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(54) **ELECTRICITY GENERATING APPARATUS UTILIZING A SINGLE MAGNETIC FLUX PATH**

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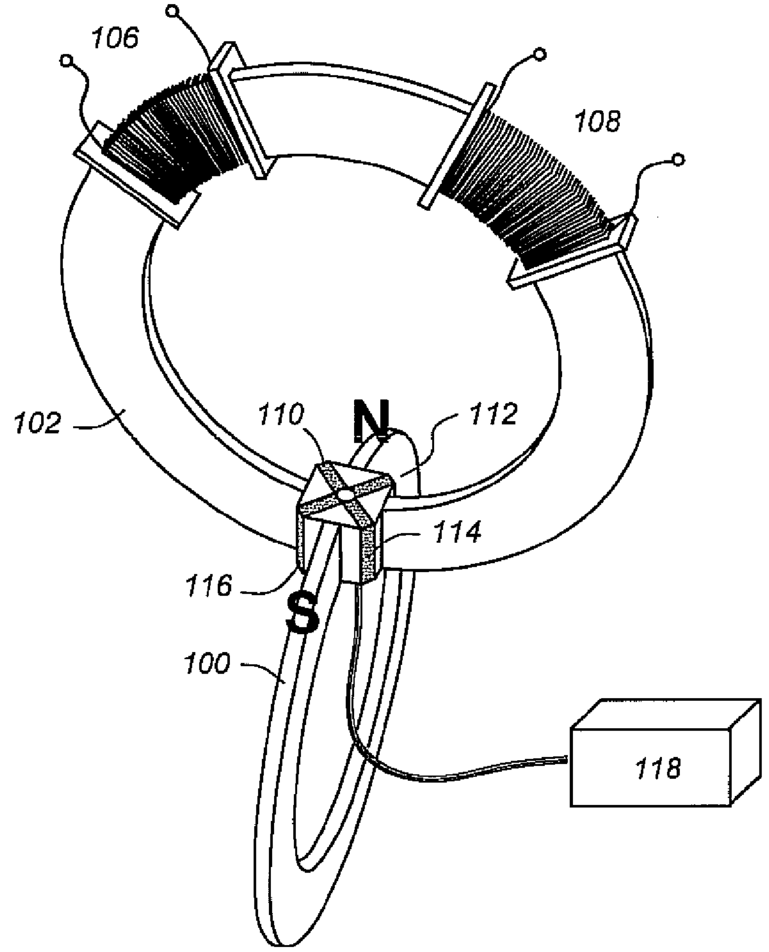
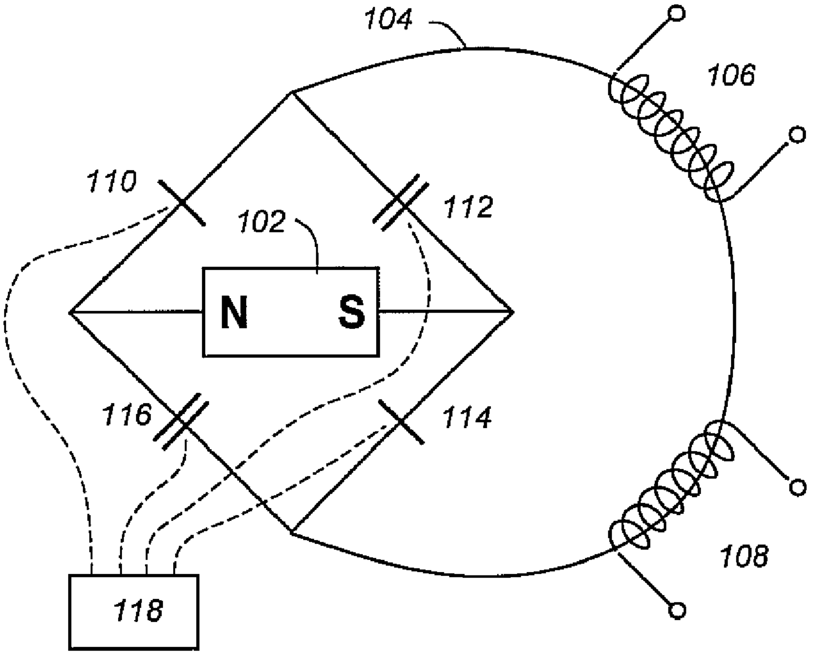
(57) **ABSTRACT**

Methods and apparatus generate electricity through the operation of a circuit based upon a single magnetic flux path. A magnetizable member provides the flux path. One or more electrically conductive coils are wound around the member, and a reluctance or flux switching apparatus is used to control the flux. When operated, the switching apparatus causes a reversal of the polarity (direction) of the magnetic flux of the permanent magnet through the member, thereby inducing alternating electrical current in each coil. The flux switching apparatus may be motionless or rotational. In the motionless embodiments, two or four reluctance switches are operated so that the magnetic flux from one or more stationary permanent magnet(s) is reversed through the magnetizable member. In alternative embodiments the flux switching apparatus comprises a body composed of high-permeability and low-permeability materials, such that when the body is rotated, the flux from the magnet is sequentially reversed through the magnetizable member.




