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INTERNATIONAL ELECTROTECHNICAL COMMISSION

TECHNICAL COMMITTEE No.61: SAFETY OF HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES

Guidance on measurement of power input based of the requirements of 10.1 and 10.2 of IEC 60335-1

Background

This guidance document has been prepared by IEC TC 61 with the support of CTL ETF 01. It is the result of several discussions held in TC 61 and in CTL ETF 01 meetings held over the years 2015-2016.

It has been revised following the discussion in IEC TC 61 meeting in May 2017. Modified parts are highlighted with red font.

The purpose of this document is to guide product designers and testing laboratories in the correct approach for the measurement of power input

The requirement in question (from the 4th paragraph of 10.1 and 10.2 in IEC 60335-1:2010/A1:2013/A2/2016) foresees that :

If the power input varies throughout the operating cycle and the maximum value of the power input exceeds, by a factor greater than two, the arithmetic mean value of the power input occurring during a representative period, then the power input is the maximum value that is exceeded for more than 10 % of the representative period. Otherwise the power input is taken as the arithmetic mean value.

The application of the above requirement poses the following questions that need to be duly clarified:

1. How should the maximum value of the power input be determined according to the requirement specified in 10.1 of IEC60335-1(5th) + AMD1 for the following behaviour of the input?
2. How should “the maximum value that is exceeded for more than 10 % of the representative period” be determined? (The input is varying due to the load at random)
3. How should the “data sampling rate” or “update rate” of an instrument be selected when measuring power input? (The determined input may vary depending on the selection of those rates)

Rationale

In the TC61 Sydney meeting held in November 2015, it was decided to ask CTL to prepare document to clarify how to determine the rated power input/current according to the requirement newly introduced in the Amendment 1 of IEC60335-1(5th edition).

In the amendment, representative period and so-called 10 % rule was newly given.

Correct approach for the measurement

1. How to determine the maximum value of the rated power input (See flowchart)
   (1) At first, it should be determined **if the power input in question is varied throughout the operating cycle.**
   (2) After checking the input,
   a. If the answer to (1) is no, the maximum value of the power input shall be measured directly.
   b. **If the answer to (1) is yes**,
   You need to confirm if the maximum value of the power input is greater than 2 x arithmetic

mean value (AMV)

I. If the power input is not greater than 2 x AMV, the AMV is the maximum value of the power input.

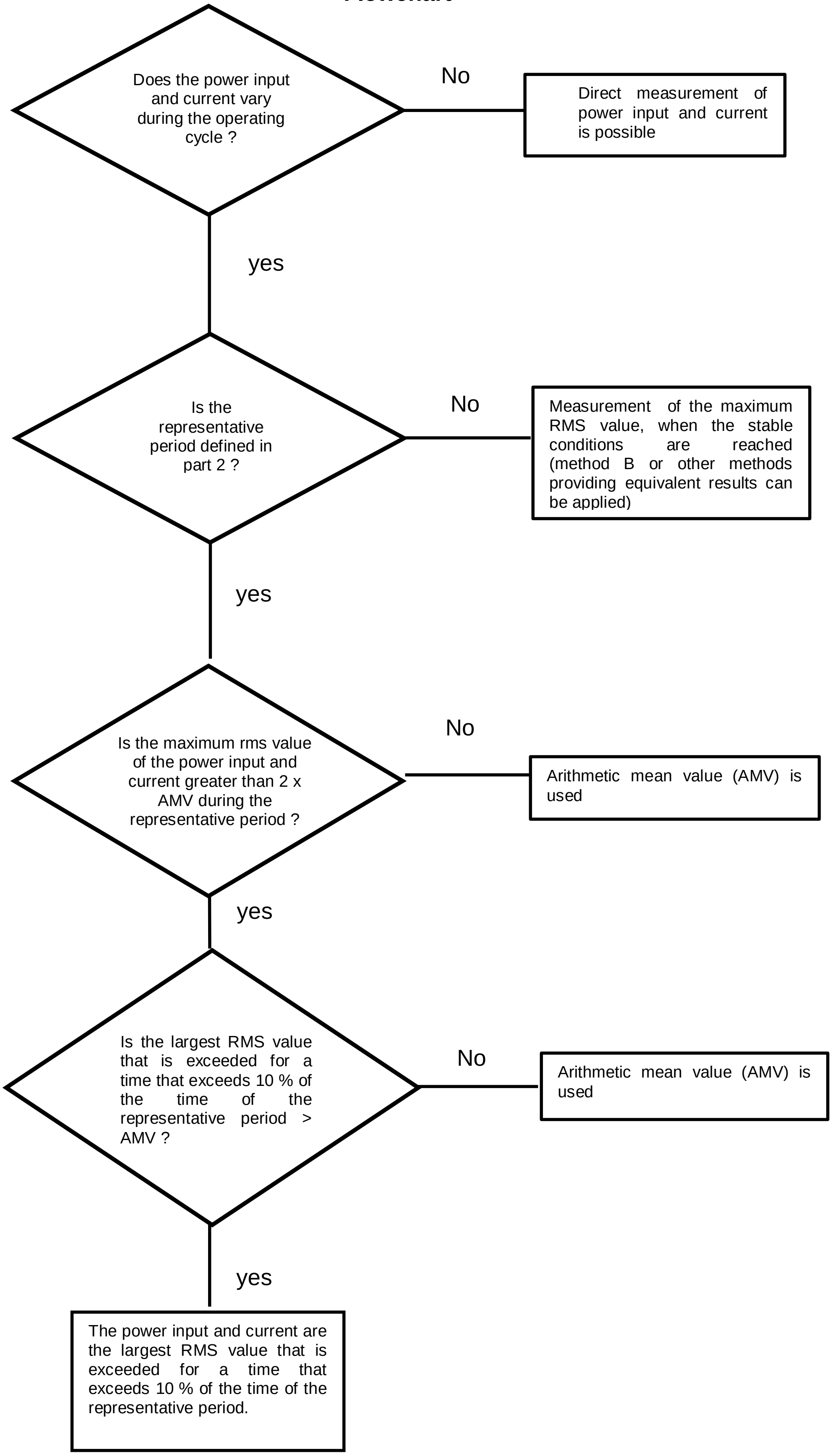
II. If it is greater than 2 x AMV, the maximum value of the power input is the value that exceeded for more than 10 % of the representative period.

