TEST REPORT
IEC 60255-151

Measuring relays and protection equipement –
Part 151: Functional requirements for over/under current protection

Report Number............................... :	TCT231016S007
Date of issue .... :	2023-11-01
Total number of pages .... :	30 pages (not included attachments)
Name of Testing Laboratory preparing the Report .... :	Shenzhen TCT Testing Technology Co., Ltd.
Applicant's name .... :	Primus Co., Ltd.
Address .... :	119 Soi Srimuang Anusorn, Sutthisarnvinijchai Rd., Dindaeng, Bangkkok 10400 THAILAND
Test specification:	
Standard .... :	IEC 60255-151:2009
Test procedure............................... :	IEC test report
Non-standard test method........... :	N/A
Test Report Form No..................... :	IEC 60255-151
Test Report Form(s) Originator.... :	TCT
Master TRF .... :	Dated 2023-03-23

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General disclaimer:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing CB Testing Laboratory. The authenticity of this Test Report and its contents can be verified by contacting the NCB, responsible for this Test Report.

Test item description ....:	GROUND FAULT PROTECTION RELAY
Trade Mark(s) ....:	PM
Manufacturer.....................................:	Same as applicant
Model/Type reference ....:	VPM-08 Series
Ratings ....:	Power Supply: 90-250 VAC/VDC, Max.5A~ CAT II

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):

☒ **CB Testing Laboratory:**	Shenzhen TCT Testing Technology Co., Ltd.	
Testing location/ address ....:	2101 & 2201, Zhenchang Factory, Renshan Industrial Zone, Fuhai Subdistrict, Bao'an District, Shenzhen, Guangdong, China	
Tested by (name, function, signature) ....:	Mick Li	
Approved by (name, function, signature) ....:	Thomas	

☐ **Testing procedure: CTF Stage 1:**		
Testing location/ address ....:		
Tested by (name, function, signature) ....:		
Approved by (name, function, signature) ..:		

☐ **Testing procedure: CTF Stage 2:**		
Testing location/ address ....:		
Tested by (name, function, signature)		
Witnessed by (name, function, signature). :		
Approved by (name, function, signature) ..:		

☐ **Testing procedure: CTF Stage 3:**		
☐ **Testing procedure: CTF Stage 4:**		
Testing location/ address ....:		
Tested by (name, function, signature) ....:		
Witnessed by (name, function, signature). :		
Approved by (name, function, signature) ..:		
Supervised by (name, function, signature) :		

List of Attachments (including a total number of pages in each attachment):

Attachment 1: Photos, 6 pages.

Summary of testing:

The product covered by this report has been tested and complies with the applicable requirements of this standard.

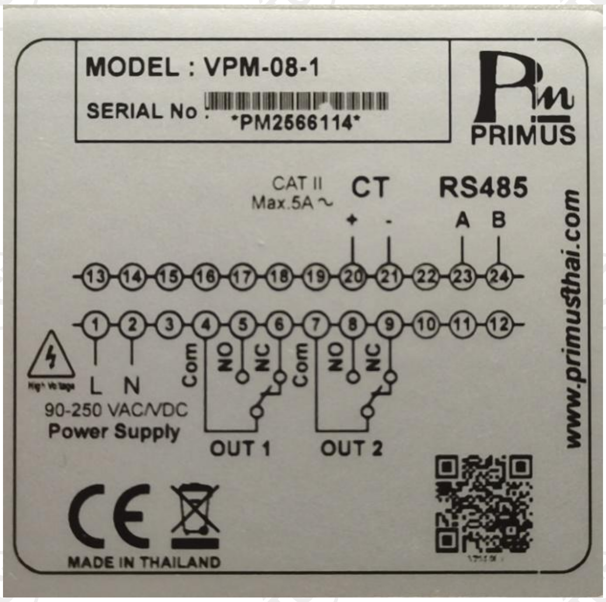
Tests performed (name of test and test clause):	**Testing location:**
All applicable tests.	See page 2 testing lab and location for details.

Summary of compliance with National Differences (List of countries addressed):

Use of uncertainty of measurement for decisions on conformity (decision rule) :

Copy of marking plate:

The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCBs that own these marks.



Note:

The above marking is the minimum requirements required by the safety standard. For the final production sample, the marking which do not give rise to misunderstanding may be added.

- Height of WEEE mark at least 7mm.

Test item particulars:	
Product group ....:	☒ end product ☐ built-in component
Classification of use by.......................................:	☐ Ordinary person ☐ Children likely present ☐ Instructed person ☒ Skilled person
Mass of equipment (kg) .... :	0.18 kg
Possible test case verdicts:	
- test case does not apply to the test object....:	N/A
- test object does meet the requirement...........:	P (Pass)
- test object does not meet the requirement....:	F (Fail)
Testing:	
Date of receipt of test item ....:	2023-10-16
Date (s) of performance of tests ....:	2023-10-16 to 2023-11-01

General remarks:

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report.
IEC-60255-151 replaces IEC-60255-4(expired).
Throughout this report a ☐ comma / ☒ point is used as the decimal separator.
The related applicable CTL decisions have been considered and the requirements found fulfilled.

Manufacturer's Declaration per sub-clause 4.2.5 of IECEE 02:

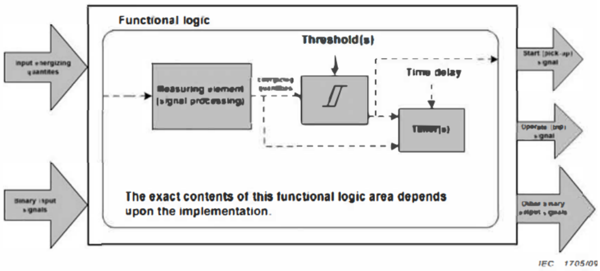
The application for obtaining a CB Test Certificate includes more than one factory location and a declaration from the Manufacturer stating that the sample(s) submitted for evaluation is (are) representative of the products from each factory has been provided ....:	☐ **Yes** ☒ **Not applicable**

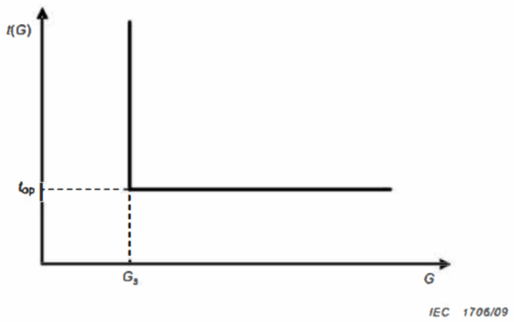
When differences exist; they shall be identified in the General product information section.

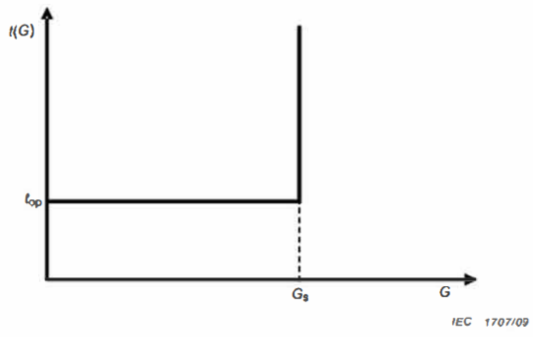
Name and address of factory (ies) .... :	Same as manufacturer.

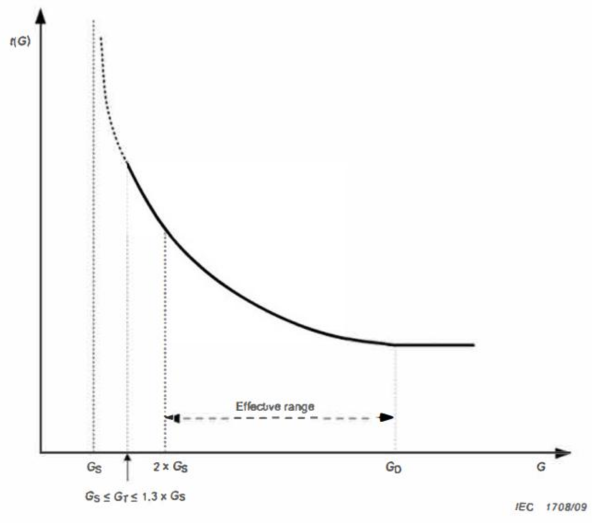
General product information and other remarks:

1. All the models are identical to testing model except for model name.

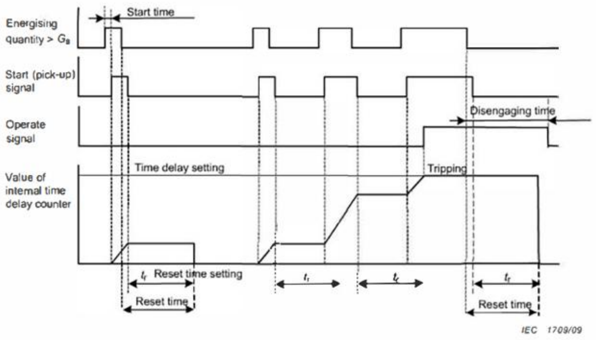
4	**Specification of the function**		P
4.1	**General**		P
	The protection function with its inputs, outputs, measuring element, time delay characteristics and functional logic is shown in Figure 1. The manufacturer shall provide the functional block diagram of the specific implementation		P
	 Figure 1 – Simplified protection function block diagram		P
4.2	**Input Energizing quantities / energizing quantities**		P
	The input energizing quantities are the measuring signals, e.g. currents and voltages (if required). Their ratings and relevant standards are specified in IEC 60255-1. Input energizing quantities can come with wires from current and voltage transformers or as a data packet over a communication port using an appropriate communication protocol (such as IEC 61850-9-2)		P
	The energizing quantities used by the protection function need not be directly the current at the secondary side of the current transformers. Therefore, the measuring relay documentation shall state the type of energizing quantities used by the protection function. Examples are:		P
	• single phase current measurement;		P
	• three phase current measurement;		N/A
	• neutral current or residual current measurement;		N/A
	• positive, negative or zero sequence current measurement.		N/A
	The type of measurement of the energizing quantity shall be stated. Examples are:		P
	• RMS value of the signal;		P
	• RMS value of the fundamental component of the signal;		N/A
	• RMS value of a specific harmonic component of the signal;		N/A
	• peak values of the signal;		N/A

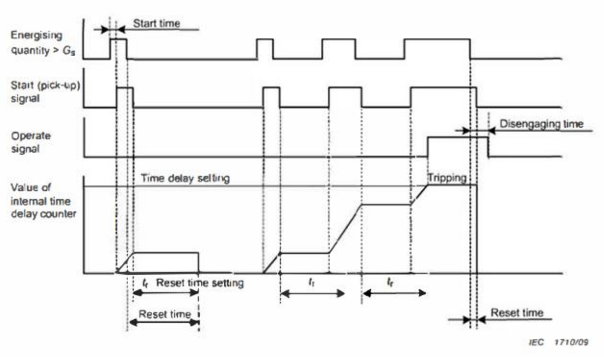
Clause	Requirement + Test	Result - Remark	Verdict
	• instantaneous value of the signal.		N/A
4.3	**Binary input signals**		P
	If any binary input signals (externally or internally driven) are used, their influence on the protection function shall be clearly described on the functional logic diagram. Additional textual description may also be provided if this can further clarify the functionality of the input signals and their intended usage.		P
4.4	**Functional logic**		P
4.4.1	**Operating characteristics**		P
4.4.1.1	**General**		P
	The relationship between operate time and characteristic quantity can be expressed by means of a characteristic curve. The shape of this curve shall be declared by the manufacturer by an equation (preferred) or by graphical means		P
	This standard specifies two types of characteristics:		P
	• independent time characteristic (i.e. definite time delay);		P
	• dependent time characteristic (i.e. inverse time delay).		N/A
	The time characteristic defines the operate time which is the duration between the instant when the input energizing quantity crosses the setting value (G_S) and the instant when the relay operates.		P
4.4.1.2	**Independent time characteristic**		P
	Independent time characteristic is defined in terms of the setting value of the characteristic quantity G_S and the operate time t_{op}. When no intentional time delay is used, then the independent time relay is denoted as an instantaneous relay.		P
	For overcurrent relays, $t(G) = t_{op}$ when $G > G_S$. The independent time characteristic is presented in Figure 2.		P
	 **Figure 2 – Overcurrent independent time characteristic**		P

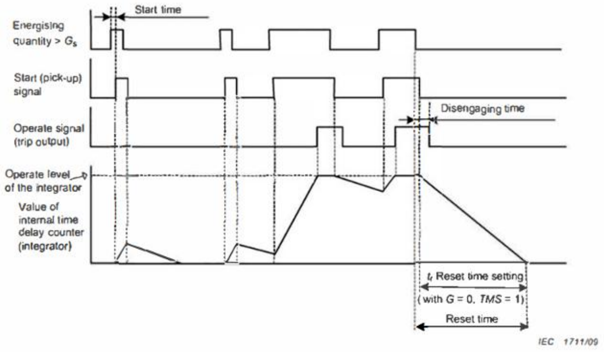
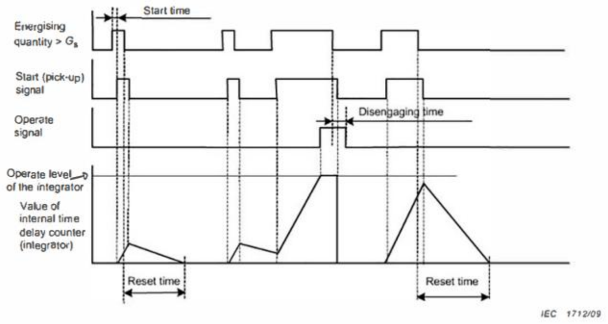
	For undercurrent relays, t(G) = t_{op} when G < G_S . The independent time characteristic is presented in Figure 3.		P
	 **Figure 3 – Undercurrent independent time characteristic**		P
4.4.1.3	**Dependent time characteristics**		N/A
	Dependent time characteristics are only defined for overcurrent relays.		N/A
	For dependent time relays the characteristic curves shall follow a law of the form:		N/A
	$$t(G) = TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha}-1}+c\right]$$ where t(G) is the theoretical operate time with constant value of G in seconds; k, c, α are the constants characterizing the selected curve; G is the measured value of the characteristic quantity; G_S is the setting value (see 3.3); TMS is the time multiplier setting (see 3.1 0). The constants, k and c, have a unit of seconds, α has no dimension.		N/A
	The dependent time characteristic is shown in Figure 4.		N/A

Clause	Requirement + Test	Result - Remark	Verdict
	 Figure 4 – Dependent time characteristic		N/A
	The effective range of the characteristic quantity for the dependent time portion of the curve shall lie between 2 × G_S and G_D. The minimum value of G_D is equal to 20 times the setting value G_S. The manufacturer shall declare the setting value range for which this is applicable. For setting values higher than this range, the manufacturer shall declare the value of $G_{D.}$		N/A
	The threshold value G_T is the lowest value of the input energizing quantity for which the relay is guaranteed to operate. G_T lies between G_S and 1,3 × G_S . Its value shall be defined by the manufacturer.		N/A
	Dependent time relays shall have a definite minimum operate time. This requirement may be defined by assigning a definite time delay for currents above a given energizing quantity level. Alternatively, the manufacturer can make the dependent time relay behaviour to cease for levels of energizing quantity in excess of a specified value (G_D /G_S), as described by the following equation:		N/A
	For G > G_D $$t(G) = TMS \cdot \left(\frac{k}{\left(\frac{G_D}{G_S} \right)^{\alpha} - 1} + c \right)$$ where		N/A

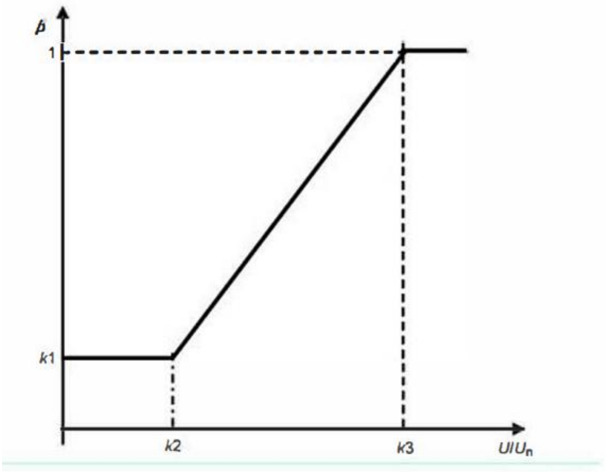
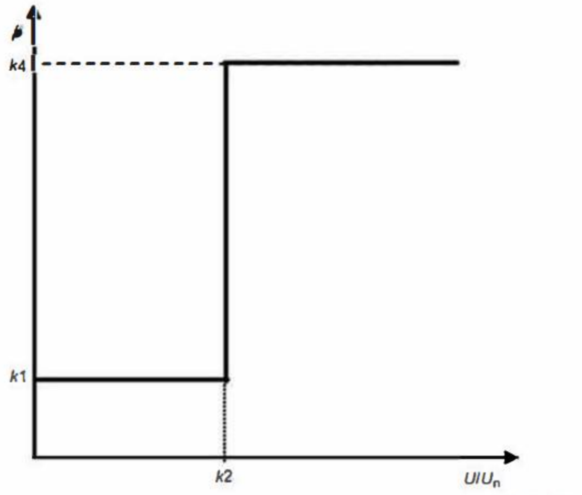
Clause	Requirement + Test	Result - Remark	Verdict
	G_D is the level of the characteristic quantity at which dependent time operation ceases and independent time operation commences (see 3.1 1); t(G) is the theoretical operate time with constant value of G in seconds; k, c, α are constants characterizing the selected curve; G is the measured value of the characteristic quantity; G_S is the setting value (see 3.3); TMS is the time multiplier setting (see 3.1 0).		
	There are six curves denoted as A, B, C, D, E and F whose coefficients for Equations (1) and (2) shall be from Annex A. The manufacturer shall declare which of these curves are implemented and state the values of G_D and G_T		N/A
	Power system fault conditions can produce time varying currents. To ensure proper coordination between dependent time relays under such conditions, relay behaviour shall be of the form described by the integration given by Equation 3.		N/A
	For G > Gs $\int_{0}^{T_0} \frac{1}{t(G)} dt = 1$ where T_0 is the operate time where G varies with time; t(G) is the theoretical operate time with constant value of G in seconds; G is the measured value of the characteristic quantity.		N/A
	Operate time is defined as the time instant when the integral in Equation (3) becomes equal to or greater than 1		N/A
4.4.2	**Reset characteristics**		P
4.4.2.1	**General**		P
	To allow users to determine the behaviour of the relay in the event of repetitive intermittent faults or for faults which may occur in rapid succession, relay reset characteristics shall be defined by the manufacturer. Different reset characteristics may be used depending upon the settings on the relay and whether the element has completed operation or not. The recommended reset characteristics are defined below.		P