104
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118

Fig - 1

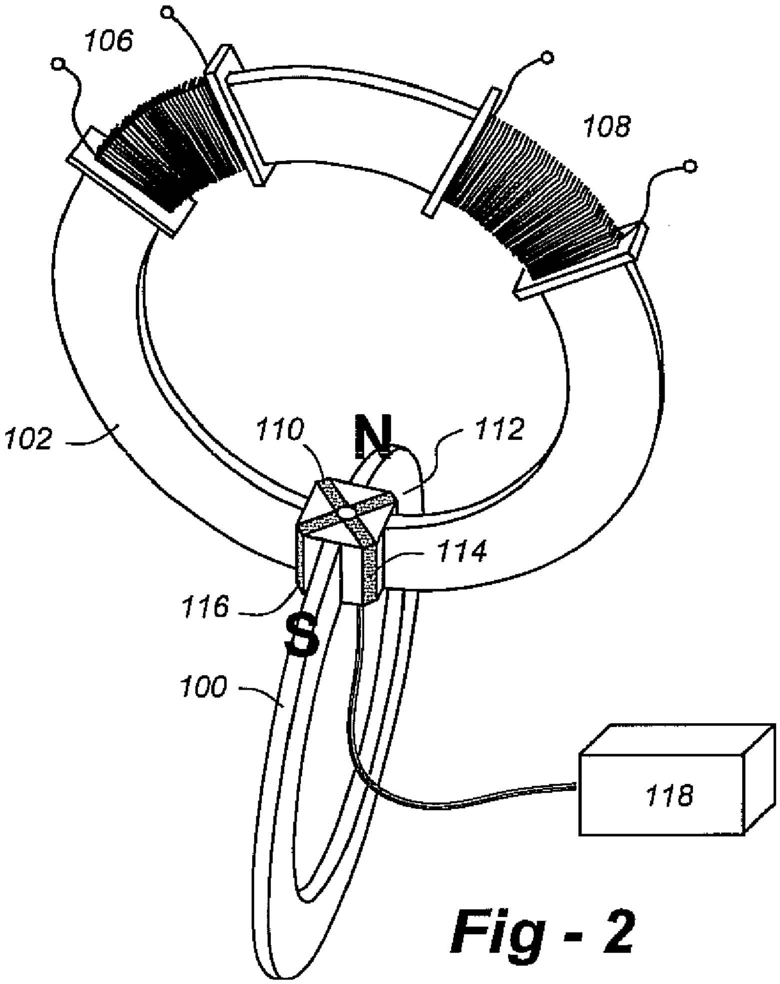
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Fig - 2

