outside of electric supply stations.***"[10] (Emphasis added.) The Handbook comment on Section 20 which is the Purpose, scope, and application of rules for Part 2 provides the following: "Section 20 describes the practical requirements related to protection of the public as well as of the supply and communications workers associated with the installation, operation, and maintenance of overhead supply and communication lines and equipment. ***It is important to highlight that this section does not cover installations located within supply stations that are secure from public access mainly because only authorized and qualified persons may enter and work within a supply station; such requirements are listed within Part 1***."[11] (Emphasis added.) Thus, it is clear, according to the authors of the NESC, generating station and substation facilities are the only items covered by Part 1, none of which are at issue in this proceeding.

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[9] *See* **Attachment C** - Institute of Electrical and Electronics Engineers ("IEEE") 2017 NESC Handbook Premier Edition, p. 85.

[10] *See* **Attachment D** - IEEE 2017 NESC Handbook Premier Edition, p. 155.

[11] *See* **Attachment E** - IEEE 2017 NESC Handbook Premier Edition, p. 175.

6. Further, the "*Seventh Interim Collection of the National Electric Safety Code Interpretations 1996-1997*" which is a document written by the NESC Committee, provides additional information on this issue. The document, in response to questions about the applicability of Part 1 and Part 2 of the Code, makes it clear that there is no correlation between Part 1 and Part 2 of the Code, and that the scope of each section has limited applicability. For example, an excerpt from the document provides that, "All of the rules in Part 1…apply only to electric supply stations, as stated in Rule 101-Scope (for Part 1)…All of the rules in Part 2… apply only to overhead lines, generally outside of electric supply stations, as stated in Rule 201 – Scope (for Part 2)."[12] Once again it is clear based on the interpretation provided by the authors of the code itself, generating station and substation facilities are the only items covered by Part 1. Staff's attempt to expand the scope of Part 1 and apply it to the overhead facilities in question in this proceeding and to find KCP&L in violation of the NESC as a result is erroneous and grossly unfair.

7. KCP&L's interpretation of the scope of Part 1 is consistent with the comments provided by the NESC Committee members as contained in the NESC Handbook, whereas Staff's interpretation is not. Further, KCP&L has consulted with an NESC Committee member who has confirmed that KCP&L's interpretation is correct.[13] As such, Staff's interpretation is not only contrary to the NESC but is also contrary to the NESC Committee members' stated intent regarding the scope of Part 1, as contained in the Handbook.

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[12] *See* **Attachment F** - NESC Committee, ASC C2, Seventh Interim Collection of the National Electrical Safety Code Interpretations 1996-1997, p. 12.

[13] *See* Affidavit of Troy B. Little, P.E., **Attachment G**.

C. KCP&L practices are not in violation of 1997 edition of the NESC which is incorporated by reference into K.A.R. 82-12-2.

8. Despite the fact that some of the discussion above involves a more recent version of the NESC Handbook, the comments contained therein are relevant to the 1997 code as well because much of the actual NESC Code language between the 1997 and the 2017 versions is the same. For example, with regard to Rule 153 – short-circuit protection of power transformers – was added to the code in 1997. The language of this rule has not changed since its inception. Rule 153 is contained in Part 1 of the code, and according to the NESC Committee members, Part 1 only pertains to generating station and substation facilities; thus, the transformers referred to in Rule 153 are power transformers located within generating stations and substations, and not distribution transformers which are located outside generating stations and substations, such as the ones in question in this docket. Similarly, Rule 161, which includes section 161A, that Staff alleges KCP&L violated, has remained unchanged since 1993. Therefore, Staff's allegation that KCP&L violated Rules 121A, 153, and 161 of the NESC based on the facts of this case is an impossibility because the facilities in question in this docket are not covered by Part 1 of the NESC.

D. KCP&L's equipment inspection, maintenance and vegetation management practices are proven adequate and effective.

9. In its 2nd Report, Staff again recommends that "the Commission order KCPL to show cause as to why the facilities discussed in the R&R are not in need of repair and/or in need of additional tree trimming." Staff has provided no objective support for its opinion that it believes the facts in this complaint are indicative of a widespread deficiency in maintenance practices by KCP&L. No evidence was provided to support Staff's claim of "tree branches in

contact with electric conductors when Staff conducted a field tour in the summer of 2016".[14] Moreover, splices in KCP&L conductors are evidence of proper line maintenance, not poor maintenance. There is no set number of splices that renders a line unsafe. A splice is a valid repair.

10. Staff's statement that it is their "*distinct impression*" that it not unusual for KCP&L's system to cause electrical house fires[15] is based upon interviews of which no records or transcripts have been provided. As such, these appear to be anecdotal and informal conversations with personnel from Consolidated Fire District No. 2 ("CFD2"), held in the context of Staff's investigation of a house fire for which the complainant – a resident of the community served by CFD2 – believes KCP&L to be at fault. In fact, Staff asserts that it "…focused on obtaining evidence that supported its analysis and recommendations"[16], which does not indicate an objective approach to these interviews. Therefore, KCP&L contends there is little objective basis to conclude that house fires caused by KCP&L facilities are widespread. Staff has provided no evidence to support such a position.

11. Part 2, Section 214 of the NESC, which does apply to the facilities in question in this proceeding, states the following: "Lines and equipment shall be inspected at such intervals as experience has shown to be necessary."[17] Per the NESC Handbook: "In general, the "experience" referred to is that of the utility responsible for operation and safety of the facilities in a manner to secure adequate and reliable results." [18] Through its existing programs, KCP&L both inspects equipment and monitors system operation based on its collective organizational

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[14] Staff's 2nd Report, p. 4.
[15] Staff's 2nd Report, p. 5.
[16] Staff's 2nd Report, p. 5.
[17] *See* **Attachment H** - IEEE 2017 NESC Handbook Premier Edition, p. 178.
[18] *See* **Attachment I** - IEEE 2017 NESC Handbook Premier Edition, p. 179.

experience and judgement, as well as its knowledge of industry best practices. In addition, KCP&L's Engineering team analyzes the performance of the KCP&L distribution system and recommends inspections, repairs, and reconstruction as deemed necessary. As noted in KCP&L's Response to Staff's Initial Report,[19] KCP&L has in place a variety of programs concerning system monitoring and safety. These programs were developed in accordance with the appropriate and applicable provisions of the NESC.

12. KCP&L maintains that Staff's recommendations regarding system-wide study and possible proactive replacement programs for transformer fuses and open-wire secondaries are not warranted by this single event. Contrary to Staff's recommendations these programs are neither trivial to study, nor easy to implement. Such programs are not only costly, but often result in disruption to customers in terms of crews in neighborhoods and backyards, and planned outages for system work. Staff's recommendations are overly broad and burdensome activities for which Staff has not given reasonable justification, and are frankly unprecedented.[20] KCP&L engineering personnel spend considerable time and effort to provide analysis, project/program management, and tactical support to previously mentioned Asset Management programs which are proven effective by a long, solid performance record. Staff has failed to provide reasonable justification for a fuse or secondary conductor replacement program to take priority over these effective existing programs.

13. KCP&L has been repeatedly recognized nationally as a top performer in the reliable delivery of electric power, and as stated in its Response to Staff's Initial Report, KCP&L has a long-standing history of serving its Kansas customers safely and reliably, winning multiple

[19] Response, pp. 9-10.
[20] *See* Affidavit of Troy B. Little, P.E. (Attachment G).

awards over the years for its efforts.[21] Similarly, KCP&L has been recognized nationally as a leader in vegetation management, again with multiple awards to its credit. Staff provides little evidence in support of its contention that a single incident overrides the precedent of KCP&L's previous safety records.

III. <u>CONCLUSION</u>

14. In conclusion, the analysis in Staff's 2nd Report is based on a misapplication of the NESC. KCP&L is not in violation of the NESC, as set forth above. Further, Staff's recommendations that the Commission require KCP&L to perform certain actions are either unnecessary or unwarranted. In fact, by Staff's own admission, it is requesting the Commission order KCP&L to undertake actions that the Commission has not required other utilities to do. As discussed in KCP&L's Response to Staff's Initial Report, Staff's recommendations in some instances would be contrary to KCP&L's approved tariffs, expand the role of public utilities, and result in expensive and unnecessary changes for all electric utilities across the state of Kansas.

WHEREFORE, for the reasons set forth above, KCP&L respectfully requests the Commission reject Staff's recommendations and instead dismiss the Complaint, with prejudice, and for other relief as the Commission deems just and reasonable.

[21] Response, pp. 9-10.

Respectfully submitted,

*/s/ Robert J. Hack*________________

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COUNSEL FOR KANSAS CITY POWER & LIGHT COMPANY

CERTIFICATE OF SERVICE

I, the undersigned, hereby certify that a true and correct copy of the above was electronically served, hand-delivered or mailed, postage prepaid, this 17th day of April 2017 to:

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INFORMATION REQUEST

Company Name: Kansas Corporation Commission
Case: 16-KCPE-195-COM
Case Description: In the Matter of the Complaint Against Kansas City Power & Light Company by Jamie Littich.
Requested By: Mary Turner
Requested From: Leo Haynos
Date Requested: January 12, 2017
Date Response Needed: January 26, 2017

Question No. 1 :
Please reference the Staff's Report and Recommendation, and provide all information and documentation in Staff's possession regarding other electric public utilities regulated by the Commission that are either do, or have been required by the Commission to:

a. Ensure that first responder field personnel "perform and conduct a failure analysis for each outage occurrence," (p. 2)
STAFF RESPONSE 1(a): Staff has no written information or documentation from electric public utilities regulated by the Commission regarding their procedures for performing and conducting failure analysis for each outage occurrence. To our knowledge, the Commission has not required electric utilities to perform failure analyses in the past. However, in an informal meeting with Westar engineering staff on July 7, 2016, they verbally explained to staff their process of providing a review and quality assurance to all outage documentation turned in by linemen.

b. Ensure that first responder field personnel "take additional steps prior to restoring service to confirm that service restoration will not cause a safety risk to adjacent customers", to the extent that "additional" refers to steps beyond those known by Staff to have been taken by KCP&L. (p. 11)

STAFF RESPONSE 1(b): Staff has no written information or documentation from electric public utilities regulated by the Commission regarding the procedures used by the utility to confirm service restoration will not cause a potential safety risk for customers that are impacted by a given outage. To our knowledge, the Commission has not required electric utilities to check with affected customers for potential safety concerns before energizing a residential transformer.

c. Either have in place or "modify its software programs such that CSRs can search a group of adjacent customers for any unusual activity related to the distribution system," (p. 11)

STAFF RESPONSE 1(c): Staff has no written information or documentation from electric public utilities regulated by the Commission regarding their Outage Management System and associated computer aided mapping capabilities that could assist a CSR in providing information to customers regarding outages in the vicinity of the customer making the inquiry. To our knowledge, the Commission has not required electric utilities to modify their OMS to provide this type of assistance to customers.