Clause	Requirement + Test	Result - Remark	Verdict
	The manufacturer shall declare if compensation of the internal measurement time (disengaging time) is included in the reset time.		P
4.4.2.2	**No intentional delay on reset**		N/A
	For G < (reset ratio) x Gs. the relay shall return to its reset state with no intentional delay as declared by the manufacturer. This reset option can apply to both dependent and independent time relays		N/A
4.4.2.3	**Definite time resetting**		N/A
	Generally, this reset characteristic is applicable to overcurrent protection.		N/A
	For G < (reset ratio) x Gs, the relay shall return to its reset state after a user-defined reset time delay, t_r. During the reset time, the element shall retain its state value as defined by $\int_0^{t_p} \frac{1}{t(G)} dt$ with t_p being the transient period during which $G > G_S$. If during the reset time period, the characteristic quantity exceeds G_S, the reset timer t_r. is immediately reset to zero and the element continues normal operation starting from the retained value		N/A
	Following $G > G_S$ for a cumulative period causing relay operation, the relay shall maintain its operated state for the reset time period after the operating quantity falls below Gs as shown in Figure 5. Alternatively, the relay may return to its reset state with no intentional delay as soon as the operating quantity falls below Gs after tripping as shown in Figure 6.		N/A
	This reset option can apply to both dependent and independent time elements. A graphical representation or this reset characteristic is shown in Figures 5 and 6 for partial and complete operation of the element.		N/A
	 Figure 5 – Definite time reset characteristic		N/A

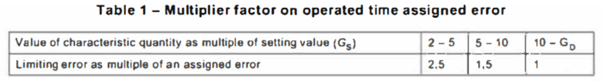
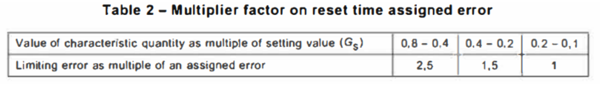
Clause	Requirement + Test	Result - Remark	Verdict
	 **Figure 6 – Definite time reset characteristic (alternative solution with instantaneous reset after relay operation)**		N/A
4.4.2.4	**Dependent time resetting**		P
	Generally, this reset characteristic is used with overcurrent protection.		P
	Following G > G_S for a transient period t_p (t_p is assumed to be less than the relay operate time), then the value I_{tp} of the integral at time t_p is given by		P
	$I_{tp} = \int_0^{t_p} \frac{1}{t(G)} dt$ (see Equation (3))		P
	Now at time Ip if G < (reset ratio) x Gs the integral resets according to the following equation:		P
	$I_{tp} - \int_0^{T_R} \frac{1}{t_R(G)} dt = 0$		P
	where T_R is the reset time.		P
	The integration starts if G < (reset ratio) x Gs		P
	t_R(G) is defined by the following equation:		P
	$t_R(G) = TMS\left(\frac{t_r}{1-\left(\frac{G}{G_S}\right)^{\alpha}}\right)$		P
	Where t_r is the setting of dependent reset time (seconds): time required to fully reset from complete operation when characteristic quantity G = zero and TMS = 1; a is the constant characterizing the selected		P

Clause	Requirement + Test	Result - Remark	Verdict
	curve; G is the measured value of the characteristic quantity; Gs is the setting value (see 3.3); TMS is the time multiplier setting (see 3.10).		
	For the curves A, B, C, D, E, F previously defined, the value of t_r, shall be in accordance with Annex A.		N/A
	Figure 7 illustrates the effect of the dependent time reset on the internal time delay counter Following $G > G_S$ for a cumulative period causing relay operation, when the operating quantity falls below G_S, the relay shall return to its reset state after the time $t_R(G)$. Alternatively, the relay may return to its reset state with no intentional delay as shown in Figure 8. The behaviour of reset time after relay operation shall be described		N/A
	 **Figure 7 – Dependent time reset characteristic**		N/A
	 Figure 8- Dependent time reset characteristic (alternative solution with instantaneous reset after relay operation)		P
4.5	**Binary output signals**		P
4.5.1	**Start (pick-up) signal**		P
	The start signal is the output of measuring and threshold elements, without any intentional time delay. If a start signal is not provided the manufacturer shall give information on how to conduct testing related to start signal as defined in Clause 6		P

Clause	Requirement + Test	Result - Remark	Verdict
4.5.2	**Operate (trip) signal**		P
	The operate signal is the output of measuring and threshold elements, after completion of any intentional operating time delay. In the case of instantaneous elements, this signal may occur at the same time as the start signal (if provided).		P
4.5.3	**Other binary output signals**		P
	If any binary output signals are available for use, their method of operation shall be clearly shown on the functional logic diagram. Additional textual description may also be provided if this can further clarify the functionality of the output signal and its intended usage		P
4.6	**Additional influencing functions/conditions**		N/A
	The manufacturer shall declare if any specific algorithms are implemented in the relay, for example:		N/A
	• insensitive to inrush current;		N/A
	• cold load pickup;		N/A
	• insensitive to false residual current due to phase current transformer saturation (when the residual current is measured with 3 phase current transformers);		N/A
	• second harmonic blocking/restrain feature		N/A
	The performances of these specific characteristics shall be described		N/A
4.7	**Specific characteristics**		N/A
	The setting value (pick-up) of voltage-dependent overcurrent protection is adjusted according to the voltage measured (phase-to-phase voltage or phase-to-neutral voltage). The adjusted setting is equal to the original setting, G_S, , multiplied by a coefficient β , defined by the following two characteristics, as shown in Figures 9 and 1 0. U is the voltage applied to relay in volts and U_n is the rated voltage in volts. The manufacturer shall declare the available values for k1 , k2, k3, k4		N/A

	 IEC 1713/09 Figure 9 – Voltage restrained characteristics		N/A
	 IEC 1714/09 Figure 10 – Voltage controlled characteristics		N/A
	For voltage-controlled operation, the preferred values for k4 are 1 and infinity (∞). If the overcurrent protection is blocked when the voltage is greater than k2 × U_n, , the value of k4 is equal to infinity (∞).		N/A
5	**Performance specification**		P
5.1	**Accuracy related to the characteristic quantity**		P
	For both independent and dependent time relays, the accuracy related to the characteristic quantity shall be declared by the manufacturer at start value. In addition, for dependent time electromechanical relays the minimum operating value G_T shall not be more than 1,3 times the setting value G_S .		P
	For both independent and dependent time relays, the reset ratio of the characteristic quantity shall be declared by the manufacturer.		P

Clause	Requirement + Test	Result - Remark	Verdict
	For both dependent and independent time relays, the manufacturer shall declare the accuracy related to the characteristic quantity along with a setting value range over which it is applicable. In addition, the manufacturer shall also declare the performance of the element under high fault current conditions (at thermal short-time withstand limit such as current = 100 × rated current).		P
	For functions with a voltage dependent element, the manufacturer shall declare additionally the accuracy related to the voltage. In order to avoid the combination of a varying characteristic quantity and a varying voltage, it is sufficient to specify the accuracy of the voltage dependency in the specified voltage range for one given value of G_s at nominal current (I_N).		N/A
5.2	**Accuracy related to the operate time**		P
	For independent time relays, the maximum permissible error of the specified operate time shall be expressed as either:		P
	• a percentage of the time setting value, or;		P
	• a percentage of the time setting value, together with a fixed maximum time error (where this may exceed the percentage value), whichever is greater. For example, ± 5% or ± 20 ms whichever is greater, or;		P
	• a fixed maximum time error.		N/A
	For dependent time relays, the reference limiting error is identified by an assigned error declared by the manufacturer, which may be multiplied by factors corresponding to different values of the characteristic quantity. For relays with a decreasing time function, the value of the assigned error shall be declared at the maximum limit of the effective range of the dependent time portion of the characteristic (G_D) as a percentage of the theoretical time. The reference limiting error shall be declared either as:		N/A
	• a theoretical curve of time plotted against multiples of the setting value of the characteristic quantity bounded by two curves representing the maximum and minimum limits of the limiting error over the effective range of the dependent time portion of the characteristic, or;		N/A
	• an assigned error claimed at the maximum limit of the effective range of the dependent time portion of the characteristic multiplied by stated factors corresponding to different values of the characteristic quantity within its effective range of the dependent time portion of the characteristic, as specified in Table 1.		N/A