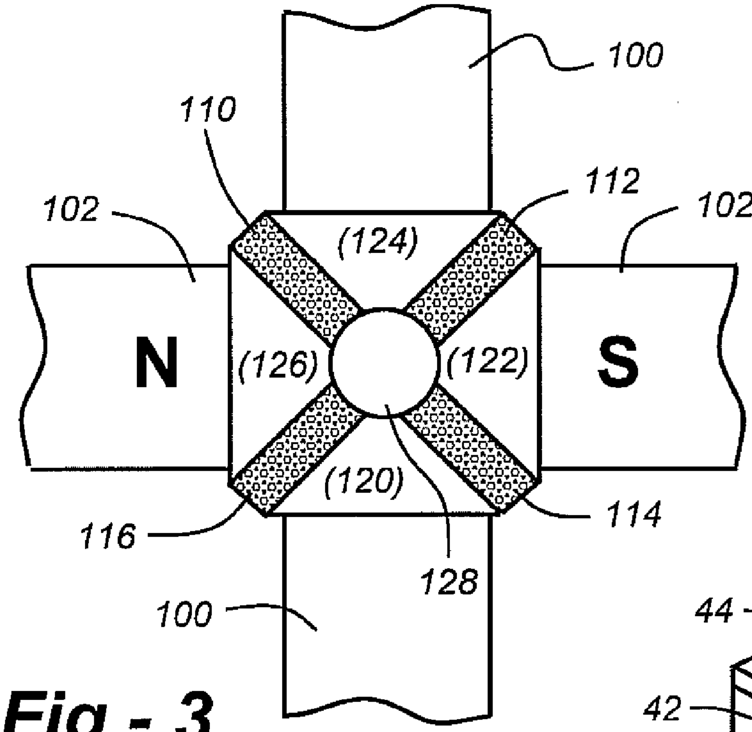


Fig - 3

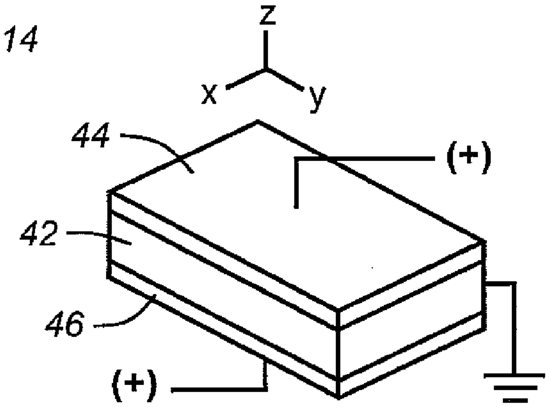


Fig - 4

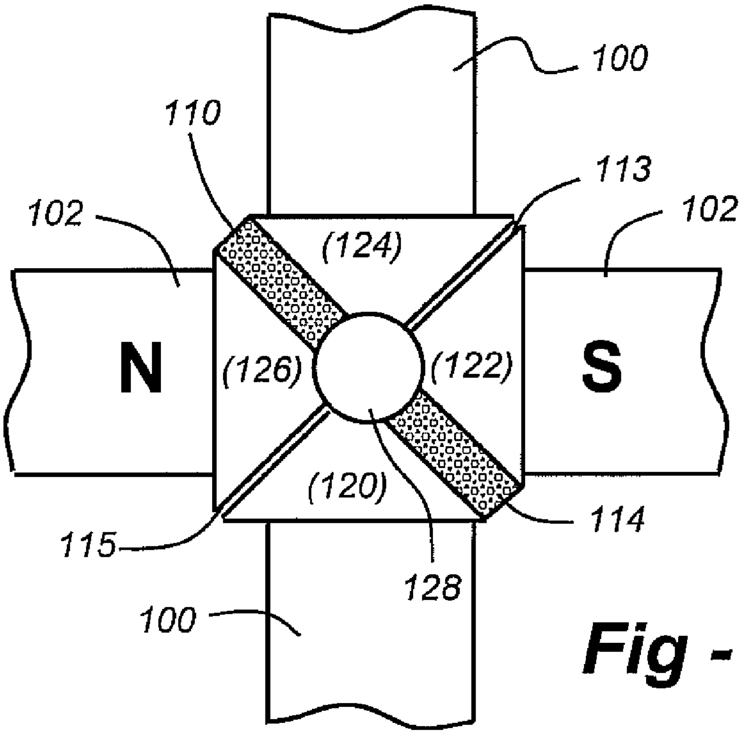


Fig - 5

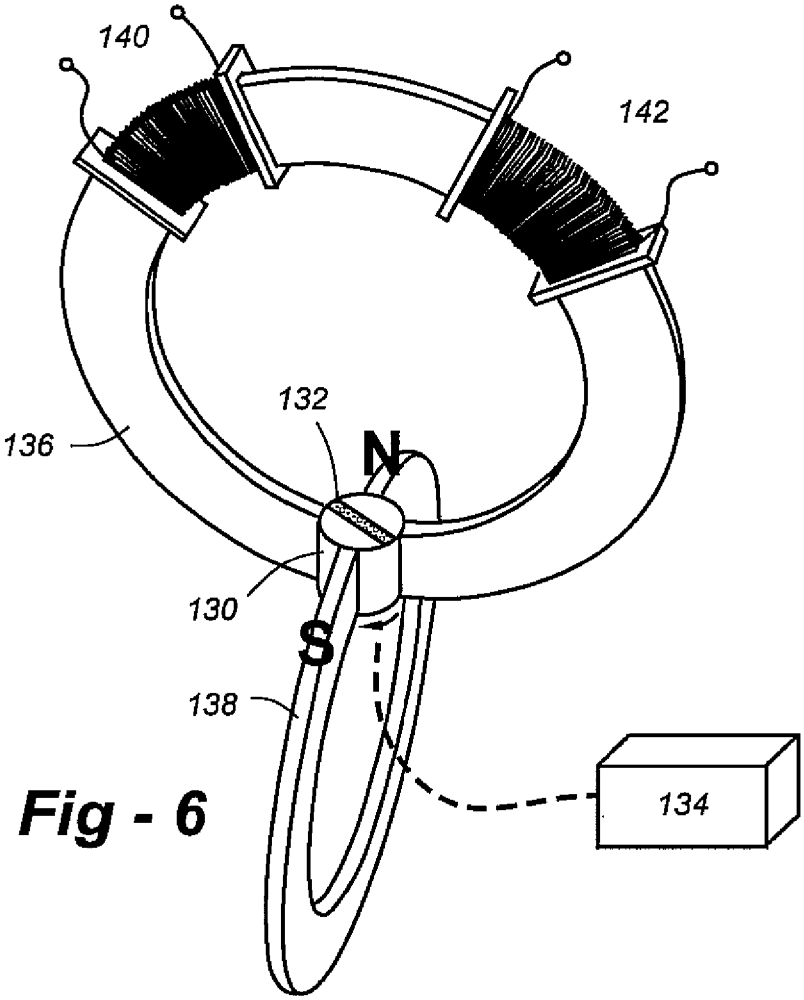


Fig - 6

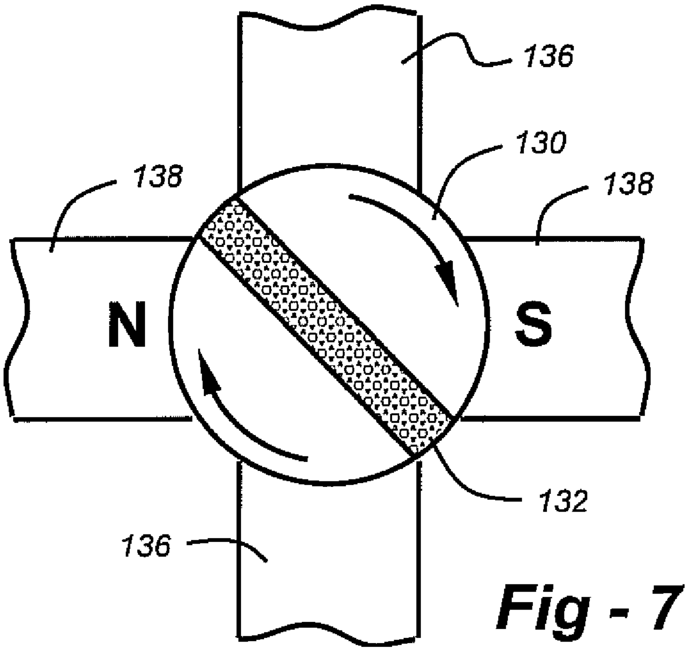
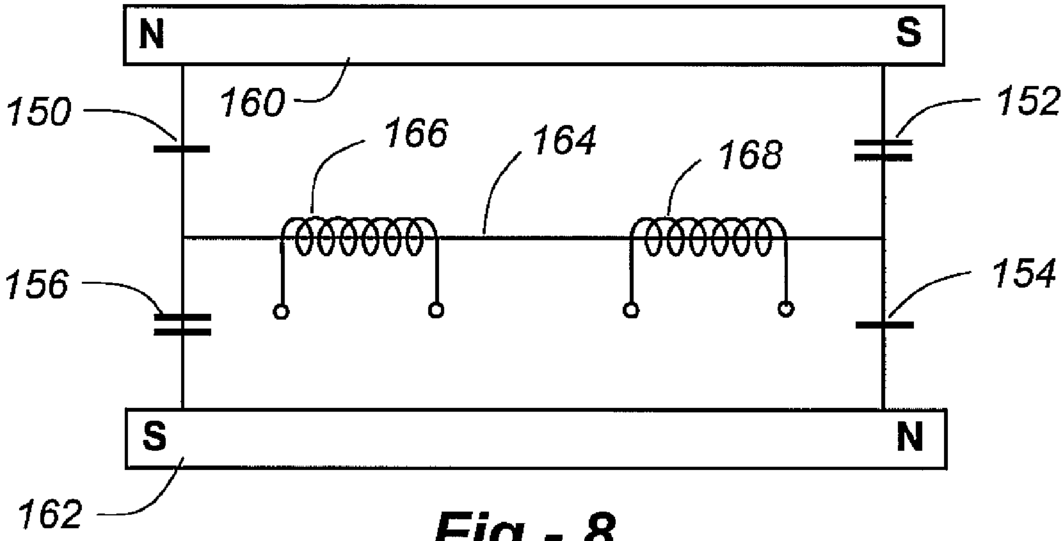


