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Overcurrent relay with unconventional curves and its application in industrial power systems

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ABSTRACT

This paper presents a generalized formulation of an inverse time overcurrent relay that can generate non-conventional inverse time curves. The proposed model considers a variable time dial position as a function of the fault current; the interaction of two dynamics, the digital representation of the movement of the induction disc (such as conventional relays) and the time dial result in time curves that can be designed for any specific protection coordination problem. The proposed relay does not require more input data that conventional relay, only the fault current in the relay location is required. The proposed model has greater flexibility for the creation of time curves than conventional relay models because it allows the incorporation of independent functions of the time lever that will result in several time curves depending on the defined application criteria. A comparison of the curve fitting between the proposed model and the curve standard model was evaluated using two cases of an industrial power system, for which the non-conventional curves allow the reduction of operation times, mechanical stress and thermal effects. Furthermore, this approach could also prevent damage to the primary equipment.

1. Introduction

The coordination of protective devices should be calculated after load-flow and short-circuit studies. These studies have been developed based on equipment specifications and the topology of the power grid. The coordination study of protective devices was developed to determine the settings of the protection devices [1,2]. In the specific case of industrial power systems, protective devices generally operate under the overcurrent principle to present dynamic responses that are similar to different disturbances in the system, which ensures the selectivity of the protection. Industrial systems have a greater diversity of overcurrent protection devices than other sections of the electric network due to the different types of loads and electrical components; electromechanical relays, digital relays, fuses and switches of low voltage are commonly used.

The time curves of overcurrent relays are appropriate for equipment protection because they allow temporary overload conditions. In addition, the coordination is simplified by the convergence of time curves. Conversely, coordination is not always calculated by using the maximum current in industrial power systems due to the large variety of time curves and damage curves of the protection system equipment. Furthermore, the time curves are asymptotic to the pickup current. Thus, the time positively correlates with the power demand. These conditions can result in long operation times of protective relays.

The use of negative sequence relays [3] provides a solution to the lack of sensitivity problem. However, the complexity of the protection scheme is increased because this type of relay must be coordinated with relays that respond to positive and negative sequences.

The protection coordination should consider the critical operating scenarios on the electric network [4]; the main objective of this approach is the protection of primary equipment, for which coordination is established for the maximum short circuit current (phase and ground). Commonly, fault currents that are not maximized result in large operating times. Reducing the operation time of the protection system is desirable because it increases the lifetime of the equipment and improves the voltage quality. Methods to reduce the stress in primary equipment via changes in the shape of the time curves and in the optimization of the coordination process are presented in [5–9].

Time curves may intersect during the coordination process, and the intersection point can be determined [10,20]. However, due to the diversity of the time curves of the protection relay and the damage curves of the primary electrical equipment, the resulting times from the coordination process allow fault currents to last up to several seconds. In the literature, different solutions that seek to minimize the duration of the fault current flowing through

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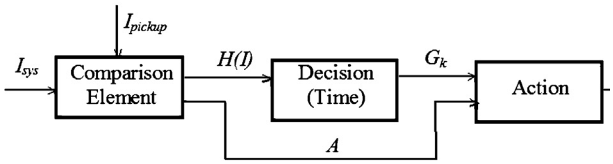

Fig. 1. Digital versions of the inverse time overcurrent relay.

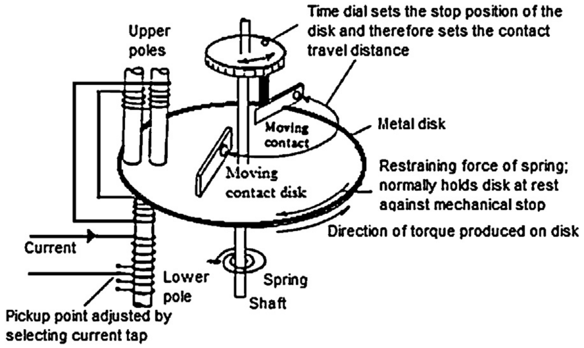

Fig. 2. Analog pattern of electromechanical relay for the proposed relay.

the primary electrical equipment by improving the performance of the overcurrent relays have been proposed. A relay that modifies the time curve of the overcurrent relay as a support of the second operation zone of a distance relay has been proposed in [11]. A relay with a universal time curve that allows coordination with a wide variety of time curves of overcurrent relays of different technologies has been proposed in [12]. An overcurrent relay model that facilitates the selection of curves using a combination of database and algorithms of curves settings based on polynomial models is presented in [13]. In this paper, we propose an inverse time overcurrent relay (phase or ground) with the capacity to generate non-conventional time curves. The conventional relay model was modified with dynamic dial function to increase its degrees of freedom and generate time curves that reduce the time interval with other relay curves or damage curve of equipment, enhancing the specific coordination scenario.

In some cases, the use of time curves established by the standards may have limitations in the protection of power systems, mainly in industrial power systems. The inadequate coordination of protection devices results in an increase in the operation times, in which increases the mechanical or electrical stress in the primary electrical equipment.

This work focused on using time curves that are not conventional as a solution to coordination problems, rather than specifying the type of function that will solve a specific problem. The complexity associated with an increase in the variety of time curves requires improved coordination; however, this complex issue can be solved by adapting the tools that allow the coordination via a graphical interaction and defining the time curve parameters as an input. This modification will result in more suitable operation times. Thus, the time curve model parameters can be supplied to the relay as part of the physical setting of the relay. The changes suggested in the proposed functions are only at software level, such as in [21]. The modification of the firmware of the relay function will allow the determination of the proposed time curve. This approach does not require additional entries; the hardware from the relay does not need to be modified.

