Journal of Al-Azhar University Engineering Sector

JAUES

Vol. 17, No. 64, July 2022, 992 - 1001

NON STANDARD OVERCURRENT RELAY FOR HIGH RESPONSE WITH SELF BACKUP PROTECTION

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Received: 21 May 2022 Accepted: 13 June 2022

ABSTRACT

The ABB REF 615 relay model is an overcurrent and earth fault relay used to protect the feeder of the real radial system of 66/11 KV Egyptian Substation NO.7 in 10^{th} Ramadan. The main objective of this paper is to create non-standard characteristics in overcurrent relays to improve the response and to operate under its failing. In the proposed model, a combined setting is utilized and consists of NI and VI curves. The working area of overcurrent relay is divided into two areas. In the first area, the VI curve is operated as back up of NI curve and in the second area, the NI curve is operated as back up of VI curve. The simulation results are verified by ETAP software. The results prove that the developed model has two advantages. The first advantage is reducing the operating time by 40% over the conventional model. The second advantage is providing self back up protection in the relay and increases the protection level if any setting fails to operate.

KEYWORDS: back up setting, ETAP software, non standard characteristics, overcurrent relay.

تحسين الخصاص القياسية لجهاز الوقاية ضد التيار الزائد لزيادة سرعة الفصل والعمل كوقاية احتياطية ذاتية

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الملخص:

يستخدم جهاز الوقاية ضد التيار الزائد والتسريب الأرضي موديل REF 615 لحماية المغذي داخل المصانع التي يتم تغذيتها من الشبكة المصرية من محطة S7) 66/11 kV) بالعاشر من رمضان. تهدف هذه الدراسة إلى تحسين خواص جهاز الوقاية عن طريق تعديل خواصه لإضافة خصائص جديدة داخل جهاز الوقاية لتحسين ورفع كفاءة الأداء وحتي يعمل مرة أخري إذا فشل في فصل العطل من المرة الأولي. يستخدم الموديل المقترح في هذا البحث المنحنيان NI وVI اللذان لهما خصائص قياسية حيث أن المساحة تحت المنحني المكون من NI و VI تم تقسيمها إلي مساحتين. في المساحة الأولي: المنحني VI يعمل كوقاية احتياطية للمنحني NI بينما في المساحة الثانية: المنحني NI يعمل كوقاية احتياطية للمنحني VI . تم اختبارهذه النتائج علي الشبكة الكهربية بإستخدام برنامج الإيتاب. تبرهن النتائج علي أن الموديل المقترح له ميزتان: الميزة الأولي أن خواصه الجديدة تقلل زمن فصل جهاز الوقاية بنسبة ٤٠٪ عن الخواص القياسية لجهاز الوقاية, الميزة الثانية هو إضافة حماية ذاتية داخل جهاز الوقاية تعمل كوقاية احتياطية إذا فشل جهاز الوقاية في فصل العطل مما يؤدي لرفع مستوي الوقاية داخل الشبكة الكهربية.

الكلمات المفتاحية : الوقاية الإحتياطية, برنامج الإيتاب, الخصائص الغير قياسية , جهاز الوقاية ضد التيار الزائد.

1. INTRODUCTION

1.1 Objective and Motivation

A system under fault needs back up protection in addition to the primary protection. If the primary protection fails to separate the fault, the back up protection can deal with this disturbance and discriminate the fault. On other words, each relay needs other relays to operate as a backup. In this paper, the proposed model produces back up protection for itself from itself. Existing of the backup protection in the system increases its protection level. The designed back up system in the proposed model minimizes its operating time than the conventional model (normal back up). The relay curve is characterized by two types: definite time and inverse time. The inverse time curve has main advantage that the higher fault currents meet lower trip time. So, overcurrent relay of REF 615 model with its inverse characteristics shall be studied in this paper to protect the feeder of the real radial system.