If for some reason the above information cannot be provided by the date requested please provide a written explanation of the reason(s).

Verification of Response

I have read the foregoing Information Request and answer(s) thereto and find the answer(s) to be true, accurate, full and complete, and contain no material misrepresentations or omissions to the best of my knowledge and belief; and I will disclose to the requestor any matter subsequently discovered which affects the accuracy or completeness of the answer(s) to this Data Request.

Signed: ______________________

Dated: 1-25-17

Maximum Available Fault Current Short Circuit Calculations

Transformer Size = kVA = 50 kVA (from transformer nameplate)
Transformer Impedance = %Z = 1.5% (from transformer nameplate)
Secondary L-L Voltage = E_{L-L} = 240 V
Secondary L-N Voltage = E_{L-N} = 120 V
Length of Secondary = L = 25 ft (assumed distance)
Constant = C = 6044 for #2 Cu (taken from Table 4 "Conductors & Bussways C Values")

<u>Maximum Available Fault Current (MAFC) Short Circuit Calculation (bolted fault) Line to Line Fault</u>

I_{L-L} = (kVA x 1000)/E_{L-L} = (50 x 1000)/240 = 208 Amps

Multiplier = 100/%Z = 100/1.5 = 66.67

I_{SC} = I_{L-L} x Multiplier = 208 x 66.67 = 13,866 Amps (MAFC at the transformer secondary)

f = (2 x L x I_{SC})/(C x E_{L-L}) = (2 x 25 x 13,866)/(6044 x 240) = .478

M = 1/(1 + f) = 1/(1 + .478) = .677

I_{SCLL} = I_{SC} x M = 13,866 x .677 = 9,387 Amps (MAFC including 25ft of #2 Cu secondary)

<u>Maximum Available Fault Current Short Circuit Calculation (bolted fault) Line to Neutral Fault</u>

I_{L-L} = (kVA x 1000)/E_{L-L} = (50 x 1000)/240 = 208 Amps

Multiplier = 100/%Z = 100/1.5 = 66.67

$I_{SC(LL)}$ = I_{L-L} x Multiplier = 208 x 66.67 = 13,866 Amps

$I_{SC(LN)}$ = $I_{SC(LL)}$ x 1.5 = 13,866 x 1.5 = 20,799 Amps (MAFC at the transformer secondary)

f = (2 x L x I_{SC})/(C x E_{L-N}) = (2 x 25 x 13,866)/(6044 x 120) = 1.43

M = 1/(1 + f) = 1/(1 + 1.43) = .412

I_{SCLL} = $I_{SC(LN)}$ x M = 20,799 x .412 = 8,569 Amps (MAFC including 25ft of #2 Cu secondary)

Three-Phase Short Circuits

Basic Point-to-Point Calculation Procedure

Step 1. Determine the transformer full load amps (F.L.A.) from either the nameplate, the following formulas or Table 1:

3Ø Transformer $$I_{F.L.A.} = \frac{kVA \times 1000}{E_{L-L} \times 1.732}$$

1Ø Transformer $$I_{F.L.A.} = \frac{kVA \times 1000}{E_{L-L}}$$

Step 2. Find the transformer multiplier. See Notes 1 and 2

$$\text{Multiplier} = \frac{100}{{}^{*}\%Z_{transformer}}$$

* **Note 1.** Get %Z from nameplate or Table 1. Transformer impedance (Z) helps to determine what the short circuit current will be at the transformer secondary. Transformer impedance is determined as follows: The transformer secondary is short circuited. Voltage is increased on the primary until full load current flows in the secondary. This applied voltage divided by the rated primary voltage (times 100) is the impedance of the transformer.

Example: For a 480 Volt rated primary, if 9.6 volts causes secondary full load current to flow through the shorted secondary, the transformer impedance is 9.6/480 = .02 = 2%Z.

* **Note 2.** In addition, UL (Std. 1561) listed transformers 25kVA and larger have a ± 10% impedance tolerance. Short circuit amps can be affected by this tolerance. Therefore, for high end worst case, multiply %Z by .9. For low end of worst case, multiply %Z by 1.1. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

Step 3. Determine by formula or Table 1 the transformer let-through short-circuit current. See Notes 3 and 4.

Note 3. Utility voltages may vary ±10% for power and ±5.8% for 120 Volt lighting services. Therefore, for highest short circuit conditions, multiply values as calculated in step 3 by 1.1 or 1.058 respectively. To find the lower end worst case, multiply results in step 3 by .9 or .942 respectively.

Note 4. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Step 4. Calculate the "f" factor.

3Ø Faults $$f = \frac{1.732 \times L \times I_{3Ø}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Line (L-L) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-L}}{C \times n \times E_{L-L}}$$

1Ø Line-to-Neutral (L-N) Faults
See Note 5 & Table 3 $$f = \frac{2 \times L \times I_{L-N}^{\dagger}}{C \times n \times E_{L-N}}$$

Where:

L = length (feet) of conductor to the fault.
C = constant from Table 4 of "C" values for conductors and Table 5 of "C" values for busway.
n = Number of conductors per phase (adjusts C value for parallel runs)
I = Available short-circuit current in amperes at beginning of circuit.
E = Voltage of circuit.

† Note 5. The L-N fault current is higher than the L-L fault current at the secondary terminals of a single-phase center-tapped transformer. The short-circuit current available (I) for this case in Step 4 should be adjusted at the transformer terminals as follows: At L-N center tapped transformer terminals, $I_{L-N} = 1.5 \times I_{L-L}$ at Transformer Terminals.

At some distance from the terminals, depending upon wire size, the L-N fault current is lower than the L-L fault current. The 1.5 multiplier is an approximation and will theoretically vary from 1.33 to 1.67. These figures are based on change in turns ratio between primary and secondary, infinite source available, zero feet from terminals of transformer, and 1.2 x %X and 1.5 x %R for L-N vs. L-L resistance and reactance values. Begin L-N calculations at transformer secondary terminals, then proceed point-to-point.

Step 5. Calculate "M" (multiplier) or take from Table 2.

$$M = \frac{1}{1+f}$$

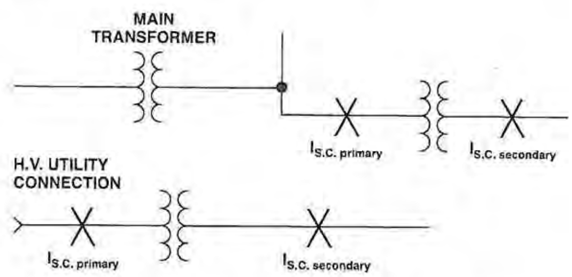
Step 6. Calculate the available short circuit symmetrical RMS current at the point of fault. Add motor contribution, if applicable.

$$I_{S.C.\,sym.\,RMS} = I_{S.C.} \times M$$

Step 6A. Motor short circuit contribution, if significant, may be added at all fault locations throughout the system. A practical estimate of motor short circuit contribution is to multiply the total motor current in amps by 4. Values of 4 to 6 are commonly accepted.

Calculation of Short-Circuit Currents at Second Transformer in System

Use the following procedure to calculate the level of fault current at the secondary of a second, downstream transformer in a system when the level of fault current at the transformer primary is known.



Procedure for Second Transformer in System

Step A. Calculate the "f" factor ($I_{S.C.\,primary}$ known)

3Ø Transformer
($I_{S.C.\,primary}$ and $I_{S.C.\,secondary}$ are 3Ø fault values)
$$f = \frac{I_{S.C.\,primary} \times V_{primary} \times 1.73\,(\%Z)}{100{,}000 \times V_{transformer}}$$

1Ø Transformer
($I_{S.C.\,primary}$ and $I_{S.C.\,secondary}$ are 1Ø fault values: $I_{S.C.\,secondary}$ is L-L)
$$f = \frac{I_{S.C.\,primary} \times V_{primary} \times (\%Z)}{100{,}000 \times V_{transformer}}$$

Step B. Calculate "M" (multiplier).

$$M = \frac{1}{1+f}$$

Step C. Calculate the short-circuit current at the secondary of the transformer. (See Note under Step 3 of "Basic Point-to-Point Calculation Procedure".)

$$I_{S.C.\,secondary} = \frac{V_{primary}}{V_{secondary}} \times M \times I_{S.C.\,primary}$$