2. Digital time overcurrent relay

The modeling of digital relays must emulate the operation of electromechanical relays [14]. Fig. 1 shows a simplified diagram of a generalized version of the digital inverse time overcurrent relay modeled by means of functions [15]. The function generator receives the phasor I_{sys} as an input, which represents the fundamental component of the current. The values of the setting I_{pickup} form the output signals of $H(I)$ and A, where $I = I_{sys}/I_{pickup}$ is the pickup current multiple [16]

$$A = \frac{K_d \theta}{\tau_s} \tag{1}$$

where K_d is damper magnet, θ is dial travel, τ_s is retension spring.

When the operation condition is completed, $I_{sys} > I_{pickup}$, the integrator introduces the time variable into the process. The output signal of the integrator is defined as follows:

$$G_k = \Delta t \sum H(I_k) \tag{2}$$

where G_k represents the value of the accumulated integrator at the instant of processing the sample k, and Δt is the sampling period.

The operating condition is fulfilled when the amplitude of the signal G_k is equal to A. The trip signal is then generated.

$$\Delta t \sum_{k=1}^{k_{op}} H(I_k) = A \tag{3}$$

The relay is operated at the instant that k reaches a value equal to k_{op} and satisfies (3). This equation considers the integration of a dynamic fault current to preserve the coordination between relays.

The time curve is created by considering a constant fault current. At this condition, I = constant value. Thus:

$$\begin{aligned} (k_{op}\Delta t)H(I) &= A \\ T(I)H(I) &= A \\ T(I) &= \frac{A}{H(I)} \end{aligned} \tag{4}$$

According to [15], $H(I)$ is $I^n - 1$. Furthermore, the time saturation, B, is included.

3. Proposed overcurrent relay model

The definition of the constant A has a direct physical relationship with the electromechanical relays, in which the induction disc is the only component that is moved by the interaction of the induced currents. Furthermore, the angular distance of the movement of the disc to the closure of contacts, the action of the damper magnet and the retention spring, which are parameters that are defined in [16], are constant. In this paper, we proposed to modify the function A such that it is variable and depends on the input. This assumption increases the degrees of freedom of the analytical expression that defines the time curve of the relay. The equivalent electromechanical relay in Fig. 2 was used to assign a dynamic behavior to the dial lever such that θ is a function of the current, $\theta(I)$.

$$A(I) = \frac{K_d \theta(I)}{\tau_S} \tag{5}$$

The objective was to define functions, $A(I)$, that can alter the dynamic response of the relay and accelerate or reduce the operation time depending on the specific application.

Therefore, the digital time overcurrent relay is modified as shown in Fig. 3 as a result of change in operating conditions and the dynamic manipulation of $A(I)$, which depends on the current I.

Substituting (4) in (3) results in the following:

$$\Delta t \sum_{k=1}^{k_{op}} \frac{A}{T(I_k)} = A$$

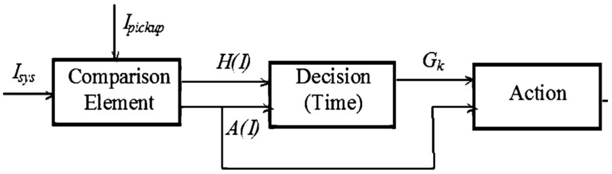

Fig. 3. Digital versions of the overcurrent relay inverse time with function of dial time variable.

A is a constant function. Thus,

$$\Delta t \sum_{k=1}^{kop} \frac{1}{T(I_k)} = 1 \tag{6}$$

This paper proposed to consider *A* as a variable function. If we consider that *A* depends on the current *I*, Eq. (7) can be developed.

$$\Delta t \sum_{k=1}^{kop} \frac{A(I_k)}{T(I_k)} = A(I) \tag{7}$$

During the operating condition, $A(I_k) = A(I)$, the time curve, $T(I)$, is not modified in the proposed model, but certain qualities defined in the time curve of the relay are maintained, such as the asymptotic behavior of the pickup current, and they fulfill the required similarity to the time curve of other protective devices and damage curves of the primary electrical equipment. Furthermore, the curves obtained with the proposed model preserved the essence of the conventional relays and contained functions that allow the increase of the degrees of freedom. These modifications primarily improve the overcurrent coordination in industrial power systems.

The function $A(I)$ for the overcurrent relay can be defined depending on the problem of coordination. This work did not intend to show an expression for each application; however, the process can be defined and simplified by adapting the coordination software [19]. If the variety of available curves that are defined in [16,17] is expanded via the incorporation of routines for curve fitting [18,20,22] in the coordination software [19], the parameters and the expression with the best fit to the desired time curve can be selected. Furthermore, the time curve could be defined in the coordination chart, and the desired model could be selected. In addition to the features of overcurrent protection, the simplicity of the mathematical model of the relay must be sufficient to be implemented in the relay. For example, polynomial expressions, which are a good option for the curve fitting of relays and fuses, are high-order expressions that will complicate the implementation.

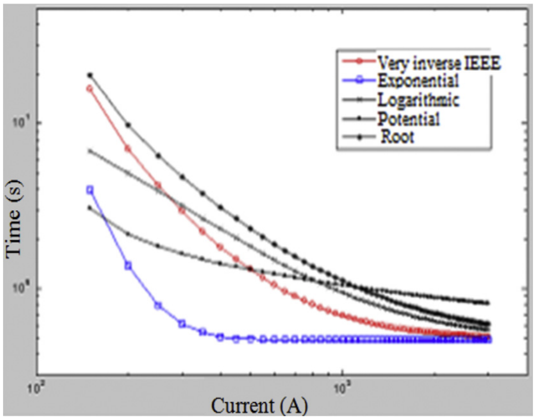

Fig. 4. Example of possible functions of $A(I_k)$.

