Basic Electrical Engineering (TEE 101)

Lecture 18: Significance of RMS value, Form Factor and Peak Factor

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Content

This lecture covers:

- Significance of RMS Value in Electrical Systems
- Form Factor
- Peak Factor
- Numerical on Form factor and Peak factor

Importance of R.M.S. Values

An alternating voltage or current is always specified in terms of r.m.s. values. RMS value is One of the most important parameter that is used to describe the strength of an Alternating Current (AC).

RMS value of an AC voltage/current is equivalent to the DC voltage/current that produces the same heating effect when applied across an identical resistor. Hence, it is also a measure of energy content in a given signal.

For example, common household appliances are rated at 230 V a.c. This is an r.m.s. value. If some other method of measurement is used, it must be specifically stated. Lacking any information to the contrary, always assume that a.c. values are r.m.s.

The following points will give the reader a clear concept about the r.m.s. values :
The domestic a.c. supply is 230 V, 50 Hz. It is the r.m.s. or effective value. It means that alternating voltage available has the same heating effect as 230 V d.c.

When we say that alternating current in a circuit is 5 A, we are specifying the r.m.s. value. It means that the alternating current flowing in the circuit has the same heating effect as 5 A d.c.

A.C. ammeters and voltmeters record r.m.s. values of alternating current and voltage respectively. AC current takes less amount of charges to supply the same amount of DC power.

Form Factor and Peak Factor

There exists a definite relation among the peak value, average value and r.m.s. value of an alternating quantity. The relationship is expressed by two factors, namely ;

- **form factor and peak factor.**

(*i*) Form factor. *The ratio of r.m.s. value to the average value of an alternating quantity is known as* **form factor** *i.e.*

$$Form\ Factor\ (K_f) = \frac{R.M.S.\ value}{Average\ value}$$

- The value of form factor depends upon the waveform of the alternating quantity.
- Its least value is 1 (*e.g.* for square wave, rectangular wave) and may be as high as 5 for other waveforms. For a sinusoidal voltage or current,

$$K_f = \frac{0.707 \times \text{Max. value}}{0.637 \times \text{Max. value}} = 1.11$$

- The form factor gives a measure of the "peakiness" of the waveform.
- The peakier the wave, the greater is its form factor and *vice-versa*.
- For instance, a sine wave is peakier than a square wave. Hence the former has a greater form factor (1·11) than the latter.
- Similarly, a triangular wave is more peaky than a sine wave and has a form factor of 1·15.
- The form factor is useful in rectifier service.

***ii*) Peak factor.** *The ratio of maximum value to the r.m.s. value of an alternating quantity is known as* **peak factor** *i.e.*

$$\text{Peak Factor}\left(K_p\right) = \frac{\text{Max. value}}{\text{R.M.S. value}}$$

The value of peak factor also depends upon the waveform of the alternating quantity.

For a sinusoidal voltage or current,

$$\text{Peak Factor}\left(K_p\right) = \frac{\text{Max. value}}{0.707 \times \text{Max.value}} = 1.414$$

- The peak factor is of much greater importance because it indicates the maximum voltage being applied to the various parts of the apparatus.
- For instance, when an alternating voltage is applied across a cable or capacitor, the breakdown of insulation will depend upon the maximum voltage.
- The insulation must be able to withstand the maximum rather than the r.m.s. value of voltage.

Note. Peak factor is also called *crest factor* or *amplitude factor*.

Example 1: *An alternating voltage* ***v = 200 sin 314t*** *is applied to a device which offers an ohmic resistance of* ***20 Ω*** *to the flow of current in one direction while entirely preventing the flow of current in the opposite direction.*
Calculate the r.m.s. value, average value, form factor and peak factor.

Solution. It is clear that the device is doing half-wave rectification. The maximum value of the rectified current is given by ;

Given:

Instantaneous value of ac voltage ***v = 200 sin 314t***

Ohmic resistance offered by the device is ***20 Ω***

$I_m = V_m/R = 200/20 =$ **10 A**

For a half-wave rectified a.c.

