[[1]](#footnote-1)

Three-phase-two-wire rural distribution network: modeling the short-circuit and protection scheme

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# I. INTRODUCTION

T

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# II. THREE-PHASE TWO-WIRE DISTRIBUTION SYSTEM

The system proposed by [1] is composed of two overhead wires in which the ground is a conductor and part active in the system, o TPTWS uses an isolation transformer to connect the two-wire system to the network. The transformer isolator and costumer transformer are connected to the ground, using the grounding structures. The ground interface can design according to the local soil and the safety requirements. For this work, ground interface is simplified as a single impedance for the analysis.

For the equivalent circuit of system is modify the capacitances between cables and between cables to the ground, so that the short circuit is represented by its intrinsic model in the Fig. 1.

Diagrama

Descrição gerada automaticamente

**Fig. 1.** Model of short circuit in TPTWS.

The impedance Zs, is the result of the series association of the isolating transformer grounding resistance (Rt1) and the equalization series impedance (Ze), that is,

|  |  |
| --- | --- |
|  | (1) |

The model of the short circuit is characterized for three fault resistances (*Raf*, *Rbf* and *Rcf*). For the solid faults, it is possible to calculate the fault current considering the following criteria,

TABLE I

Criteria used of fault values

|  |  |  |  |
| --- | --- | --- | --- |
|  | Raf (Ω) | Rbf (Ω) | Rcf (Ω) |
| Three-phase fault | 0 | 0 | 0 |
| Two-phase fault AB | 0 | 0 | ∞ |
| Two-phase fault AC | 0 | ∞ | 0 |
| Two-phase fault BC | ∞ | 0 | 0 |

The analysis of faults with the presence of fault resistance can be performed by changing the value of the resistance Rcf. To simplify the equations, it is possible to obtain the following series impedances:

|  |  |
| --- | --- |
|  | (2) |
|  | (3) |
|  | (4) |

***Fig. 1*** shows the equivalent circuit of the T2F network with the equivalent impedances.

Diagrama

Descrição gerada automaticamente

**Fig. 2.** Short circuit diagram: model with reduced replacement.

Applying Kirchhoff's Voltage Law, we have,

|  |  |
| --- | --- |
|  | (5) |
|  | (6) |

Solving equation (6) for the current I2, we have,

|  |  |
| --- | --- |
|  | (7) |

Substituting equation (7) into (5), we get,

|  |  |
| --- | --- |
|  | (8) |

Making the distribution in the third term of equation (8), we obtain,

|  |  |
| --- | --- |
|  | (9) |

Solving equation (9) for the current I1, we arrive at,

|  |  |
| --- | --- |
|  | (10) |

Substituting equation (10) into (7), we obtain:

|  |  |
| --- | --- |
|  | (11*)* |

Therefore, it is possible to equate the phase currents resulting from the fault, that is,

|  |  |
| --- | --- |
|  | (12*)* |
|  | (13*)* |
|  | (14*)* |

# III. STUDY OF CASE

A. *Short Circuit in end of line fault*

The test system is the same as shown in ***Fig. 2*** Short circuit diagram: model with reduced replacement.. In ***Fig. 3*** it is possible to see the fault model inserted at the end of the test system line.

Diagrama, Esquemático

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**Fig. 3.** Model for end of line fault.

For the short-circuit study at the end of the line, a fault resistance of 40 Ω was considered. Table 1 presents the values of the resistors Raf, Rbf, Rcf used in the simulation.

## B. Internal short circuit to the Line

Diagrama, Esquemático

Descrição gerada automaticamente

**Fig. 4.** Model for internal of line fault.

TABLE II

Fault impedance values

|  |  |  |  |
| --- | --- | --- | --- |
| Type of fault | *Raf* (Ω) | *Rbf* (Ω) | *Rcf* (Ω) |
| Three-phase fault | 0 | 0 | 40 |
| Two-phase fault AB | 20 | 20 |  |
| Two-phase fault AC | 0 |  | 40 |
| Two-phase fault BC |  | 0 | 40 |

Use either the Microsoft Equation Editor or the MathType plugin, which can be obtained from <https://store.wiris.com/en/products/mathtype/download>. For help with formatting and placing equations, refer to the *IEEE Editing Math Guide* at <http://journals.ieeeauthorcenter.ieee.org/wp-content/uploads/sites/7/Editing-Mathematics.pdf> and the *IEEE MathType Tutorial for Microsoft Word Users* at <http://journals.ieeeauthorcenter.ieee.org/wp-content/uploads/sites/7/IEEE-Math-Typesetting-Guide-for-MS-Word-Users.pdf>.