2. “10 % of the representative period” should only be applied at the following conditions (See also “Spread sheet technique for the 10% rule” in Annex 1):
   (1) The power input is varied throughout the operating cycle, and
   (2) The representative period is defined in Part 2
   In this case, all the data measured during the representative period must be stored into a spread sheet in descending order in order to identify that the “power input is the maximum value that is exceeded for more than 10 % of the representative period”

3. Data sampling rate and update rate(See also “Sampling rate in the attached document)
   (1) “Data sampling rate” is normally fixed in the instruments used for the test and the value 5 kHz is usually sufficient when considering the supply frequency of power supply, 50-60Hz. You should pick up suitable instruments with such sampling rate. (Current instruments in the market have sufficient sampling speed)
   (2) “Update rate” setting is to be set considering the following points.
   The meaning of “update rate” is the period (e.g. 1 AC cycle) pre-set in the instrument to calculate the RMS values to be recorded for the 10% spread sheet
   a. Too short update rate makes necessary to prepare big data storage area for collecting data during the representative period. *The shortest data to be recorded is the RMS value calculated during the “update rate” of 1 AC cycle*
   b. Too long update rate may affect the result depending on the variation of the power input behaviours.
   An “update rate” ≥ of 1 AC cycle and ≤ of the 10% of the minimum ON and OFF period of the duty cycle is accurate enough

How to identify rated power input /current according to 10.1/10.2 of IEC 60335-1:2010/A1:2013/A2/2016)

Flowchart



Explanation of terms in the flowchart

Method B

- Wait until the stable conditions are reached.
- Measure the maximum RMS value during the ON time.
- Period of time to calculate RMS value (update rate): ≥ 1 AC cycle and ≤ 10% of the minimum ON time

“10% of the time”

- Record the RMS value (or AMV power) for each AC cycle in a spreadsheet.
- Put the values in descending order of magnitude.
- From spread sheet obtain the value at a time that is 10% of the representative period. This is the limit value that is not exceed for more than 10% the time of the representative period.

Flowchart refers to the Current measurement. In case of Power measurement consider AMV power = $V_{rms}I_{rms}\cos\Theta$ instead of RMS current.

NOTE: If the input current varies then it is necessary to use $V_{rms}I_{rms}\cos\Theta$ to obtain the measured input power in the last box of the flow chart. This means it is always necessary to measure the current in such case.
Some examples of representative period (RP) are: **Breadmaker -** RP1 mixing the dough; RP2 baking the bread. **Washing machine** - RP1 filling with water; RP2 washing; RP3 rinsing; RP4 water extraction; RP5 spinning; RP6 braking. **PTC hair straightener** – by definition in IEC 60335-2-23 is 30 min. **Oven** – RP1 heating up to set point; RP2 control oven temperature at set point. **Motor- compressor** – inverter driven **Electric fence energiser** – during charging of the voltage doubler circuit **Automatic coffee machine** – each coffee type selection

ANNEX

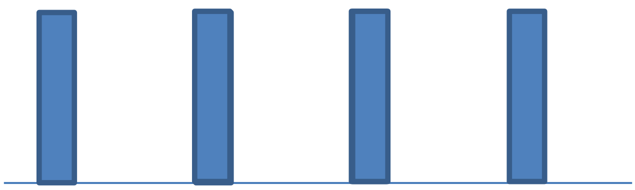
Additional information to guide on the understanding of the measurement procedures

This annex is used only for the reference purposes and it is needed to refer standards applied, since some items may be still under consideration

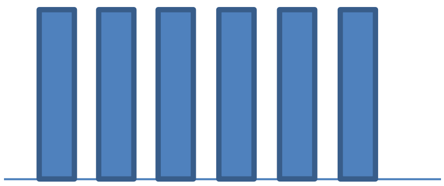
Q1. Does the current vary due to duty cycle control?

Yes – is the current during the on time constant
Yes (Typical for a non-PTC heating element) – is the duty cycle constant
Yes - Is the Duty cycle ≥ 50%
Yes – Arithmetic mean value (AMV) is used
No – Maximum value of the on time is used.

RMS Input current constant



Duty cycle < 50%

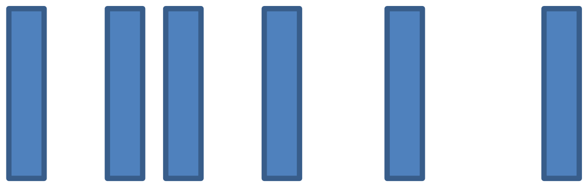


Duty cycle > 50%

Q2. Does the current vary due to duty cycle control?

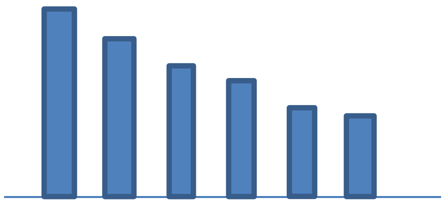
Yes – is the current during on time constant or is the on duty cycle constant
No (Typical for a controlled PTC heating element) – Then
Calculate the RMS value during each on time
Calculate Arithmetic mean value (AMV) over the representative period
Is maximum RMS value of the on times > 2AMV
No - then use the AMV
Yes - then apply the 10% rule using a spread sheet technique.
Note that when calculating the RMS value during each on time:
It is recommended that the number of samples should be not less than k = 5x where x is the period of one cycle of the current waveform. So if the period is 20 ms, then at least 100 samples should be obtained/period. Continuous streaming of the data to memory is required.