1.2 Literature Review

Non standard curves of inverse characteristics is carried out in directional overcurrent relay (DOCR) relay to solve the coordination problem. The proposed method for suitable time settings is genetic algorithm [1]. Non standard curves of inverse characteristics and distance relay is carried out to improve the relay sensitivity during fault. The used model of OC relays consists of five settings for coordination improvement during using the distance relay. The results reduce the number of not coordinated relays [2]. Economic and technical benefits of relays and fuses are integrated in the adaptive protection. It is based on inverse time settings for OC relays [3]. New method is introduced to decrease the coordination time and operating time for main and back up protections. The proposed technique is tested on IEEE 3, 8, 30 bus systems. The results are compared with different proposed methods [4]. New approach based on interval analysis to cancel the miscoordination between DOCRs is introduced. Converting the inequality constraints to interval constraint is the main idea of the proposed approach which gives reduction in coordination constraints . The systems of IEEE 14, 30 bus are tested to prove the ability of interval method [5]. Mataheuristic algorithm is proposed in [6] to improve the DOCR coordination. The proposed approach is tested on IEEE 30, 118, 300 bus. The results improve the coordination performance and minimize the unwanted load shedding. Adaptive protection system by Fuzzy Logic depends on the pre-fault current and the current variation is proposed. The analysis is performed using ATP EMTP software [7]. This adaptive method based on logic and decision making gives more flexibility and high performance with automatically operation and high sensitivity of OC relays. The distribution system with distributed generator (DG) is tested. Fault Currrent Limiter (FCL) is used to limit and reduce the short circuit level of distribution network with DG. Existing the DG and FCL causes transient currents when fault occurs. Genetic Algorithm introduces dynamic model for OC relays to treat this problem and for optimal relay setting [8]. Existing FACTS devices in transmission line causes disoperation of distance relay. Series shunt compensator has more effects on relay performance than any

FACTS device. Provided method for eliminating unified power flow controller (UPFC) effects on distance relay is presented [9]. In [10], a multi-objective optimization algorithm is proposed to find the optimum operation point considering the number of setting changes, the number of setting groups and total protection time. In [11], metaheuristic optimization method is proposed. The relays operating and pairs discrimination times are significantly reduced. For the 30-bus power system, the obtained total relays operating time using the proposed method satisfying a highly reliable coordination is less than 1/10 of those obtained from conventional coordination methods. In [12], an optimization technique of particle swarm optimization (PSO), genetic algorithm (GA), teaching learning based optimization (TLBO) algorithm is proposed for solving overcurrent relays (OCRs) coordination problem due to specific features of the network such as the presence of DG. The proposed approach allows obtaining better operational times without losing the coordination between main and backup relays. In [13], this research shows the effect of curve type of overcurrent functions and the location of analyzed faults on directional overcurrent relays (DOCRs) coordination. The tested relay curve type is Extremely Inverse, Normal Inverse and very inverse for better performance of optimal coordination. The results with Extremely Inverse curves were between 7 and 16 times faster than results with Normal Inverse curves.

1.3 Main Contribution of this work

The main purpose from designing nonstandard relay model is to reduce the relay operating time by about 40% and inserting additional protection for increased protection level to the real system. The main contribution of this work can be given as:

- ✓ Studying the real relay (REF 615) in the market and simulated by ETAP software.
- ✓ Designing non standard characteristics for the relay to run as a back up of itself.
- ✓ Reduction of relay tripping time using the proposed model.
- ✓ Increasing of the protection level in the system using the proposed model.

1.4 Paper Organization

The rest of paper is prepared as follows: Section 2 describes the proposed methodology applied on the real system. Section 3 provides the results of the proposed methodology. Section 4 discusses the obtained results and presents the main achievements. Section 5 presents the conclusions of the study.

2. The Proposed Methodology

In this paper, the digital relay REF 615 model is utilized for protecting the feeders connected to 40 MVA transformer in S7 Egyptian Substation, 10th Ramadan. Ten feeders in the real system, eight of them are in service for feeding the factories according their loads and other two feeders are out of service as back up. The REF 615 relay is used to protect the feeder inside factory while the relay 7SJ602 is utilized for feeder protection inside substation. This research is concentrated on REF 615 overcurrent relay. The single line diagram of real radial network and feeder components are shown in Fig. 1 and Fig. 2 respectively.