Fig. 4 shows several examples of time curves obtained from various analytical expressions. The type of expressions required for $A(I)$ should be simple. The computational requirements for the implementation of the relay model during dynamic conditions necessitate the consideration of the computational burden of the entire protection scheme during a three-phase to ground fault, in which the protection scheme must activate all phase and ground units. Fig. 5 shows the dynamic behavior evaluation of the proposed relay model in comparison with the conventional relay model. The proposed relay model is expected to meet and improve the coordination operation criteria over the conventional relay model.

A time curve similar to the IEEE very inverse curve [18,20] (Fig. 5a) was defined to evaluate the dynamics of the proposed model for constant and dynamic fault currents. The operation times of the integration process of both relay models are equal ($A = 20 \times \exp(-I/50)$, $B = 0.491$ and $H = I^2 - 1$, for the proposed relay). Fig. 5b shows these times for constant currents, and Fig. 5c shows these times for variable currents. This finding confirms that the implementation of the proposed model will have the same functional characteristics as the conventional relays. In Fig. 5c, the fault current (I) is scaled for plotting purposes.

4. Methodology and application

This paper presents the methodology used to design a new flexible time curve for an inverse time overcurrent relay. This methodology improves the coordination with the time curves of other overcurrent protective devices. We include coordination examples where the time operation is reduced for specific conventional relays using the proposed relay. Fig. 6 shows the graphing routines and curve fitting algorithms to simplify the design process for unconventional curves. In all examples the relay setting was based in equipment capacity with overload criterion [1].

4.1. Case I. Overcurrent protection coordination in an industrial power system with a voltage level of 13,800/4160 V

The arrangements of primary electrical elements in industrial power systems that use overcurrent protection devices, such as a transformer-cable-motor, need protection coordination. This arrangement (power supply-consumer) requires the modification of the shape of the time curves to decrease the CTI (current–time interval) and improve the coordination with the damage curve of the protected elements, such as that presented in [3]. The protection coordination of this case study (Fig. 7) and many similar cases shows large time margins when using the characteristic standard curves [4]. Fig. 8 shows a coordination graph that was obtained from the study of the industrial power system shown in Fig. 7. The setting of the overcurrent protection can be improved in two ways. The first is to replace the relay PD-5 (MTR relay stall time) [2] with a flexible relay curve, and the second is to protect the damage curve XF2-1 of the transformer Category III by modifying the relay curves of PD-2 and PD-3 [13] using the proposed relay model.

4.1.1. Coordination results of the new non-conventional flexible function implementation

The proposed model was defined according to (7). The function $A(I)$ was obtained using the methodology described in Fig. 6.

The protection coordination using the proposed relay model in the following PD-5, PD-3 and PD-2 relays was compared with the base case and showed a significant reduction in the operation time. Appendix A, Table A.1 presents the coordination results for overload motor protection, including the measurement of reduced stress ($-\Delta I^2 t$) when using the proposed model of the relay. One of these two opportunities for the improvement of the overcurrent protection using the flexible curve model could protect against