Fig - 7


N
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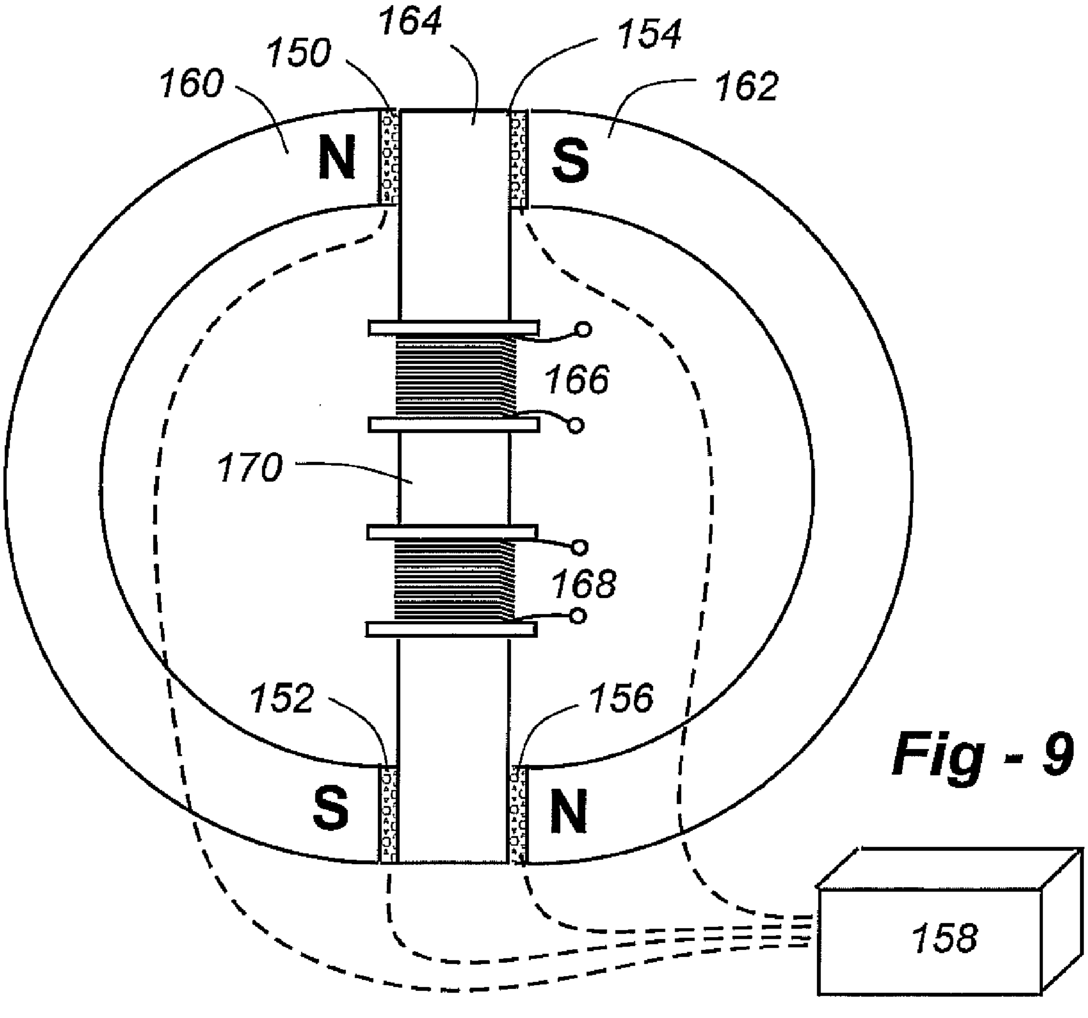
160
150
152
166
164
168
156
154
S
N
162

Fig - 8


164
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156
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158