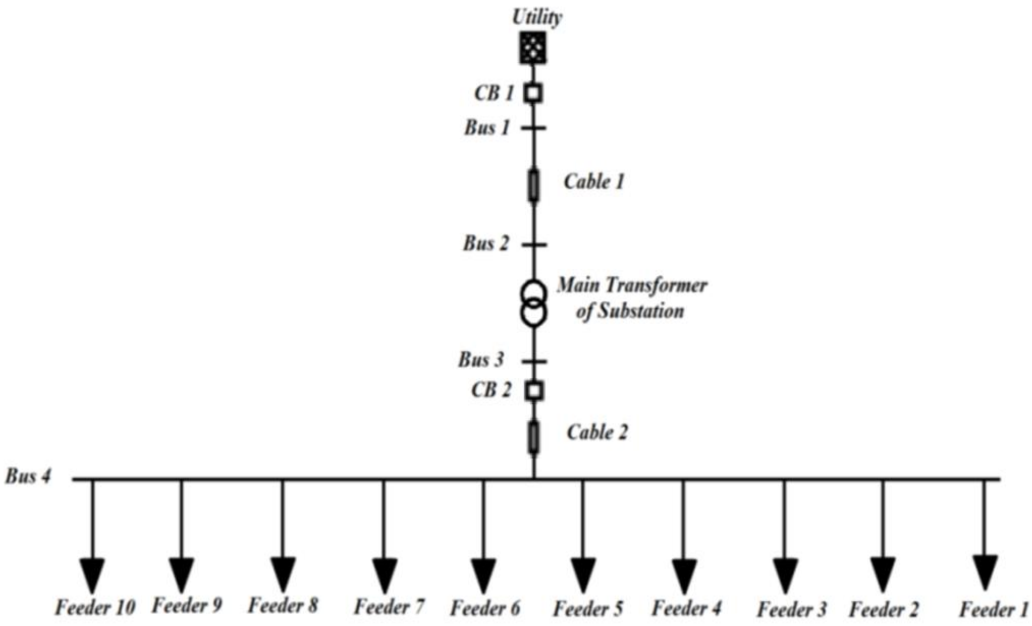

Fig. 1: Single Line Diagram of real radial system

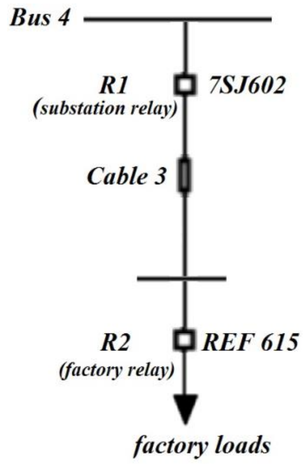

Fig. 2: Feeder components with its protective elements

The overcurrent relay operates if the fault current exceeds its pick up current setting. The overcurrent relay REF 615 is including these categories of inverse relay curves: ANSI - Normal Inverse and ANSI - Very Inverse as shown in Fig. 3. The ANSI NI and VI curves of the ABB REF 615 relay model are used to simulate the overcurrent relay setting to protect the feeder against faults. The ANSI tripping time characteristics of REF 615 relay curves can be expressed by this equation of (1) and its parameters is given in Table 1.

$$t = TDS*\left[\frac{\alpha}{\left(\frac{I}{Ip}\right)^{\beta} - 1} + \delta\right]$$

(1)

Where t : relay tripping time in sec, TDS : time dial setting, I : fault current in [A], Ip : pick up current in [A] and α, β, δ : fixed parameters as given in Table 1