RMS Input current constant
Duty cycle not constant



RMS Input current not constant

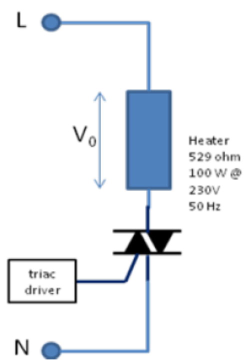
Duty cycle constant

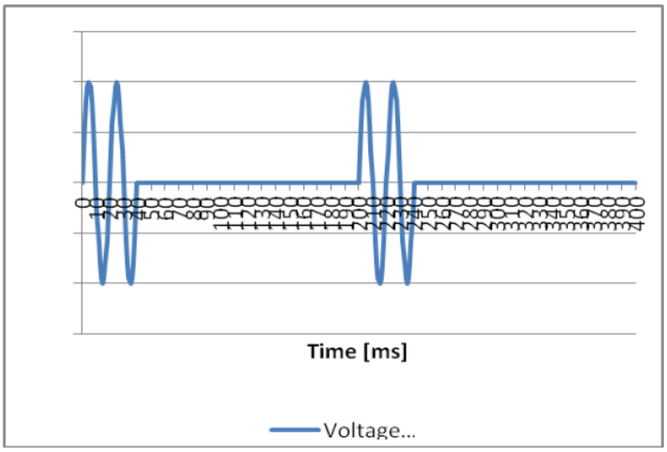


Q3. Does the current vary due to duty cycle control?

No (Typical of uncontrolled PTC heating element, automatic coffee machine or inverter driven motor-compressor) – sample the current over the whole of the representative period It is recommended that the number of samples should be not less than k = 5x where x is the period of one cycle of the current waveform. So if the period is 20 ms then at least 100 samples should be obtained/period. Continuous streaming of the data to memory is required. Calculate the RMS value during each cycle of current waveform. Calculate Arithmetic mean value (AMV) over the representative period Is maximum RMS value the cycles of the current waveform > 2AMV No - then use the AMV Yes - then apply the 10% rule using the spread sheet technique.

Example of an input control regime



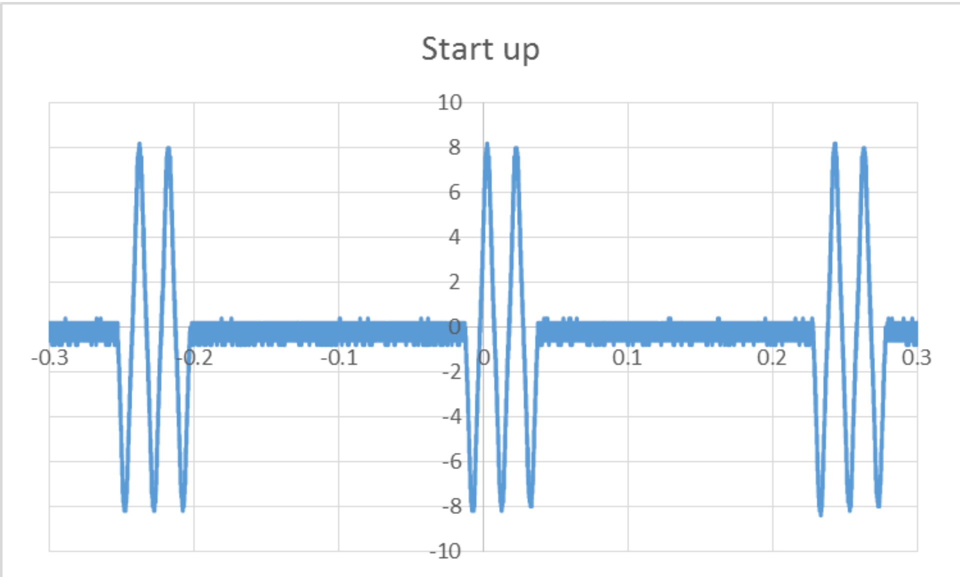


Dutycycle: ON = 40 ms OFF=160 ms TOT = 200 ms

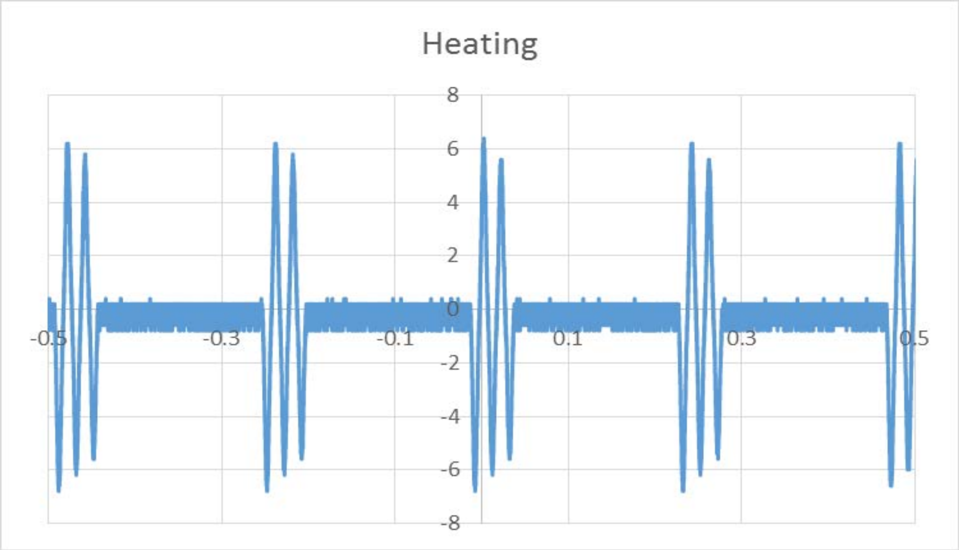
Input current waveforms of PTC hair straightener

