Permanent Magnet Generator – The Energy Source of the Future

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Abstract

The permanent magnet generator is a special transformer that contains a ferrite magnet. It converts the static magnetic field of the permanent magnet to time-varying magnetic field, thereby producing electric energy without moving parts. Due to their compact size and long service time, permanent magnet generators may replace the energy sources known currently.

Description

The parts of the simulated generator include a ferrite core with a ferrite magnet in its centre, an input coil, two output coils, and a coupled inverter, which is not shown (Fig. 1).

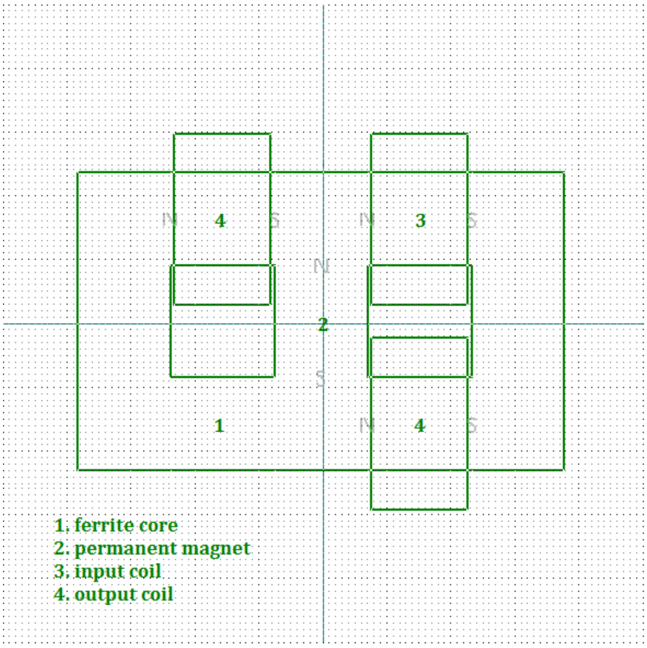

Fig. 1

The exact parameters of the generator that can be seen in the VIZIMAG magnetic field simulation below are as follows: As for the ferrite core, its outer dimensions are $152x93x29\ mm$, its inner dimensions are $94x35\ mm$, and its complex permeability calculated for $B_r/2 = 0.2\ T$ average remanent induction of the permanent magnet is $\mu_r = 2200$. The mean length of the magnetic field lines in the ferrite core is $l = 354\ mm$, and the column cross-section of the ferrite core is $A = 841\ mm^2$. The permanent magnet is a ceramic ferrite type magnet with dimensions of $29x35x29\ mm$, and its remanent induction $B_r = 0.4\ T$. The number of turns of the input coil is $N_1 = 10$, while the number of turns of the two output coils is also $N_2 = 10$ each. The frequency of the alternating current is $f = 50\ KHz$.

When the generator is out of use, the magnetic field lines of the permanent magnet are split into two branches in the ferrite core of the generator (Fig. 2). In order to get a time-varying magnetic field, the static magnetic field has to be set in motion by means of the input coil.

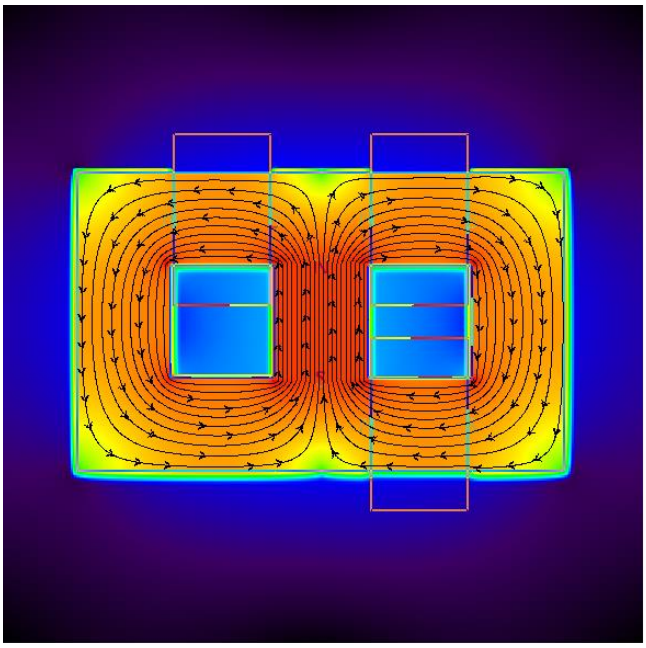

Fig. 2

When the generator is switched on, the alternating current of the input coil has triangular waveform and deflects (pumps) the magnetic field lines that branch into two in the ferrite core alternately to the output coils on the left and on the right (Fig. 3).