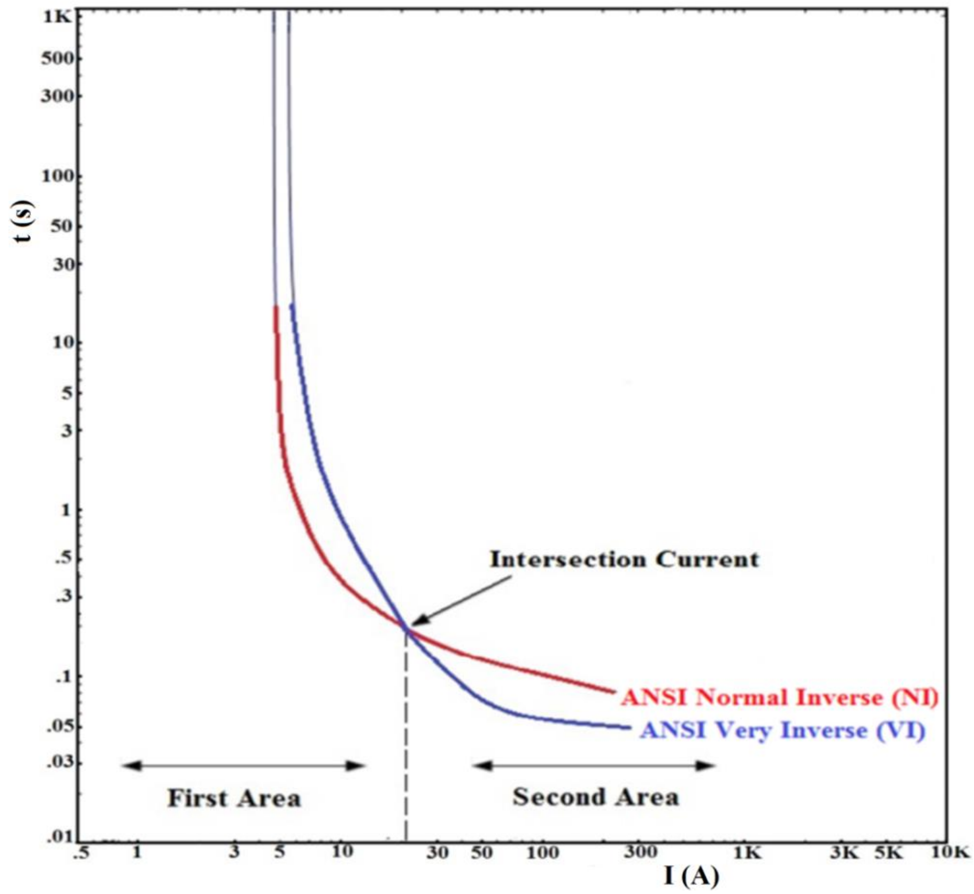

Fig. 3: The used relay curve types

Table 1: ANSI/IEEE parameters of standard relay curves of REF 615 model

Characteristic curve	α	β	δ
Normal Inverse (NI)	0.0086	0.02	0.0185
Very Inverse (VI)	19.61	2	0.491
Extremely Inverse (EI)	28.2	2	0.1217

To obtain the intersection current between ANSI NI and VI curves as shown in Fig. 3, the operating time of all these curves at the intersection current are equal. So, the operating time equation of NI is equal to the operating time of VI as given in Eq. (3).

- At the intersection current, the trip time of ANSI NI curve = trip time of ANSI VI curve , i.e;

$$TDS*\left[\frac{0.0086}{\left(\frac{I}{Ip}\right)^{0.02}-1}+0.0185\right]=TDS*\left[\frac{19.61}{\left(\frac{I}{Ip}\right)^{2}-1}+0.491\right] \quad (3)$$

From Fig. 3, the NI curve has minimum operating time in the first area compared to the VI curve. In the second area, the VI curve has minimum operating time than NI curve. From Fig. 3, according to the proposed technique, if the fault current lies on the first area, the overcurrent relay will operate by its NI curve. If the relay fails to operate at its NI curve, it will operate as back up of itself by VI curve. If a fault current lies on the second area, the overcurrent relay will operate at its VI curve. If the relay fails to operate at its VI curve, it will operate as back up of itself by NI curve. Using the overcurrent relay to operate as back up of itself gives additional protection which achieves maximum protection level for the network.

Practically, in commercial relays, the overcurrent relays often provide three individual settings to protect the devices and can be setted separately and individually. The three settings are I>, I>>, I>>> . The proposed strategy uses two settings activated in REF 615 OC relay in the same time for designing mixed curves for improving the relay response during faults. In this work, the two groups from the ABB, REF 615 (OC1 and OC2 levels in ETAP software) were used. Each group (OC level) has two settings for fault currents passes through phase: overcurrent setting and instantaneous setting. The first setting (I>) is the overcurrent setting of OC1 and setted on ANSI – Normal Inverse (NI). The second setting (I>>) is the overcurrent setting of OC2 and setted on ANSI – Very Inverse (VI).

To summarize the previous details, the proposed technique divides the fault currents into two areas as shown in Fig. 3 and given in Table 2. Each area has certain setting according to its proposed curve. The two areas are:

i. The first area is the area from the minimum current ($I_{min.}$= pick up current) to the intersection current (Io) ;i.e , $I_{min.} \leq I_f \leq I_o$. Its time period is setted on NI setting (I>).

ii. The second area is the area greater than intersection current (I_o) which obtained to be equal to 1650 A; i.e, $I_f > I_o$. Its time period is setted on VI setting (I>>).