Current waveforms:

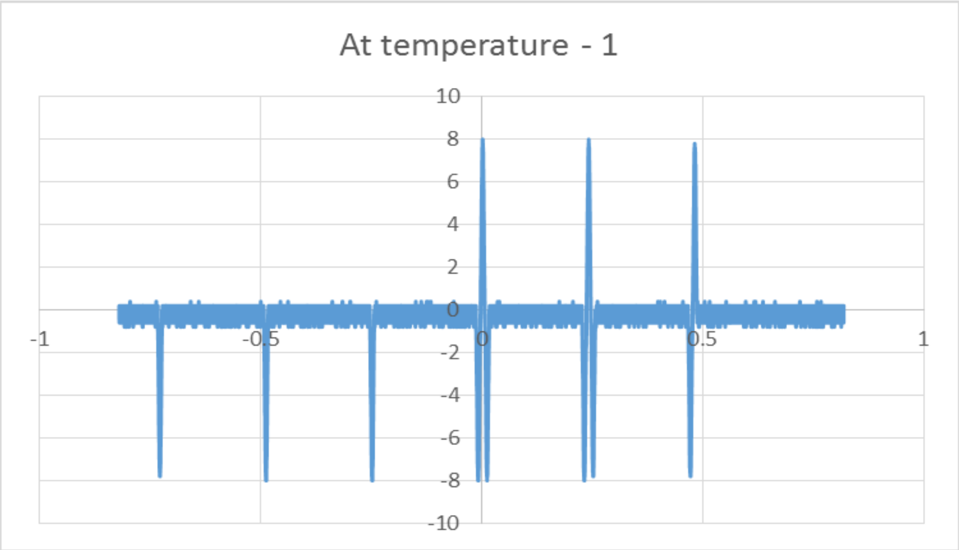
1) At start up



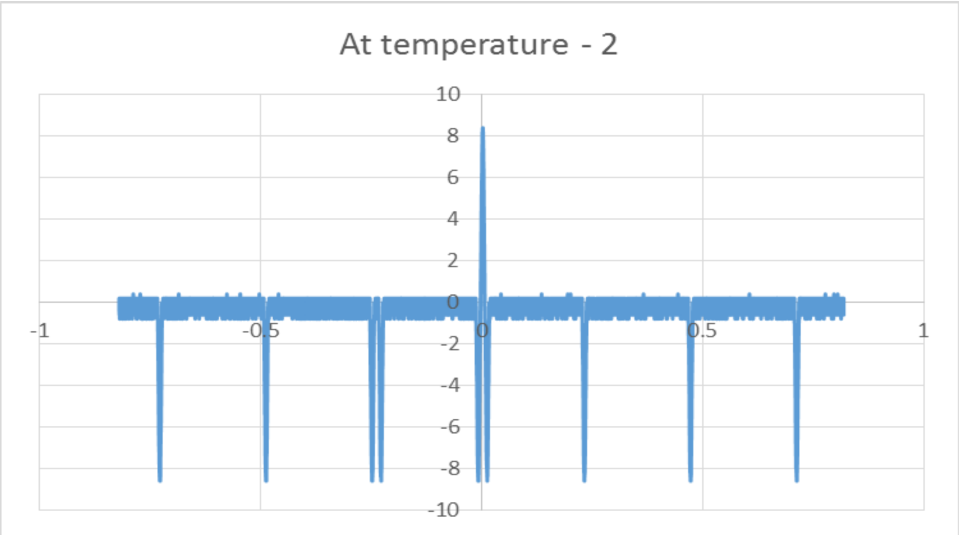
2) Heating near temperature, showing effect of PTC



3) At temperature - 1



4) At temperature – 2



1. Spread sheet technique for the 10% rule - Current

Use the spread sheet functions to calculate the rms value of current for each cycle Put the calculated value of current for each cycle into a spread sheet in descending order of magnitude (remember the magnitude calculated is the RMS value of each cycle) From the spread sheet obtain the value at a time that is 10% of the representative period – this is limit value that is not exceeded for more than 10% of the time of the representative period.

If the appliance is marked with rated power input rather than rated current it is necessary to sample both the input current and voltage. The instantaneous input power is then calculated from the current and voltage samples. The AMV of the input power is then calculated – this automatically takes into account reactive power when the pf is less than unity. For most appliances the pf will be unity or lagging close to it.
Note that for power the AMV = $V_{rms}I_{rms}\cos\Theta$ where $\cos\Theta$ = power factor

2. Spread sheet technique for the 10% rule – power input

Enter the voltage and current samples into a spread sheet and calculate the instantaneous power input samples by multiplying the voltage and current samples. Use the spread sheet functions to calculate the AMV value of power input for each cycle. Put the calculated value of power input for each cycle into a spread sheet in descending order of magnitude (remember the magnitude calculated is the AMV value of each cycle) From the spread sheet obtain the value at a time that is 10% of the representative period – this is limit value that is not exceeded for more than 10% of the time of the representative period.