<table>
<tr><th>Clause</th><th>Requirement + Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>
Table 1 – Multiplier factor on operated time assigned error
<table>
<tr><td>Value of characteristic quantity as multiple of setting value (G_S)</td><td>2 – 5</td><td>5 – 10</td><td>10 – G_D</td></tr>
<tr><td>Limiting error as multiple of an assigned error</td><td>2,5</td><td>1,5</td><td>1</td></tr>
</table></td><td></td><td>N/A</td></tr>
<tr><td></td><td>For both dependent and independent time relays, the manufacturer shall declare the maximum limiting error related to the operate time along with a setting range of time delay over which it is applicable.</td><td></td><td>N/A</td></tr>
<tr><td></td><td>The manufacturer shall declare if the internal measurement time of the characteristic quantity and the output contact operation time is included in the time delay setting or if it is in addition to the time delay setting.</td><td></td><td>N/A</td></tr>
<tr><td>5.3</td><td>Accuracy related to the reset time</td><td></td><td>P</td></tr>
<tr><td></td><td>For relays with no intentional reset delay, the manufacturer shall declare the reset time of the element.</td><td></td><td>N/A</td></tr>
<tr><td></td><td>For relays with a definite time delay on reset, the maximum permissible error of the specified reset time shall be expressed as either</td><td></td><td>N/A</td></tr>
<tr><td></td><td>• a percentage of the reset time setting value, or;</td><td></td><td>N/A</td></tr>
<tr><td></td><td>• a percentage of the reset time setting value, together with a fixed maximum time error (where this may exceed the percentage value), whichever is greater. For example, ± 5% or ±20 ms whichever is greater, or;</td><td></td><td>N/A</td></tr>
<tr><td></td><td>• a fixed maximum time error.</td><td></td><td>N/A</td></tr>
<tr><td></td><td>For relays with a dependent time delay on reset, the maximum permissible error is identified by an assigned error declared by the manufacturer, which may be multiplied by factors corresponding to different values of the characteristic quantity. For relays with a decreasing time function, the value of the assigned error shall be declared at the reference condition as a percentage of the theoretical time. The maximum permissible error shall be declared either as:</td><td></td><td>P</td></tr>
<tr><td></td><td>• a theoretical curve of time plotted against multiples of the setting value of the characteristic quantity bounded by two curves representing the maximum and minimum limits of the permissible error, or;</td><td></td><td>P</td></tr>
<tr><td></td><td>• an assigned error claimed at the reference condition, multiplied by stated factors corresponding to different values of the characteristic quantity, as specified in Table 2</td><td></td><td>P</td></tr>
<tr><td></td><td>
Table 2 – Multiplier factor on reset time assigned error
<table>
<tr><td>Value of characteristic quantity as multiple of setting value (G_S)</td><td>0,8 – 0.4</td><td>0.4 – 0.2</td><td>0.2 – 0,1</td></tr>
<tr><td>Limiting error as multiple of an assigned error</td><td>2,5</td><td>1,5</td><td>1</td></tr>
</table></td><td></td><td>P</td></tr>
<tr><td></td><td>For both dependent and independent time relays, the manufacturer shall declare the maximum limiting</td><td></td><td>P</td></tr>
</table>

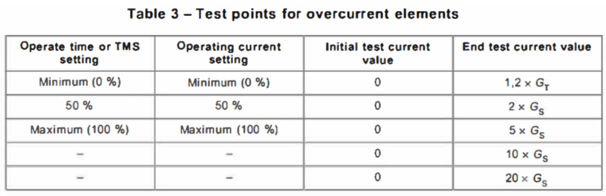
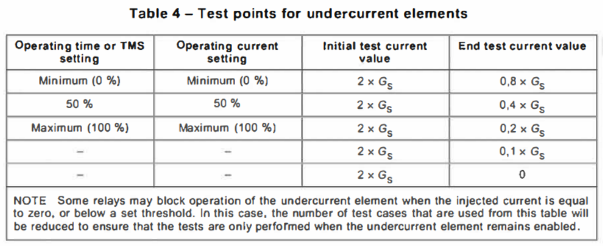
Clause	Requirement + Test	Result - Remark	Verdict
	error related to the reset time along with a setting range of time delay over which it is applicable		
	The manufacturer shall declare if the internal measurement time (disengaging time) is included in the reset time setting or if it is in addition to the reset time setting.		P
5.4	**Transient performance**		N/A
5.4.1	**Transient overreach**		N/A
	For independent time overcurrent protection, the manufacturer shall declare as a percentage error of start value (G_S) the effect of applying waveforms with maximum d.c. offset associated with systems having an X/R ratio up to 120 (primary time constant of 380 ms at 50 Hz or 320 ms at 60 Hz).		N/A
5.4.2	**Overshoot time**		N/A
	The manufacturer shall declare the overshoot time.		P
5.4.3	**Response to time varying value of the characteristic quantity**		P
	To ensure proper coordination with dependent lime relays, the relay performance under time varying fault current conditions (characteristic quantity varies with time) shall be tested. The manufacturer shall declare any additional errors, but in all cases, the additional error shall be less than 15 %		P
5.5	**Current transformer requirements**		P
	The manufacturer shall provide guidance on the class and sizing of the current transformers (refer to IEC 60044 series of standards).		P
6	**Functional test methodology**		P
6.1	**General**		P
	Tests described in this clause are for type tests. These tests shall be designed in such a way as to exercise all aspects of hardware and firmware (if applicable) of the over/under current protection relay. This means that injection of current shall be at the interface to the relay, either directly into the conventional current transformer input terminals, or an equivalent signal at the appropriate interface. Similarly, operation shall be taken from output contacts wherever possible or equivalent signals at an appropriate interface.		P
	If for any reason it is not possible to measure the results from signal input to output, the point of application of the characteristic quantity and the signal interface used for measurement shall be declared by the manufacturer. For relays where the settings are in primary values one current transformer ratio can be selected for performing the		P

Clause	Requirement + Test	Result - Remark	Verdict
	tests		
	In order to determine the accuracy of the relay in steady state conditions, the injected characteristic quantity shall be a sinusoid of rated frequency and its magnitude should be varied according to the test requirements.		P
	Some of the tests described in the following subclauses can be merged to optimize the test process. Depending upon the technology of the relay being tested, it may be possible to reduce the number of test points in line with the limited range and step-size of available settings. However, the test points listed should be used or the nearest available setting if the exact value can not be achieved.		P
	In the following subclauses, the test settings to be used are expressed in a percentage of the available range with 0 % representing the minimum available setting and 100 % representing the maximum available setting. Similarly 50 % would represent the mid-point of the available setting range. The actual setting to be used can be calculated using the following formula:		P
	$S_{AV} = (S_{MAX} - S_{MIN})X + S_{MIN}$ where S_{AV} is the actual setting value to be used in the test; S_{MAX} is the maximum available setting value; S_{MIN} is the minimum available setting value; X is the test point percentage value expressed in the test methodology (see Tables 3, 4, 5 and 6).		P
	For example, for the operating current setting in Table 5, assuming the available setting range is 0,1 A to 4,0 A, the actual operating current settings to be used would be: 0,10 A; 2,05 A; 4,00 A.		N/A
	The following subclauses refer to a rated current of the relay and it is denoted as I_n.		N/A
6.2	**Determination of steady state errors related to the characteristic quantity**		P
6.2.1	**Accuracy of setting (start) value**		P
	In order to determine the accuracy of the setting value (G_S) the characteristic quantity (magnitude) should be varied slowly and the start output of the element monitored for operation. For overcurrent protection, the characteristic quantity shall be increased according to the criteria below:		P
	• The initial value of the characteristic quantity shall be below the setting value by at least 2 times the specified accuracy of the element.		P

Clause	Requirement + Test	Result - Remark	Verdict
	• The ramping steps shall be at least 10 times smaller than the accuracy specified for the element		P
	• The step time shall be at least twice the specified start time value and not more than 5 times the specified start time value.		P
	EXAMPLE		N/A
	If the setting value is 1 A, accuracy ± 10% and start time 20 ms, the initial ramp start value is 0,8 A, ramp step size of 0,01 A, with a step time of 40 ms to 100 ms.		N/A
	For undercurrent protection, the characteristic quantity shall be decreased from an initial value which is above the start value by at least twice the specified accuracy of the element. The ramping process is similar to the overcurrent protection.		N/A
	Sufficient test points should be used to assess the performance over the entire setting range of the element but as a minimum 1 0 settings shall be used with a concentration towards lower start settings where errors are relatively more significant. Preferred values are: minimum setting (or 0 % of the range); 0,5 %; 1 %; 2 %; 3 %; 5 %; 10 %; 30 %; 60 %; maximum setting (or 100 % of the range).		N/A
	For an overcurrent relay, each test point shall be repeated at least 5 times to ensure repeatability of results, with the maximum and average error values of all the tests being used for the accuracy claim. Additional checks shall be performed at maximum setting value selected to ensure operation occurs for a current value near the short-time thermal withstand limit (such as 100 × rated current) applied to the relay.		N/A
	For an undercurrent relay, each test point shall be repeated at least 5 times to ensure repeatability of results, with the maximum and average error values of all the tests being used for the accuracy claim.		N/A
	The accuracy of the voltage dependent element is tested for a given setting of Gs for a definite time characteristic. The manufacturer has to specify the chosen value of Gs. The values for the factors k1, k2, k3, k4 shall be specified.		N/A
	Example values:		N/A
	• characteristic as in Figure 9: k1 =0,25; k2=0,25; k3=1,0.		N/A
	• characteristic as in Figure 10: k1 = 1 ; k2=0,8; k3=0,8; k4 = infinity (function disabled) or highest possible setting.		N/A
	The accuracy of the voltage dependent element is tested for the following points:		N/A