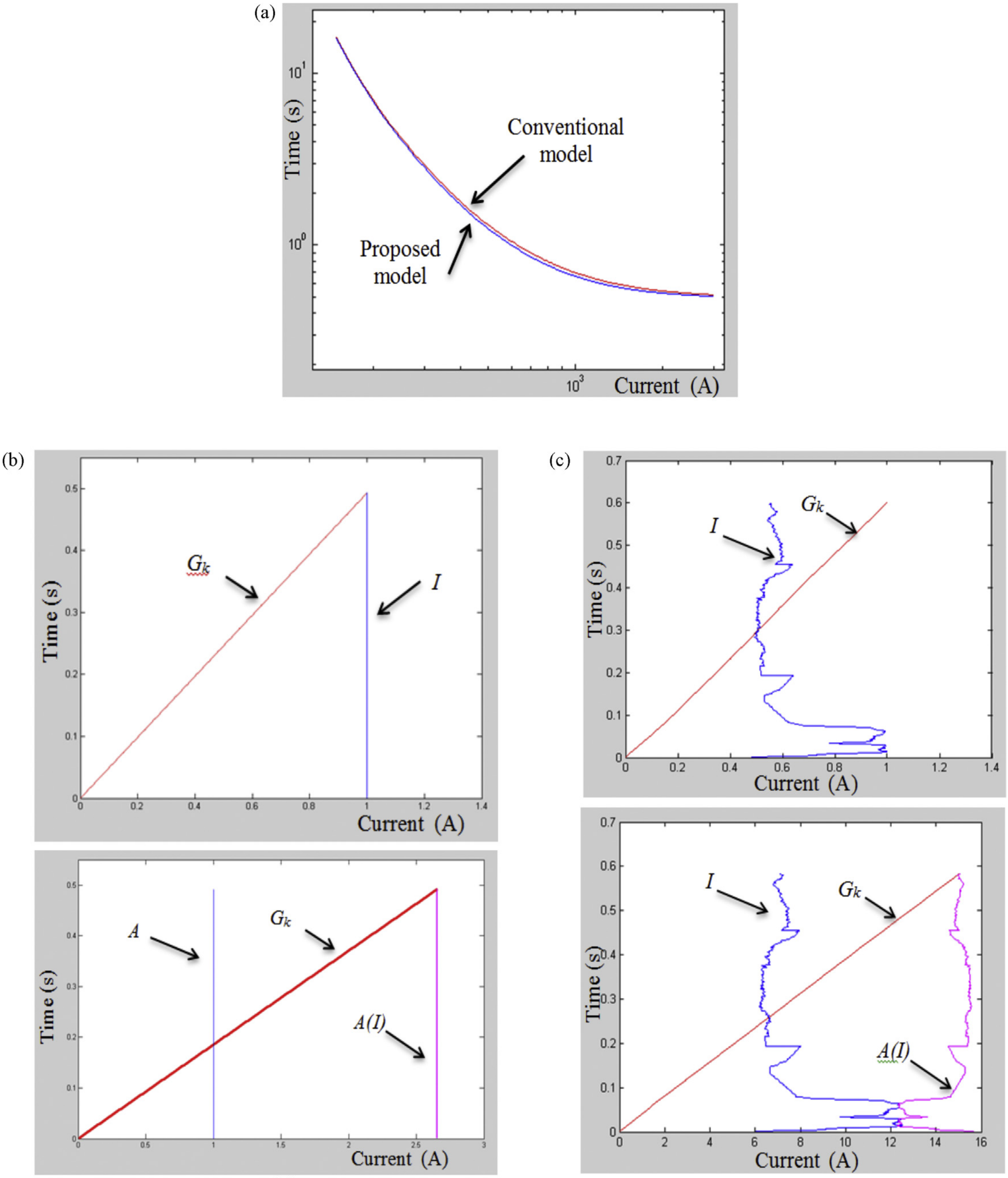

Fig. 5. Dynamic behavior comparison of the proposed model and the conventional model: (a) time curves, (b) the integrator output signals with constant Top = 0.49 s, (c) output of the integrator with dynamic signals Top = 0.58 s.

overloads, short circuits and low performance. The new time curve was set near the starting motor curve. Also we can observe that in high current the time improvement is reduced, this is due to the principle of overcurrent protection. The greatest benefit is obtained for values close to pickup current. In Table A.1 we observe negative values at the bottom, due to the crossing of curves between different slopes of proposed and conventional relay; this condition does not represent a substantial error due the overload protection is accomplish. The benefit of the flexible curve was the resultant adequate protection of the power transformer category III damage curve fault-through, especially in the section that corresponded to the effect of mechanical stress as shown in Appendix A, Tables A.2, A.3 and Fig. 9; furthermore, the average time value and the stress factor in the proposed time curves PD-5N, PD-3 N and PD-2N were reduced.

4.2. Case II. Overcurrent protection coordination in an industrial power system with a voltage level of 11,000 V with a main feeder and three branch circuits

The industrial power system needs to coordinate with the upstream relay of utility; this coordination is often difficult due to the different shapes of the time curves. Fig. 10 shows a distribution system with a coordination problem, and their characteristic protection curves are shown in Fig. 11. Due to the use of different standard curves, the characteristic coordinated standard curves show high time margins between the fuse-relay and between the relay-relay.

Fig. 12 shows the coordination graph that was obtained from the study of the industrial power system. The protection setting can be improved in two ways; the first is the coordination of the fuse

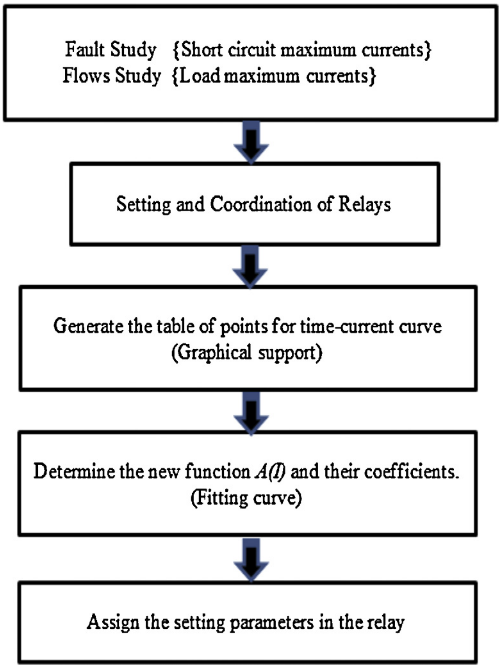

Fig. 6. Design methodology for unconventional curves.

PD-02 and PD-05 relay curve with IEEE EI (extremely inverse) in [12], and the second is between the relays PD-06 IEEE EI and R_{princi} IS (inverse standard) in [13].

4.2.1. Results of the implementation of the new non-conventional flexible function

The proposed model was defined according to (6). The function $A(I)$ was obtained using the methodology described in Fig. 6. The

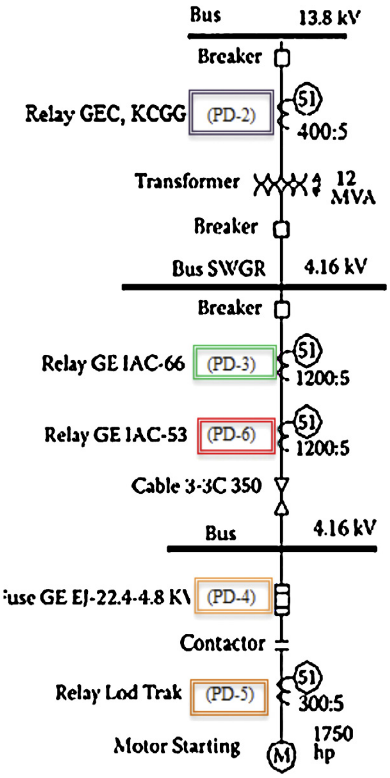

Fig. 7. Industrial power system with voltage level of 13,800/4160 V.