Short Circuit Current Calculations

Three-Phase Short Circuits

System A

Available Utility
Infinite Assumption

1500 KVA Transformer, 480V, 3Ø, 3.5%Z, 3.45%X, .56%R

$I_{f.l.}$ =1804A

25' - 500kcmil
6 Per Phase
Service Entrance
Conductors in Steel Conduit

2000A Switch

KRP-C-2000SP Fuse

Fault X_1

400A Switch

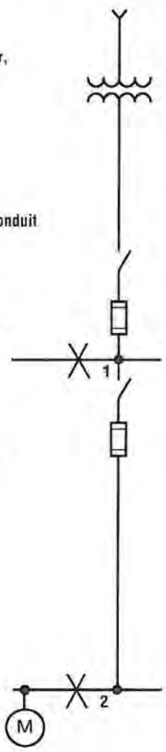
LPS-RK-400SP Fuse

50' - 500 kcmil
Feeder Cable
in Steel Conduit

Fault X_2

Motor Contribution

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \dfrac{1500 \times 1000}{480 \times 1.732} = 1804A$

Step 2. $\text{Multiplier} = \dfrac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1804 \times 28.57 = 51{,}540A$

$I_{S.C.\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS} = 51{,}504 + 7{,}216 = 58{,}720A$

Step 4. $f = \dfrac{1.732 \times 25 \times 51{,}540}{22{,}185 \times 6 \times 480} = 0.0349$

Step 5. $M = \dfrac{1}{1 + .0349} = .9663$

Step 6. $I_{S.C.sym\ RMS} = 51{,}540 \times .9663 = 49{,}803A$

$I_{S.C.motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total S.C.\ sym\ RMS\ (fault\ X_1)} = 49{,}803 + 7{,}216 = 57{,}019A$

Fault X_2

Step 4. Use $I_{S.C.sym\ RMS}$ @ Fault X_1 to calculate "f"

$f = \dfrac{1.732 \times 50 \times 49{,}803}{22{,}185 \times 480} = .4050$

Step 5. $M = \dfrac{1}{1 + .4050} = .7117$

Step 6. $I_{S.C.sym\ RMS} = 49{,}803 \times .7117 = 35{,}445A$

$I_{sym\ motor\ contrib} = 4 \times 1{,}804^* = 7{,}216A$

$I_{total\ S.C.\ sym\ RMS\ (fault\ X_2)} = 35{,}445 + 7{,}216 = 42{,}661A$

*Assumes 100% motor load. If 50% of this load was from motors, $I_{S.C.}$ motor contrib. $= 4 \times 1{,}804 \times .5 = 3608A$

System B

Available Utility
Infinite Assumption

1000 KVA Transformer, 480V, 3Ø, 3.5%Z

$I_{f.l.}$= 1203A

30' - 500 kcmil
4 Per Phase
Copper in PVC Conduit

1600A Switch

KRP-C-1500SP Fuse

Fault X_1

400A Switch

LPS-RK-350SP Fuse

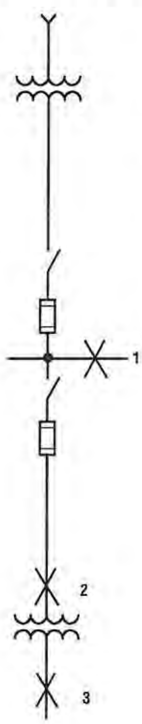
20' - 2/0
2 Per Phase
Copper in PVC Conduit

Fault X_2

225 KVA transformer, 208V, 3Ø 1.2%Z

Fault X_3

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \dfrac{1000 \times 1000}{480 \times 1.732} = 1203A$

Step 2. $\text{Multiplier} = \dfrac{100}{3.5} = 28.57$

Step 3. $I_{S.C.} = 1203 \times 28.57 = 34{,}370A$

Step 4. $f = \dfrac{1.732 \times 30 \times 34{,}370}{26{,}706 \times 4 \times 480} = .0348$

Step 5. $M = \dfrac{1}{1 + .0348} = .9664$

Step 6. $I_{S.C.sym\ RMS} = 34{,}370 \times .9664 = 33{,}215A$

Fault X_2

Step 4. $f = \dfrac{1.732 \times 20 \times 33{,}215}{2 \times 11{,}424 \times 480} = .1049$

Step 5. $M = \dfrac{1}{1 + .1049} = .905$

Step 6. $I_{S.C.sym\ RMS} = 33{,}215 \times .905 = 30{,}059A$

Fault X_3

Step A. $f = \dfrac{30{,}059 \times 480 \times 1.732 \times 1.2}{100{,}000 \times 225} = 1.333$

Step B. $M = \dfrac{1}{1 + 1.333} = .4286$

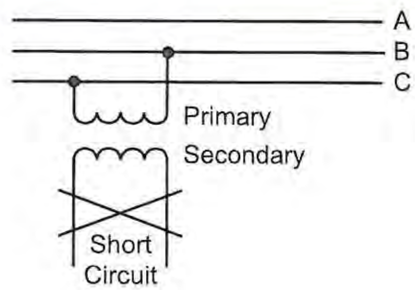
Step C. $I_{S.C.\ sym\ RMS} = \dfrac{480 \times .4286 \times 30{,}059}{208} = 29{,}731A$

Single-Phase Short Circuits

Short circuit calculations on a single-phase center tapped transformer system require a slightly different procedure than 3Ø faults on 3Ø systems.

1. It is necessary that the proper impedance be used to represent the primary system. For 3Ø fault calculations, a single primary conductor impedance is only considered from the source to the transformer connection. This is compensated for in the 3Ø short circuit formula by multiplying the single conductor or single-phase impedance by 1.73.

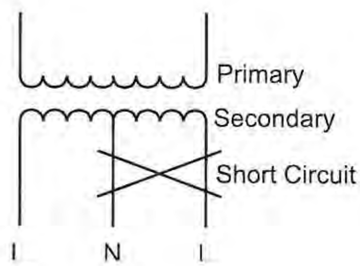
   However, for single-phase faults, a primary conductor impedance is considered from the source to the transformer and back to the source. This is compensated in the calculations by multiplying the 3Ø primary source impedance by two.



2. The impedance of the center-tapped transformer must be adjusted for the half-winding (generally line-to-neutral) fault condition.

   The diagram at the right illustrates that during line-to-neutral faults, the full primary winding is involved but, only the half-winding on the secondary is involved. Therefore, the actual transformer reactance and resistance of the half-winding condition is different than the actual transformer reactance and resistance of the full winding condition. Thus, adjustment to the %X and %R must be made when considering line-to-neutral faults. The adjustment multipliers generally used for this condition are as follows:

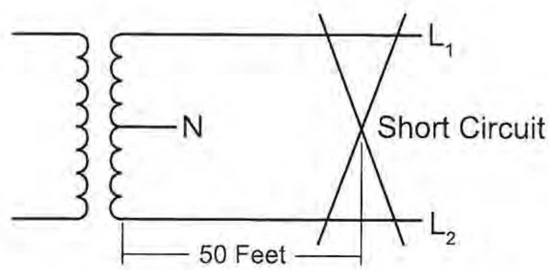
   - 1.5 times full winding %R on full winding basis.
   - 1.2 times full winding %X on full winding basis.



Note: %R and %X multipliers given in "Impedance Data for Single Phase Transformers" Table may be used, however, calculations must be adjusted to indicate transformer kVA/2.

3. The impedance of the cable and two-pole switches on the system must be considered "both-ways" since the current flows to the fault and then returns to the source. For instance, if a line-to-line fault occurs 50 feet from a transformer, then 100 feet of cable impedance must be included in the calculation.

   The calculations on the following pages illustrate 1Ø fault calculations on a single-phase transformer system. Both line-to-line and line-to-neutral faults are considered.



Note in these examples:

a. The multiplier of 2 for some electrical components to account for the single-phase fault current flow,

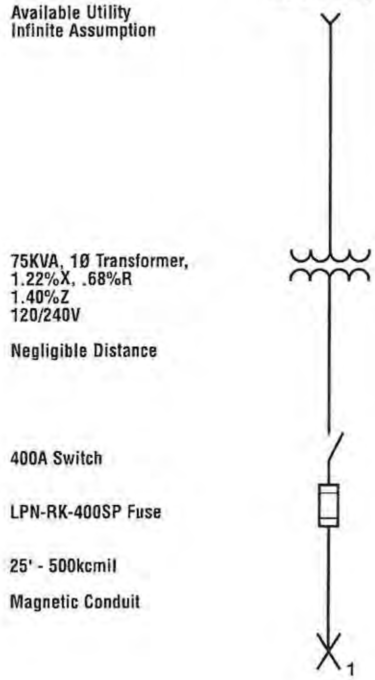
b. The half-winding transformer %X and %R multipliers for the line-to-neutral fault situation, and

c. The kVA and voltage bases used in the per-unit calculations.

Single-Phase Short Circuits

Line-to-Line Fault @ 240V — Fault X_1

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.} = 312.5 \times 71.43 = 22{,}322A$

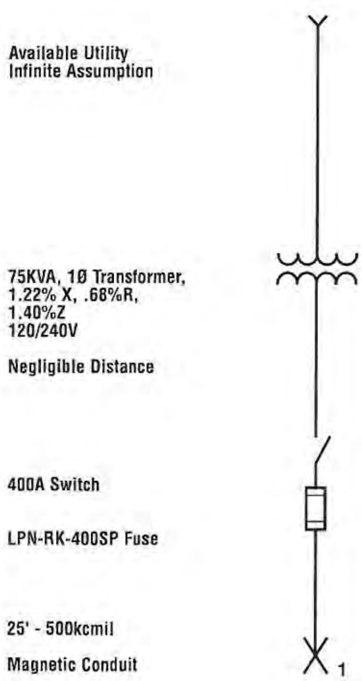
Step 4. $f = \frac{2 \times 25 \times 22{,}322}{22{,}185 \times 240} = .2096$

Step 5. $M = \frac{1}{1 + .2096} = .8267$

Step 6. $I_{S.C.\ L\text{-}L\ (X_1)} = 22{,}322 \times .8267 = 18{,}453A$

Line-to-Neutral Fault @ 120V — Fault X_1

One-Line Diagram



Fault X_1

Step 1. $I_{f.l.} = \frac{75 \times 1000}{240} = 312.5A$

Step 2. $\text{Multiplier} = \frac{100}{1.40} = 71.43$

Step 3. $I_{S.C.\ (L\text{-}L)} = 312.5 \times 71.43 = 22{,}322A$

$I_{S.C.\ (L\text{-}N)} = 22{,}322 \times 1.5 = 33{,}483A$

Step 4. $f = \frac{2^{*} \times 25 \times 22{,}322 \times 1.5}{22{,}185 \times 120} = .6288$

Step 5. $M = \frac{1}{1 + .6288} = .6139$

Step 6. $I_{S.C.\ L\text{-}N\ (X_1)} = 33{,}483 \times .6139 = 20{,}555A$

*Assumes the neutral conductor and the line conductor are the same size.