Clause	Requirement + Test	Result - Remark	Verdict
	• characteristic as in Figure 9: U/U N =0,8×k2; k2; 0,5×(k2+k3); k3; 1,1×k3		N/A
	• characteristic as in Figure 1 0: U/U N =0,8×k2; 1,1×k2		N/A
	In order to determine the accuracy of the voltage dependent element, the characteristic quantity G_s is varied slowly with a fixed voltage according to the tested point in the voltage characteristic. The start output of the element monitored for operation. The characteristic quantity is increased according to the criteria below:		N/A
	• The initial value of the characteristic quantity shall be below the setting value by at least 2 times the specified accuracy of the element.		N/A
	• The ramping steps shall be at least 10 times smaller than the accuracy specified for the element.		N/A
	• The step time shall be at least 2 times the specified value and not more than five times the specified value.		N/A
	The error of the voltage dependent element is then calculated as:		N/A
	$G - \beta \times G_s$ where G is the value of the characteristic quantity where the start output is activated; β is taken from Figures 9 or 1 0 according to the applied voltage U/U N		N/A
	For the calculation of relative errors, G s is used as a reference instead of β×G s in order to avoid increasing values resulting from low values for β		N/A
	Each test point shall be repeated at least 5 times to ensure repeatability of results, with the maximum and average error values of all the tests being used for the accuracy claim.		N/A
6.2.2	**Reset ratio determination**		P
	In order to determine the reset ratio, the element shall be forced to operate, and then the characteristic quantity should be varied slowly while monitoring the output of the element with no intentional delay on reset. For overcurrent protection, the characteristic quantity shall be decreased according to the criteria below:		P
	• The initial value of the characteristic quantity shall be above the start value by at least 2 times the specified accuracy of the element.		P

Clause	Requirement + Test	Result - Remark	Verdict
	• The ramping steps shall be at least 10 times smaller than the accuracy specified for the element.		P
	• The step time shall be at least 2 times the specified disengaging time value and not more than 5 times the specified disengaging time value		P
	If reset doesn't occur within the time interval, the element is considered to have not reset and, the next lower value of current shall be used.		P
	EXAMPLE		N/A
	If the setting value is 1 A, accuracy ± 10 % and disengaging time 20 ms the initial ramp startvalue is 1,2 A, ramp step size of 0,01 A with a step time of 40 ms to 100ms.		N/A
	For undercurrent protection, the characteristic quantity shall be increased from an initial value which is below the start value by at least 2 times the specified accuracy of the element. The ramping process is similar to the overcurrent protection.		N/A
	The rest ratio shall be calculated as follows: $\text{Reset ratio (\%)} = (I_{\text{reset}}/I_{\text{start}}) \times 100$ where I $_{\text{start}}$ is the start value of the current and I reset is the reset value of the current.		N/A
	Sufficient test points should be used to assess the performance over the entire setting range of the element, but as a minimum ten settings shall be used, with a concentration towards lower start settings where errors are relatively more significant. Preferred values are: minimum setting (or 0 % of the range); 0,5 %; 1 %; 2 %; 3 %; 5 %; 10 %; 30 %; 60 %;maximum setting (or 100 % of the range).		P
	For overcurrent relay, each test point shall be repeated at least 5 times to ensure repeatability of results, with the minimum and average values of all the tests being used for the accuracy claim.		P
	For undercurrent relay, each test point shall be repeated at least 5 times to ensure repeatability of results, with the maximum and average values of all the tests being used for the accuracy claim.		P
6.3	**Determination of steady state errors related to the start and operate time**		P

<table>
<tr><th>Clause</th><th>Requirement + Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>In order to determine the steady state errors of the operate time, current shall be applied to the relay with no intentional delay and no d.c. component, and the start and operate output contacts of the element monitored. The switching point of the current from initial test value to end test value shall be at the zero crossing of the waveform. Tests shall be conducted on an individual phase basis. Sufficient test points should be used to assess the performance over the entire time delay or time multiplier setting range, at various operating current values and throughout the effective range of the dependent time portion of the characteristic. Each test point shall be repeated at least 5 times to ensure the repeatability of results, with the maximum and average value of the five attempts being used for the analysis. The times recorded for the operate output contact provides a measure of the operating time accuracy, whilst the times recorded for the start output contact provides a measure of element start time. The following test points, Table 3 for overcurrent elements and Table 4 for undercurrent elements, are suggested.</td><td></td><td>P</td></tr>
<tr><td></td><td>
Table 3 – Test points for overcurrent elements
<table>
<tr><th>Operate time or TMS setting</th><th>Operating current setting</th><th>Initial test current value</th><th>End test current value</th></tr>
<tr><td>Minimum (0 %)</td><td>Minimum (0 %)</td><td>0</td><td>$1,2 \times G_T$</td></tr>
<tr><td>50 %</td><td>50 %</td><td>0</td><td>$2 \times G_S$</td></tr>
<tr><td>Maximum (100 %)</td><td>Maximum (100 %)</td><td>0</td><td>$5 \times G_S$</td></tr>
<tr><td>–</td><td>–</td><td>0</td><td>$10 \times G_S$</td></tr>
<tr><td>–</td><td>–</td><td>0</td><td>$20 \times G_S$</td></tr>
</table></td><td></td><td>P</td></tr>
<tr><td></td><td>
Table 4 – Test points for undercurrent elements
<table>
<tr><th>Operating time or TMS setting</th><th>Operating current setting</th><th>Initial test current value</th><th>End test current value</th></tr>
<tr><td>Minimum (0 %)</td><td>Minimum (0 %)</td><td>$2 \times G_S$</td><td>$0,8 \times G_S$</td></tr>
<tr><td>50 %</td><td>50 %</td><td>$2 \times G_S$</td><td>$0,4 \times G_S$</td></tr>
<tr><td>Maximum (100 %)</td><td>Maximum (100 %)</td><td>$2 \times G_S$</td><td>$0,2 \times G_S$</td></tr>
<tr><td>–</td><td>–</td><td>$2 \times G_S$</td><td>$0,1 \times G_S$</td></tr>
<tr><td>–</td><td>–</td><td>$2 \times G_S$</td><td>0</td></tr>
<tr><td colspan="4">NOTE Some relays may block operation of the undercurrent element when the injected current is equal to zero, or below a set threshold. In this case, the number of test cases that are used from this table will be reduced to ensure that the tests are only perfofmed when the undercurrent element remains enabled.</td></tr>
</table></td><td></td><td>P</td></tr>
<tr><td>6.4</td><td>Determination of steady state errors related to the reset time</td><td></td><td>P</td></tr>
<tr><td></td><td>In order to determine the steady state errors of the reset time, current shall be applied to the relay to cause element operation. With operation complete, the current applied to the relay shall be stepped to the initial test current value for one second, and then stepped to the end test current value with no intentional delay and a suitable output contact of the element monitored. If an output contact is not available, then the procedure described in Annex B can be applied to determine the reset time of the relay.</td><td></td><td>P</td></tr>
</table>

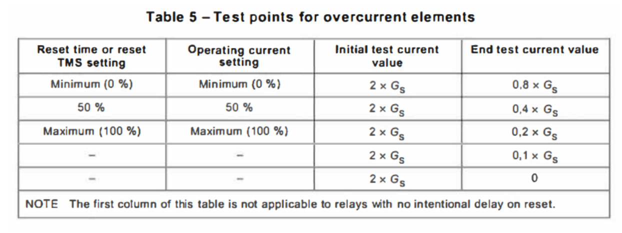
	Sufficient test points should be used to assess the performance over the entire reset time delay or reset time multiplier setting range, at various operating current values and throughout the effective range of the dependent time portion of the characteristic. Each test point shall be repeated at least 5 times to ensure the repeatability of results, with the maximum and average value of the five attempts being used for the analysis. The time recorded by monitoring the start contact provides a measure of the disengaging time of the element, whilst other suitable signals shall be used to give a measure of the reset time accuracy. The following test points, Table 5 for overcurrent elements and Table 6 for undercurrent elements, are suggested.		P
			P

Table 5 – Test points for overcurrent elements

Reset time or reset TMS setting	Operating current setting	Initial test current value	End test current value
Minimum (0 %)	Minimum (0 %)	$2 \times G_S$	$0{,}8 \times G_S$
50 %	50 %	$2 \times G_S$	$0{,}4 \times G_S$
Maximum (100 %)	Maximum (100 %)	$2 \times G_S$	$0{,}2 \times G_S$
–	–	$2 \times G_S$	$0{,}1 \times G_S$
–	–	$2 \times G_S$	0

NOTE The first column of this table is not applicable to relays with no intentional delay on reset.