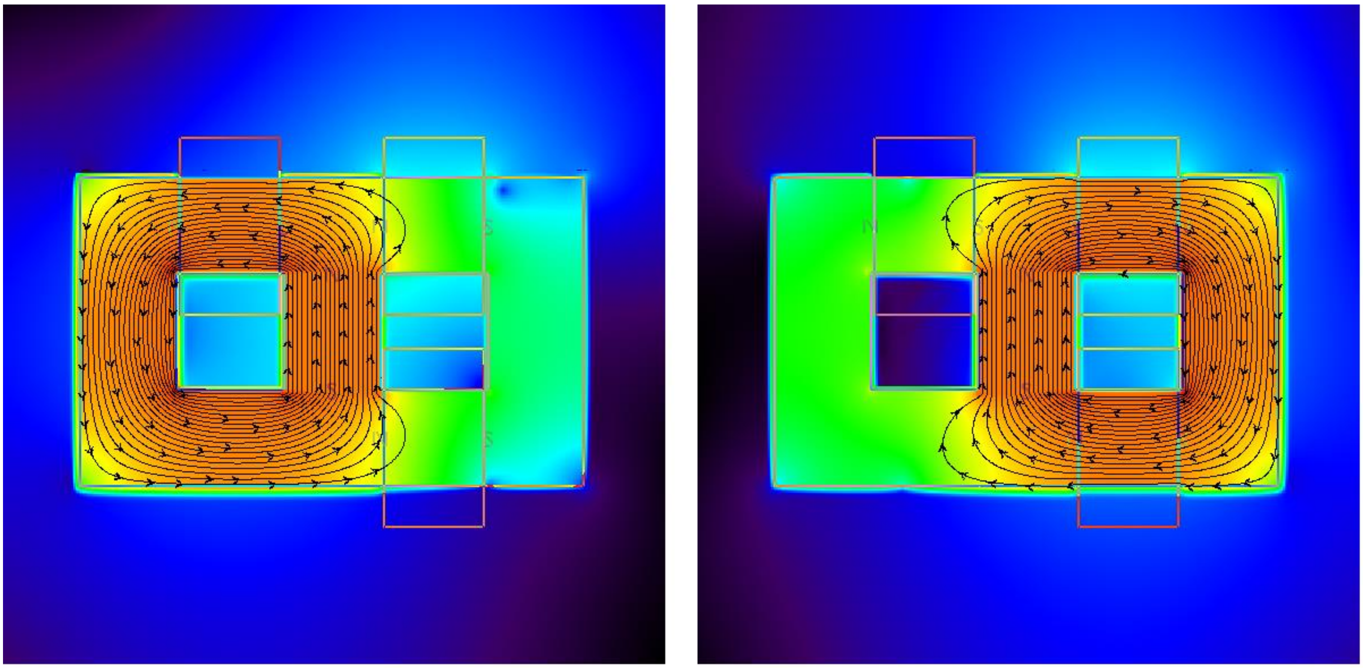

Fig. 3

As shown, the density of the magnetic field lines doubles first at the output coil on the left, then at the output coil on the right, while the direction of the magnetic field lines does not change. Consequently, the time-varying magnetic flux induces a so-called pulsating direct current in the output coils with a triangular waveform, and it is twice as high as the alternating current in the input coil.

To make use of the entire change of magnetic flux at the output coils, at the moment the generator starts up, i.e. at t_0 time, the alternating current of the input coil has to start from its peak value (Fig. 4/A), and so the root mean square (RMS) value of the current in the output coils will be twice as high as the RMS value of the current in the input coil (Fig. 4/B). It must be noted that in the case of a triangular signal the RMS value is the same either for alternating current and for pulsating direct current: $I_{RMS} = I_{max}/\sqrt{3}$.

A. Waveform and root mean square (RMS) value of the input coil current

B. Waveform and root mean square (RMS) value of the output coil current

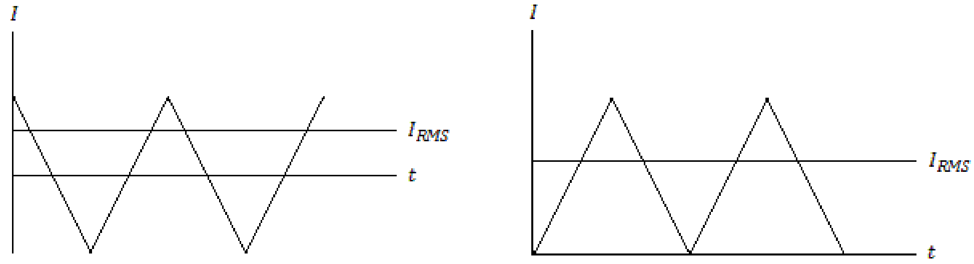

Fig. 4

Now let's take a look at the current, voltage and power calculations for the input and output coils of the permanent magnet generator model used in the VIZIMAG simulation, based on the data specified above. The following calculations apply to an ideal transformer.