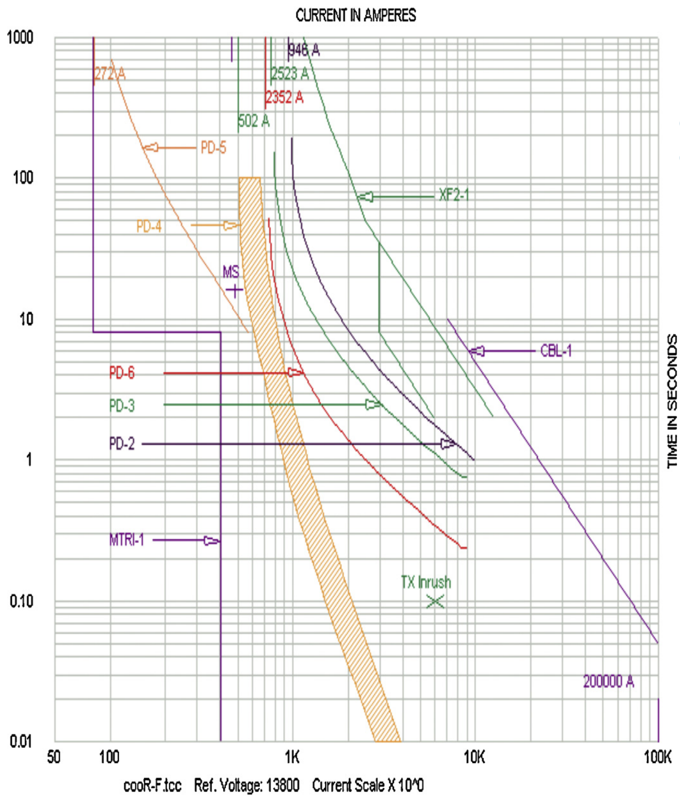

Fig. 8. Coordination graph of the industrial power system for Case I.

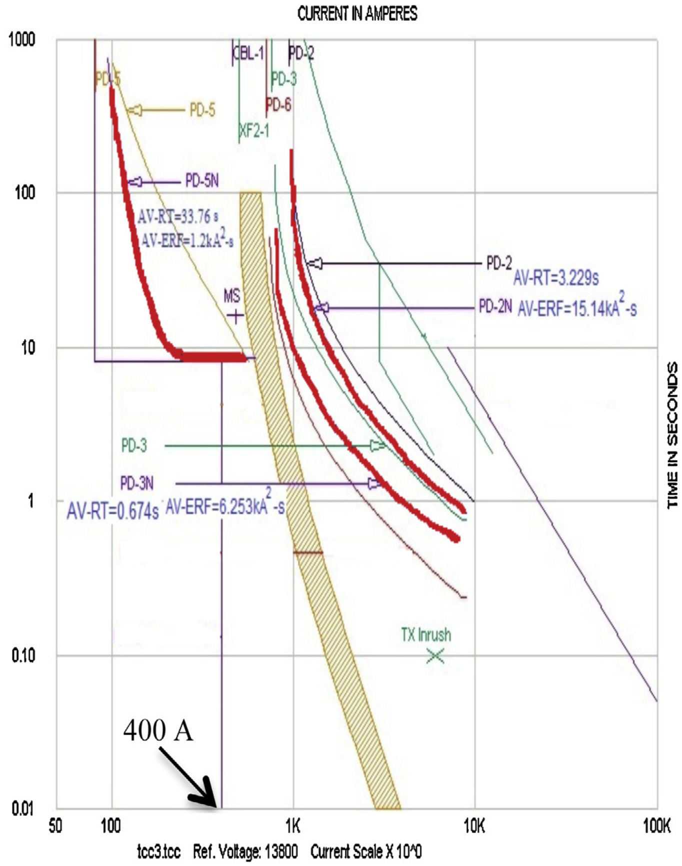

Fig. 9. Coordination graph using the proposed flexible relays in PD-5, PD-3 and PD-2.

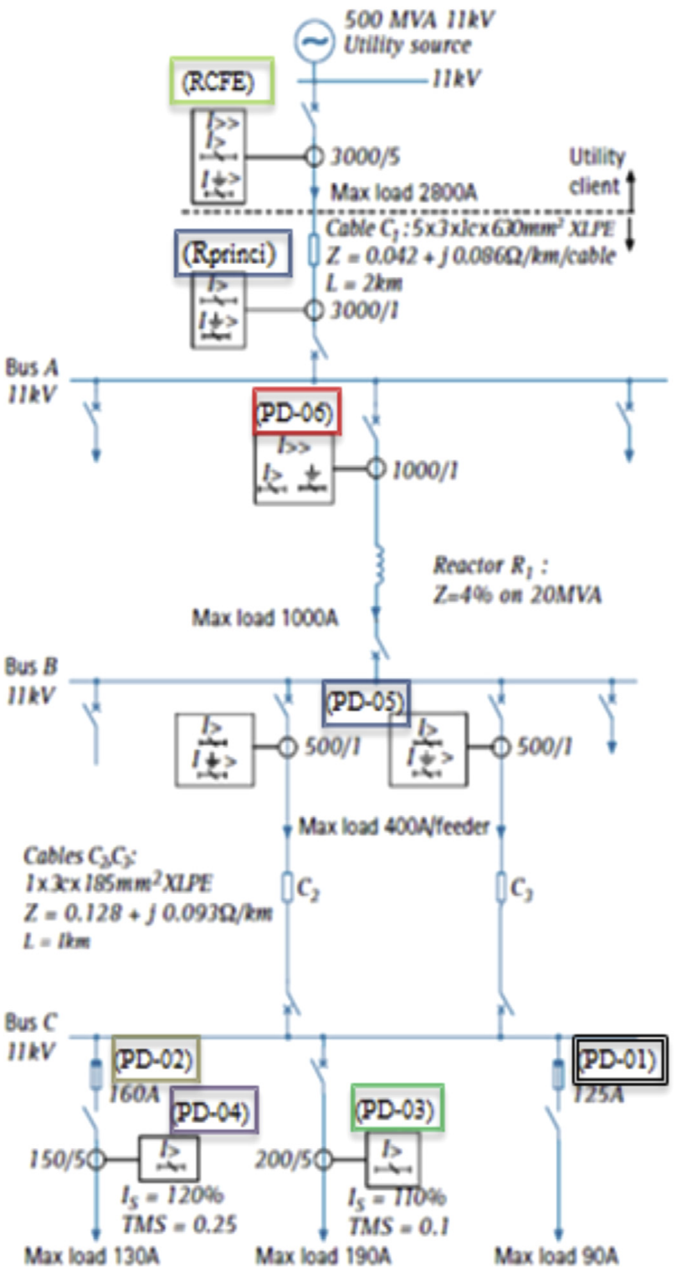

Fig. 10. Industrial power system with a voltage level of 11,000 V.

results are shown in Fig. 12. The relay characteristic curves, R_{princN}, and PD-05NC showed a reduced operation time and an average reduction of the stress factor. The results are shown in Appendix B, Tables B.1 and B.2.