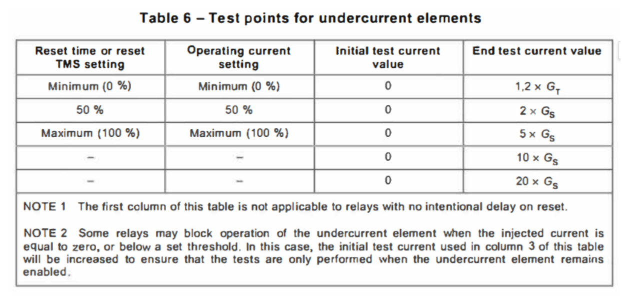
			P

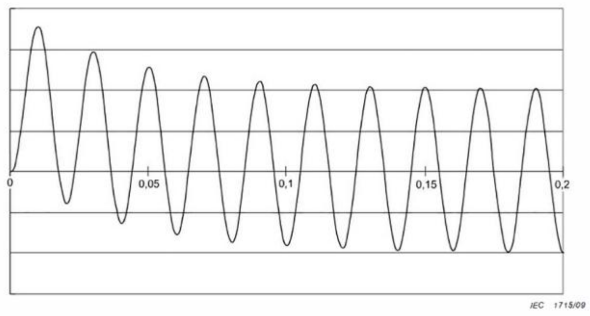
Table 6 – Test points for undercurrent elements

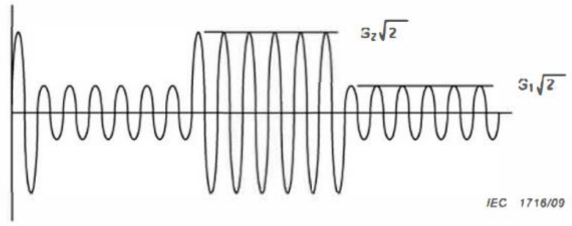
Reset time or reset TMS setting	Operating current setting	Initial test current value	End test current value
Minimum (0 %)	Minimum (0 %)	0	$1{,}2 \times G_T$
50 %	50 %	0	$2 \times G_S$
Maximum (100 %)	Maximum (100 %)	0	$5 \times G_S$
–	–	0	$10 \times G_S$
–	–	0	$20 \times G_S$

NOTE 1 The first column of this table is not applicable to relays with no intentional delay on reset.

NOTE 2 Some relays may block operation of the undercurrent element when the injected current is equal to zero, or below a set threshold. In this case, the initial test current used in column 3 of this table will be increased to ensure that the tests are only performed when the undercurrent element remains enabled.

6.5	**Determination of transient performance**		N/A
6.5.1	**General**		N/A
	The transient performance tests are performed at reference conditions where the setting value is $G_S = 1 \times I_n$.		N/A
6.5.2	**Transient overreach**		N/A
	This test is designed to view the effect of an offset waveform on the start value accuracy of the element. With the relay setting G_S set to reference conditions, current shall be applied (with no offset) starting at $0{,}9 \times G_S$ and then increasing until starting just occurs. The current magnitude shall then be reduced by 2 % and then re-applied to the relay to ensure that relay starting does not occur when the current is stepped from 0 A to the test magnitude (starting current minus 2 %). A similar test may also be performed such that a step from 0 A to the test current plus 2 % causes operation.		N/A

Clause	Requirement + Test	Result - Remark	Verdict
	With the test current magnitude established, tests shall be performed with the maximum d.c. offset present and with a constant X/R ratio up to 120 (preferred test points are for X/R ratios of 10, 40 and 120). Typical test waveform is shown in Figure 11 for a 50 Hz nominal frequency. During the tests, current shall be stepped from 0 A to the test current magnitude with no intentional delay, and relay operation shall be monitored for at least the duration of the time constant of the current waveform. If the element starts to operate, the test shall be re-performed with a higher setting for G_S until application of the offset waveform does not cause relay starting. Five successive non-operations for a given setting value indicate that the transient overreach stability point has been reached.		N/A
	The transient overreach at each X/R value is given by:		N/A
	$\text{Transient overreach (in \%)} = \left(\frac{\text{Setting at which no operation occurs for offset waveform}}{\text{Setting at which no operation occurs for waveform without offset}} - 1 \right) \times 100$		N/A
	 **Figure 11 – Typical test waveform for transient overreach**		N/A
6.5.3	**Overshoot time**		N/A
	Overshoot time is relevant for overcurrent relay and it is not applicable for undercurrent relay.		N/A
	With the relay setting at reference conditions (setting value of I n), current shall be switched from an initial value of zero to 5 × G_S and the relay operate time shall be measured as a maximum value out of five attempts. With this known operating time, the same current of 5 × G_S shall be applied for a period of time 5 ms less than the maximum operate time and then reduced to zero with no intentional delay. If relay operation occurs, the period of time for which the current is injected shall be reduced by a further 5 ms, and the test shall be performed again. The injection time shall be decreased further until five successive injections of current do not cause the relay to operate.		N/A

Clause	Requirement + Test	Result - Remark	Verdict
	The difference in time between the current injection period and the measured relay operate time is the relay overshoot time.		N/A
	For an independent time overcurrent relay, a current of 2 × G_S shall be used instead of 5 × G_S and a time delay of 200 ms shall be used for this test. Overshoot time test is not required for an instantaneous overcurrent function.		N/A
6.5.4	**Response to time varying value of the characteristic quantity for dependent time relays**		N/A
	The test waveform or the characteristic quantity is shown in Figure 12, which represents a 50 Hz or 60 Hz waveform modulated by a square wave so that the changes in magnitude or the sine-wave occur at zero crossings.		N/A
	 **Figure 12 – Test waveform**		N/A
	The frequency of the modulating square-wave shall not be higher than 1/10 of the main frequency , so that the transient behaviour of the relay does not affect the operate time.		N/A
	The magnitudes G $_1$ and G $_2$ of the characteristic quantity are both above G $_S$, the setting value of the characteristic quantity. The magnitudes are selected so that the operate time of the relay is much greater than the period of the modulating square wave.		N/A
	With the above conditions, the theoretical operate time T_0 is: $T_0 = \frac{2\times T_1\times T2}{T_1+T_2}$ where T $_1$ is the operate time for characteristic quantity equal to G $_1$; T $_2$ is the operate time for characteristic quantity equal to G $_2$		N/A
	Recommended values for the time varying characteristic quantity are given in Table 7 where the frequency of the modulating square-wave is 1 /1 0 of the main frequency. With values of Table 7, the measured operate time shall not differ from T_0 by more than 15 %.		N/A

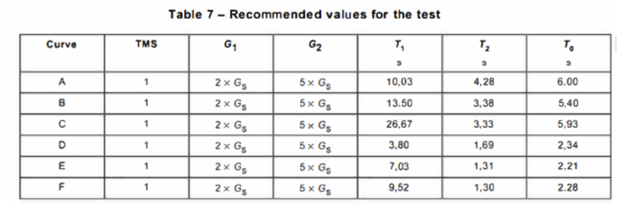
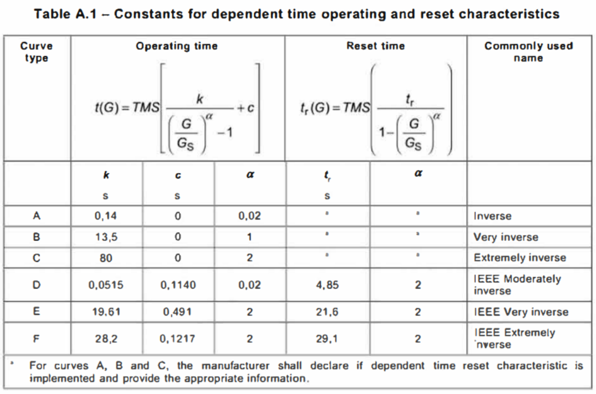
			N/A

Table 7 – Recommended values for the test

Curve	TMS	G_1	G_2	T_1 s	T_2 s	T_0 s
A	1	$2 \times G_S$	$5 \times G_S$	10,03	4,28	6,00
B	1	$2 \times G_S$	$5 \times G_S$	13.50	3,38	5,40
C	1	$2 \times G_S$	$5 \times G_S$	26,67	3,33	5,93
D	1	$2 \times G_S$	$5 \times G_S$	3,80	1,69	2,34
E	1	$2 \times G_S$	$5 \times G_S$	7,03	1,31	2,21
F	1	$2 \times G_S$	$5 \times G_S$	9,52	1,30	2.28

7	**Documentation requirements**		P
7.1	**Type test report**		P
	The type test report for the functional elements described in this standard shall be in accordance with IEC 60255-1. As a minimum the following aspects shall be recorded:		P
	• Equipment under test: This includes details of the equipment / function under test as well as specific details such as model number, firmware version shall be recorded as applicable.		P
	• Test equipment: equipment name, model number, calibration information.		P
	• Functional block diagram showing the conceptual operation of the element including interaction of all binary input and output signals with the function.		P
	• Details of the input energizing quantity and the type of measurement being used by the function.		P
	• Details of the available characteristic curves/operation for both operating and reset states that have been implemented in the function, preferably by means of an equation.		N/A
	• The value of G_T in the case of dependent time curves being implemented.		N/A
	• Details of the behaviour of the function for currents in excess of G_D, and its value.		N/A
	• Details of all settings utilised by the function, including k_1, k_2, k_3 and k_4 in the case of voltage-dependent elements.		N/A
	• Details of any specific algorithms that are implemented to improve the applicability of this function to a real power system, and their performance claims. In the case of generic algorithms that are used by more than one function, for example voltage transformer supervision, it is sufficient to describe the operation of the algorithm once within the user documentation but its effect on the operation of all functions that use it shall be described.		N/A

