[[1]](#footnote-1)

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

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# I. INTRODUCTION

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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

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**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 TPTWS network with the equivalent impedances.

Diagrama

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**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*)* |

So, we define the short circuit equations for the TPTWS system.

# III. STUDY OF CASE

The maximum value of the short-circuit current during the transient period, in the simulation is the application of (15), so we can define the values of short-circuit current in each of its topologies different from the case studies.

We approach the comparisons of short circuits with equations in relation to simulations and models of short circuits in lines, the models are a simple analysis with construction accuracy equal to the real model.

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

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 |

1. *Short Circuit in end of line.*

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

The short circuits at the end of the line, or short circuit of transformer terminals are low, because the characteristics of these shorts are due to problems that require involvement or animals or be caused by people.

## B. Internal short circuit to the Line

Diagrama, Esquemático

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

The test system is the same as shown in **Fig. 3**. In **Fig. 4** it is possible to see the fault model inserted at the end of the test system line.

Short circuits on lines in rural networks are common and can have several causes, even more so in SWER topology systems.

The farmer's machinery touches, trees touch, cable breakage and a combination of several problems involving the environment can be mentioned.

Common transient faults are:

* Momentary contact between bare conductors.
* Atmospheric discharges.
* Electric arc opening.
* Material insulation failure.

Permanent faults are considered that human intervention is necessary for correction before the complete circuit reclosure. Some of the faults can eventually become a permanent fault, so these most common permanent faults are:

* Falling of trees on top of distribution lines.
* Traffic accidents involving power poles.
* Acts of vandalism.

So, to avoid undue interruptions, the protections must be well considered, thus avoiding problems of selectivity and system reliability, very important indexes when related to the protection of network rural systems.

# IV. Test and RESULTS

The three-phase two-wire systems was built based in the topology show on (FIGURE) and electrical compatibility is show on (FIGURE).

Along with this proposed topology, we can also convert maximum short data by maximum load of the isolating transformer.

The base system is 120 kVA, 13.8 kV, 60 Hz. The system was modeled considering 10 Ω of earth resistance and using a line length of 60 km. The power supply was limited to this level, as passing this power through could affect the security of the system.

The base values of the system are changed only to create the scan table of the maximum values according to the power of the isolating transformer. Exceptionally, at that moment, the power of the system is changed, to create these, short-circuit models.

TABLE III

Power used in the modification.

|  |
| --- |
| **Transformer Power (kVA)** |
| 15 |
| 25 |
| 30 |
| 37,5 |
| 45 |
| 50 |
| 75 |
| 100 |
| 112,5 |
| 150 |
| 200 |
| 225 |
| 250 |
| 300 |

The power used according to TABLE III, is due to the unlimited power to be transferred by the system, so the capacities must be checked for short circuit tests to know if the same three-phase circuit protection analysis can be used.

# 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.

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.

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