$I_{r.m.s.} = I_m/2$ and $I_{av} = I_m/\pi$

Hence,

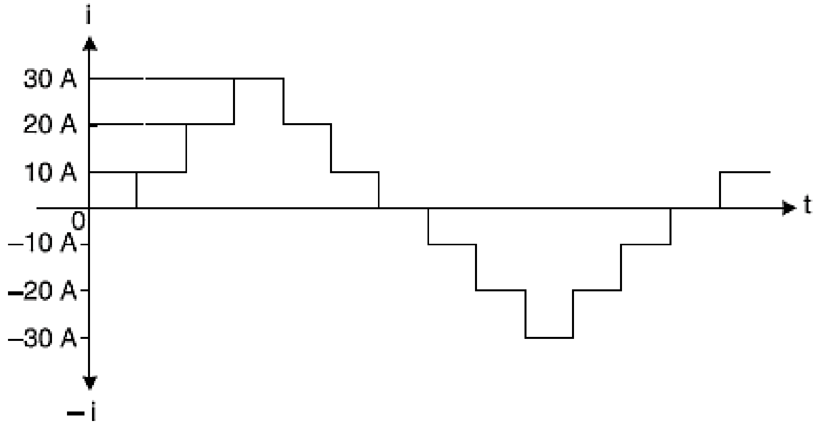
$I_{r.m.s.} = 10/2 =$ **5 A**

$I_{av} = 10/\pi =$ **3·18 A**

Form factor $= I_{r.m.s.}/I_{av} = 5/3{\cdot}18 =$ **1·57**

Peak factor $= I_m/I_{r.m.s} = 10/5 =$ **2**

Example 2. *A current has the following steady values in amperes for equal intervals of time changing instantaneously from one value to the next [See Figure below].*
0, 10, 20, 30, 20, 10, 0, −10, −20, −30, −20, −10, 0, etc.
Calculate (i) average value (ii) r.m.s. value (iii) form factor and (iv) peak factor.



Solution. (*i*)
$$I_{av} = \frac{i_1 + i_2 + i_3 + i_4 + i_5 + i_6}{6}$$
$$= \frac{0+10+20+30+20+10}{6} = \frac{90}{6} = \mathbf{15A}$$

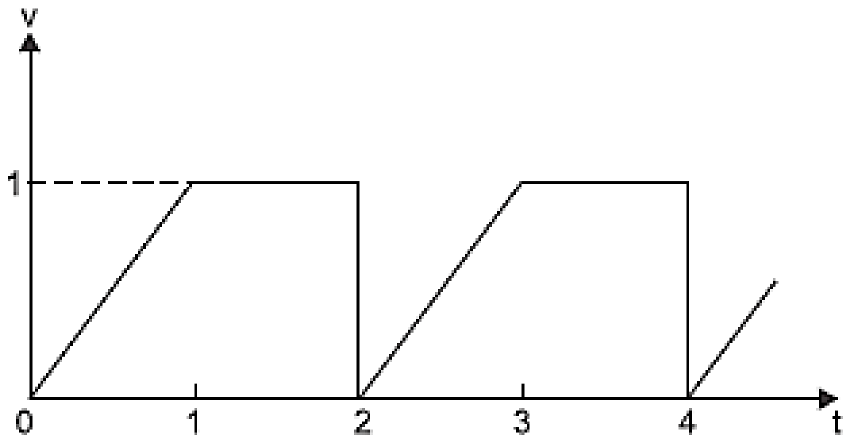
(*ii*)
$$I^2_{r.m.s.} = \frac{i_1^{\ 2} + i_2^{\ 2} + i_3^{\ 2} + i_4^{\ 2} + i_5^{\ 2} + i_6^{\ 2}}{6}$$
$$= \frac{0^2 + 10^2 + 20^2 + 30^2 + 20^2 + 10^2}{6} = \frac{1900}{6} = 316.67$$

or
$$I_{r.m.s.} = \sqrt{316.67} = \mathbf{17.8A}$$

(*iii*)
$$\text{Form factor} = \frac{I_{r.m.s}}{I_{av}} = \frac{17.8}{15} = \mathbf{1.19}$$

