Impact Analysis of Distributed Generation on Protection Devices Coordination in Power Distribution Systems

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I. Introduction

This document provides additional information concerning the paper "Impact Analysis of Distributed Generation on Protection Devices Coordination in Power Distribution Systems" published in ISGT LA 2021.

II. Characteristics of Protection Devices

Protection devices more common employed in distribution networks are fuses, switchgears and reclosers [1]. Usually, automatic sectionalizing switches include overcurrent relays.

A. Fuses

Fuses are the simpler devices used in protection systems. Fuse's operative characteristics depend on both its dimensions and electrical resistivity. Fuses type K and T are usually employed in distribution network branches, where the first type acts faster than the second. Fuses are still divided into two groups, according to your nominal current:

- Preferential fuses: 6, 10, 15, 25, 40, 65, 100, 140 e 200 A;
- Non-preferential fuses: 8, 12, 20, 30, 50 e 80 A.

Fuse models are differentiated according to their operating characteristics or time vs. current curves, which are used in coordination studies. Its operating curves are determined from a set of samples, obtained through tests performed by the manufacturer. An example of minimum fusion (MM) and maximum interruption (TC) fuse curves are shown in Fig. 1.

Fuses coordination with inverse time characteristic of overcurrent relays must consider the acting time of both

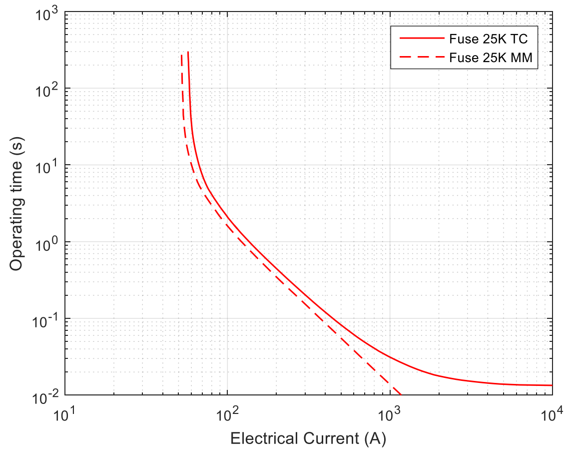

Fig. 1 – Time-current curves of the 25K link fuse

with inverse time (51 function), allowing the adjacent device acts and isolates the smallest part of the distribution network as possible.

Operating curves of overcurrent relays are usually standardized based on IEC 60255 (1989) or IEEE C37.112 (1997). According to IEC 60255, adopted in this work, the operating curve of overcurrent relays is determined using (1).

$$t = TMS\frac{\beta}{\left(\frac{I}{I_p}\right)^{\alpha} - 1} \tag{1}$$

Since TMS is a multiplicative factor for time adjustment, I the current that sensitizes the relay and I_p refers to the device pickup current. Values of α and β are constant and depend on the characteristic of the curve used. Curve types are shown in Table 1.

III. Coordination and Selectivity of Protection Devices

SC currents for different fault types allow determining protection device's sensitivity. Nominal values for fuses must be greater than 1.5 times the load current of their respective branch and less than 25% of the minimum earth fault current with 20 Ω fault impedance, $I_{min}^{1\emptyset}$. Usually, distribution companies generalize the recommended impedance value in their standards to 40 Ω. However, for the test system used, an impedance of 20 Ω adequately represents the overload problems of the tested system. The same fault is used to coordinate fuses with overcurrent relays, in functions 51 and 50 for phase and ground units.

Reclosers are usually composed of two or three overcurrent phase units and one ground. Fig. 2 shows the schematics with secondary relays. One possible configuration is the direct connection of relays to the primary network. However, despite being the most economical option, the scheme with primary relays is technically inferior to the options indicated in Fig. 2 [2]. Schemes with secondary relays allow greater flexibility and precision in the adjustment of protection devices. Both models in Fig. 2 can be used in the

TABLE I. IEC 60255 Constants

Relay operating curve	α	β
Standard inverse (NI)	0,02	0,14
Very inverse (VI)	1	13,5
Extremely inverse (EI)	2	80

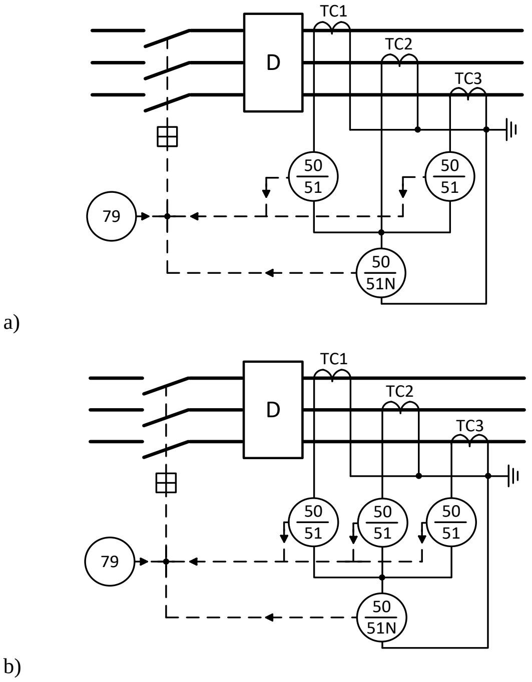

Fig. 2 – Usual recloser schemes

proposed methodology without compromising its operation or quality results.

