

MONOPHASE ELECTRIC POWER GENERATOR

The present invention concerns a monophasic electric power generator including a rotor having an axis of rotation and including magnetic means with $2N$ magnetic poles arranged regularly at the periphery of said rotor and generating outside said rotor $2N$ radial magnetic fields of alternate directions; and a stator including at least one coil and coupling means for magnetically coupling said coil to said magnetic means. In particular, the present invention concerns an electric power generator of small volume able in particular to be integrated in a timepiece comprising an oscillating weight.

One object of the present invention is to provide a monophasic generator having great efficiency and thus a very good yield, while being easy to manufacture at a relatively low cost.

The invention thus concerns a generator having the features mentioned in claim 1 annexed hereto.

Other objects and advantages of the present invention will be made clear by the description of some of the embodiments thereof which will be given hereinafter, such embodiments being described purely by way of non-limiting example. This description will be made with reference to the annexed drawings in which:

- Figure 1 is a plan view of a first embodiment of the generator according to the present invention;

- Figure 2 is a cross-section of the generator of Figure 1 along the line II-II of said Figure 1;

- Figure 3 is a plan view of a second embodiment of the generator according to the present invention;

- Figure 4 is a cross-section of the generator of Figure 3 along the line IV-IV of said Figure 3;

- Figure 5 is a plan view of another embodiment of the generator according to the present invention; and

- Figure 6 is a cross-section of the generator of Figure 5 along the line VI-VI of said Figure 5.

In the embodiment shown in Figures 1 and 2, the generator according to the present invention, which is designated by the general reference 1, includes a rotor and a stator respectively designated by the references 2 and 3.

Rotor 2 includes a shaft 4, which has only been partially shown, able to rotate in bearings, not shown, about its axis A. As will be made clear hereinafter, this axis A constitutes the axis of rotation of rotor 2.

Rotor 2 also includes a hub 5 attached to shaft 4 and having, in this example, the shape of a straight and regular decagonal cylinder, whose axis coincides with axis of rotation A of shaft 4. Hub 5 thus has ten flat rectangular faces parallel to axis A.

For a reason which those skilled in the art will easily understand, hub 5 is preferably made of a soft magnetic material having low reluctance. However, for manufacturing and assembly reasons, said hub 5 can, in particular, be made of steel.

Moreover, rotor 2 includes, in this example, ten bipolar magnets designated by the common reference 6, each having the shape of a parallelepiped rectangle and each fixed onto one of the lateral faces of hub 5.

Those skilled in the art will easily understand that the means used to fixed magnets 6 to hub 5, which can be of various natures and have not been shown, must have as low a reluctance as possible.

The magnetisation axes of magnets 6, which are symbolised by non-referenced arrows in Figure 1, all have a radial direction, but have alternating directions of magnetisation. Magnets 6 thus have at the periphery of rotor 2, an even number, equal to ten in the present example, of alternately north and south poles. Magnets 6 thus generate, at the exterior of rotor 2, ten radial magnetic fields of alternate directions. According to whether they have a north magnetic pole or a south magnetic pole at the periphery of rotor 2, magnets 6 will

be respectively designated hereinafter by the reference 6a or 6b.

Stator 3 of generator 1 includes a first and a second stator plate respectively designated by the references 7 and 8 and both having the general shape of a flat circular ring centred on axis of rotation A and perpendicular thereto. These stator plates 7 and 8 are at a distance from each other, each of them being located at least approximately in the vicinity of one of the end faces of hub 5, and they are both made of a soft magnetic material.

In the present example, stator 3 also includes a first series of five teeth, all designated by the reference 9, made of a soft magnetic material and arranged regularly around rotor 2 in the space which separates the latter from stator plates 7 and 8. Teeth 9 are offset angularly at an angle of $360^\circ/N$ and are parallel to axis of rotation A of rotor 2, they are mechanically and magnetically connected to stator plate 7 and extend in the direction of stator plate 8.