Table 2: The proposed time setting

REF 615 Setting	Relay Curve	Setting
I>	ANSI NI	Pick up current = 492 A
		TDS = 0.65
I>>	ANSI VI	Pick up current = 492 A
		TDS = 0.1

The flowchart in Fig. 4 illustrates the proposed strategy. According to the fault current, the relay activates its setting. If its setting fails to operate, the backup setting will be operated to protect the device. This means that, in the first area, if *I*> fails to operate, the *I*>> setting should operate as a backup. In the second area, if *I*>> setting fails to operate, the *I*> setting should runs as a backup.

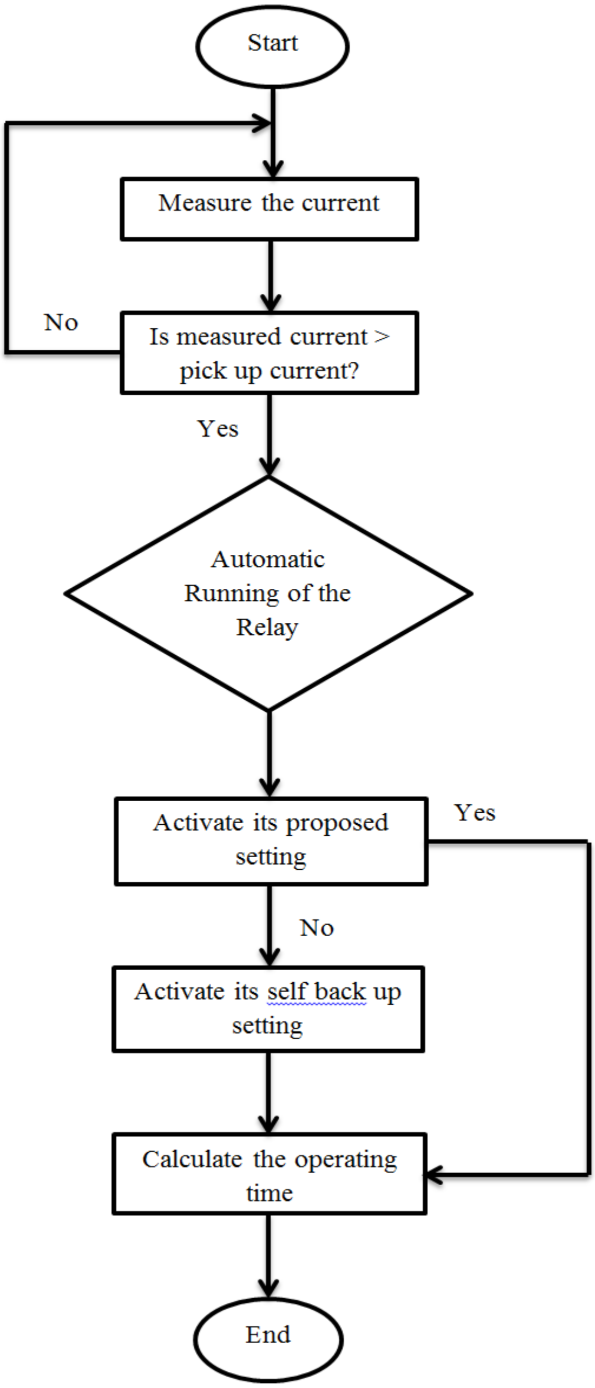

Fig. 4: Flowchart for the proposed strategy of the REF 615 relay

3. Results and Discussions

3.1. The effect of the proposed technique

In this paper, feeder 7 is tested for example as case study. Applying the proposed methodology gives more inverse degree of relay operating time that reduces this tripping time according to the proposed settings in each area as given in Table 3. When the degree of operating setting is increased, the tripping time is minimized as observed in Table 3. More fault current means less operating time.