IV. Results

The proposed method was implemented in C ++ programming language for its speed and computational efficiency. Simulations were performed in the real distribution system available in [4]. This three-phase system is aerial and unbalanced, with a nominal voltage of 13.8kV, 7.065kVA of nominal power. The substation transformer (SE) has a grounded wye-delta connection. Distribution network protection includes seven reclosers and seven fuses. Details are shown in Fig. 3.

Simulations were performed on a computer with an Intel® Core ™ i7-8700 CPU @ 3.20GHz and 16GB of memory.

References

[1] Geraldo Kindermann, "Proteção de sistemas elétricos de potência." Editora da UFSC 1 (1999).

[2] E. D. Pioli, E. Vicentini, A. Monteiro, H. G. Bueno, F. R. Sassaki – R.B Queiroga, "Proteção de Redes de Distribuição Aérea Primária".

[3] K. Pereira, B. R. Pereira, J. Contreras, and J. R. S. Mantovani, "A multiobjective optimization technique to develop protection systems of distribution networks with distributed generation," *IEEE Trans. Power Syst.*, vol. 33, no. 6, pp. 7064–7075, 2018, doi: 10.1109/TPWRS.2018.2842648.

[4] Laboratório de pesquisa em planejamento de sistemas de energia elétrica – LaPSEE - Sistema Prático 135 Barras - Trifásico e Desequilibrado (http://www.feis.unesp.br/#!/departamentos/engenharia-eletrica/pesqui-sas-e-projetos/lapsee/downloads/materiais-de-cursos1193/).

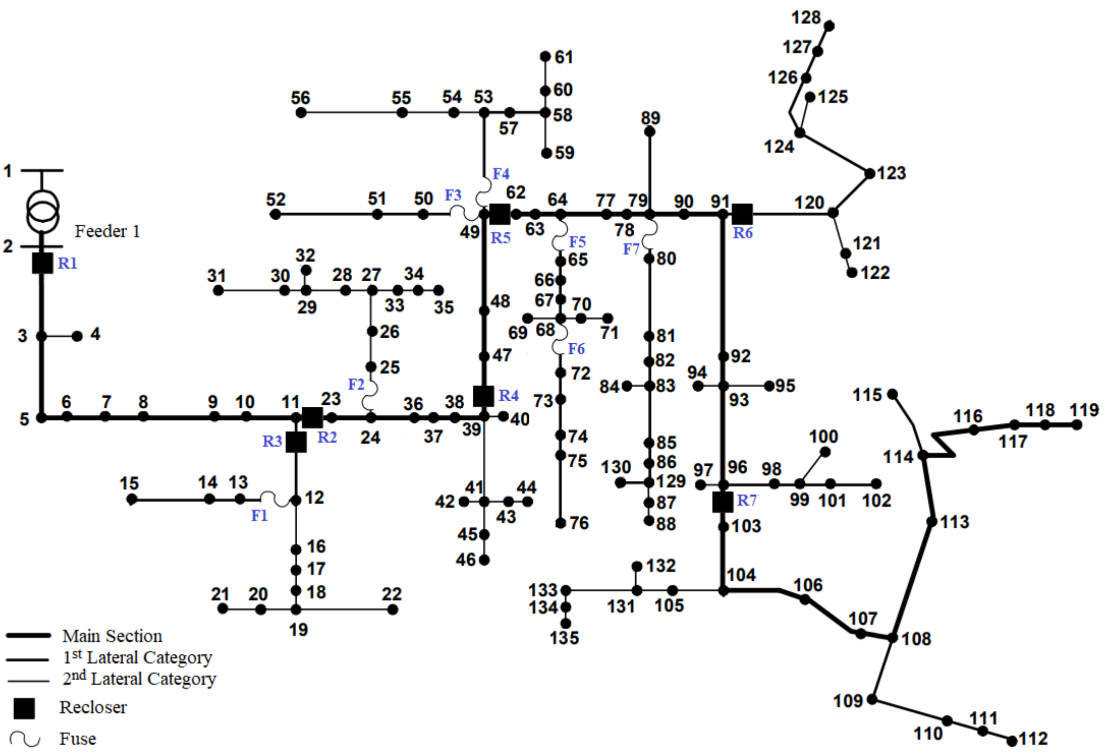

Fig. 3 – Real unbalanced distribution system with 135 buses.