3.Sampling rate

Sampling rate required – for typical input current from a 50 Hz supply to get sufficient accuracy of the rms value of current should be sampled at interval of no more than 0,2 ms (5000 Hz) Sampling rate required – for typical input current from a 50 Hz supply to get sufficient accuracy of the AMV of the input power the current input and voltage should be samples at interval of no more than 0,2 ms (5000 Hz) The data storage capability should be such that all of the sample data can be stored without being affected by the refresh rate – so continuous streaming of the data to memory is required. The software should then be such that the variation in the rms value of the current or AMV of the power input can be calculated as it varies throughout the representative period. For hair straightener with a PTC heating element the representative is defined as 30 min hence the minimum number of sample to be stored is 30x60x50x100 = 9x 10^6 samples (more would be better) For an inverter driven motor compressor if a pull down is considered to be the representative period (for instance, the pull down time has not been fixed in the relevant standard) and is 6 h, hence the maximum number of samples of current and voltage to be stored is 6x60x60x50x100 = 108 x 10^6 samples

For mains supply to an appliance – it is assumed that the input voltage is sinusoidal with no harmonic content. See 5.15 of Part 1. The current drawn by a non-linear load will be non-sinusoidal and in general will have half-wave symmetry. In this case power is delivered to the load by the product of voltage and current of the same frequency. For a sinusoidal voltage with no harmonic content power comes from the product of the voltage and the fundamental component of the current with the same frequency as the voltage.
Hence if $V(t) = V_p \sin\omega t$ and $I(t)$ is a non-sinusoidal current with half-wave symmetry that is sampled k times during each half-cycle then power will be given by:

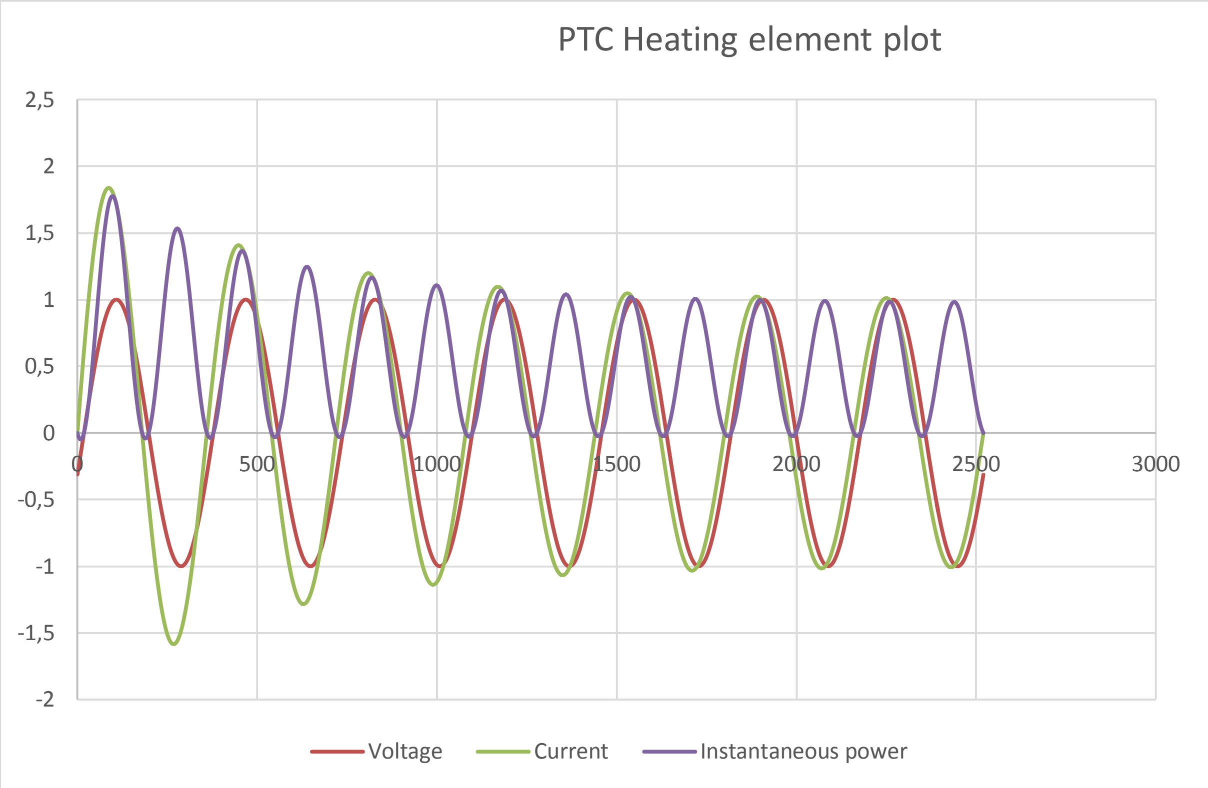
$$P_{AMV} = \frac{2}{k} \sum I(t) V_p \sin \omega t$$

If half-wave symmetry is not present then, sampling is necessary over each cycle then

