Title: METHODS AND APPARATUSES RELATED TO ENERGY PRODUCTION AND TRANSMISSION

Abstract: The present invention provides methods and apparatuses related to the generation and transmission of electrical energy. Embodiments of the present invention provide linear generators, as defined and described herein. Embodiments of the present invention provide towers and tower base sections suitable for use with electrical generators and with electrical transmission lines. Embodiments of the present invention provide methods of transmitting and generating electrical power. Embodiments of the present invention provide an electrical generation and transmission system, comprising one or more electricity generators each configured to support and interface electrical power with an electrical transmission line. Embodiments of the present invention provide electrical generation and transmission systems, comprising two or more wind turbine systems, each comprising a tower configured to support a wind turbine generator and to support electrical transmission lines, and a wind turbine generator mounted with the tower; and an electrical power transmission line mounted with the towers and configured to transmit electrical power along the transmission line and to interface electrical power with the wind turbine generators.
Methods and Apparatuses Related to Energy Production and Transmission

Technical Field

[0001] This application relates to the field of production and transmission of energy, and more specifically to the production and transmission of electrical energy.

Background Art

[0002] Adequate, cost-effective, and environmentally-friendly energy supplies are necessary for the modern world. Conventional fossil fuels have many problems, forcing civilization to research and develop alternative energy sources. In order to survive the energy crisis many companies in the energy industry are inventing new ways to extract energy from renewable sources. Many such technologies convert energy into electricity for convenient transmission to users. Electricity is also widely regarded as "clean" energy for applications such as transportation, where hybrid and all-electric vehicles offer attractive alternatives to conventional gasoline or diesel-powered vehicles.

[0003] The conversion of solar energy to electricity using photovoltaic technologies has experienced great progress recently, with increased efficiencies and decreased costs. The conversion of wind energy to electricity has also experienced great progress, with wind farms being used for commercial electricity production. Wind and solar generation, however, each require that the generators be placed where environmental conditions are most favorable. Photovoltaic systems generally must be placed where there is ample sunshine for greatest cost effectiveness. Wind turbines generally must be placed where there is sufficient and reliable wind for greatest cost effectiveness. The most desirable locations, unfortunately, are often not near the largest consumers of electricity or near connection points to the electricity transmission network (the "power grid" or just the "grid"). Also, both photovoltaic and wind generators are generally not amenable to generation of large amounts of electricity at a single site, as is the case with conventional power plants. Instead, the photovoltaic panels and wind turbines are commonly distributed over a large area. Consequently, the adoption of such technologies is dependent on cost-effective transmission of the generated electricity to users or grid connection points. Other proposed alternative energy generation methods, for example conversion of tidal energy, geothermal energy, and others, have similar characteristics and therefore are also sensitive to the availability of cost-effective transmission of the generated electricity to users or grid connection points.

[0004] Typically, electrical power transmission is between the power plant and a substation near a populated area. Electricity distribution is the delivery from the substation to the consumers. Electric power transmission allows distant energy sources (such as hydroelectric, nuclear, fossil fuel, solar, wind, or other types of power plants) to be connected to consumers in population centers, and may allow exploitation of low-grade fuel resources that would otherwise be too costly to transport to
generating facilities, and energy sources such as solar and wind that are by their nature not
transportable. Due to the large amount of power involved, transmission normally takes place at high
voltage (110 kV or above). Electricity is usually transmitted over long distance through overhead
power transmission lines. Underground power transmission is commonly used only in densely
populated areas because of its high cost of installation and maintenance, and because the high
reactive power produces large charging currents and difficulties in voltage management.

[0005] Conventional electrical transmission technology incurs energy losses due to the resistance in
the transmission lines, and costs to install and maintain the lines, and costs due to acquisition of land
for easements to route the lines. Companies that provide electrical transmission facilities model and
manage their lines and power transmission closely to optimize their cost-effectiveness. Installing
new lines is very expensive, and is only justified by a need to transmit large amounts of electrical
power through the new line. Consequently, many otherwise promising sites for sources such as
solar, wind, tidal, and geothermal are not developed, since the relatively low power output,
distributed generation characteristics, and remote locations do not justify the cost of installing new
transmission lines. Some industry experts believe that the key to adoption of alternative electrical
generation technologies is in cost-effective transmission technologies.

Disclosure of Invention

[0006] Embodiments of the present invention provide linear generators, as defined and described
herein. Embodiments of the present invention provide towers and tower base sections suitable for
use with electrical generators and with electrical transmission lines. Embodiments of the present
invention provide methods of transmitting and generating electrical power.

[0007] Embodiments of the present invention provide an electrical generation and transmission
system, comprising one or more electricity generators each configured to support and interface
electrical power with an electrical transmission line.