Clause	Requirement + Test	Result - Remark	Verdict
	• Test method and settings: This includes details of the test procedure being used as well as the settings that are applied to the equipment under test to facilitate the testing. This may include settings other than those for the function being tested. This permits repeat testing to be performed with confidence that the same test conditions are being used		P
	• Test results: For every test case outlined in the test method and settings, the complete sets of results are recorded as well as a reference to the particular test case. From these results, accuracy claims are established.		P
	• Test conclusions: Based upon the recorded test results, all claims required by Clause 5 of this standard shall be clearly stated. Where appropriate, these claims are compared with the performance specifications contained in this standard to allow individual pass / fail decisions to be given, as well as an overall pass / fail decision for the entire function.		P
7.2	**Other user documentation**		P
	Not all users insist on viewing the complete type test documentation, but require a subset of the information that it contains. For this purpose, as a minimum the following aspects shall be recorded in generally available user documentation although this may not be required in a single document:		P
	• Functional block diagram showing the conceptual operation of the element including interaction of all binary input and output signals with the function		P
	• Details of the input energizing quantity and the type of measurement being used by the function.		P
	• Details of the available characteristic curves/operation for both operating and reset states that have been implemented in the function, preferably by means of an equation.		N/A
	• The value of G_T in the case of dependent time curves being implemented.		N/A
	• Details of the behaviour of the function for currents in excess of G_D , and its value.		N/A
	• Details of all settings utilised by the function, including k1, k2, k3 and k4 in the case of voltage-dependent elements.		N/A

<table>
<tr><td></td><td>• Details of any specific algorithms that are implemented to improve the applicability of this function to a real power system, and their performance claims. In the case of generic algorithms that are used by more than one function, for example voltage transformer supervision, it is sufficient to describe the operation of the algorithm once within the user documentation but its effect on the operation of all functions that use it shall be described.</td><td></td><td>P</td></tr>
<tr><td></td><td>• All claims required by Clause 5 of this standard shall be clearly stated.</td><td></td><td>P</td></tr>
<tr><td>**Annex A**</td><td>**Constants for dependent time operating and reset characteristics**</td><td></td><td>N/A</td></tr>
<tr><td></td><td>Table A.1 shows the constant for dependent time operating and reset characteristics</td><td></td><td>N/A</td></tr>
<tr><td></td><td>
Table A.1 – Constants for dependent time operating and reset characteristics
<table>
<tr><th>Curve type</th><th colspan="3">Operating time
$t(G)=TMS\left[\frac{k}{\left(\frac{G}{G_S}\right)^{\alpha}-1}+c\right]$</th><th colspan="2">Reset time
$t_r(G)=TMS\left(\frac{t_r}{1-\left(\frac{G}{G_S}\right)^{\alpha}}\right)$</th><th>Commonly used name</th></tr>
<tr><td></td><td>k
s</td><td>c
s</td><td>α</td><td>t_r
s</td><td>α</td><td></td></tr>
<tr><td>A</td><td>0,14</td><td>0</td><td>0,02</td><td>[a]</td><td>[a]</td><td>Inverse</td></tr>
<tr><td>B</td><td>13,5</td><td>0</td><td>1</td><td>[a]</td><td>[a]</td><td>Very inverse</td></tr>
<tr><td>C</td><td>80</td><td>0</td><td>2</td><td>[a]</td><td>[a]</td><td>Extremely inverse</td></tr>
<tr><td>D</td><td>0,0515</td><td>0,1140</td><td>0,02</td><td>4,85</td><td>2</td><td>IEEE Moderately inverse</td></tr>
<tr><td>E</td><td>19,61</td><td>0,491</td><td>2</td><td>21,6</td><td>2</td><td>IEEE Very inverse</td></tr>
<tr><td>F</td><td>28,2</td><td>0,1217</td><td>2</td><td>29,1</td><td>2</td><td>IEEE Extremely inverse</td></tr>
<tr><td colspan="7">[a] For curves A, B and C, the manufacturer shall declare if dependent time reset characteristic is implemented and provide the appropriate information.</td></tr>
</table></td><td></td><td>N/A</td></tr>
<tr><td>**Annex B**</td><td>**Reset time determination for relays with trip output only**</td><td></td><td>N/A</td></tr>
<tr><td>**B.1**</td><td>**General**</td><td></td><td>N/A</td></tr>
<tr><td></td><td>Measuring relays and protection equipment have different output configurations. For equipment that has only a trip output the determination of a dependent reset time can be achieved by many different methods. The following clause describes an example of such a test method.</td><td></td><td>N/A</td></tr>
<tr><td>**B.2**</td><td>**Test method**</td><td></td><td>N/A</td></tr>
</table>

<table>
<tr><th>Clause</th><th>Requirement + Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>The determination of the reset time for relays without an appropriate contact can be achieved using the following method to determine a basic accuracy of the reset time. A current of twice the setting is applied to the relay for a pre-determined length of time such that the unit does not operate but will have reached 90 % of its trip value. The current is then reduced instantaneously to a pre-determined value below setting for a fixed time. After this time has elapsed, the current is instantaneously increased to twice the setting value until the element trips. The trip time is determined based on the value of the internal integrator. This is shown graphically in Figure B.1 . The test method is repeated with the applied current being reduced to a different value on each occasion. This generates a range of trip times from which the reset times can be extrapolated and with sufficient points a reset curve can be created.</td><td></td><td>N/A</td></tr>
<tr><td></td><td>