Impedance & Reactance Data

Transformers

Table 1. Short-Circuit Currents Available from Various Size Transformers

(Based upon actual field nameplate data or from utility transformer worst case impedance)

Voltage and Phase	kVA	Full Load Amps	% Impedance†† (Nameplate)	Short Circuit Amps†
120/240 1 ph.*	25	104	1.5	12175
	37.5	156	1.5	18018
	50	208	1.5	23706
	75	313	1.5	34639
	100	417	1.6	42472
	167	696	1.6	66644
120/208 3 ph.**	45	125	1.0	13879
	75	208	1.0	23132
	112.5	312	1.11	31259
	150	416	1.07	43237
	225	625	1.12	61960
	300	833	1.11	83357
	500	1388	1.24	124364
	750	2082	3.50	66091
	1000	2776	3.50	88121
	1500	4164	3.50	132181
	2000	5552	4.00	154211
	2500	6940	4.00	192764
277/480 3 ph.**	75	90	1.00	10035
	112.5	135	1.00	15053
	150	181	1.20	16726
	225	271	1.20	25088
	300	361	1.20	33451
	500	602	1.30	51463
	750	903	3.50	28672
	1000	1204	3.50	38230
	1500	1806	3.50	57345
	2000	2408	4.00	66902
	2500	3011	4.00	83628

*Single-phase values are L-N values at transformer terminals. These figures are based on change in turns ratio between primary and secondary, 100,000 KVA primary, zero feet from terminals of transformer, 1.2 (%X) and 1.5 (%R) multipliers for L-N vs. L-L reactance and resistance values and transformer X/R ratio = 3.

**Three-phase short-circuit currents based on "infinite" primary.

†† UL listed transformers 25 KVA or greater have a ±10% impedance tolerance. Short-circuit amps shown in Table 1 reflect –10% condition. Transformers constructed to ANSI standards have a ±7.5% impedance tolerance (two-winding construction).

† Fluctuations in system voltage will affect the available short-circuit current. For example, a 10% increase in system voltage will result in a 10% greater available short-circuit currents than as shown in Table 1.

Table 2. "M" (Multiplier) $M = \frac{1}{1+f}$

f	M	f	M	f	M
0.01	0.99	0.50	0.67	7.00	0.13
0.02	0.98	0.60	0.63	8.00	0.11
0.03	0.97	0.70	0.59	9.00	0.10
0.04	0.96	0.80	0.55	10.00	0.09
0.05	0.95	0.90	0.53	15.00	0.06
0.06	0.94	1.00	0.50	20.00	0.05
0.07	0.93	1.20	0.45	30.00	0.03
0.08	0.93	1.50	0.40	40.00	0.02
0.09	0.92	1.75	0.36	50.00	0.02
0.10	0.91	2.00	0.33	60.00	0.02
0.15	0.87	2.50	0.29	70.00	0.01
0.20	0.83	3.00	0.25	80.00	0.01
0.25	0.80	3.50	0.22	90.00	0.01
0.30	0.77	4.00	0.20	100.00	0.01
0.35	0.74	5.00	0.17		
0.40	0.71	6.00	0.14		

Impedance Data for Single-Phase Transformers

kVA 1Ø	Suggested X/R Ratio for Calculation	Normal Range of Percent Impedance (%Z)*	Impedance Multipliers** For Line-to-Neutral Faults for %X	for %R
25.0	1.1	1.2–6.0	0.6	0.75
37.5	1.4	1.2–6.5	0.6	0.75
50.0	1.6	1.2–6.4	0.6	0.75
75.0	1.8	1.2–6.6	0.6	0.75
100.0	2.0	1.3–5.7	0.6	0.75
167.0	2.5	1.4–6.1	1.0	0.75
250.0	3.6	1.9–6.8	1.0	0.75
333.0	4.7	2.4–6.0	1.0	0.75
500.0	5.5	2.2–5.4	1.0	0.75

*National standards do not specify %Z for single-phase transformers. Consult manufacturer for values to use in calculation.

**Based on rated current of the winding (one-half nameplate kVA divided by secondary line-to-neutral voltage).

Note: UL Listed transformers 25 kVA and greater have a ± 10% tolerance on their impedance nameplate.

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Impedance Data for Single-Phase and Three-Phase Transformers-Supplement†

kVA 1Ø	3Ø	%Z	Suggested X/R Ratio for Calculation
10	—	1.2	1.1
15	—	1.3	1.1
	75	1.11	1.5
	150	1.07	1.5
	225	1.12	1.5
	300	1.11	1.5
333	—	1.9	4.7
	500	1.24	1.5
500	—	2.1	5.5

†These represent actual transformer nameplate ratings taken from field installations.

Note: UL Listed transformers 25kVA and greater have a ±10% tolerance on their impedance nameplate.

Table 3.
Various Types of Short -Circuit Currents as a Percent of Three Phase Bolted Faults (Typical).

Three Phase Bolted Fault	100%
Line-to-Line Bolted Fault	87%
Line-to-Ground Bolted Fault	25-125%* (Use 100% near transformer, 50% otherwise)
Line-to-Neutral Bolted Fault	25-125% (Use 100% near tansformer, 50% otherwise)
Three Phase Arcing Fault	89% (maximum)
Line-to-Line Arcing Fault	74% (maximum)
Line-to-Ground Arcing Fault (minimum)	38% (minimum)

*Typically much lower but can actually exceed the Three Phase Bolted Fault if it is near the transformer terminals. Will normally be between 25% to 125% of three phase bolted fault value.

Conductors & Busways "C" Values

Table 4. "C" Values for Conductors

AWG or kcmil	Three Single Conductors, Conduit, Steel 600V	Steel 5kV	Steel 15kV	Nonmagnetic 600V	Nonmagnetic 5kV	Nonmagnetic 15kV	Three-Conductor Cable, Conduit, Steel 600V	Steel 5kV	Steel 15kV	Nonmagnetic 600V	Nonmagnetic 5kV	Nonmagnetic 15kV
Copper												
14	389	-	-	389	-	-	389	-	-	389	-	-
12	617	-	-	617	-	-	617	-	-	617	-	-
10	981	-	-	982	-	-	982	-	-	982	-	-
8	1557	1551	-	1559	1555	-	1559	1557	-	1560	1558	-
6	2425	2406	2389	2430	2418	2407	2431	2425	2415	2433	2428	2421
4	3806	3751	3696	3826	3789	3753	3830	3812	3779	3838	3823	3798
3	4774	4674	4577	4811	4745	4679	4820	4785	4726	4833	4803	4762
2	5907	5736	5574	6044	5926	5809	5989	5930	5828	6087	6023	5958
1	7293	7029	6759	7493	7307	7109	7454	7365	7189	7579	7507	7364
1/0	8925	8544	7973	9317	9034	8590	9210	9086	8708	9473	9373	9053
2/0	10755	10062	9390	11424	10878	10319	11245	11045	10500	11703	11529	11053
3/0	12844	11804	11022	13923	13048	12360	13656	13333	12613	14410	14119	13462
4/0	15082	13606	12543	16673	15351	14347	16392	15890	14813	17483	17020	16013
250	16483	14925	13644	18594	17121	15866	18311	17851	16466	19779	19352	18001
300	18177	16293	14769	20868	18975	17409	20617	20052	18319	22525	21938	20163
350	19704	17385	15678	22737	20526	18672	22646	21914	19821	24904	24126	21982
400	20566	18235	16366	24297	21786	19731	24253	23372	21042	26916	26044	23518
500	22185	19172	17492	26706	23277	21330	26980	25449	23126	30096	28712	25916
600	22965	20567	17962	28033	25204	22097	28752	27975	24897	32154	31258	27766
750	24137	21387	18889	29735	26453	23408	31051	30024	26933	34605	33315	29735
1,000	25278	22539	19923	31491	28083	24887	33864	32689	29320	37197	35749	31959
Aluminum												
14	237	-	-	237	-	-	237	-	-	237	-	-
12	376	-	-	376	-	-	376	-	-	376	-	-
10	599	-	-	599	-	-	599	-	-	599	-	-
8	951	950	-	952	951	-	952	951	-	952	952	-
6	1481	1476	1472	1482	1479	1476	1482	1480	1478	1482	1481	1479
4	2346	2333	2319	2350	2342	2333	2351	2347	2339	2353	2350	2344
3	2952	2928	2904	2961	2945	2929	2963	2955	2941	2966	2959	2949
2	3713	3670	3626	3730	3702	3673	3734	3719	3693	3740	3725	3709
1	4645	4575	4498	4678	4632	4580	4686	4664	4618	4699	4682	4646
1/0	5777	5670	5493	5838	5766	5646	5852	5820	5717	5876	5852	5771
2/0	7187	6968	6733	7301	7153	6986	7327	7271	7109	7373	7329	7202
3/0	8826	8467	8163	9110	8851	8627	9077	8981	8751	9243	9164	8977
4/0	10741	10167	9700	11174	10749	10387	11185	11022	10642	11409	11277	10969
250	12122	11460	10849	12862	12343	11847	12797	12636	12115	13236	13106	12661
300	13910	13009	12193	14923	14183	13492	14917	14698	13973	15495	15300	14659
350	15484	14280	13288	16813	15858	14955	16795	16490	15541	17635	17352	16501
400	16671	15355	14188	18506	17321	16234	18462	18064	16921	19588	19244	18154
500	18756	16828	15657	21391	19503	18315	21395	20607	19314	23018	22381	20978
600	20093	18428	16484	23451	21718	19635	23633	23196	21349	25708	25244	23295
750	21766	19685	17686	25976	23702	21437	26432	25790	23750	29036	28262	25976
1,000	23478	21235	19006	28779	26109	23482	29865	29049	26608	32938	31920	29135

Note: These values are equal to one over the impedance per foot and based upon resistance and reactance values found in IEEE Std 241-1990 (Gray Book), IEEE Recommended Practice for Electric Power Systems in Commerical Buildings & IEEE Std 242-1986 (Buff Book), IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems. Where resistance and reactance values differ or are not available, the Buff Book values have been used. The values for reactance in determining the C Value at 5 KV & 15 KV are from the Gray Book only (Values for 14-10 AWG at 5 kV and 14-8 AWG at 15 kV are not available and values for 3 AWG have been approximated).