Fig - 9

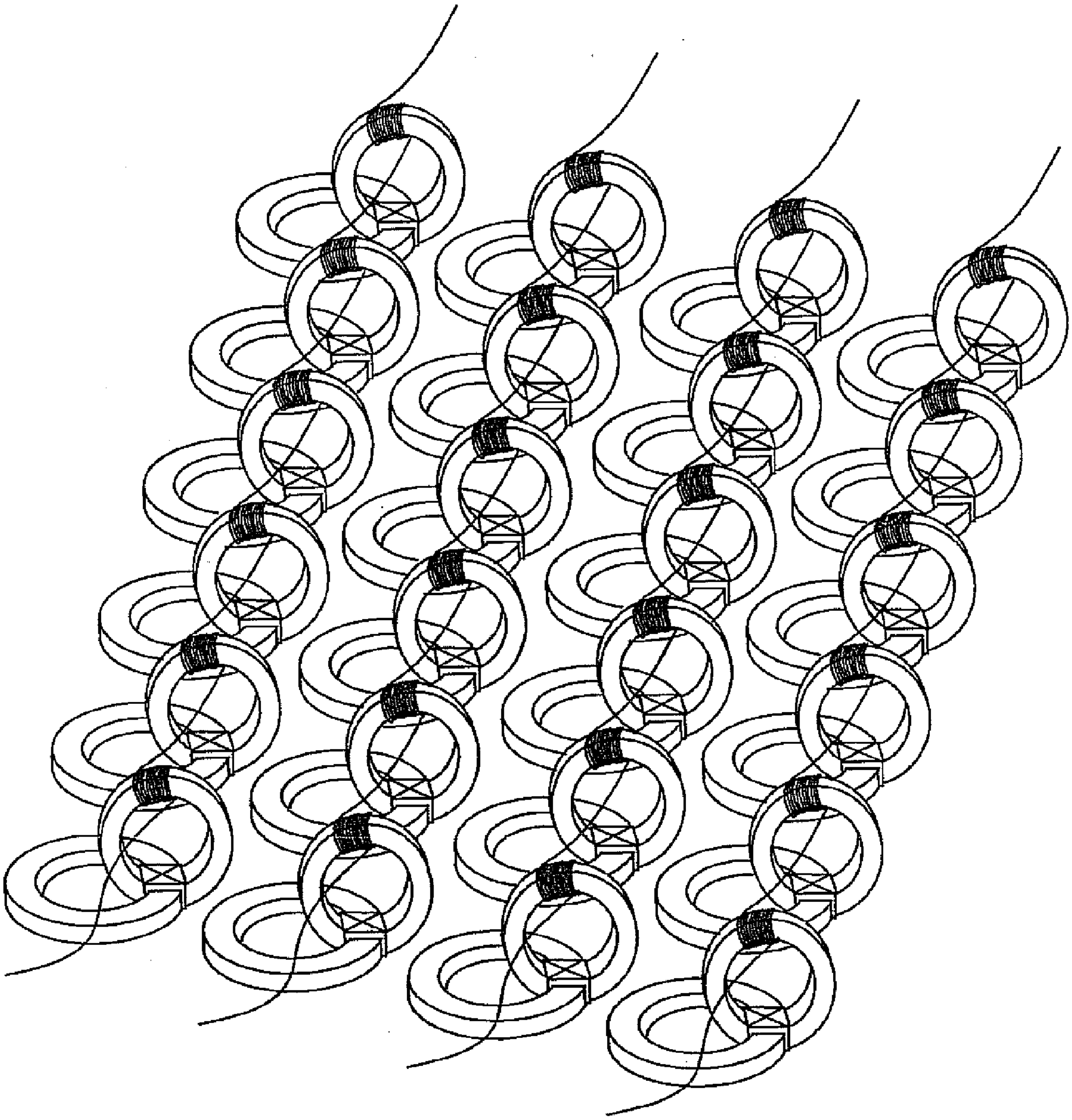

Fig - 10

ELECTRICITY GENERATING APPARATUS UTILIZING A SINGLE MAGNETIC FLUX PATH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Ser. Nos. 60/792,602; 60/792,596; 60/792,594; and 60/792,595, all filed Apr. 17, 2006. The entire content of each application is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to methods and apparatus wherein the magnetic flux from one or more permanent magnets is reversed repeatedly in polarity (direction) through a single flux path around which there is wound a conducting coil or coils for the purpose of inducing electricity in the coils.

BACKGROUND OF THE INVENTION

[0003] The electromechanical and electromagnetic methods involved in motional electric generators and alternators are well known. Alternators and generators often employ permanent magnets and usually have a rotor and a stator and a coil or coils in which an EMF (electromotive force) is induced. The physics involved for producing electricity is described by the generator equation $V=\int(v\times B)\cdot dl$.

[0004] Permanent magnets made of materials that have a high coercively, a high magnetic flux density a high magnetic motive force (mmf), and no significant deterioration of magnetic strength over time are now common. Examples include ceramic ferrite magnets (Fe_2O_3); samarium cobalt ($SmCO_5$); combinations of iron, neodymium, and boron; and others.

[0005] Magnetic paths for transformers are often constructed of laminated ferrous materials; inductors often employ ferrite materials, which are used for higher frequency operation for both devices. High performance magnetic materials for use as the magnetic paths within a magnetic circuit are now available and are well suited for the (rapid) switching of magnetic flux with a minimum of eddy currents. An example is the FINEMET® nanocrystalline core material made by Hitachi of Japan.

[0006] According to Moskowitz, "Permanent Magnet Design and Application Handbook" 1995, page 52, magnetic flux may be thought of as flux lines which always leave and enter the surfaces of ferromagnetic materials at right angles, which never can make true right-angle turns, which travel only in straight or curved paths, which follow the shortest distance, and which follow the path of lowest reluctance.

[0007] A "reluctance switch" is a device that can significantly increase or decrease (typically increase) the reluctance (resistance to magnetic motive force) of a magnetic path in a direct and rapid manner and subsequently restore it to its original (typically lower) value in a direct and rapid manner. A reluctance switch typically has analog characteristics. By way of contrast, an off/on electric switch typically has a digital characteristic, as there is no electricity "bleed-through." With the current state of the art, reluctance switches have magnetic flux bleed-through. Reluctance switches may be implemented mechanically, such as to cause keeper movement to create an air gap, or electrically by several means, or by other means. One electrical means is that of using control coils wound around the flux paths. Another electrical means is the placement within the flux path of certain classes of materials that change (typically increase) their reluctance upon the application of electricity. Another electrical means is to saturate a region of the switch material so that the reluctance increases to that of air by inserting conducting electrical wires into the material as described by Konrad and Brudny in "An Improved Method for Virtual Air Gap Length Computation," in IEEE Transactions on Magnetics, Vol. 41, No. 10, October 2005.

[0008] The patent literature describes a number of constructs that have been devised to vary the amounts of magnetic flux in alternate flux paths by disproportionately dividing the flux from a stationary permanent magnet or magnets between or among alternate flux paths repeatedly for the purpose of generating electricity. The increase of flux in one magnetic path and the corresponding decrease in the other path(s) provide the basis for inducing electricity when coils are wound around the paths. The physics involved for producing electricity by these constructs is described by the transformer equation $V=-\int dB/dt\cdot ds$. A variety of reluctance switching means have been employed to cause the flux to be increased/decreased through a particular alternate path with a corresponding decrease/increase in the other path and to do so repeatedly.

[0009] A means of switching flux along alternate paths between the opposite poles of a permanent magnet have included the flux transfer principle described by R. J. Radus, Engineers' Digest, July, 1963.

[0010] A result of providing alternate flux paths of generally similar geometry and permeability is that, under particular conditions, the alternate path first selected or the path selected for the majority of the flux will remain a "preferred path" in that it will retain more flux and the other path, despite the paths having equal reluctance. (There is not an automatic equalization of the flux among similar paths.) Moskowitz, "Permanent Magnet Design and Application Handbook" 1995, page 87 discusses this effect with regard to the industrial use of permanent magnets to lift and release iron and steel by turning the permanent magnet on and (almost) off via reluctance switching that consists of the electric pulsing of coils wound around the magnetic flux paths (the reluctance switches).

[0011] Experimental results with four iron rectangular bars (relative permeability=1000) placed together in a square with a bar permanent magnet (flux density measured at one pole=5000 Gauss) between two of the opposing bars roughly in a center position showed that removal and replacement of the one of the end bars that is parallel to the bar magnet will result in about 80% of the flux remaining in the bar that remained in contact. The results further showed that the preferred path must experience an increase of reluctance about 10× of that of the available alternate path before its disproportionate flux condition will yield and transfer to the alternate path.

[0012] Flynn U.S. Pat. No. 6,246,561; Patrick, et al. U.S. Pat. No. 6,362,718; and Pedersen U.S. Pat. No. 6,946,938 all disclose a method and apparatus for switching (dividing) the quantity of magnetic flux from a stationary permanent magnet or magnets between and among alternate paths for the purpose of generating electricity (and/or motive force).