Table 3: Trip time of relay showing the effect of the proposed technique

Fault Current (kA)	Proposed Setting	Operating Time (ms)
0.797	*I>*	588
1.152	*I>*	338
1.384	*I>*	279
1.943	*I>>*	183
5.904	*I>>*	62.9

3.2. Under failing relay setting:

As given in Table 4; In the first area (before 1650 A), When *I>* and *I>>* settings are activated, the relay operates on minimized operating time as given in Table 4. When I> setting fails to operate, the relay operates but in longer time and protect the system. In the second area (after 1650 A), If *I>* fails to operate, the relay runs on the same operating time when *I>* & *I>>* activated, so the results didn't change.

Table 4: Trip time of proposed model when *I> and I>>* activated vs trip time of proposed model when *I>* fail

Fault Current (kA)	Operating Time (ms)	
	when *I> & I>>* activated	when *I>* fails
0.797	588	1256
1.152	338	486
1.384	279	333
1.943	183	183
1.964	181	181

As given in Table 5; In the first area (less than 1650 A), When *I>* and *I>>* is activated, the relay operates on the same tripping times when I>> setting fails to run, so the results didn't change. In the second area (greater than 1650 A), the operating time was minimized when *I>* and *I>>* was activated. If *I>>* setting fails to operate, the relay runs and protect the system but in longer time.

Table 5: Trip time of proposed model when *I> and I>>* activated vs trip time of proposed model when *I>>* fail

Fault Current (kA)	Operating Time (ms)	
	when *I> & I>>* activated	when *I>>* fails
0.797	588	588
1.152	338	338
1.384	279	279
1.943	213	183
1.964	211	181

3.3. Comparison study:

According to the proposed model, when fault occurs, the relay operates on the main proposed curve. If it fails, it will operate on its back up proposed curve. If the back up proposed curve fails, the next relay will operate to separate the fault. This is the sequence of operation between protective elements to isolate and separate the fault.

Table 6 gives the trip time of the proposed model compared to the conventional model. The conventional model uses standard curve (NI curve) for feeder protection while the proposed model uses the non standard curve (NI curve in the first area plus VI curve in the second area). When a fault occurs, the operating time of the relay is reduced according to the proposed model compared to than the standard NI curve as given in Table 6.

Table 7 proves that the proposed model can deal with the relay failing successfully due to its back up system. If the relay fails to run, it will operate on its proposed back up curve. In this case, the proposed model gives additional protection in the system. On other words, in the first area, the setting *I*>> is a back up of the setting *I*> and in the second area, the setting *I*> is a back up of the setting *I*>>. Hence, the maximum protection level is achieved. Another advantage, the additional back up protection in the nearest relay to fault means that it will separate the fault by 100%, so the fault location can be detected easily and then, the reasons of fault. While the conventional model cann't deal with this situation well and when relay fail to operate, the next relay will operate to separate the fault at high operating time as given in Table 7.

Table 6: Nonstandard proposed model vs nonstandard back up model

Fault Current (kA)	Operating Time (ms)	
	proposed model	when proposed model fails
1.943	183	213
4	103	143
5	68.3	130

Table 7: Proposed model under relay failing vs the conventional model

Fault Current (kA)	Operating Time (ms)	
	Proposed Model	Conventional Model
0.797	1256	2210
1.152	486	1079
1.384	333	833
1.943	213	571

4. Discussions of the obtained results and main achievements

From the obtained results, the possibility of the REF 615 settings to run as back up of each other is achieved. The proposed model provides two advantages. The first profit is reducing the operating time of primary protection by about 40% as given in Table 3. The second profit is the self back up protection in the relay where the relay can deal with the fault under relay failing as given in Table 4 and Table 5. Comparison study between the proposed and conventional models is performed using Table 6 and Table 7. The previous results prove that the proposed model minimizes the tripping time of the relay and maximize the protection level in the network.

5. Conclusions

The proposed model of overcurrent relay is tested on the real radial system of 66/11 kV Egyptian substation S7 in 10^{th} Ramadan using ETAP software. From the obtained results, in this system, not only the other relays run as backup of the current relay, but also the settings of the relay run as backup for themselves. The results indicate that the non standard model has lower tripping times compared to the standard model. The operating time during fault is reduced by about 40%. Under relay failing, the proposed model produces new advantage to operate as back up of itself. In the first area, If I> setting fails to run, the setting I>> will operate as back up of itself. In the second area, if I>> setting fails, the setting I> will operate as back up of itself. Thus, the provided model takes faster action during any fault and increases the protection level of the system.

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