The graphical and tabular results of the coordination using the proposed model in the PD-05 and R_{princi} relays were compared with the base case and showed a significant reduction in the operation time. In Appendix B, the tabular results include the values of the reduced stress ($-\Delta I^2 t$) when using the proposed relay model.

The data points of the time–current curves define the proposed function. In the coordination cases presented, the non-conventional curve was slightly better for the mathematical model of time curve standards. The error of the proposed function was 1.5% or less, and this value fit in the standard 4% deviation of the error function. Appendices A and B show the comparison of results of the fitting curves with their respective values of the parameter estimates from the standard and non-standard functions.

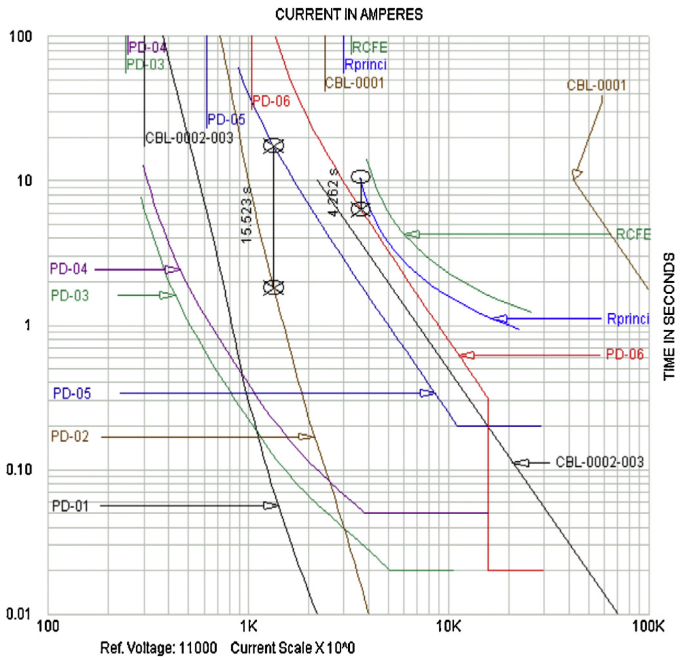

Fig. 11. Coordination graph of industrial power system of case II.

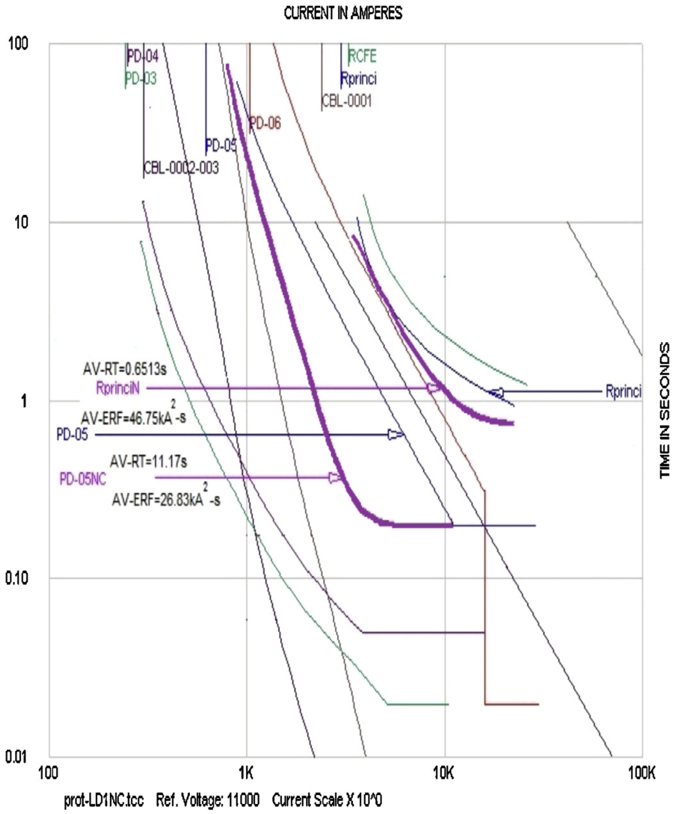

Fig. 12. Coordination graph using the proposed flexible curve in the relay PD-05 (EI) indicated as PD-05NC and using the proposed flexible curve in the R_{princi} (SI) indicated as $R_{princiN}$.

5. Conclusions

The proposed model of time overcurrent relay allows the creation of time curves that are not conventional and can reduce the exposure time of primary equipment to short circuit currents.

By increasing the degrees of freedom in the relay model, certain conditions can be obtained that allow the definition of analytical expressions for the relay model for a specific coordination problem. The implementation of the proposed relay model in industrial power systems improves the coordination overall by reducing the operation times via the damage curves of primary equipment and other overcurrent protection devices. The proposed model of an overcurrent relay with non-conventional curves allows the reduction of mechanical stress and thermal effects and could prevent damage to primary elements in the industrial power system. Furthermore, this relay could reduce energy consumption via electrical losses during fault conditions. In addition, it can increase the lifetime of the primary equipment.

The most appropriate function, $A(I)$, may depend on the case study. However, the dynamic nature of the relay model results in better setting.