Table 5. "C" Values for Busway

Ampacity	Busway Plug-In Copper	Feeder Aluminum	Feeder Copper	High Impedance Aluminum	High Impedance Copper
225	28700	23000	18700	12000	—
400	38900	34700	23900	21300	—
600	41000	38300	36500	31300	—
800	46100	57500	49300	44100	—
1000	69400	89300	62900	56200	15600
1200	94300	97100	76900	69900	16100
1350	119000	104200	90100	84000	17500
1600	129900	120500	101000	90900	19200
2000	142900	135100	134200	125000	20400
2500	143800	156300	180500	166700	21700
3000	144900	175400	204100	188700	23800
4000	—	—	277800	256400	—

Note: These values are equal to one over the impedance per foot for impedance in a survey of industry.

Voltage Drop Calculations

Ratings of Conductors and Tables to Determine Volt Loss

With larger loads on new installations, it is extremely important to consider volt loss in mind, otherwise some very unsatisfactory problems are likely to be encountered.

The actual conductor used must also meet the other sizing requirements such as full-load current, ambient temperature, number in a raceway, etc.

How to Figure Volt Loss

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps) by the *figure* shown in table for the kind of current and the size of wire to be used, by one over the number of conductors per phase.

Then, put a decimal point in front of the last 6 digits–you have the *volt loss* to be expected on that circuit.

Example – 6 AWG copper wire in 180 feet of iron conduit–3 phase, 40 amp load at 80% power factor.
Multiply feet by amperes: 180 x 40 = 7200
Multiply this number by number from table for 6 AWG wire three-phase at 80% power factor: 7200 x 745 = 5364000

Multiply by $\frac{1}{\#/\text{phase}}$ $5364000 \times \frac{1}{1} = 5364000$

Place decimal point 6 places to left.
This gives volt loss to be expected: 5.364V
(For a 240V circuit the % voltage drop is $\frac{5.364}{240} \times 100$ or 2.23%).

These Tables take into consideration *reactance on AC circuits* as well as resistance of the wire.

Remember on short runs to check to see that the size and type of wire indicated has sufficient ampere capacity.

How to Select Size of Wire

Multiply *distance* (length in feet of one wire) by the *current* (expressed in amps), by one over the number of conductors per phase.

Divide that figure into the permissible *volt loss* multiplied by 1,000,000.

Look under the column applying to the type of current and power factor for the figure nearest, but not above your result – you have the size of wire needed.

Example – Copper in 180 feet of steel conduit–3 phase, 40 amp load at 80% power factor–Volt loss from local code equals 5.5 volts.
Multiply feet by amperes by $\frac{1}{\#/\text{phase}}$ $180 \times 40 \times \frac{1}{1} = 7200.$
Divide permissible volt loss multiplied by 1,000,000 by this number: $\frac{5.5 \times 1{,}000{,}000}{7200} = 764.$

Select number from Table, three-phase at 80% power factor, that is nearest but not greater than 764. This number is 745 which indicates the size of wire needed: 6 AWG.

Line-to-Neutral

For line to neutral voltage drop on a 3 phase system, divide the three phase value by 1.73. For line to neutral voltage drop on a single phase system, divide single phase value by 2.

Open Wiring

The volt loss for open wiring installations depends on the separation between conductors. The volt loss is approximately equal to that for conductors in non-magnetic conduit. 310.15 offers a method to calculate conductor ampacity.

Installation in Conduit, Cable or Raceway

NEC® Tables 310.16 through 310.19 give allowable ampacities (current-carrying capacities) for not more than three conductors in a conduit, cable, or raceway. Where the number of conductors exceeds three the allowable ampacity of each conductor must be reduced as shown in the following tables:

Installation in Conduit, Cable or Raceway per 310.15(B)(2)(a)

The Number of Conductors In One Conduit, Raceway Or Cable	Percentage of Values In Tables 310.16 And 310.18
4 to 6	80%
7 to 9	70%
10 to 20	50%
21 to 30	45%
31 to 40	40%
41 and over	35%

Conditions Causing Higher Volt Loss

The voltage loss is increased when a conductor is operated at a higher temperature because the resistance increases.

If type RH, RHW, THW, or THWN wire (75°C wire) is loaded to near its full rating, or if room temperature is 15°C higher than normal, add the following percentages to get the volt loss.

Conditions Causing Higher Volt Loss

	Direct	Single Or Three Phase–Power Factor				
Wire Size	Current	100%	90%	80%	70%	60%
14 to 4 AWG	5.0%	5.0%	4.8%	4.7%	4.7%	4.6%
2 to 3/0 AWG	5.0%	5.0%	4.2%	3.8%	3.5%	3.3%
4/0 AWG to 500 kcmil	5.0%	5.0%	3.1%	2.6%	2.4%	2.0%
600 kcmil to 1000 kcmil	5.0%	5.0%	2.5%	2.2%	1.6%	1.3%

If type RHH, THHN or XHHW wire (90°C. wire) is loaded to near its full rating or if room temperature is 30°C higher than normal, add *twice* the above percentages to get the volt loss.

Room Temperature Affects Ratings

The ampacities (carrying capacities) of conductors are based on a room temperature of 86°F or 30°C. If room temperature is higher, the ampacities are reduced by using the following multipliers; (for 0-2000 volt, insulated conductors not more than 3 conductors in raceway or direct buried, Table 310.16).

Room Temperature Affects Ratings

Room		Ampacity Multiplier		
Temperature	TW	THW, THWN	THHN, XHHW*	
°C	°F	(60°C Wire)	(75°C Wire)	(90°C Wire)
31-35	87-95	.91	.94	.96
36-40	96-104	.82	.88	.91
41-45	105-113	.71	.82	.87
46-50	114-122	.58	.75	.82
51-55	123-131	.41	.67	.76
56-60	132-140	–	.58	.71
61-70	141-158	–	.33	.58
71-80	159-176	–	–	.41

COOPER **Bussmann**

Voltage Drop Calculations

Copper Conductors — Ratings & Volt Loss†

Conduit	Wire Size	Ampacity Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)	Direct Current	Volt Loss (See explanation prior page.) Three-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%	Single-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%
Steel Conduit	14	20*	20*	25*	6140	5369	4887	4371	3848	3322	6200	5643	5047	4444	3836
	12	25*	25*	30*	3860	3464	3169	2841	2508	2172	4000	3659	3281	2897	2508
	10	30	35*	40*	2420	2078	1918	1728	1532	1334	2400	2214	1995	1769	1540
	8	40	50	55	1528	1350	1264	1148	1026	900	1560	1460	1326	1184	1040
	6	55	65	75	982	848	812	745	673	597	980	937	860	777	690
	4	70	85	95	616	536	528	491	450	405	620	610	568	519	468
	3	85	100	110	490	433	434	407	376	341	500	501	470	434	394
	2	95	115	130	388	346	354	336	312	286	400	409	388	361	331
	1	110	130	150	308	277	292	280	264	245	320	337	324	305	283
	0	125	150	170	244	207	228	223	213	200	240	263	258	246	232
	00	145	175	195	193	173	196	194	188	178	200	227	224	217	206
	000	165	200	225	153	136	162	163	160	154	158	187	188	184	178
	0000	195	230	260	122	109	136	140	139	136	126	157	162	161	157
	250	215	255	290	103	93	123	128	129	128	108	142	148	149	148
	300	240	285	320	86	77	108	115	117	117	90	125	133	135	135
	350	260	310	350	73	67	98	106	109	109	78	113	122	126	126
	400	280	335	380	64	60	91	99	103	104	70	105	114	118	120
	500	320	380	430	52	50	81	90	94	96	58	94	104	109	111
	600	335	420	475	43	43	75	84	89	92	50	86	97	103	106
	750	400	475	535	34	36	68	78	84	88	42	79	91	97	102
	1000	455	545	615	26	31	62	72	78	82	36	72	84	90	95
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	14	20*	20*	25*	6140	5369	4876	4355	3830	3301	6200	5630	5029	4422	3812
	12	25*	25*	30*	3464	3464	3158	2827	2491	2153	4000	3647	3264	2877	2486
	10	30	35*	40*	2420	2078	1908	1714	1516	1316	2400	2203	1980	1751	1520
	8	40	50	55	1528	1350	1255	1134	1010	882	1560	1449	1310	1166	1019
	6	55	65	75	982	848	802	731	657	579	980	926	845	758	669
	4	70	85	95	616	536	519	479	435	388	620	599	553	502	448
	3	85	100	110	470	433	425	395	361	324	500	490	456	417	375
	2	95	115	130	388	329	330	310	286	259	380	381	358	330	300
	1	110	130	150	308	259	268	255	238	219	300	310	295	275	253
	0	125	150	170	244	207	220	212	199	185	240	254	244	230	214
	00	145	175	195	193	173	188	183	174	163	200	217	211	201	188
	000	165	200	225	153	133	151	150	145	138	154	175	173	167	159
	0000	195	230	260	122	107	127	128	125	121	124	147	148	145	140
	250	215	255	290	103	90	112	114	113	110	104	129	132	131	128
	300	240	285	320	86	76	99	103	104	102	88	114	119	120	118
	350	260	310	350	73	65	89	94	95	94	76	103	108	110	109
	400	280	335	380	64	57	81	87	89	89	66	94	100	103	103
	500	320	380	430	52	46	71	77	80	82	54	82	90	93	94
	600	335	420	475	43	39	65	72	76	77	46	75	83	87	90
	750	400	475	535	34	32	58	65	70	72	38	67	76	80	83
	1000	455	545	615	26	25	51	59	63	66	30	59	68	73	77