The maximum input coil current that deflects half of the magnetic field lines that branch into two in the ferrite core from one side to the other can be calculated with the following formula:

$$I_{1(max)} = \frac{0.95 B_r l}{2\mu_0 \mu_r N_1} = 2.434\ A$$

where B_r is the remanent induction of the permanent magnet, l is the mean magnetic field line length in the ferrite core, μ_0 is the permeability of vacuum, μ_r is the relative permeability of the ferrite core, calculated for $B_r/2$ average remanent induction of the permanent magnet, and N_1 is the number of turns of the input coil.

In the above equation, the $\frac{0.95B_r}{2}$ expression represents the average value of the magnetic induction in each branch of the magnetic loop that branches into two in the ferrite core.

The change of the magnetic induction induced by the alternating current in the input coil is:

$$dB_1 = \frac{0.95 B_r}{2}$$

from which the change of the magnetic flux is:

$$d\Phi_1 = dB_1 A = \frac{0.95 B_r A}{2}$$

where A is the column cross section of the ferrite core.

Thus the maximum voltage of the input coil is:

$$V_{1(max)} = N_1 \frac{d\Phi_1}{dt_1} = N_2 \frac{d\Phi_1}{T/4} = N_1 \frac{d\Phi_1}{1/4f} = \frac{4fN_1 0.95 B_r A}{2} = 319.58\ V$$

where dt_1 is the time period during which the alternating current in the input coil reaches its maximum starting from I_0 (Fig. 4/A), T is the period and f is the frequency of the alternating current.

Therefore, the apparent power input of the input coil is:

$$S_1 = \frac{V_{1(max)}}{\sqrt{3}} \cdot \frac{I_{1(max)}}{\sqrt{3}} = V_1 I_1 = 259.18\ W$$

where V_1 and I_1 are the RMS values of the triangular alternating voltage and current of the input coil.

Since the number of magnetic field lines always doubles at the output coils, the maximum current in the output coil is:

$$I_{2(max)} = \frac{0.95 B_r l}{\mu_0 \mu_r N_2} = 4.868\ A$$

where N_2 is the number of turns of the output coil.

The change of magnetic induction at the output coil is:

$$dB_2 = 0.95 B_r$$

from which the change of the magnetic flux is:

$$d\Phi_2 = dB_2 A = 0.95 B_r A$$

Thus the maximum voltage induced on the output coil is:

$$V_{2(max)} = N_2 \frac{d\Phi_2}{dt_2} = N_2 \frac{d\Phi_2}{T/2} = N_2 \frac{d\Phi_2}{1/2f} = 2fN_2 0.95 B_r A = 319.58\ V$$

where dt_2 is the time period during which the pulsating direct current in the output coil reaches its maximum starting from I_0 (Fig. 4/B).

Therefore, the apparent power output of the output coil is:

$$S_2 = \frac{V_{2(max)}}{\sqrt{3}} \cdot \frac{I_{2(max)}}{\sqrt{3}} = V_2 I_2 = 518.57\ W$$

where V_2 and I_2 are the RMS values of the triangular pulsating voltage and current for the output coil.

As it can be seen from the above equations, if $N_1 = N_2$, V_1 and V_2 voltages of the input and output coils are the same, while I_2 current in the output coil is exactly the double of I_1 current in the input coil.

Based on the above calculations, the apparent output power of the simulated generator is $2x518\ W$ on the two output coils, while the apparent input power of the input coil is only $259\ W$. From this the useful output power of the generator is $777\ W$.

Therefore, ideally the output coil delivers twice the input power, i.e. the efficiency is 200 percent. The total efficiency of the two output coils is 400 percent, which means that the output power of the generator is four times as much as the input power. At the same time, the efficiency of real generators are always lower than the ideal value because of actual losses.

The generator can be started by applying V_1 alternating voltage and I_1 alternating current to the input coil, which immediately starts the energy generation process. By means of an inverter connected to the generator, a fraction of the plus power can be fed back to the input coil in the form of alternating voltage and current, thereby ensuring the continuous operation of the generator independent of an external energy source.

The permanent magnet generator described in the VIZIMAG simulation is just an example, since the power output depends only on design and sizing. The generator provides energy as long as the permanent magnet becomes demagnetized.

References:

[1] W.G. Hurley, W.H. Wolfle: *Transformers and Inductors for Power Electronics: Theory, Design and Applications*; © 2013 John Wiley & Sons Ltd., ISBN: 978-1-119-95057-8