Appendix A. Case I. Results of the implementation of the new non-conventional flexible function and curve fit evaluation

Figs. A.1 and A.2

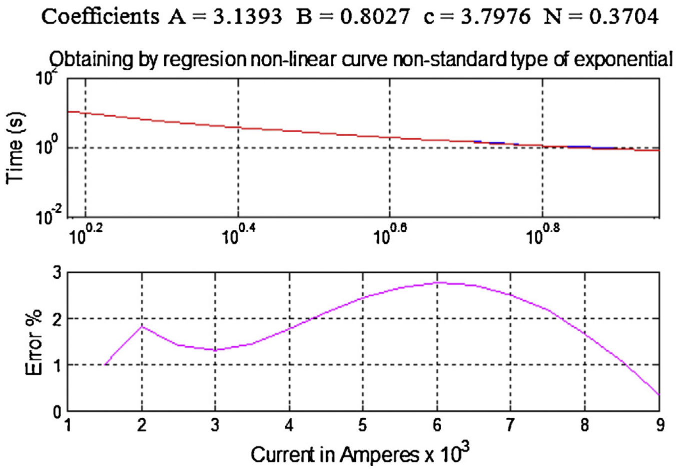

Fig. A.1. Fitting curve of case I.

Table A.1
Data curves (standard) and non-conventional (flexible) relay in the PD-5 motor, introducing the reduced time and reduce stress factor.

MTR relay stall time for the motor, PD-5 $I_{pickup} = 85$ A		Non-conventional relay PD-5N (proposed) for the motor $A(I) = Ae^{-I/C}$ $A = 12$, $C = 0.4$, $B = 8.5$		
I_{OL} (kA)	t_{std} (s)	t_{nstd} (s)	$T_{reduced}$ (s)	$(-)\Delta I^2 t$ (kA^2 s)
0.105	760.526	615.665	144.86	1.5971
0.155	172.024	40.5322	131.49	3.1590
0.205	83.0459	12.4979	70.548	2.9647
0.255	50	9.4839	40.516	2.6345
0.305	33.6829	9.0749	24.608	2.289
0.355	24.3266	9.0124	15.314	1.9299
0.405	18.4311	8.5021	8.929	1.4645
0.455	14.4644	8.5004	4.9643	1.0277
0.505	11.6626	8.5001	2.1625	0.5515
0.555	9.6077	8.5000	0.1077	0.0332
0.605	8.0546	8.5000	−0.4454	−0.1630
0.655	6.8515	8.5000	−1.6485	−0.7072
0.695	6.0739	8.5000	−2.4261	−1.1718

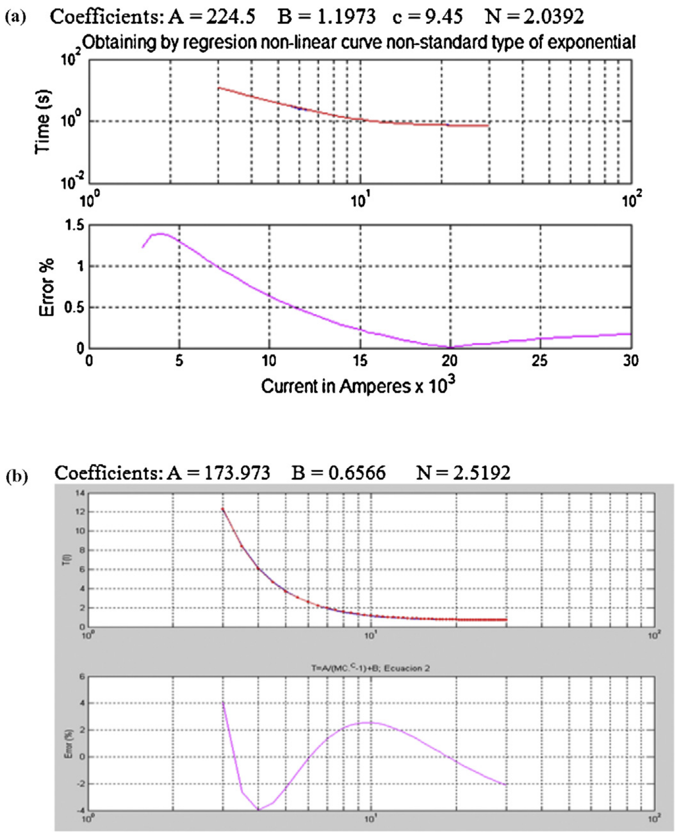

Fig. A.2. Curve time model of case II: (a) proposed model, (b) standard model.

Table A.2
Comparison of conventional data curve (standard) and proposed non-conventional relays PD-3 vs. PD-3N.

Primary relay VI PD-6 $I_{pickup} = 720$ A		Backup relay VI PD-3 $I_{pickup} = 750$ A		Non-conventional Relay PD-3N $A(I) = Ae^{-I/C}$ $A = 14.5$, $C = 6.5$, $B = 0.5$			
I_{fault} (kA)	t_{op} (s)	t_{op} (s)	CTI (s)	t_{op} (s)	CTI (s)	$T_{reduced}$ (s)	$-\Delta I^2 t$ (kA^2 s)
1.0	6.9428	20.25	13.31	14.67	7.730	5.5770	5.577
1.5	2.4923	6.750	4.258	4.764	2.272	1.9862	4.469
2.0	1.5187	4.050	2.531	2.809	1.290	1.2411	4.964
2.5	1.0921	2.893	1.801	1.989	0.896	0.9043	5.652
3.0	0.8526	2.250	1.392	1.545	0.692	0.7052	6.347
3.5	0.6992	1.841	1.142	1.272	0.572	0.5694	6.975
4.0	0.5927	1.558	0.965	1.089	0.497	0.4685	7.496
4.5	0.5143	1.350	0.836	0.961	0.447	0.3891	7.879
5.0	0.4542	1.191	0.737	0.867	0.413	0.3242	8.105
5.5	0.4067	1.066	0.659	0.796	0.390	0.2694	8.149
6.0	0.3682	0.964	0.596	0.742	0.374	0.2223	8.003
6.5	0.3363	0.880	0.544	0.699	0.363	0.1810	7.647
7.0	0.3095	0.810	0.501	0.666	0.356	0.144	7.076
7.5	0.2867	0.750	0.463	0.638	0.352	0.112	6.277
8.0	0.2670	0.698	0.431	0.616	0.349	0.082	5.242
8.5	0.2499	0.653	0.403	0.598	0.348	0.055	3.974
9.0	0.2348	0.614	0.379	0.583	0.348	0.030	2.462

Table A.3
Comparison of conventional data curve (standard) and proposed non-conventional relays PD-2 vs. PD-2N.