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

Aluminum Conductors — Ratings & Volt Loss†

Conduit	Wire Size	Ampacity Type T, TW (60°C Wire)	Type RH, THWN, RHW, THW (75°C Wire)	Type RHH, THHN, XHHW (90°C Wire)	Direct Current	Volt Loss (See explanation two pages prior.) Three-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%	Single-Phase (60 Cycle, Lagging Power Factor.) 100%	90%	80%	70%	60%
Steel Conduit	12	20*	20*	25*	6360	5542	5039	4504	3963	3419	6400	5819	5201	4577	3948
	10	25	30*	35*	4000	3464	3165	2836	2502	2165	4000	3654	3275	2889	2500
	8	30	40	45	2520	2251	2075	1868	1656	1441	2600	2396	2158	1912	1663
	6	40	50	60	1616	1402	1310	1188	1061	930	1620	1513	1372	1225	1074
	4	55	65	75	1016	883	840	769	692	613	1020	970	888	799	708
	3	65	75	85	796	692	668	615	557	497	800	771	710	644	574
	2	75	90	100	638	554	541	502	458	411	640	625	580	529	475
	1	85	100	115	506	433	432	405	373	338	500	499	468	431	391
	0	100	120	135	402	346	353	334	310	284	400	407	386	358	328
	00	115	135	150	318	277	290	277	260	241	320	335	320	301	278
	000	130	155	175	259	225	241	234	221	207	260	279	270	256	239
	0000	150	180	205	200	173	194	191	184	174	200	224	221	212	201
	250	170	205	230	169	148	173	173	168	161	172	200	200	194	186
	300	190	230	255	141	124	150	152	150	145	144	174	176	173	168
	350	210	250	280	121	109	135	139	138	134	126	156	160	159	155
	400	225	270	305	106	95	122	127	127	125	110	141	146	146	144
	500	260	310	350	85	77	106	112	113	113	90	122	129	131	130
	600	285	340	385	71	65	95	102	105	106	76	110	118	121	122
	750	320	385	435	56	53	84	92	96	98	62	97	107	111	114
	1000	375	445	500	42	43	73	82	87	89	50	85	95	100	103
Non-Magnetic Conduit (Lead Covered Cables or Installation in Fibre or Other Non-Magnetic Conduit, Etc.)	12	20*	20*	25*	6360	5542	5029	4490	3946	3400	6400	5807	5184	4557	3926
	10	25	30*	35*	4000	3464	3155	2823	2486	2147	4000	3643	3260	2871	2480
	8	30	40	45	2520	2251	2065	1855	1640	1423	2600	2385	2142	1894	1643
	6	40	50	60	1616	1402	1301	1175	1045	912	1620	1502	1357	1206	1053
	4	55	65	75	1016	883	831	756	677	596	1020	959	873	782	668
	3	65	75	85	796	692	659	603	543	480	800	760	696	627	555
	2	75	90	100	638	554	532	490	443	394	640	615	566	512	456
	1	85	100	115	506	433	424	394	360	323	500	490	455	415	373
	0	100	120	135	402	346	344	322	296	268	400	398	372	342	310
	00	115	135	150	318	277	281	266	247	225	320	325	307	285	260
	000	130	155	175	252	225	234	223	209	193	260	270	258	241	223
	0000	150	180	205	200	173	186	181	171	160	200	215	209	198	185
	250	170	205	230	169	147	163	160	153	145	170	188	185	177	167
	300	190	230	255	141	122	141	140	136	130	142	163	162	157	150
	350	210	250	280	121	105	125	125	123	118	122	144	145	142	137
	400	225	270	305	106	93	114	116	114	111	108	132	134	132	128
	500	260	310	350	85	74	96	100	100	98	86	111	115	115	114
	600	285	340	385	71	62	85	90	91	91	72	98	104	106	105
	750	320	385	435	56	50	73	79	82	82	58	85	92	94	95
	1000	375	445	500	42	39	63	70	73	75	46	73	81	85	86

* The overcurrent protection for conductor types marked with an (*) shall not exceed 15 amperes for 14 AWG, 20 amperes for 12 AWG, and 30 amperes for 10 AWG copper; or 15 amperes for 12 AWG and 25 amperes for 10 AWG aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

† Figures are L-L for both single-phase and three-phase. Three-phase figures are average for the three-phase.

COOPER Bussmann

Common Electrical Terminology

Ohm
The unit of measure for electric resistance. An ohm is the amount of resistance that will allow one amp to flow under a pressure of one volt.

Ohm's Law
The relationship between voltage, current, and resistance, expressed by the equation E = IR, where E is the voltage in volts, I is the current in amps, and R is the resistance in ohms.

One Time Fuses
Generic term used to describe a Class H nonrenewable cartridge fuse, with a single element.

Overcurrent
A condition which exists on an electrical circuit when the normal load current is exceeded. Overcurrents take on two separate characteristics – overloads and short-circuits.

Overload
Can be classified as an overcurrent which exceeds the normal full load current of a circuit. Also characteristic of this type of overcurrent is that it does not leave the normal current carrying path of the circuit – that is, it flows from the source, through the conductors, through the load, back through the conductors, to the source again.

Peak Let-Through Current, Ip
The instantaneous value of peak current let-through by a current-limiting fuse, when it operates in its current-limiting range.

Renewable Fuse (600V & below)
A fuse in which the element, typically a zinc link, may be replaced after the fuse has opened, and then reused. Renewable fuses are made to Class H standards.

Resistive Load
An electrical load which is characteristic of not having any significant inrush current. When a resistive load is energized, the current rises instantly to its steady-state value, without first rising to a higher value.

RMS Current
The RMS (root-mean-square) value of any periodic current is equal to the value of the direct current which, flowing through a resistance, produces the same heating effect in the resistance as the periodic current does.

Semiconductor Fuses
Fuses used to protect solid-state devices. See "High Speed Fuses."

Short-Circuit
Can be classified as an overcurrent which exceeds the normal full load current of a circuit by a factor many times (tens, hundreds or thousands greater). Also characteristic of this type of overcurrent is that it leaves the normal current carrying path of the circuit – it takes a "short cut" around the load and back to the source.

Short-Circuit Current Rating
The maximum short-circuit current an electrical component can sustain without the occurrence of excessive damage when protected with an overcurrent protective device.

Single-Phasing
That condition which occurs when one phase of a three-phase system opens, either in a low voltage (secondary) or high voltage (primary) distribution system. Primary or secondary single-phasing can be caused by any number of events. This condition results in unbalanced currents in polyphase motors and unless protective measures are taken, causes overheating and failure.

Threshold Current
The symmetrical RMS available current at the threshold of the current-limiting range, where the fuse becomes current-limiting when tested to the industry standard. This value can be read off of a peak let-through chart where the fuse curve intersects the A - B line. A threshold ratio is the relationship of the threshold current to the fuse's continuous current rating.

Time-Delay Fuse
A fuse with a built-in delay that allows temporary and harmless inrush currents to pass without opening, but is so designed to open on sustained overloads and short-circuits.

Voltage Rating
The maximum open circuit voltage in which a fuse can be used, yet safely interrupt an overcurrent. Exceeding the voltage rating of a fuse impairs its ability to clear an overload or short-circuit safely.

Withstand Rating
The maximum current that an unprotected electrical component can sustain for a specified period of time without the occurrence of extensive damage.

Electrical Formulas

To Find	Single-Phase	Two-Phase	Three-Phase	Direct Current
Amperes when kVA is known	$\frac{kVA \times 1000}{E}$	$\frac{kVA \times 1000}{E \times 2}$	$\frac{kVA \times 1000}{E \times 1.73}$	Not Applicable
Amperes when horsepower is known	$\frac{HP \times 746}{E \times \%\ eff. \times pf}$	$\frac{HP \times 746}{E \times 2 \times \%\ eff. \times pf}$	$\frac{HP \times 746}{E \times 1.73 \times \%\ eff. \times pf}$	$\frac{HP \times 746}{E \times \%\ eff.}$
Amperes when kilowatts are known	$\frac{kW \times 1000}{E \times pf}$	$\frac{kW \times 1000}{E \times 2\ pf}$	$\frac{kW \times 1000}{E \times 1.73 \times pf}$	$\frac{kW \times 1000}{E}$
Kilowatts	$\frac{I \times E \times pf}{1000}$	$\frac{I \times E \times 2 \times pf}{1000}$	$\frac{I \times E \times 1.73 \times pf}{1000}$	$\frac{I \times E}{1000}$
Kilovolt-Amperes	$\frac{I \times E}{1000}$	$\frac{I \times E \times 2}{1000}$	$\frac{I \times E \times 1.73}{1000}$	Not Applicable
Horsepower	$\frac{I \times E\ \%\ eff. \times pf}{746}$	$\frac{I \times E \times 2 \times \%\ eff. \times pf}{746}$	$\frac{I \times E \times 1.73 \times \%\ eff. \times pf}{746}$	$\frac{I \times E \times \%\ eff.}{746}$
Watts	$E \times I \times pf$	$I \times E \times 2 \times pf$	$I \times E \times 1.73 \times pf$	$E \times I$

$$\text{Energy Efficiency} = \frac{\text{Load Horsepower} \times 746}{\text{Load Input kVA} \times 1000}$$

$$\text{Power Factor} = pf = \frac{\text{Power Consumed}}{\text{Apparent Power}} = \frac{W}{VA} \text{ or } \frac{kW}{kVA} = \cos\theta$$

I = Amperes; E = Volts; kW = Kilowatts; kVA = Kilovolt-Amperes
HP = Horsepower; % eff. = Percent Efficiency; pf = Power Factor

Section 10.
Purpose and scope of rules

(In the 1941 Code and prior editions, Section 10 was titled "Protective Arrangements of Stations and Substations." In the major revisions of the 1971 Code, old Section 10 was restructured and divided; much of it, including the title, was moved to Section 11. The 2017 Code made no changes to this section.)