[0008] Embodiments of the present invention provide electrical generation and transmission
systems, comprising two or more wind turbine systems, each comprising a tower configured to
support a wind turbine generator and to support electrical transmission lines, and a wind turbine
generator mounted with the tower; and an electrical power transmission line mounted with the
towers and configured to transmit electrical power along the transmission line and to interface
electrical power with the wind turbine generators.

[0009] Embodiments of the present invention provide an electrical generator and transmission
system, comprising a support tower as described herein, an electrical generator mounted with the
support tower, an interface between the electrical generator and an electrical transmission line
mounted with the tower.
[0010] Embodiments of the present invention provide support towers comprising an elongated member comprising 6 hexagonal elements, joined such that a central hexagonal space is created, and having a foundation interface at one end and an electrical generator interface at another end.

[0011] Embodiments of the present invention provide support towers comprising an elongated member having a roughly hexagonal cross-section, with intermediate elements extending from each vertex of the hexagon to an axis roughly along the center of the elongated member, and having a foundation interface at one end and an electrical generator interface at another end.

[0012] Embodiments of the present invention provide support towers comprising a plurality of roughly cylindrical members, mounted with each other to form an elongated member; and a mounting interface at one end of the elongated member suitable for interfacing with a foundation, and a mounting interface at another end of the elongated member suitable for interfacing with an electrical generator.

[0013] Embodiments of the present invention provide an electrical generation and transmission system, comprising a plurality of electrical generator stations each comprising an electrical generator mounted with a generator tower, wherein the generator tower comprises features adapted to support an electrical transmission line; a plurality of transmission towers, each comprising features adapted to support an electrical transmission line; wherein the electrical generation stations and transmission towers are disposed in an arrangement extending from a start location to an end location; and an electrical transmission line mounted with the generator towers and the transmission towers such that electricity can be communicated between the start and end locations.

[0014] In some such embodiments, one or more transformers can be placed in communication with an electrical generator and with the electrical transmission line such that the transformer communicates electrical energy therebetween. In some embodiments, such transformers can mount with a single electrical generator. In some such embodiments, such transformers can mount with a plurality of electrical generators. Embodiments of the present invention can include wind turbine generators, photovoltaic generators, and biomass generators.

[0015] Embodiments of the present invention can provide an electrical generation and transmission system that also comprises an energy storage facility.

[0016] Embodiments of the present invention can comprise generator stations that are disposed in a body of water and that extend above the body of water such that an electrical transmission line and electrical generator are supported above the water. Embodiments of the present invention provide electrical energy dispensing outlets disposed with electrical generator stations.

[0017] Advantages and novel features will become apparent to those skilled in the art upon examination of the following description or can be learned by practice of the invention. The
advantages of the invention can be realized and attained by means of the methods, example embodiments, and combinations specifically described in the disclosure and in the appended claims.

Brief Description of Drawings

[0018] Fig. 1 is a schematic illustration of conventional transmission system.

Fig. 2 is a schematic illustration of a conventional transmission line.

Fig. 3 is a schematic illustration of an example linear generator according to the present invention.

Fig. 4(a-e) are schematic illustrations of example embodiments of a tower base suitable for use with a linear generator according to the present invention.

Fig. 5 is a schematic illustration of design considerations associated with linear generator towers according to the present invention.

Fig. 6(a-g) are schematic illustrations of example linear generator embodiments according to the present invention.

Fig. 7 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water.

Fig. 8 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water.

Fig. 9 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water.

Fig. 10 is a schematic illustration of an embodiment of the present invention including energy storage capability.

Description of the Invention

[0019] The following description and examples illustrate some exemplary embodiments of the disclosed invention in detail. Those of skill in the art will recognize that there are numerous variations and modifications of this invention that are encompassed by its scope. Accordingly, the description of a certain exemplary embodiment should not be deemed to limit the scope of the invention or its embodiments.

[0020] Fig. 1 is a schematic illustration of conventional transmission system. See, e.g., http://www.osha.gov/SLTC/etools/electric_pwer/illustrated_glossary/index.html visited Oct. 15, 2008. A typical power generation, transmission and distribution system has these components:

1. Power Generation Plants
2. Substations
   a. Step-up Transmission Substation
   b. Step-down Transmission Substation
   c. Distribution Substation
d. Underground Distribution Substation

3. Transmission Lines
   a. Overhead Transmission Lines
   b. Subtransmission Lines
   c. Underground Transmission Lines

4. Distribution Systems
   a. Industrial Customer
   b. Commercial Customer
   c. Residential Customer
   d. Transportation Customer

[0021] The term "power generation plant" as used herein is a broad term, and is to be given its ordinary and customary meaning to a person of ordinary skill in the art (and is not to be limited to a special or customized meaning) and refers without limitation to a facility designed to produce electric energy from another form of energy, such as coal, natural gas, nuclear, hydroelectric, solar, geothermal, tidal, and wind.