Moreover, stator 3 includes a second series of five teeth, all designated by the reference 10, also made of a soft magnetic material and also arranged regularly around rotor 2 in the space which separates the latter from stator plates 7 and 8, each tooth 10 being also located between two of teeth 9. Teeth 10 are thus also offset angularly at an angle of $360^\circ/N$. Moreover, they are also parallel to axis of rotation A of rotor 2, but they are mechanically and magnetically connected to stator plate 8 and extend in the direction of stator plate 7.

It can be seen that the total number of teeth 9 and 10 of stator 3 is equal to the total number of magnets 6a and 6b of rotor 2 and that, when the latter occupies a position such as that in Figure 1, each of teeth 9 and 10 is located facing one of magnets 6a and 6b.

It is clear that the various components of generator 1 which have just been described are dimensioned and arranged so that rotor 2 can rotate freely, without touching any of the elements of stator 3, but so that the

distance which separates magnets 6a and 6b from teeth 9 and 10 is such that the mutual magnet-coil flux and the reluctant couple together have advantageous values.

Still in the present example, stator 3 also includes a first arm 11 and a second arm 12, both made of a soft magnetic material, which are respectively mechanically and magnetically connected to the exterior of stator plate 7 and the exterior of stator plate 8.

Those skilled in the art will easily see that the two units respectively formed by stator plate 7, teeth 9 and arm 11, and by stator plate 8, teeth 10 and arm 12, are preferably each made in the form of a single same part, for example by cutting and bending a sheet of suitable material.

Moreover, those skilled in the art will see that these two parts can be identical, which simplifies the manufacture of the generator and decreases its cost price.

Stator 3 also includes a coil 13 wound around a core 14 whose ends 14a and 14b are respectively mechanically and magnetically connected to arms 11 and 12.

Core 14 of coil 13 is of course also made of a soft magnetic material having low reluctance, and the means which assure the connection thereof to arms 11 and 12, which have not been shown, are also arranged so as to have as low a reluctance as possible.

Core 14 of coil 13 assures a mechanical connection between the two aforementioned units. But it is generally necessary to reinforce this mechanical connection by fixing one or more struts to these units, so as to guarantee that these latter keep mutually correct positions in all circumstances. For a reason which will easily be understood by those skilled in the art, such struts, which have not been shown, must be made of a non-magnetic material.

Those skilled in the art will also understand that, according to the relative dimensions of the various components of generator 1, it may be necessary to arrange other struts between each of ends 14a and 14b of core 14

and arm 11 and, respectively, 12, such struts having of course to be made of a soft magnetic material having a low reluctance.

Those skilled in the art will also see that
5 considerations similar to those which have just been made with respect to connecting struts for the aforementioned units and/or with respect to struts for connecting the ends of the core coil to the respective arms could also be made in the case of other embodiments of the generator
10 according to the present invention which will be described hereinafter. These considerations will therefore not be repeated.

It should also be noted that the various components of stator 3 which have just been described are formed,
15 dimensioned and arranged in relation to each other so that the unit formed by stator plate 7, teeth 9 and arm 11 on the one hand, and the unit formed by stator plate 8, teeth 10 and arm 1 on the other hand are magnetically connected only via core 14 of coil 13.

20 As is easily seen, as a result of the structure and arrangement of the various components of generator 1 which have just been described, when rotor 2 rotates with respect to stator 3, coil 13 generates an electric voltage in response to the variations in the magnetic flux,
25 originating from magnets 6a and 6b, which passes through core 14 alternately in one direction and the other.

The fact that coil 13 of generator 1 is wound onto a core, in this case core 14, greatly facilitates the manufacturing and handling thereof.

30 Moreover, all other things being equal, the mean length of the turns of coil 13 of generator 1, and thus the total length of the wire which forms said coil 13, are much smaller than the mean length of the turns of the coil of this known generator and, respectively, than the total
35 length of wire which forms said latter coil.

As a result of these two facts, the cost price of coil 13 of generator 1, and thus the cost price of the latter, are lower than the cost price of the known

generator coil and, respectively, than the cost price of the latter.