$$P_{AMV} = \frac{1}{k} \sum I(t) V_p \sin \omega t$$

SOME EXAMPLES

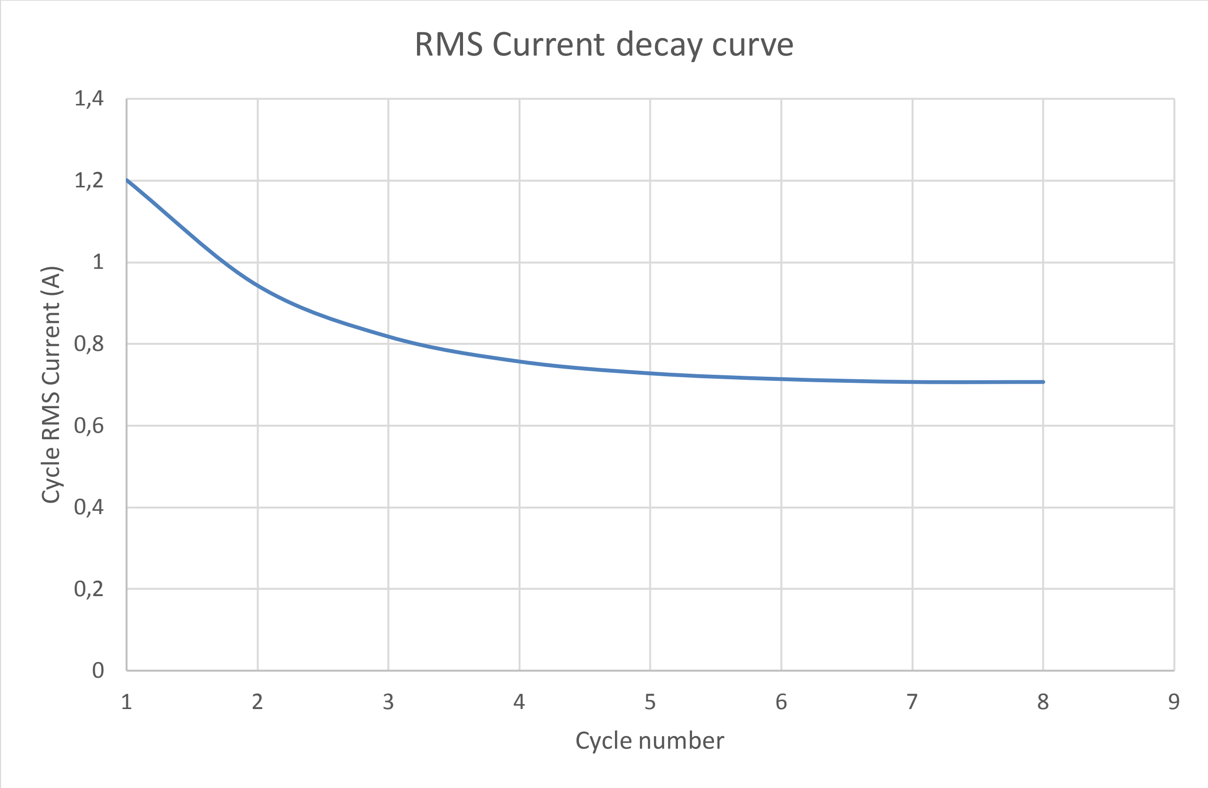
Current waveform through a PTC heating element from a sinusoidal voltage supply.
$V(t) = V_p \sin(\omega t)$
$I(t) = I_p [1 + e^{-t/\tau}] \sin(\omega t + \Theta)$
$P(t) = V_p I_p [1 + e^{-t/\tau}] \sin(\omega t) \sin(\omega t + \Theta)$
$\Theta = \cos^{-1}\lambda$
Where τ = the PTC heating element time constant
λ = the steady state power factor of the circuit.
The plot below is valid for a sample rate of 5 kHz; $\tau = 0.1$ s; $\lambda = 0.95$; $\Theta = 18.2^o$; $V_p = 1$; $I_p = 1$



In the steady state $I_{rms} = 1/\sqrt{2} = 0.707$ A and the AMV of the power = $V_{rms}I_{rms}\lambda = 0.475$ W

Current Cycle number	RMS value of current (A)	AMV of power (W)
1	1.201	0.807
2	0.943	0.633
3	0.818	0.549
4	0.757	0.508
5	0.728	0.515
6	0.714	0.489
7	0.707	0.475
8	0.707	0.475

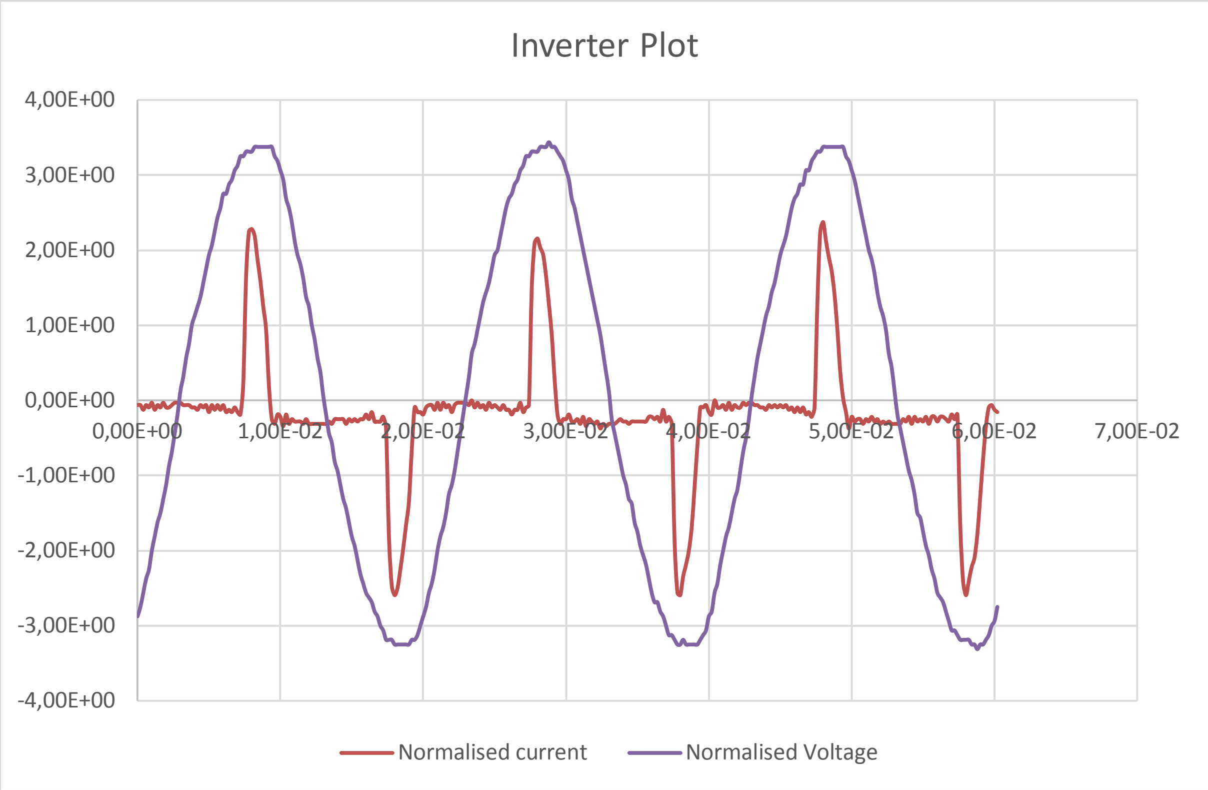
A curve showing the decay over the cycles is:



AMV of the power for each cycle is given by $I_{rms}V_{rms}\cos(\Theta)$
This technique can be used to analysis the waveform for the PTC hair straightener and similar PTC heater current waveforms

Refrigerator inverter input

The following plot shows the input current from start – the inverter being a soft start type. This waveform was followed over the whole time data was collected (one hour approximately) at a sample rate of 5 kHz.



The current plot normalisation factor is 10 and the voltage plot normalisation factor is 0.01

The rms value of the voltage from the plot data is 234.5 V.

The rms value of the current from the plot data is 0.80.4 mA (3 cycles)

The rms value of each cycle from the plot data is:

Cycle 1: 80.9 mA

Cycle 2: 80.9 mA

Cycle 3: 80.6 mA

This technique can be used to analysis other different types of inverter input waveforms.

The rms value is calculated from

$$I_{rms} = \sqrt{\frac{1}{n}\sum_{k=1}^{n} I_k^2}$$

Where

n is the number of samples of I taken in 1 cycle at a rate of x kHz (typically x = 5)

Ik are the individual samples of I(t) taken over 1 cycle

Example of appliance with “10% value < AMV”.

Appliance under test : Hair straightener

Supply voltage = 230 V - 50 Hz

Representative period according to EN60335-2-23 = 30 min

Power meter with sampling rate 2 MHz

RMS Values calculated on 1 AC cycle (update rate = 20 ms).

We recorded 50 RMS values/sec obtaining a total of 1800 s * 50 = 90.000 values.

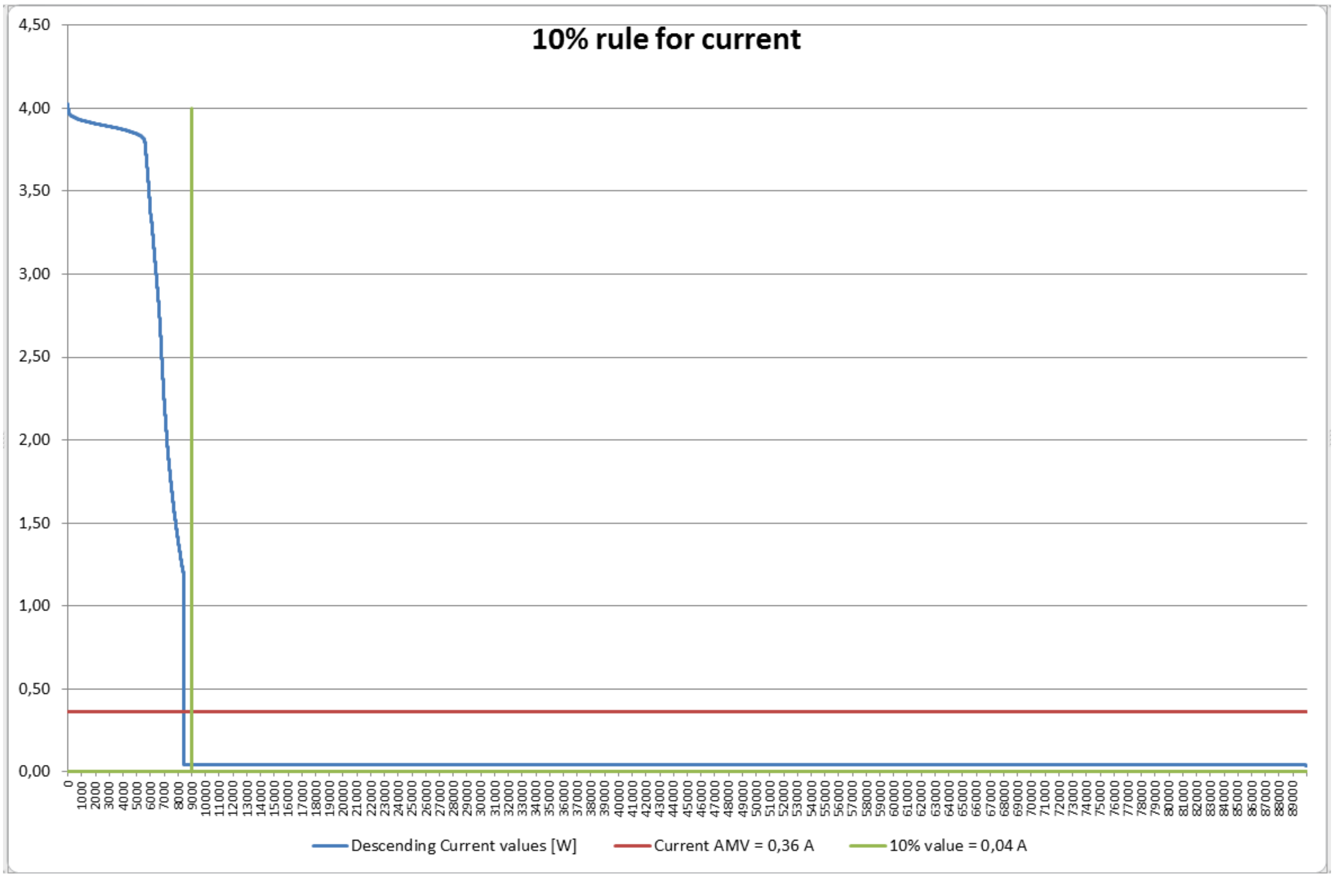
Test results for current using “10% rule”.