100. Purpose

The purpose of Part 1 of this Code is the practical safeguarding of persons during the installation, operation, or maintenance of electric supply stations and their associated equipment.

Rule 100. *(Rule 100 [Scope of the rules] of the 1941 Code and prior editions was moved to Rule 101 in the 1971 Code.)*

The purpose of Part 1 is to provide *practical* safeguarding of persons performing installation, operation, or maintenance duties in electric supply stations; see the discussion of Rule 010.

101. Scope

Part 1 of this Code covers the electric supply conductors and equipment, along with the associated structural arrangements in electric supply stations, that are accessible only to qualified personnel. It also covers the conductors and equipment employed primarily for the utilization of electric power when such conductors and equipment are used by the utility in the exercise of its function as a utility.

Rule 101. *(Rule 100 [Scope of the rules] of the 1941 Code and prior editions changed little over the years until it was moved to this position in the 1971 Code. Significant changes were made in the 1971 and 1981 NESC. Prior Rule 101 [Applications of the rules and exemptions] was moved to Rule 102 in the 1971 Code.)*

In all editions, Part 1 only applies where the covered facilities are accessible to qualified persons. Where the requirements of Rule 110A (Enclosure of equipment) are not met, the area is considered to be accessible to unqualified personnel and Part 2 applies. Where the requirements of Rule 110A are met, the area is considered to be accessible only to qualified persons and Part 1 applies.

Part 1 covers electric supply equipment, conductors, and structural arrangements in indoor and outdoor generating stations, switching stations and substations, whether owned and operated by an electric utility or an industrial or commercial complex. Part 1 covers public and private utility systems including utility-interactive generation systems owned and operated by an independent power producer. In the 1941 Code and prior editions, Part 1 applied to similar equipment, including generators, motors, storage batteries, transformers, lightning arresters, etc., when located in factories, mercantile establishments, vehicles or elsewhere, provided the equipment is in separate rooms or enclosures. Some exemptions were added in the 1941 Code.

Exemptions were added in the 1971 Code for (1) installations in mines, ships, railway rolling equipment, aircraft, automotive equipment and (2) conductors and equipment used primarily for the utilization of electric power, except those in electric supply stations. Specifically excluded were industrial and commercial establishments not under the control of, and accessible only to, qualified persons. The definition of *qualified* is included in Section 2 of the Code. Examples given for such exclusions were apartment houses and sopping centers. However, the power delivery systems involved with some of the commercial "megaplexes" of today differ little from a public utility system and are under qualified control, thus allowing the NESC to be applicable. Note also that the NEC contains footnotes for installations above 600 V referencing the user to the NESC requirements.

Attachment C
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Section 16.
Conductors

(This is Section 15 of the 1941 Code and prior editions; former Section 16 was moved to Section 17 in the 1971 Code.)

The scope of Section 16 is conductors that connect the electric energy sources, such as transmission lines and generators, to power transmission equipment and utilization equipment, such as transformers and motors. This section does not cover conductors that are engineered and manufactured as part of electrical equipment. Conductors that are integral with rotating equipment, storage batteries, transformers and regulators, etc., are covered in other sections of this part of the Code. However, conductors that are integral with metal-enclosed bus are covered by this section. This section covers conductors used for transmission of electric power, control signals, and analog and digital data signals (instrumentation). As used in this section, the term "conductor" includes the devices that connect to electrical equipment, such as connectors and stress cones, as well as equipment such as splices and shield wires.

The 2017 Code added a *NOTE* to Rule 162A to refer readers to IEEE Std 605™-2008 [B36] for more information on conductor supports during fault current conditions.

160. Application

Conductors shall be suitable for the location, use, and voltage. Conductors shall have ampacity that is adequate for the application.

Rule 160. *(This rule was created in the 1993 Code. Rule 160 in the 1990 Code was moved to Rule 161 in the 1993 Code.)*

The first sentence of Rule 160 of the 1990 Code was moved to this location in the 1993 Code, and an ampacity requirement was added.

161. Electrical protection

A. Overcurrent protection required

Conductors and insulation shall be protected against excessive heating by the design of the system and by overcurrent, alarm, indication, or trip devices.

B. Grounded conductors

Conductors normally grounded for the protection of persons shall be arranged without overcurrent protection or other means that could interrupt their continuity to ground.

C. Insulated power cables

Insulated power cable circuits shall be provided with short-circuit protection that will isolate the short circuit from the supply.

Rule 161. *(This rule was formed as Rule 160 in the 1971 Code from Rules 150 and 165 of the 1941 Code and prior editions; former Rule 150C was deleted in the 1971 Code. Former Rule 160A was moved to Rule 170 in the 1971 Code; former Rule 160B was moved to Rule 173B. A new Rule 160C was added in the 1990 Code to require short-circuit protection on insulated power cable. The rule was renumbered to Rule 161 in the 1993 Code when the new Rule 160 [Applications] was added. Former Rule 161 was moved to Rule 172 in the 1971 Code.)*

Rule 161 applies in electric supply stations; there is no corresponding rule specifying overcurrent protection for electric supply lines outside of electric supply stations.

Protection of persons in the vicinity of switches or conductors, or operating switches on circuits, requires that live conductors have adequate, automatic protection against currents that are large enough

Attachment D
Page 1 of 1

Section 20.
Purpose, scope, and application of rules

Section 20 describes the practical requirements related to protection of the public as well as of the supply and communications workers associated with the installation, operation, and maintenance of overhead supply and communication lines and equipment. It is important to highlight that this section does not cover installations located within supply stations that are secure from public access mainly because only authorized and qualified persons may enter and work within a supply station; such requirements are listed within Part 1. Section 20 contains information about applicable OSHA work rules related to activities around energized parts of utility and non-utility construction personnel that are not covered by the NESC work rules, and it includes additional requirements such as *EXCEPTION*s referenced to Rules 162A and 238C in other parts of the Code.

Beginning with the 1981 Code, changes have been made to accommodate the "general" statements from all parts in previous Code editions into a new set of rules numbered Rules 010–016.

200. Purpose

The purpose of Part 2 of this Code is the practical safeguarding of persons during the installation, operation, or maintenance of overhead supply and communication lines and their associated equipment.

Rule 200. In the 1977 Code and later editions of the NESC, it is made clear by choice of wording that the purpose of these rules is the *practical* safeguarding of persons during the installation, operation, or maintenance of overhead supply and communication lines and their associated equipment (see Section 1).

201. Scope

Part 2 of this Code covers supply and communication conductors and equipment in overhead lines. It covers the associated structural arrangements of such systems and the extension of such systems into buildings. The rules include requirements for spacing, clearances, and strength of construction. They do not cover installations in electric supply stations except as required by Rule 162A.

NOTE 1: Part 4 contains the approach distances and work rules required of supply and communication employers and their employees working on or near supply and communication lines and equipment.

NOTE 2: The approach distances to energized parts, and other requirements applicable to the activities of utility or non-utility construction personnel, and others in close proximity to existing supply lines are governed by the Occupational Health and Safety Administration (OSHA), federal, state, or local statutes or regulations.

Rule 201. *(See Rule 202 for a discussion of Rule 201B, Rule 201C, and Rule 201D of the 1968 Code and prior editions. See also Rules 010–016.)*

Rule 201 was revised extensively in the 1977 Code. The present Rule 201 is a clarifying expansion of Rule 201A of the 1968 Code and prior editions. It is also made clear in the 1977 revision that Part 2 of the Code was not intended to apply to electric supply stations. In essence, Part 2 of the NESC is the general case, with Part 1 (Electric Supply Stations) and Part 3 (Underground Lines) as the exceptions to the general case.

Although Part 2 contains *no* requirements that directly apply to electric supply stations (Part 1) or to underground lines (Part 3), Part 2 does have the following interactions with Parts 1 and 3.

(1) Part 2 duplicates some of the requirements of Part 3 for risers on overhead structures. This duplication limits the opportunity for code users dedicated to either overhead line work or underground line work to miss the requirements applicable to underground cables as they run up a structure to connect to an overhead system.

Attachment E
Page 1 of 1

INTERPRETATION (26 February 1997)

The answer to your first question is no; the BIL values in Table 124-1 do not apply to distribution lines outside an electric supply substation. All of the rules in Part 1, which includes Rules 124A1 and Table 124-1, apply only to electric supply stations, as stated in Rule 101-Scope (for Part 1).

Likewise the rated dry flashover values of insulators in Table 273-1 apply only to overhead lines. All of the rules in Part 2, which includes Rule 273 and Table 273-1, apply only to overhead lines, generally outside of electric supply stations, as stated in Rule 201—Scope(for Part 2). In Rule 201, the reference to Rule 110D should be to Rule 162.

There is no correlation between Tables 124-1 and 273-1; they apply to different situations. Selection of an appropriate BIL for electric distribution structures is a design consideration; it is not covered in the NESC because the NESC is a performance standard, not a design manual. BIL is only one of many overhead line design criteria which has an impact on lightning performance of shield wire lines. On the other hand, having a BIL considerably less than 300 kV, say 110 kV BIL, results in excellent lightning performance when surge arresters are installed on the line at frequent intervals. Therefore, line BIL need not be a set minimum level, such as 300 kV, to minimize flashovers.