Moreover, and again all other things being equal, the electric resistance of coil 13 of generator 1 is lower
5 than that of the known generator coil since the total length of wire which forms said coil 13 is smaller than that of the wire forming the coil of the known generator.

It follows that the Joule effect losses which take place in coil 13 are lower than in the case of the known
10 generator, and the yield of generator 1 is thus higher than that of this known generator. It also follows that the variations in the voltage supplied by generator 1 according to whether the latter supplies current or not are lower than in the case of the known generator.

15 Those skilled in the art will easily see that rotor 2 of generator 1 can include a different number of permanent magnets 6a and 6b than ten, this number being however always even and always equal to the total number of teeth included in stator 3.

20 Likewise, and whatever the number thereof, magnets 6a and 6b can be replaced by a single multi-polar permanent magnet, this multi-polar magnet of course being arranged so as to have at the periphery of rotor 2 as many magnetic poles as the bipolar magnet assembly which it replaces and
25 so that the magnetic fields which it generates at the exterior of rotor 2 are also radial and of alternate directions.

Generally, it is seen that the rotor of a generator such as that which has just been described includes
30 magnetic means, formed by several bipolar permanent magnets or by an annular multi-polar permanent magnet, having 2N magnetic poles arranged regularly at the periphery of the rotor and generating at the exterior of this latter 2N radial magnetic fields of alternate
35 directions. It can also be said that the stator of such a generator includes two series each having N teeth, the N teeth of the first series and the N teeth of the second series being magnetically connected to the first and,

respectively, the second stator plate included in said stator.

Those skilled in the art will also see that the preceding considerations obviously apply to the other
5 embodiments of the generator according to the present invention which will be described hereinafter. These considerations will not therefore be repeated.

In the embodiment shown in Figures 3 and 4, the generator according to the present invention, which is
10 generated by the general reference 21, includes a rotor which is designated by the same reference 2 as the rotor of generator 1 of Figures 1 and 2 since it is identical to the latter. This rotor 2 of generator 21 will not therefore be described again.

15 Generator 21 also includes a stator, designated by the reference 22, which includes identical components 7 to 14 to the components of stator 3 of generator 1 designated by the same references and arranged like the latter. These components 7 to 14 will not therefore be described again.

20 Stator 22 also includes a third arm 23 connected to stator plate 7 and a fourth arm 24 connected to stator plate 8, and a second coil 25 wound onto a core 26 whose ends 26a and 26b are respectively connected to arms 23 and 24.

25 It can easily be seen that, in generator 21 of Figures 3 and 4, the magnetic flux originating from magnets 6a and 6b separates into two at least substantially equal portions, one of which passes through core 14 of coil 13 and the other passes through core 26 of
30 coil 25.

It can also be seen that, when rotor 2 rotates with respect of stator 22, each of coils 13 and 25 generates an electric voltage in response to the variations in the portion of the magnetic flux which passes through its core
35 14 or 16 respectively.

It will be noted that stator plate 7 with its two arms 11 and 23 is, in the embodiment shown in Figures 3 and 4, identical to stator plate 8 with its two arms 12

and 24, which reduces the manufacturing cost of the generator.

Moreover, the fact that generator 21 includes two coils has the advantage that only half of the total magnetic flux passes through the core of said coils, which allows the cross-section of the cores to be decreased without increasing the risk of magnetic saturation of the latter and/or reducing such risk of magnetic saturation. Thus, for a given number of turns, this embodiment allows the electric resistance to be reduced and thus the Joule effect losses compared to the embodiment described hereinbefore with reference to Figures 1 and 2. Moreover, with straight coil cores facilitating the winding of the electric wire, the arrangement of the present embodiment allows a large number of turns to be obtained while limiting the space requirement of the generator and maintaining a compact shape for it. The advantage of this embodiment also applied to curve cores with parallel winding of the turns onto the cores.

It is to be noted that, in the generators according to the present invention such as generators 1 and 21 described hereinbefore, it is possible to fix a part made of a non-magnetic material, fitted with a support bearing for shaft 4 of rotor 2, to one or the other of stator plates 7 and 8. Such an embodiment of these generators has not been shown.