TABLE I

This is a Sample of a Table Title



## A. Equations

Number equations consecutively with equation numbers in parentheses flush with the right margin of the column, as in (1). First use the equation editor to create the equation. Then

select the “Equation” markup style. Press the tab key and write the equation number in parentheses. To make your equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Use parentheses to avoid ambiguities in denominators. Punctuate equations when they are part of a sentence, as in

*Bp* + *H*2 = 40. (1)

Be sure that the symbols in your equation have been defined before the equation appears or immediately following. Italicize symbols (*T* might refer to temperature, but T is the unit tesla). When referring to an equation or formula, use simply “(1),” not “Eq. (1)” or “equation (1),” except at the beginning of a sentence: “Equation (1) is ... .”

# IV. Guidelines for Graphics Preparation and Submission

## A. Types of Graphics

The following list outlines the different types of graphics published in IEEE journals. They are categorized based on their construction, and use of color / shades of gray:

* 1. **Color/Grayscale Figures**  
     Figures that are meant to appear in color, or shades of black/gray. Such figures may include photographs,   
     illustrations, multicolor graphs, and flowcharts.
  2. **Line Art Figures**  
     Figures that are composed of only black lines and shapes. These figures should have no shades or half-tones of gray, only black and white.
  3. **Tables**  
     Data charts which are typically black and white, but sometimes include color.

## B. Multipart Figures

These are figures compiled of more than one sub-figure presented side-by-side or stacked. If a multipart figure is made up of multiple figure types (one part is line art, and another is grayscale or color), the figure should meet the stricter guidelines.

## C. File Formats for Graphics

Format and save your graphics using a suitable graphics processing program that will allow you to create the images as PostScript (PS), Encapsulated PostScript (.EPS), Tagged Image File Format (.TIFF), Portable Document Format (.PDF), JPEG, or Portable Network Graphics (.PNG). These programs can re-size them and adjust the resolution settings. If you created your source files in one of the following programs you will be able to submit the graphics without converting to a PS, EPS, TIFF, PDF, or PNG file: Microsoft Word, Microsoft PowerPoint, or Microsoft Excel. Though it is not required, it is strongly recommended that these files be saved in PDF format rather than DOC, XLS, or PPT. Doing so will protect your figures from common font and arrow stroke issues that occur when working on the files across multiple platforms. When submitting your final files, your graphics should all be submitted individually in one of these formats along with the manuscript.

## D. Sizing of Graphics

Most charts, graphs, and tables are one column wide (3.5 inches / 88 mm / 21 picas) or page wide (7.16 inches / 181 millimeters / 43 picas). The maximum depth a graphic can be is 8.5 inches (216 millimeters / 54 picas). When choosing the depth of a graphic, please allow space for a caption. Figures can be sized between column and page widths if the author chooses, however, it is recommended that figures not be sized less than column width unless when necessary.

The final printed size of author photographs is exactly   
1 in wide by 1.25 in tall (25.4 mm x 31.75 mm / 6 picas x 7.5 picas). Author photos printed in editorials measure 1.59 in wide by 2 in tall (40 mm x 50 mm / 9.5 picas x 12 picas).

## E. Resolution

The proper resolution of your figures will depend on the type of figure it is as defined in the “Types of Figures” section. Author photographs, color, and grayscale figures should be at least 300dpi. Line art, including tables should be a minimum of 600dpi.

## F. Vector Art

In order to preserve the figures’ integrity across multiple computer platforms, we accept files in the following formats: .EPS/.PDF/.PS. All fonts must be embedded or text converted to outlines in order to achieve the best-quality results.

## G. Color Space

The term “color space” refers to the entire sum of colors that can be represented within the said medium. For our purposes, the three main color spaces are grayscale, RGB (red/green/blue), and CMYK (cyan/magenta/yellow/black). RGB is generally used with on-screen graphics, whereas CMYK is used for printing purposes.

All color figures should be generated in RGB or CMYK color space. Grayscale images should be submitted in grayscale color space. Line art may be provided in grayscale OR bitmap colorspace. Note that “bitmap colorspace” and “bitmap file format” are not the same thing. When bitmap color space is selected, .TIF/.TIFF/.PNG are the recommended file formats.

## H. Accepted Fonts Within Figures

When preparing your graphics, IEEE suggests that you use one of the following Open Type fonts: Times New Roman, Helvetica, Arial, Cambria, or Symbol. If you are supplying EPS, PS, or PDF files, all fonts must be embedded. Some fonts may only be native to your operating system; without the fonts embedded, parts of the graphic may be distorted or missing.