See also IR 355, dated January 27, 1984, which reads in part: Part 1 of the NESC applies where the requirements of Rule 110A are met; otherwise, the installation must meet the requirements of Part 2 of the Code.

BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Complaint Against	)	
Kansas City Power & Light Company	)	Docket No. 16-KCPE-195-COM
by Jamie Littich.	)	

AFFIDAVIT OF TROY B. LITTLE

I, Troy B. Little, being of sound mind and body, and being first duly sworn under oath, do hereby testify as to the following to be true based on my own personal knowledge:

1. I am over eighteen (18) years old, have not been convicted of a felony, and am competent to testify.

2. I am a qualified electrical engineer with almost 30 years of experience and I'm currently employed as President and Chief Operating officer of Brooks Jackson & Little, Inc., an engineering consulting firm in Baton Rouge, Louisiana.

3. I have appeared and been qualified as an expert in multiple jurisdictions and in both state and federal courts. My qualifications have included expertise in electrical engineering, forensic engineering, the National Electrical Safety Code (NESC), electrical accident reconstruction, electrical utility operating practices, fire cause and origin, and other issues.

4. For the last four years, I've been a member of the NESC Committee, a group responsible for reviewing, interpreting, and drafting parts of the NESC. I use the NESC almost daily for my job.

5. At the request of KCP&L, I've reviewed the following documents:

   a. The Littich Complaint

   b. KCP&L's Answer and Motion to Dismiss

   c. Staff's First and Second Report and Recommendation

d. KCP&L's Responses to Staff's Report and Recommendation

6. Based on my review, my opinions are:

7. KCP&L is correct in its assertion that Part 1 of the NESC does not apply to the overhead facilities involved in the Littich matter. Rather, NESC's Part 1 is limited to "Installation and Maintenance of Electric Supply Stations and Equipment," just as the title states. KCP&L is also correct that overhead facilities are addressed in Part 2, which is titled "Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communications Lines." Staff is incorrect that Part 1, Section 10, 101. Scope, applies to the overhead conductors in this matter.

8. Therefore, after my review of the documents listed in paragraph 5, above, it is my opinion to a reasonable degree of electrical engineering certainty that KCP&L has not violated either Part 1 or Part 2 of the NESC.

9. Staff's assertion that a fuse on the primary transformer should have blown due to a fault on the secondary is false. Transformer fuses are not designed to blow for a secondary downstream fault.

10. In particular, the available data strongly suggests that this incident was a high impedance fault, not a bolted ground fault as Staff suggests.

11. I have never encountered a utility that must forensically investigate each outage to determine its cause, as Staff recommends KCP&L be required to do. I have never encountered a utility that must ensure the safety of each customer's side of service before restoring power, as recommended by Staff. I believe that such measures would cause insufferable delay and add unreasonable expense.

12. Finally, KCP&L's Customer Service Representative (CSR) did a better than average job at processing the call during this event by correctly concluding that the customer would need to consult an electrician before power could be restored. Many utilities' CSRs actions are not knowledgeable about electrical systems and merely pass on information to workers in the field.

13. I offer all of the above opinions to a reasonable degree of engineering certainty.

Further Affiant sayeth naught.

Troy B. Little

STATE OF Louisiana.)
) SS.
COUNTY OF E. Baton Rouge.)

On this 17th day of April, 2017, before me personally appeared **Troy B. Little**, to me known to be the person described herein and who executed the foregoing instrument, and acknowledged that he executed the same as her free act and deed.

IN TESTIMONY WHEREOF, I have hereunto set my hand and affixed my official seal in the County and Commonwealth aforesaid, the day and year first above written.

NOTARY PUBLIC

Cheryl D. Bourgeois
Notary ID# 66798

My Commission Expires:

at death

necessary between utility organizations locating facilities in the same area or on the same structure. Rule 212 is intended to cover the influence of supply facilities on communications facilities. It does not refer to the induction influence of supply facilities on any other facilities. However, general common sense indicates that application of this rule to pipelines is also reasonable.

IEEE Std 776 [B39] and IEEE Std 1137 [B51] may be used to help determine the influence of supply lines on communication lines and the susceptibility of communication lines to induced voltages.

213. Accessibility

All parts that must be examined or adjusted during operation shall be arranged so as to be accessible to authorized persons by the provision of adequate climbing spaces, working spaces, working facilities, and clearances between conductors.

Rule 213. *(This rule was renumbered from Rule 212 in the 1977 Code. The previous Rule 213 [Inspection and tests of lines and equipment] was renumbered to Rule 214.)*

Although it is necessary to isolate line conductors and equipment for protection of the public, it is essential that such facilities safely be accessible to authorized persons, in order to facilitate adjustment or repairs required to maintain service that is as reliable and safe as is practical. Other rules of the Code, particularly those of Section 23, specify in detail the proper clearances and spacings for conductors, as well as the proper location of the wires and apparatus required to provide safe accessibility for authorized employees.

214. Inspection and tests of lines and equipment

Rule 214. *(This rule was renumbered from Rule 213 in the 1977 Code. Previous Rule 214 [Isolation and guarding] was discontinued in the extensive 1977 revision of Part 2, because the requirements duplicated those in Section 23 in large measure.)*

The NESC recognizes that facilities placed in service may have various opportunities and propensities to wear, break, become damaged, or otherwise be affected adversely by conditions such that continued service in that state would be inappropriate for safety reasons.

As a result there are two sets of requirements for inspections and tests—one for those lines and equipment that are *in service*, and another for those lines or equipment, or portions thereof, that may be *out of service*.

The distinction between being in service or being out of service is not affected by whether customer facilities currently are connected to the utility system; customers might or might not be connected to a utility system or system component regardless of whether it is in or out of service. Rather, the distinction between being in service or out of service hinges upon whether a subject line or equipment is connected to a utility system as an integral, functional part or extension of the system.

Facilities that are out of service include those that intentionally are disconnected from the system, whether by manual operation or disconnection by a worker or by automatic operation of sectionalizing devices, for the purposes of system protection, maintenance, reconstruction, removal, abandonment, etc.

Definitions of *in-service* and *out of service* were added in the 1993 Code to limit the opportunity for misinterpretation of the requirements of Rule 214A and Rule 214B.

A. When in service

1. Initial compliance with rules

   Lines and equipment shall comply with these safety rules when placed in service.

2. Inspection

   Lines and equipment shall be inspected at such intervals as experience has shown to be necessary.

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NOTE: It is recognized that inspections may be performed in a separate operation or while performing other duties, as desired.

3. Tests

   When considered necessary, lines and equipment shall be subjected to practical tests to determine required maintenance.

4. Inspection records

   Any conditions or defects affecting compliance with this Code revealed by inspection or tests, if not promptly corrected, shall be recorded; such records shall be maintained until the conditions or defects are corrected.

5. Corrections

   a. Lines and equipment with recorded conditions or defects that would reasonably be expected to endanger human life or property shall be promptly corrected, disconnected, or isolated.

   b. Other conditions or defects shall be designated for correction.

Rule 214A. It is not intended that new construction shall be inspected by state or city officials before being put into use, or that such official inspections regularly shall be made. The operating utility, or other responsible party if so designated by the operating utility, is required to perform such inspections or practical tests in such a manner and at such intervals as experience has shown to be necessary.

In general, the "experience" referred to is that of the utility responsible for operation and safety of the facilities in a manner to secure adequate and reliable results. If the responsible utility does not have experience with such an installation under such conditions, and information is available elsewhere, good design practice would suggest that such information should be examined.

The utility is responsible for considering the conditions of service to which the installation reasonably can be expected to be exposed. It is not contemplated that provisions must be made for all *possible* occurrences if such occurrences are not also *reasonably expected to occur.* Neither is it expected that all parts and components necessarily will require either inspections or tests, although some parts may require both. The 2002 Code clarified in a *NOTE* to Rule 214A2 that inspections may be performed while performing other duties; separate inspections are not required.

The phrase "from time to time" was deleted from the inspection requirements in the 1984 Code. This language could be misinterpreted to imply that a specific schedule was intended. While schedules may be appropriate for some inspections, they may not be necessary for others.

In 2012, the title of Rule 214A4 was changed from "Records of defects" to "Inspection records." The title of Rule 214A5 was changed from "Remedying defects" to "Corrections." The term *conditions* was added to both rules to recognize that the inspection requirements have always been intended to identify and correct both defective parts, such as damaged or deteriorated insulators, crossarms, guys, etc., *and* noncompliant conditions, such as clearance problems. The inspection requirements have never covered merely defective parts; they have always covered identification and correction of noncompliant conditions, as well. The new titles were added to more appropriately describe the NESC's long-standing intent than were expressed by the previously used term *defect*.

The 2017 Code modified Rule 215A5 to clarify that *human* life is the life addressed in that rule.

When inspections or tests identify defects or conditions that affect compliance with the NESC, and such defects or conditions are not corrected immediately, they are required to be recorded until corrected. Identified defects that reasonably could be expected to endanger life or property are required to be remedied promptly. The intention of the rule is that, when items are identified as needing repair or replacement, either (1) the work will be done at that time or (2) the condition will be recorded to be addressed later. There is no requirement to record items that are addressed initially or to keep records after the work has been done.

Some lines and equipment in some locations may require daily inspections; lines and equipment in other locations may need only annual, or even less frequent, inspections. As a result, this rule could not be made specific. For example, if the concern is only with decay and weakening of pole timber, experience shows that some treated poles have lasted 60 or more years, while others have only lasted half that time—*or less*. Also, there is definite evidence that decay is influenced by the amount of rainfall, and hence moisture, in the soil. This, of course, varies from one part of the country to another.

Attachment I
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