In the embodiment shown in Figures 5 and 6, the generator according to the present invention, which is designated as a whole by the reference 31, includes a rotor which is also designated by the same reference 2 as the rotor of generator 1 of Figures 1 and 2 since it is also identical to the latter. This rotor 2 of generator 31 will therefore not be described again either.

Generator 31 also includes a stator, designated by the reference 32, which includes two stator plates 33 and 34 each having, in this example, the shape of annular plates centred on axis of rotation A. Stator plates 33 and 34 are made of a soft magnetic material and are arranged

on either side of rotor 2, at a certain distance from the latter. Each of stator plates 33 and 34 has an unreferenced central opening through which shaft 4 of rotor 2 passes.

5 It is to be noted that, if required, a support bearing for shaft 4 can be arranged in one and/or the other of the central openings arranged in stator plates 33 and 34. Such an embodiment of generator 31 has not been shown.

10 Stator 32 also includes two series of five teeth respectively designated by the references 9 and 10 since they are similar to teeth 9 and 10 of generators 1 and 21 described hereinbefore.

15 Teeth 9 of stator 32 are arranged regularly around rotor 2 and are mechanically and magnetically connected to the periphery of stator plate 33. Teeth 10 of stator 32 are also arranged regularly around rotor 2, each between two of teeth 9, and they are mechanically and magnetically connected to the periphery of stator plate 34.

20 As in generators 1 and 21, teeth 9 and 10 of generator 31 extend parallel to axis of rotation A of rotor 2 in the direction of stator plate 34 and, respectively, stator plate 33. Likewise, the total number of teeth 9 and 10 of stator 32 is equal to the total
25 number of magnets 6a and 6b of rotor 2 and, when the latter occupies a position such as that shown in Figure 5, each of teeth 9 and 10 is located facing one of magnets 6a and 6b. Moreover, the various components of generator 31 which have just been described are obviously dimensioned
30 and arranged so that rotor 2 can rotate freely, without touching any of the elements of stator 32, but so that the distance separating magnets 6a and 6b of teeth 9 and 10 is such that the mutual magnet-coil magnetic flux and the reluctant couple together have advantageous values.

35 Stator 32 also includes a first arm 35 and a second arm 36, both made of a soft magnetic material, which are respectively mechanically and magnetically connected to the periphery of stator plate 33 and to the periphery of

stator plate 34. It will be noted that it is possible to provide several arms or one arm separating into several branches to connect a stator plate to core 14.

In this case also, the two units respectively formed
5 by stator plate 33, teeth 9 and arm 35, and by stator plate 34, teeth 10 and arm 36 are preferably each made in the form of a single same part.

Stator 32 also includes a coil 13 wound around a core 14. Ends 14a and 14b of core 14 are respectively
10 mechanically and magnetically connected to arms 35 and 36 by fixing means which have not been shown in detail. It will simply be noted that, in this case, a first strut 37 made of a soft magnetic material is arranged between end 14a of core 14 and arm 35 and a second strut, not visible
15 in Figures 5 and 6 and similar to the first, is arranged between end 14b of core 14 and arm 36.

However, the various components of stator 32 which have just been described can be formed, dimensioned and arranged in relation to each other so that the unit formed
20 by stator plate 33, teeth 9 and arm 35, and the unit formed by stator plate 34, teeth 10 and arm 36 are only magnetically connected via core 14 of coil 13.

The operation of generator 31 will not be described since it is entirely similar to that of generators 1 and
25 21 described hereinbefore. Moreover, generator 31 has the same advantages as those of generators 1 and 21 described hereinbefore. It will be mentioned however that, with respect to these latter and all other things being equal, generator 31 can be more compact, which may facilitate the
30 use thereof in a device such as a wristwatch where the available height is limited.

In another of its embodiments, the generator according to the present invention includes, in addition to all the components of generator 31 which have just been
35 described, a third and a fourth arm respectively mechanically and magnetically connected to stator plate 33 and stator plate 34, and a second coil wound onto a core whose ends are also respectively mechanically and

magnetically connected to such third and fourth arm. Such an embodiment has not been shown since the realisation thereof follows easily from the description of the other embodiments of the generator according to the present invention which was made hereinbefore.