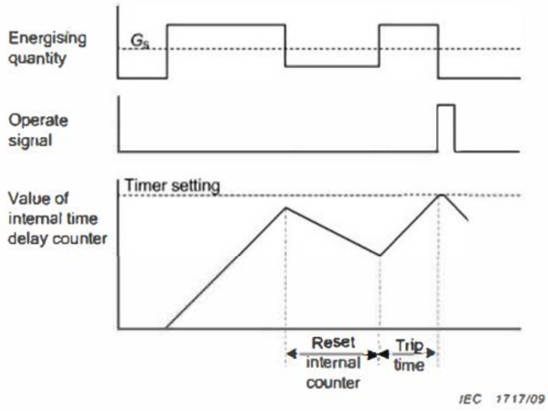


Figure B.1 – Dependent reset time determination

</td><td></td><td>N/A</td></tr>
</table>

--- End of Report ---

Photo 1-External view

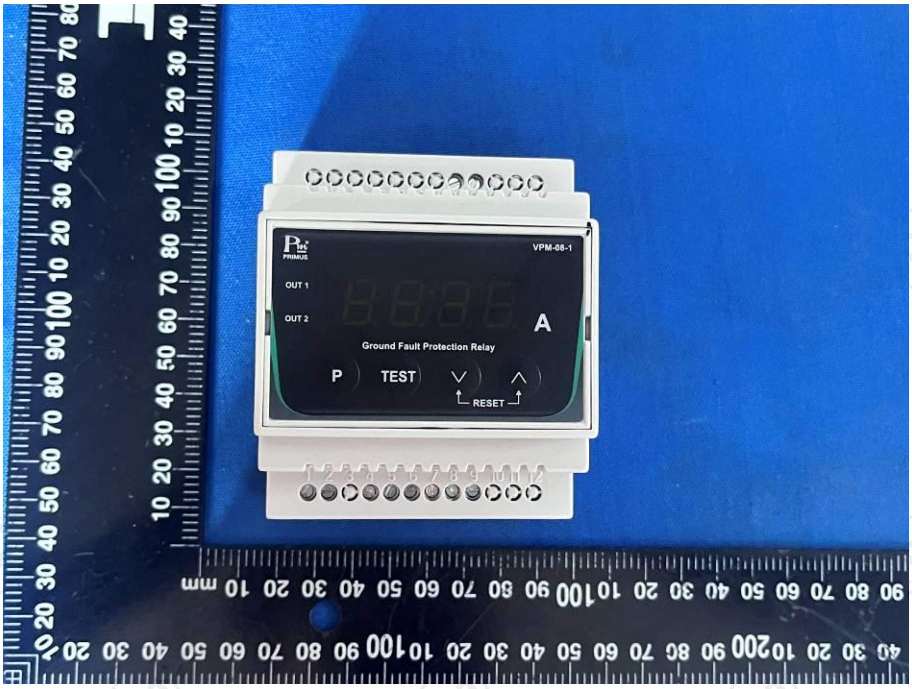


Photo 2-External view

Photo 3-External view

Photo 4-External view

Photo 5-External view

Photo 6-External view

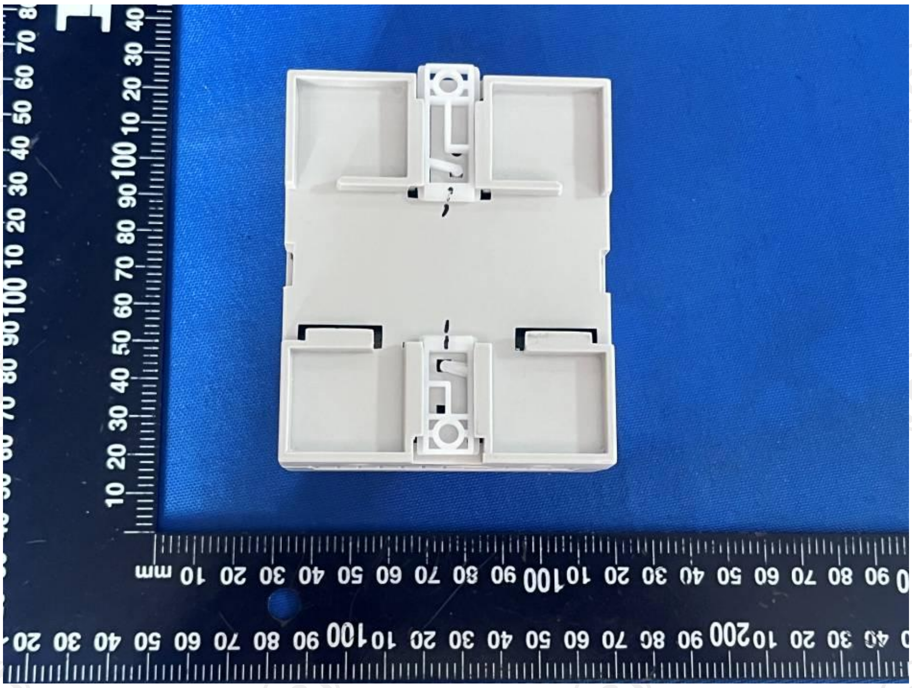


Photo 7-Internal view

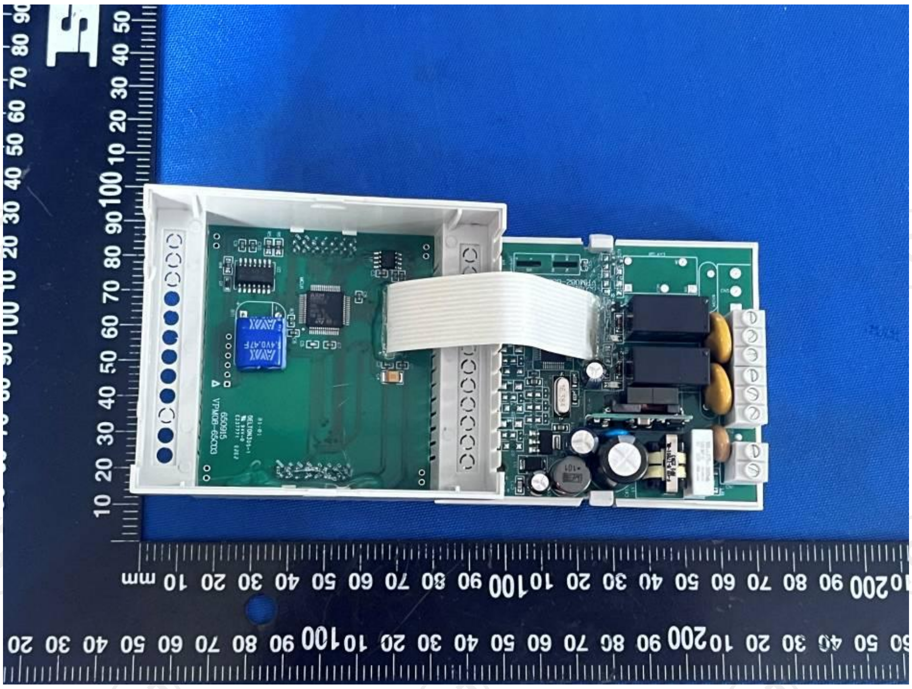


Photo 8-Internal view

Photo 9-Internal view

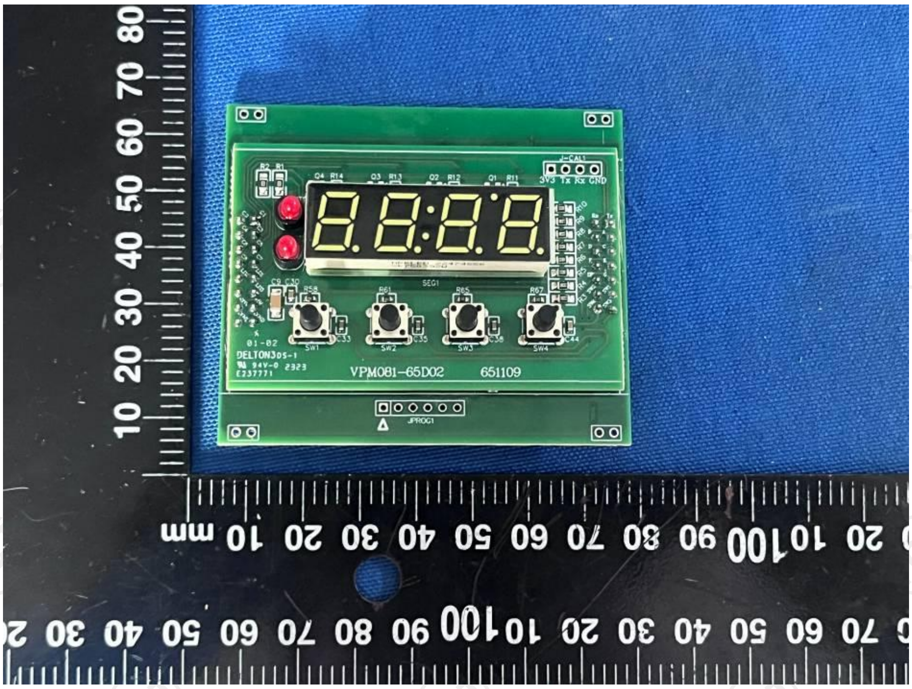


Photo 10-Internal view

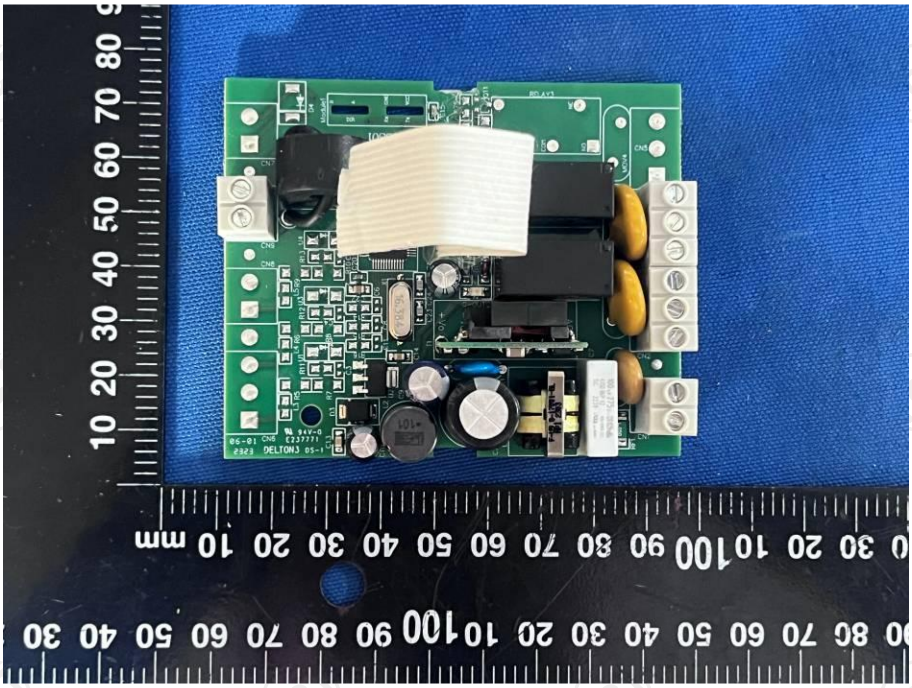
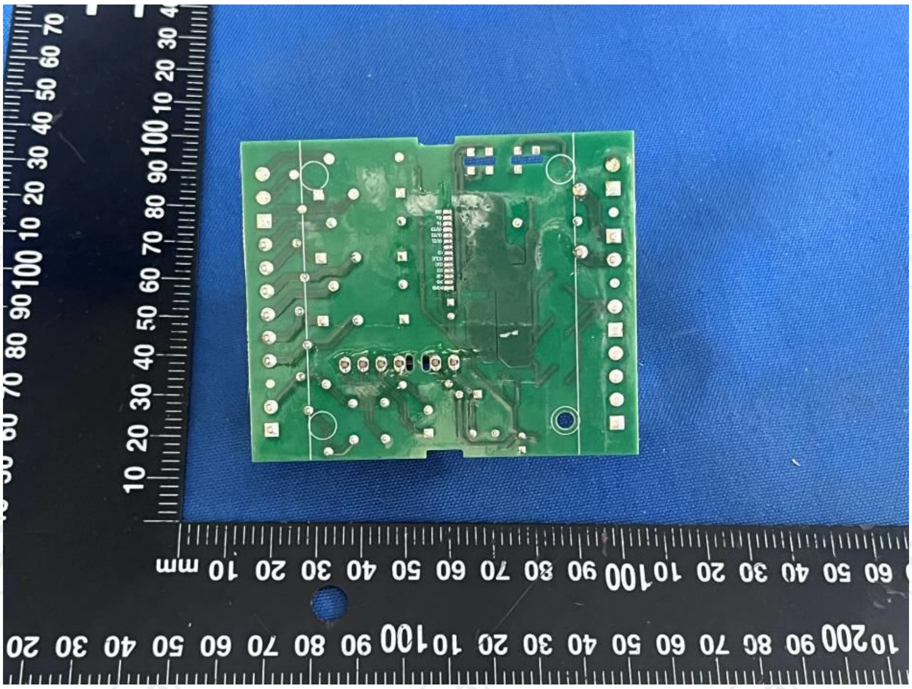


Photo 11-Internal view



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