They provide for the increase of magnetic flux in one path with a corresponding decrease in the other path(s). There are always at least two paths.

SUMMARY OF THE INVENTION

[0013] The present invention relates to methods and apparatus for the production of electricity through the operation of a circuit based upon a single magnetic flux path. A magnetizable member provides the flux path. One or more electrically conductive coils are wound around the member, and a reluctance or flux switching apparatus is used to control the flux. When operated, the switching apparatus causes a reversal of the polarity (direction) of the magnetic flux of the permanent magnet through the member, thereby inducing alternating electrical current in each coil.

[0014] According to the invention, the flux switching apparatus may be motionless or rotational. In the motionless embodiments, four reluctance switches are operated by a control unit that causes a first pair of switches to open (increasing reluctance), while another pair of switches close (decreasing reluctance). The initial pair is then closed as the other pair is opened, and so on. This 2×2 opening and closing cycle repeats and, as it does, the magnetic flux from the stationary permanent magnet(s) is reversed in polarity through the magnetizable member, causing electricity to be generated in the conducting coils. An alternative motionless embodiment uses two reluctance switches and two gaps of air or other materials.

[0015] In alternative embodiments, the flux switching apparatus comprises a body composed of high-permeability and low-permeability materials, such that when the body is rotated, the flux from the magnet is sequentially reversed through the magnetizable member. In the preferred embodiment the body is cylindrical having a central axis, and the body rotates about the axis. The cylinder is composed of a high-permeability material except for section of low-permeability material that divided the cylinder into two half cylinders. At least one electrically conductive coil is wound around the magnetizable member, such that when the body rotates an electrical current is induced in the coil. The body may be rotated by mechanical, electromechanical or other forces.

[0016] A method of generating electrical current, comprises the steps of providing a magnetizable member with an electrically conductive coil wound therearound, and sequentially reversing the flux from a permanent magnet through the member, thereby inducing electrical current in the coil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] FIG. **1** is a schematic diagram of a magnetic circuit according to the invention;

[0018] FIG. **2** is a perspective view of an embodiment of the invention based upon motionless magnetic flux switches;

[0019] FIG. **3** is a detail drawing of a motionless flux switch according to the invention;

[0020] FIG. **4** is a detail drawing of a reluctance switch according to the invention

[0021] FIG. **5** is a detail drawing of an alternative motionless flux switch according to the invention which utilizes gaps of air or other materials;

[0022] FIG. **6** is a schematic diagram of a system using a rotary flux switch according to the invention;

[0023] FIG. **7** is a detail drawing of a rotary flux switch according to the invention;

[0024] FIG. **8** is a schematic diagram of a circuit according to the invention utilizing two permanent magnets and a single flux path;

[0025] FIG. **9** shows one possible physical embodiment of the apparatus with the components of FIG. **8**, including a reluctance switch control unit; and

[0026] FIG. **10** shows and array of interconnected electrical generators according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] FIG. **1** is a schematic diagram of a magnetic circuit according to the invention utilizing a motionless flux switch. The circuit includes the following components: a permanent magnet **102**, single flux path **104**, conducting coils **106**, **108**, and four reluctance switches **110**, **112**, **114**, **116**. Under the control of unit **118**, reluctance switches **110**, **114** open (increasing reluctance), while switches **112**, **116** close (decreasing reluctance). Reluctance switches **110**, **114** then close, while switches **112**, **116** open, and so on. This 2×2 opening and closing cycle repeats and, as it does, the magnetic flux from stationary permanent magnet **102** is reversed in polarity through single flux path **104**, causing electricity to be generated in conducting coils **106**, **108**.

[0028] An efficient shape of permanent magnet **102** is a "C" in which the poles are in close proximity to one another and engage with the flux switch. The single flux is carried by a magnetizable member **100**, also in a "C" shape with ends that are in close proximity to one another and also engage with the flux switch. In this and in other embodiments, the 2×2 switching cycle is carried out simultaneously. As such, control circuit **118** is preferably implemented with a crystal-controlled clock feeding digital counters, flip-flops, gate packages, or the like, to adjust rise time, fall time, ringing and other parasitic effects. The output stage of the control circuit may use FET (field-effect switches) to route analog or digital waveforms to the reluctance switches as required.

[0029] FIG. **2** is a perspective of one possible physical embodiment of the apparatus using the components of FIG. **1**, showing their relative positions to one another. Reluctance switches **110**, **112**, **114**, **116** may be implemented differently, as described below, but will usually occupy the same relative position within the apparatus. FIG. **3** is a detail drawing of the motionless flux switch. Connecting segments **120**, **122**, **124**, **126** must be made of a high-permeability ferromagnetic material. The central volume **128** may be a through-hole, providing an air gap, or it may be filled with glass, ceramic or other low-permeability material. A superconductor or other structure exhibiting the Meissner effect may alternatively be used.

[0030] In the embodiment depicted in FIGS. **2** and **3**, reluctance switches **110**, **112**, **114**, **116** are implemented with a solid-state structure facilitating motionless operation. The currently preferred motionless reluctance switch is described by Toshiyuki Ueno & Toshiro Higuchi, in the paper "Investigation on Dynamic Properties of Magnetic Flux Control Device composed of Lamination of Magnetostrictive Material Piezoelectric Material," The University of Tokyo 2004, the entirety of which is incorporated herein by reference. As shown in FIG. **4**, this switch is made of a laminate of a GMM (Giant Magnetostrictive Material **42**), a TbDyFe alloy, bonded on both sides by a PZT (Piezoelectric) material **44**, **46** to which electricity is applied. The application of electricity to the PZT creates strain on the GMM, which causes its reluctance to increase.

[0031] Other arrangements are applicable, including those disclosed in pending U.S. Patent Application Serial no. 2006/0012453, the entire content of which is incorporated herein by reference. These switches disclosed in this reference are based upon the magnetoelectric (ME) effects of liquid crystal materials in the form of magnetorestrictive and piezoelectric effects. The properties of ME materials are described, for example, in Ryu et al, "Magnetoelectric Effect in Composites of Magnetorestrictive and Piezoelectric Materials," Journal of Electroceramics, Vol. 8, 107-1 19 (2002), Filipov et al, "Magnetoelectric Effects at Piezoresonance in Ferromagentic-Ferroelectric Layered Composites," Abstract, American Physical Society Meeting (March 2003) and Chang et al., "Magneto-band of Stacked Nanographite Ribbons," Abstract, American Physical Society Meeting (March 2003). The entire content of each of these papers are also incorporated herein.