Numerous modifications can be made to the generator according to the present invention of which a few embodiments were described hereinbefore, without thereby departing from the scope of this invention.

Thus, for example, the stator of a generator according to the present invention can include more than two coils, this stator then including the number of arms which is necessary to mechanically and magnetically connect the ends of the core of each of said coils to the first and second stator plates.

Likewise, these arms can have different shapes to those which they have in the examples described hereinbefore.

It is thus possible to give these arms such a shape that the coil or coils of the generator are not located in immediate proximity to the stator plates of the generator, and/or to bend the arms so that the coil or coils are located higher or lower, with respect to the rest of the generator, than they are in the examples described hereinbefore. These various modifications to the shape of the arms allow, if required, the design and manufacture of the device using a generator according to the present invention to be simplified, in particular when the available space in such device is limited and the latter has to include other components having a relatively large volume.

It is also possible to give the generator coil, or coils, the shape of a thin flat disc with a core whose axis is parallel to the axis of rotation of the rotor of such generator instead of being perpendicular to said axis as in the examples described hereinbefore. In such a case, the arms mechanically and magnetically connecting the core

or cores to the stator stator plates are obviously formed and arranged in accordance therewith.

Such an arrangement of the coil or coils allows, if required, a generator having a small thickness to be made
5 while including one or more coils having a large number of turns. This arrangement also allows, if required, the cross-section of the core of the coil or coils to be increased and thus the density of the magnetic flux passing through the core of cores and thus the risk that
10 they will be saturated by such flux to be decreased.



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CLAIMS

1. Monophase electric power generator including:

- a rotor (2) having an axis of rotation (A) and including magnetic means (6a; 6b) with $2N$ magnetic poles arranged regularly at the periphery of said rotor (2) and
5 generating at the exterior of said rotor (2) $2N$ radial magnetic fields of alternate directions; and
- a stator (2; 22; 32) including at least one coil (13; 25) and coupling means for coupling said coil (13; 25) to said magnetic means including a first (7; 33) and a
10 second (8; 34) stator plate at a distance from each other, a first series of N teeth (9) magnetically connected to said first stator plate (7; 33), arranged regularly around said rotor and offset angularly at $360^\circ/N$, said first series of N teeth extending parallel to said axis of
15 rotation (A) in the direction of said second stator plate (8; 34), a second series of N teeth (10) magnetically connected to said second stator plate (8; 34), arranged regularly around said rotor and offset angularly at $360^\circ/N$, said second series of N teeth being each located
20 between two adjacent teeth (9) of said first series of teeth and extending parallel to said axis of rotation (A) in the direction of said first stator plate (7; 33), and connecting means for magnetically connecting said first (7; 33) and said second (8; 34) stator plate; said coil
25 (13; 25) being wound around a core (14; 26) forming said connecting means, said core having a first (14a; 26a) and a second (14b; 26b) end which are magnetically connected to said first (7; 33) and, respectively, to said second (8; 34) stator plate.

30 2. Generator according to claim 1, characterised in that said stator plates (7, 8) both have the general shape of a circular ring centred on said axis of rotation (A), and in that said teeth of said first and second series (9, 10) are respectively connected to the interior of said
35 first and second stator plates (7, 8).

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3. Generator according to claim 1, characterised in that said stator plates (33, 34) both have the general shape of an annular plate centred on said axis of rotation (A), and in that said teeth (9, 10) are arranged at the
5 periphery of said stator plates (33, 34).

4. Generator according to claim 1, characterised in that said stator (3; 22; 32) includes at least a second coil (25) wound around a second core (26) having a first (26a) and a second (26b) end, and in that said connecting
10 means further include said second core (26) and are arranged so that said first (26a) and second (26b) ends of said second core (26) are magnetically connected to said first (7; 33) and, respectively, said second stator plate (8; 34).

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