[0022] The term "substation" as used herein is a broad term, and is to be given its ordinary and customary meaning to a person of ordinary skill in the art (and is not to be limited to a special or customized meaning) and refers without limitation to a high-voltage electric system facility, used to switch generators, equipment, and circuits or lines in and out of a system, and also used to change AC voltages from one level to another, and/or change alternating current to direct current or direct current to alternating current. Some substations are small with little more than a transformer and associated switches. Others are very large with several transformers and dozens of switches and other equipment. A step-up transmission substation receives electric power from a nearby generating facility and uses a large power transformer to increase the voltage for transmission to distant locations. A transmission bus is used to distribute electric power to one or more transmission lines. There can also be a tap on the incoming power feed from the generation plant to provide electric power to operate equipment in the generation plant. Step-down transmission substations are located at switching points in an electrical grid. They connect different parts of a grid and are a source for subtransmission lines or distribution lines. The step-down substation can change the transmission voltage to a subtransmission voltage, usually 69 kV. The subtransmission voltage lines can then serve as a source to distribution substations. Sometimes, power is tapped from the subtransmission line for use in an industrial facility along the way. Otherwise, the power goes to a distribution substation. Distribution substations are located near to the end-users. Distribution
substation transformers change the transmission or subtransmission voltage to lower levels for use by end-users. Typical distribution voltages vary from 34,500Y/19,920 volts to 4,160Y/2400 volts.

[0023] The term **transmission lines** as used herein is a broad term, and is to be given its ordinary and customary meaning to a person of ordinary skill in the art (and is not to be limited to a special or customized meaning) and refers without limitation to apparatuses that carry electric energy from one point to another in an electric power system. They can carry alternating current or direct current or a system can be a combination of both. Also, electric current can be carried by either overhead or underground lines. Some characteristics that distinguish transmission lines from distribution lines are that they are operated at relatively high voltages, they transmit large quantities of power and they transmit the power over large distances. Overhead AC transmission lines generally carry 3-phase current. The voltages vary according to the particular grid system they belong to. Transmission voltages vary from 69 kv up to 765 kv. The DC voltage transmission tower has lines in pairs rather than in threes (for 3-phase current) as in AC voltage lines. One line is the positive current line and the other is the negative current line. Subtransmission lines carry voltages reduced from the major transmission line system. Typically, 34.5 kv to 69 kv, this power is sent to regional distribution substations. Sometimes the subtransmission voltage is tapped along the way for use in industrial or large commercial operations. Some utilities categorize these as transmission lines. Underground transmission lines are more common in populated areas. They may be buried with no protection, or placed in conduit, trenches, or tunnels.

[0024] The term **distribution system** as used herein is a broad term, and is to be given its ordinary and customary meaning to a person of ordinary skill in the art (and is not to be limited to a special or customized meaning) and refers without limitation to an apparatus or system that originates at a distribution substation and includes the lines, poles, transformers and other equipment needed to deliver electric power to the customer at the required voltages. Most industries need 2,400 to 4,160 volts to run heavy machinery and usually their own substation or substations to reduce the voltage from the transmission line to the desired level for distribution throughout the plant area. They usually require 3-phase lines to power 3-phase motors. Commercial customers are usually served at distribution voltages, ranging from 14.4 kv to 7.2 kv through a service drop line which leads from a transformer on or near the distribution pole to the customer's end use structure. They may require 3-phase lines to power 3-phase motors. The distribution electricity is reduced to the end use voltage (120/240 volts single phase) via a pole mounted or pad-mounted transformer. Power is delivered to the residential customer through a service drop line which leads from the distribution pole transformer to the customer's structure, for overhead lines, or underground. Currently the only electric transportation systems are light rail and subway systems. A small distribution substation
reduces the local distribution voltage to the transportation system requirements. The overhead lines supply electric power to the transportation system motors and the return current lines are connected to the train tracks.

[0025] As can be seen from publicly-available illustrations of the power distribution grid in almost any country, there are large areas where there has been no need for electrical transmission lines. Consequently, alternative energy generators in those areas would not be able to deliver generated electricity to users, making large parts of the world effectively unavailable for implementation of such alternative energy generators, including regions that may be especially well-suited to particular alternative energy generation technologies.