[0032] Further alternatives include materials that may sequentially heated and allowed to cool (or cooled and allowed to warm up or actively heated and cooled) above and below the Currie temperature, thereby modulating reluctance. Gadolinium is a candidate since its Currie point is near room temperature. High-temperature superconductors are other candidates, with the material being cooled in an insulated chamber at a temperature substantially at or near the Currie point. Microwave or other energy sources may be used in conjunction with the control unit to effectuate this switching. Depending upon how rigidly the switches are contained, further expansion-limiting 'yokes' may or may not be necessary around the block best seen in FIG. **4**.

[0033] FIG. **5** is a detail drawing of an alternative motionless flux switch according to the invention which utilizes gaps of air or other materials. This embodiment uses two electrically operated reluctance switches **110**, **114**, and two gaps **113**, **115**, such that when the switches are activated in a prescribed manner, the flux from the magnet **102** is blocked along the switch segments containing the switches and forced through the gap-containing segments, thereby reversing the flux through the magnetizable member **100**. Upon activation of the two reluctance switches **110**, **114**, the flux, seeking a path of significantly lower reluctance, flips back to the original path containing the (non deactivated) reluctance switches, thereby reversing the flux through the member **100**. Note that the flux switches may also be electromagnetic to saturate local regions of the switch such that reluctance increases to that of air (or gap material), creating a virtual gap as described by Konrad and Brudny in the Background of the Invention.

[0034] More particularly, flux switching apparatus according to this embodiment uses a permanent magnet having a north pole 'N' and a south pole 'S' in opposing relation across a gap defining a volume. A magnetizable member with ends 'A' and 'B' is supported in opposing relation across a gap sharing the volume, and a flux switch comprises a stationary block in the volume having four sides, **1-4**, with two opposing sides interfaced to N and S, respectively and with the other two opposing sides being interfaced to A and B, respectively. The block is composed of a magnetizable material segmented by two electrically operated magnetic flux switches and two gaps filled with air or other material (s). A control unit in electrical communication with the flux switches is operative to:

[0035] a) passively allow a default flux path through sides **1-2** and **3-4**, then

[0036] b) actively establish a flux path through sides **2-3** and **1-4**, and

[0037] c) repeat a) and b) on a sequential basis.

[0038] As an alternative to a motionless flux switch, a rotary flux switch may be used to implement the 2×2 alternating sequence. Referring to FIGS. **6** and **7**, cylinder **130** with flux gap **132** is rotated by a motive means **134**. This causes the halves of cylinder **130** to provide two concurrent and separate magnetic flux bridges (i.e., a "closed" reluctance switch condition), in which a given end of magnetizable member **136** is paired up with one of the poles of stationary permanent magnet **138**. Simultaneously, the other end of single flux path carrier **136** is paired up with the opposite pole of stationary permanent magnet **138**.

[0039] FIG. **7** is a detail view of the cylinder. Each 90° rotation of the cylinder causes the first flux bridges to be broken (an "open" reluctance switches condition) and a second set of flux bridges to be created in which the given end of member **136** is then bridged with the opposite pole of stationary permanent magnet **138**. A full rotation of cylinder **130** causes four such reversals. Each flux reversal within single flux path **2** causes an electric current to be induced in conducting coil(s) **140**, **142**. In this embodiment, it is important to keep a precise, consistent spacing between each of the "halves" of (rotating) cylinder **130** in relation to the poles of permanent magnet **138** and the ends of flux path carrier **136** as the magnetic flux bridges are provided by the cylinder **130** as it rotates.

[0040] Rotating cylinder **130** is made of high magnetic permeability material which is divided completely by the flux gap **132**. A preferred material is a nanocrystalline material such as FINEMET® made by Hitachi. The flux gap **132** may be air, glass, ceramic, or any material exhibiting low magnetic permeability. A superconductor or other structure exhibiting the Meissner effect may alternatively be used.

[0041] An efficient shape of magnetizable member **136** is a "C" in which its opposing ends are curved with a same radius as cylinder **130** and are in the closest possible proximity with rotating cylinder **130**. Permanent magnet **138** is also preferably C-shaped in which the opposing poles are curved with a same radius as cylinder **130** and are in the closest possible proximity with rotating cylinder **130**. Manufacturing and assembly considerations may dictate other shapes.

[0042] While the embodiments described thus far utilize a single permanent magnet, other embodiments are possible according to the invention utilizing a plurality of permanent magnets while nonetheless generating a single flux path. FIG. **8** depicts a circuit utilizing two permanent magnets and a single flux path. FIG. **9** shows one possible physical embodiment of the apparatus based upon the components of FIG. **8**, including a reluctance switch control unit **158**.

[0043] Under the control of unit **158**, reluctance switches **150**, **152** open (increasing reluctance), while switches **154**, **156** close (decreasing reluctance). Reluctance switches **150**, **152** then close, while switches **154**, **156** open, and so on. This 2×2 opening and closing cycle repeats and, as it does, the magnetic flux from stationary permanent magnets **160**,

162 is reversed in polarity through the magnetizable member, causing electricity to be generated in conducting coils **166**, **168**.

[0044] In the preferred implementation of this embodiment, the magnets are arranged with their N and S poles reversed. The magnetizable member is disposed between the two magnets, and there are four flux switches, SW**1**-SW**4**, two between each end of the member and the poles of each magnet. The reluctance switches are implemented with the structures described above with reference to FIGS. **1** to **3**.

[0045] For added particularity, assume the first magnet has north and south poles, N**1** and S**1**, the second magnet has north and south poles, N**2** and S**2** and the member has two ends A and B. Assuming SW**1** is situated between N**1** and A, SW**2** is between A and S**2**, SW**3** is between N**2** and B, and SW**4** is between B and S**1**, the control circuitry operative to activate SW**1** and SW**4**, then activate SW**2** and SW**3**, and repeat this process on a sequential basis. As with the other embodiments described herein, for reasons of efficiency, the switching is carried out simultaneously.