max RMS current value = 4.03 A

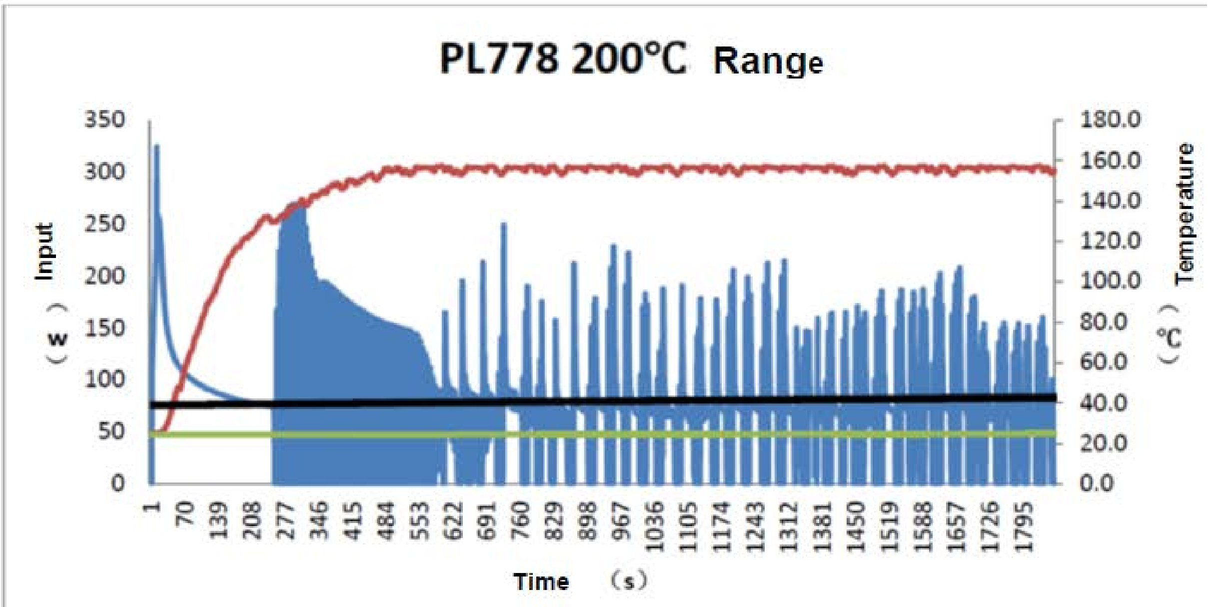
AMV of RMS current on the representative period = 0.36 A

therefore we have to do the 10% rule obtaining 0.04 A < AMV

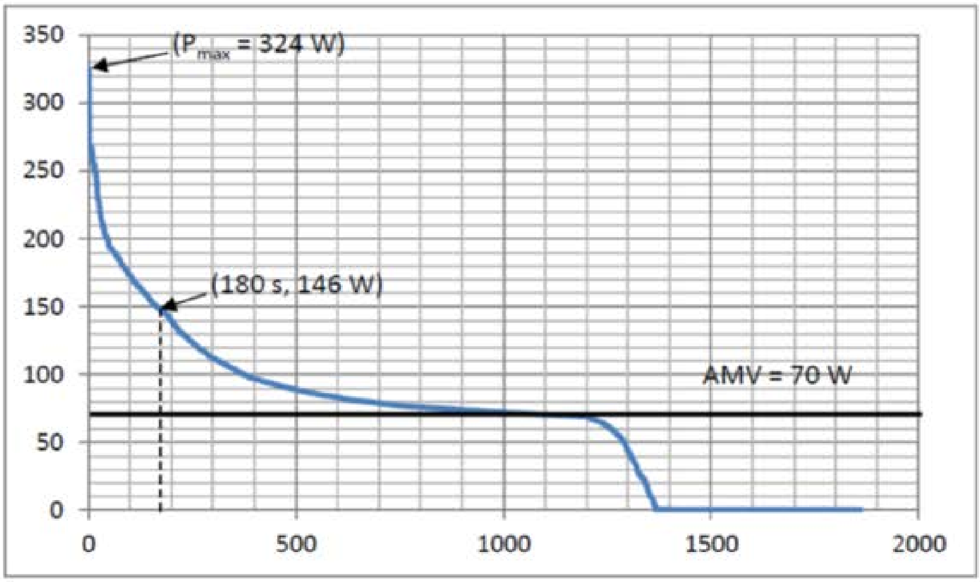
According to the proposal: Rated current = 0.36 A



Added example of 10% rule



Curling Iron/Hair Straightener Power/time profile



According to IEC 60335-2-23 the representative period (RP) = 30 min = 1800 s

Since 2 x AMV < P_{max} it is necessary to apply the 10 % rule

10% of the RP = 180 s

From the power/time profile in descending order of the power input values, the power input at 180 s (10% of the RP) = 146 W.

Power input values less than 146 W are exceeded for a time of more 180 s (10% of the RP) and Power input values greater than 146 W are exceeded for a time of less than 180 s (10% of the RP).

So the Power input value of 146 W can be taken as the value to compare with rated power input.

End of Annex