(*iv*)
$$\text{Peak factor} = \frac{I_m}{I_{r.m.s}} = \frac{30}{17.8} = \mathbf{1.68}$$

Example 3. *Find the average value, r.m.s. value, form factor and peak factor of the voltage wave shown in Figure below*



Solution. The wave can be represented mathematically as :
$v = t$ for $0 < t < 1$; $v = 1$ for $1 < t < 2$

$$\text{Average value, } V_{av} = \frac{1}{2}\left[\int_0^1 t\,dt + \int_1^2 dt\right]$$

$$= \frac{1}{2}\left[\frac{t^2}{2}\right]_0^1 + \frac{1}{2}[t]_1^2 = 0.25 + 0.5 = \mathbf{0.75V}$$

$$V^2_{r.m.s.} = \frac{1}{2}\int_0^1 t^2 dt + \frac{1}{2}\int_1^2 dt$$

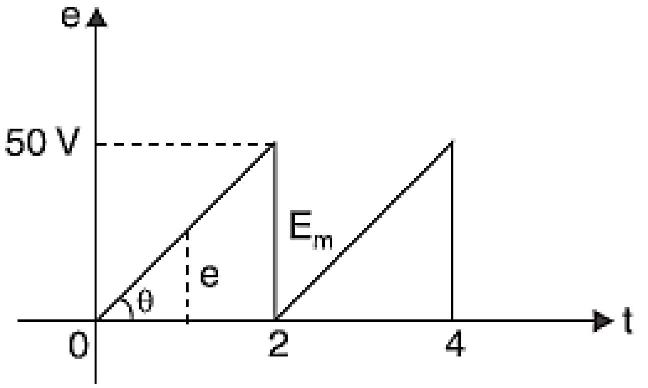
$$= \frac{1}{2}\left[\frac{t^3}{3}\right]_0^1 + \frac{1}{2}[t]_1^2 = \frac{1}{6} + \frac{1}{2} = \frac{4}{6}$$

$$V_{r.m.s.} = \sqrt{\frac{4}{6}} = \mathbf{0.8165\ V}$$

$$\textit{Form Factor}\ (K_f) = \frac{0.8165}{0.75} = 1.0886$$

$$\textit{Peak Factor}\ (K_p) = \frac{1}{0.8165} = 1.225$$

Example 4. *Determine the form factor and peak factor of the sawtooth wave shown in Figure below*



Solution. The equation of the voltage wave is given by $e = kt$ where k is the slope (*i.e.*, tan θ) of the curve. Referring to the Figure shown, the slope of the curve is $Em/2$.

$$e = \frac{E_m}{2} t$$

$$E^2_{r.m.s.} = \frac{1}{2}\int_0^2 e^2 dt = \frac{1}{2}\int_0^2 \frac{E_m^2 t^2}{4} dt$$

$$= \frac{E_m^2}{8}\left[\frac{t^3}{3}\right]_0^2 = \frac{E_m^2}{3}$$

$$E_{r.m.s.} = E_m/\sqrt{3} = 50/\sqrt{3} = 28.87 \text{ V}$$

$$E_{av.} = \frac{\text{Area under curve}}{\text{Length of base}} = \frac{(1/2)\times 50\times 2}{2} = 25 \text{ V}$$

$$Form\ Factor\ (K_f) = \frac{28.87}{25} = 1.1548$$

$$Peak\ Factor\ (K_p) = \frac{50}{28.87} = 1.7319$$

Thank You