[0046] In all of the embodiments described herein the material used for the permanent magnet(s) may be either a magnetic assembly or a single magnetized unit. Preferred materials are ceramic ferrite magnets (Fe_2O_3), samarium cobalt ($SmCO_5$), or combinations of iron, neodymium, and boron. The single flux path is carried by a material having a high magnetic permeability and constructed to minimize eddy currents. Such material may be a laminated iron or steel assembly or ferrite core such as used in transformers. A preferred material is a nanocrystalline material such as FINEMET®. The conducting coil or coils are wound around the material carrying the single flux path as many turns as required to meet the voltage, current or power objectives. Ordinary, standard, insulated, copper magnet wire (motor wire) is sufficient and acceptable. Superconducting materials may also be used. At least some of the electricity induced in the conducting coils may be fed back into the switch control unit. In this mode of operation, starting pulses of electricity may be provided from a chemical or solar battery, as required.

[0047] Although in the embodiments of FIGS. **2** and **6** the magnet and flux-carrying materials are flat elements lying in orthogonal planes with flux-carrying material lying outside the volume described by the magnet, the flux path may be disposed 'within' the magnet volume or configured at an angle. The physical scale of the elements may also be varied to take advantage of manufacturing techniques or other advantages. FIG. **10**, for example, shows an array of magnetic circuits, each having one or more coils that may be in series, parallel, or series-parallel combinations, depending upon voltage or current requirements. In each case the magnets may be placed or fabricated using techniques common to the microelectronics industry. If mechanical flux switches are used they may be fabricated using MEMs-type techniques. If motionless switches are used, the materials may be placed and/or deposited. The paths are preferably wound in advance then picked and placed into position as shown. The embodiment shown in FIG. **9** is also amenable to miniaturization and replication.

We claim:

1. An electrical generator, comprising:

a permanent magnet generating flux;

a magnetizable member;

an electrically conductive coil wound around the magnetizable member; and

flux switching apparatus operative to sequentially reverse the flux from the magnet through the member, thereby inducing electrical current in the coil.

2. The electrical generator of claim **1**, wherein the flux switching apparatus includes a plurality of motionless, solid-state reluctance switches.

3. The electrical generator of claim **2**, wherein the reluctance switches are composed of a Giant Magnetostrictive Material (GMM) and Piezoelectric (PZT) material.

4. The electrical generator of claim **1**, wherein:

the permanent magnet forms a first loop with a north end 'N' and a sound end 'S' in opposing relation across a gap defining a volume;

the magnetizable member forms a second with ends 'A' and 'B' in opposing relation across a gap sharing the same volume; and

the flux switching apparatus is disposed in the volume and operative to:

a) magnetically couple N with A and S with B, then

b) magnetically couple N with B and S with A, and

c) repeat steps a) and b) on a sequential basis.

5. The electrical generator of claim **4**, wherein the flux switching apparatus comprises:

a stationary block in the volume having four sides, **1**-**4**, with two opposing sides interfaced to N and S, respectively, and with the other two opposing sides being interfaced to A and B, respectively, the block being composed of a magnetizable material segmented by four electrically operated magnetic reluctance switches; and

a control unit in electrical communication with the flux switches, the unit being operative to:

a) establish a flux path through sides **1**-**2** and **3**-**4**, then

b) establish a flux path through sides **2**-**3** and **1**-**4**, and

c) repeat a) and b) on a sequential basis.

6. The electrical generator of claim **4**, wherein the flux switching apparatus comprises:

a stationary block in the volume having four sides, **1**-**4**, with two opposing sides interfaced to N and S, respectively, and with the other two opposing sides being interfaced to A and B, respectively, the block being composed of a magnetizable material segmented by two electrically operated magnetic reluctance switches and two gaps of air or other materials; and

a control unit in electrical communication with the flux switches, the unit being operative to:

a) passively allow a default flux path through sides **1**-**2** and **3**-**4**, then

b) actively establish a flux path through sides **2**-**3** and **1**-**4**, and

c) repeat a) and b) on a sequential basis.

7. The electrical generator of claim **4**, wherein the flux switching apparatus comprises a body composed of high-permeability and low-permeability materials, such that when the body is rotated, the flux from the magnet is sequentially reversed through the magnetizable member.

8. The rotary flux switching apparatus of claim **7**, wherein the cylinder is composed of a high-permeability material except for section of low-permeability material that divided the cylinder into two half cylinders.

9. The rotary flux switching apparatus of claim **7**, wherein the body is mechanically rotated.

10. The rotary flux switching apparatus of claim **7**, wherein the body is electromechanically rotated.

11. The electrical generator of claim **1**, wherein at least a portion of the electrical current induced in the coil is used to operate the flux switching apparatus.

12. The electrical generator of claim **1**, further comprising:

first and second permanent magnets generating magnetic flux in opposite directions; and

a plurality of flux switches operative to sequentially reverse the flux from the magnets through the member, thereby inducing electrical current in the coil.

13. The electrical generator of claim **12**, wherein:

the magnets are arranged with their N and S poles reversed;

the magnetizable member is disposed between the two magnets; and

there are four flux switches, SW**1**-SW**4**, two between each end of the member and the poles of each magnet.

14. The electrical generator of claim **12**, wherein:

the first magnet has north and south poles, N**1** and S**1**;

the second magnet has north and south poles, N**2** and S**2**;

the member has two ends A and B;

SW**1** is between N**1** and A;

SW**2** is between A and S**2**;

SW**3** is between N**2** and B;

SW**4** is between B and S**1**; and

further including control circuitry operative to:

a) activate SW**1** and SW**4**, then

b) activate SW**2** and SW**3**, and

c) repeat steps a) and b) on a sequential basis.

15. A method of generating electrical current, comprising the steps of:

providing a magnetizable member with an electrically conductive coil wound therearound; and

sequentially reversing the flux from a permanent magnet through the member, thereby inducing electrical current in the coil.

16. The method of claim **15**, further including the step of using at least a portion of the electrical current induced in the coil to sequentially reverse the flux from the permanent magnet through the member.

17. The method of claim **15**, further including the step of sequentially reversing the flux from a plurality of permanent magnets through the member, thereby inducing electrical current in the coil.

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