A safe option when finalizing your figures is to strip out the fonts before you save the files, creating “outline” type. This converts fonts to artwork which will appear uniformly on any screen.

## I. Using Labels Within Figures

1. **Figure Axis Labels**
   1. Figure axis labels are often a source of confusion. Use words rather than symbols. As an example, write the quantity “Magnetization” or “Magnetization *M*,” not just “*M*.” Put units in parentheses. Do not label axes only with units. For example, write “Magnetization (A/m)” or “Magnetization (Am−1),” not just “A/m.” Do not label axes with a ratio of quantities and units. For example, write “Temperature (K),” not “Temperature/K.”
   2. Multipliers can be especially confusing. Write “Magnetization (kA/m)” or “Magnetization (103 A/m).” Do not write “Magnetization (A/m) × 1000” because the reader would not know whether the top axis label means 16000 A/m or 0.016 A/m. Figure labels should be legible, approximately 8- to 10-point type.
2. **Subfigure Labels in Multipart Figures and Tables**

Multipart figures should be combined and labeled before final submission. Labels should appear centered below each subfigure in 8-point Times New Roman font in the format of (a) (b) (c).

## J. Referencing a Figure or Table Within Your Article

When referencing your figures and tables within your article, use the abbreviation “Fig.” even at the beginning of a sentence. Do not abbreviate “Table.” Tables should be numbered with Roman numerals.

## K. Submitting Your Graphics

Because IEEE will do the final formatting of your article, all figures, figure captions, and tables can be placed at the end of your article. However, if you do place your figures within the article, they should be placed at the top of the page, closest to the first mention in the text. Figures should be submitted as individual files, separate from the manuscript in one of the file formats listed above. Place figure captions below the figures; place table headings above the tables. Do not include captions as part of the figures, or put them in “text boxes” linked to the figures. Also, do not place borders around the outside of your figures.

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All IEEE Transactions, Journals, and Letters allow an author to publish color figures on IEEE *Xplore* at no charge, and automatically convert them to grayscale for print versions. In most journals, figures and tables may alternatively be printed in color if an author chooses to do so. Please note that this service comes at an extra expense to the author. If you intend to have print color graphics, you will have the opportunity to indicate this in the Author Gateway and will be contacted by PubOps to confirm the charges.

# V. Conclusion

## A conclusion section is not required. Although a conclusion may review the main points of the article, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

Appendix

Appendixes, if needed, appear before the acknowledgment.

Acknowledgment

The preferred spelling of the word “acknowledgment” in American English is without an “e” after the “g.” Use the singular heading even if you have many acknowledgments. Avoid expressions such as “One of us (S.B.A.) would like to thank ... .” Instead, write “F. A. Author thanks ... .” In most cases, sponsor and financial support acknowledgments are placed in the unnumbered footnote on the first page, not here.

References

[1] P. R. de O. Borges, “REPOTENCIALIZAÇÃO DE SISTEMAS DE DISTRIBUIÇÃO RURAIS MONOFÁSICOS POR MEIO DE DOIS CABOS AÉREOS E O SOLO COMO A TERCEIRA,” 2017.

# J. U. Duncombe, “Infrared navigation—Part I: An assessment of feasibility,” *IEEE Trans. Electron Devices*, vol. ED-11, no. 1, pp. 34–39, Jan. 1959, doi: 10.1109/TED.2016.2628402.

1. E. P. Wigner, “Theory of traveling-wave optical laser,” *Phys. Rev*., vol. 134, pp. A635–A646, Dec. 1965.
2. P. Kopyt *et al., “*Electric properties of graphene-based conductive layers from DC up to terahertz range,” *IEEE THz Sci. Technol.,* to be published, doi: 10.1109/TTHZ.2016.2544142. *(Note: If a paper is still to be published, but is available in early access, please follow ref [5]).)*
3. R. Fardel, M. Nagel, F. Nuesch, T. Lippert, and A. Wokaun, “Fabrication of organic light emitting diode pixels by laser-assisted forward transfer,” *Appl. Phys. Lett.*, vol. 91, no. 6, Aug. 2007, Art. no. 061103.
4. D. Comite and N. Pierdicca, "Decorrelation of the near-specular land scattering in bistatic radar systems," *IEEE Trans. Geosci. Remote Sens.*, early access, doi: 10.1109/TGRS.2021.3072864. (*Note: This format is used for articles in early access. The doi must be included.)*
5. H. V. Habi and H. Messer, "Recurrent neural network for rain estimation using commercial microwave links," *IEEE Trans. Geosci. Remote Sens.*, vol. 59, no. 5, pp. 3672-3681, May 2021. [Online]. Available: https://ieeexplore.ieee.org/document/9153027

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