Backup 2 relay VI PD-2 I_{pickup} = 950 A		Non-conventional relay PD-2N $A(I) = Ae^{-I/C}$ $A = 2.5$, $C = 3.8$, $B = 0.6$			
t_{op} (s)	CTI (s)	t_{op} (s)	CTI (s)	$T_{reduced}$ (s)	$-\Delta I^2 t$ (kA^2 s)
166.72	146.47	124.49	111.05	42.233	42.23
15.156	8.4060	11.193	6.9742	3.963	8.916
7.9392	3.8892	5.8142	3.3901	2.125	8.500
5.3782	2.4854	3.9154	2.2303	1.4628	9.142
4.0664	1.8164	2.9500	1.6552	1.1164	10.05
3.2691	1.4282	2.3686	1.3079	0.9005	11.03
2.7332	1.1755	1.9822	1.0731	0.7510	12.01
2.3482	0.9982	1.7081	0.9024	0.6401	12.96
2.0583	0.8671	1.5047	0.7721	05536	13.84
1.8321	0.7663	1.3484	0.6689	0.4837	14.63
1.6507	0.6864	1.2252	0.5852	0.4255	15.32
1.5021	0.6217	1.1260	0.5158	0.3761	15.89
1.3779	0.5679	1.0448	0.4574	0.3331	16.32
1.2727	0.5227	0.9775	0.4077	0.2952	16.60
1.1824	0.4842	0.9208	0.3647	0.2616	16.74
1.1041	0.4509	0.8728	0.3276	0.2313	16.71
1.0355	0.4219	0.8318	0.2952	0.2037	16.50

Appendix B. Case II. Results of the implementation of the new non-conventional flexible function and curve fit evaluation

Table B.1
Comparison of conventional data curve (standard) and proposed non-conventional relays PD-05.

Primary fuse PD-02		Standard relay backup PD-05 I_{pickup} = 620 A		Non-standard relay (flexible curve) $A(I) = Ae^{-I/C}$			
I_{fault} (kA)	t_{rab} (s)	Δt (s)	t_{std} (s)	Δt (s)	t_{nstd} (s)	$T_{reduced}$ (s)	$-\Delta I^2 t$ (kA^2 s)
0.8	50.09	70.21	120.3	26.461	76.551	43.749	27.999
1.0	9.11	40.84	49.95	16.657	25.767	24.183	24.183
1.2	3.1	26.03	29.13	9.125	12.225	16.905	24.343
1.4	1.4	18.12	19.52	5.2974	6.6974	12.302	24.112
1.6	0.67	13.46	14.13	3.325	3.9950	10.135	25.945
1.8	0.35	10.42	10.77	2.1818	2.5318	8.2382	26.691
2.0	0.2	8.30	8.50	1.4853	1.6853	6.8147	27.258
2.2	0.133	6.767	6.90	1.0271	1.1721	5.7279	27.723
2.4	0.09	5.63	5.72	0.7598	0.8498	4.8702	28.052
2.6	0.0625	4.7575	4.82	0.5818	0.6418	4.1782	28.244
2.8	0.0465	4.0737	4.12	0.4567	0.5047	3.6153	28.344
3.2	0.028	3.093	3.12	0.3219	0.3499	2.7701	28.366
4.0	0.01	1.99	1.96	0.2300	0.2400	1.7200	27.520

Table B.2
Comparison of conventional data curve (standard) and proposed non-conventional (flexible) in the relay R_{princi}, introducing the reduced time and the energy saved factor.

Primary relay EI PD-06 I_{pickup} = 1060 A		Standard relay backup SI R_{princi} I_{pickup} = 3000 A		Non-standard relay (flexible curve) $A(I) = Ae^{-I/C}$			
I_{fault} (kA)	t_{rab} (s)	Δt (s)	t_{std} (s)	Δt (s)	t_{nstd} (s)	$T_{reduced}$ (s)	$-\Delta I^2 t$ (kA^2 s)
3.5	6.8670	5.6030	12.47	1.5739	8.4409	4.0291	49.35
4.0	5.1360	1.5360	6.672	1.0469	6.1829	0.4891	7.825
6.0	2.1907	0.5670	2.758	0.3956	2.5863	0.1717	6.181
7.0	1.5959	0.6570	2.253	0.3408	1.9367	0.3160	15.48
8.0	1.2152	0.7280	1.9430	0.3339	1.5491	0.3939	25.21
9.0	0.9565	0.7760	1.7330	0.3476	1.3041	0.4289	34.74
10.0	0.7727	0.8070	1.5800	0.3696	1.1423	0.4377	43.77
11.0	0.6374	0.8250	1.4624	0.3943	1.0317	0.4307	52.11
12.0	0.5348	0.8346	1.3694	0.4193	0.9541	0.4153	59.80
13.0	0.4551	0.8325	1.2936	0.4432	0.8983	0.3953	66.80
14.0	0.3921	0.8384	1.2305	0.4654	0.8575	0.3730	73.11
15.0	0.3413	0,8357	1.1770	0.4858	0.8271	0.3499	78.73
20.0	0.3413	0.6543	0.9956	0.4177	0.7590	0.2366	94.64

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