[0026] Fig. 2 is a schematic illustration of an exemplary conventional transmission line. Towers (also called pylons) are typically truss structures, designed to carry both the dead weight of the electrical lines as well as dynamic loads due to wind and storms. Each tower generally comprises a trussed tower, with cross arms mounted with the tower. Insulators mount with the cross arms and support the electrical wires or conductors. Spacers and dampers mount with the wires and the towers. Conventional truss-type towers for transmission lines are generally limited to about 1600 feet between towers, due in part to considerations such as the weight of the wires to be supported and manufacturing and installation constraints. Other designs are also used, with similar purposes and constraints.

[0027] Fig. 3 is a schematic illustration of an example linear generator according to the present invention. The Term "linear generator" is intended to be a broad term, and not limited to any specific example embodiment, but rather to include all arrangements and configurations of generators and transmission lines described or enabled herein. First and second wind generator stations are shown; the invention contemplates other generator types such as photovoltaic, tidal, geothermal, and others such as those described elsewhere herein and including any applicable generation technology, and contemplates any number of generator stations. Each generator station provides for electrical energy generation and provides support for transmission lines. The figure shows a linear arrangement for simplicity of presentation, and is referred to as a "linear" generator for ease of reference; however, the invention contemplates curved or angled arrangements, and other network topologies such as interconnected webs (in some such topologies, not all of the generator stations need to also support transmission lines). The figure shows a conventional transmission tower positioned intermediate to the two generators. Towers supporting wind turbines can be placed about 5 to 7 blade diameters apart; for currently available 3MW turbines, towers can be about 1 mile apart, for currently available 1.5MW turbines, towers can be closer together due to smaller blade diameter. If the desired spacing between turbine towers is greater than that desired
for transmission line support, then conventional towers (e.g., truss-type or other designs suitable for local use) can be placed between the turbine towers to provide the necessary support for the transmission line.

[0028] Each generator station comprises a tower having a base that is suitable for carrying the loads required for an electrical transmission line as well as the loads required by the particular generator. The base of each generator station is accordingly significantly different than that generally required for either a conventional generator application or a conventional transmission line application, as discussed in more detail elsewhere herein. The intermediate transmission tower is not required in all embodiments of the present invention, but can be useful in embodiments where the generator stations require a minimum separation greater than is desirable for transmission line support. As an example, some wind turbines must be separated from neighboring turbines by a minimum separation, which separation can in some instances be greater than the free span of electrical transmission line desired for cost-effective operation. In such embodiments, one or more intermediate transmission towers can facilitate connection of the transmission line between such generator stations. Each generator station connects with the transmission line, such that the overall system provides both transmission of electrical power and generation of electrical power. Such a linear generator can be connected to a conventional electrical grid in various manners, for example through another transmission line or directly to a substation. The combination of generation and transmission in the same system can provide many unprecedented advantages. As an example, land use is reduced by the combination of generation and transmission in a single easement. As another example, the cost of the transmission line can be offset by the value of the electrical power generated. As another example, the cost of installing generator station towers can be recouped in two ways—once from their use in generating electricity, and a second time in their use as part of the transmission line. Each generator station can have its own interface to the transmission line (e.g., a step up transformer), or groups of generator stations can share a single interface to the transmission line. Conventional transmission line easements in the U.S. are often 110 feet wide. Embodiments of the present invention can be installed in such easements—while the blades of some wind turbines might overhang the easement, they can be rotated to within the easement if service is required.

[0029] Fig. 4(a-d) are schematic illustrations of cross-sections of example embodiments of a tower base section suitable for use with a linear generator according to the present invention, where the "tower base section" is the portion of the tower that supports both the transmission line and the generator; the portion above the transmission line can be a tower typical for use with the particular generator in use. In each example, the tower base can be of uniform cross-section, or can change (e.g., taper), as desired by considerations such as cost of fabrication, materials costs, transportation costs, and the like.
difficulties and costs, local conditions, and effect on wind and other loads. In the example of Fig. 4a, a roughly tubular base cross-section is formed by the annular space between inner and outer circles. The tubular cross-section can be formed of a metal sheet rolled into a cylinder, or as a fill material such as concrete disposed between inner and outer forms.

[0030] In the example of Fig. 4b, 6 triangles combine to form a single hexagonal tower base cross-section. The cross-section can be formed, as an example, by forming 6 members with triangular cross-sections and then joining them together, or, as another example, by forming three members with triangular cross-sections and joining them with external plates that form the remaining intermediate triangular cross-sections, or, as another example, by forming a member with a hexagonal cross-section and mounting intermediate webs that together make the individual triangles in the cross-section.

[0031] In the example of Fig. 4c, 7 members with circular cross-sections have been joined to form a tower base. The members can be formed as individual cylinders and then joined on site, as an example.

[0032] In the example of Fig. 4d, 6 members with hexagonal cross-sections have been joined together (leaving an inner space that also has a hexagonal cross-section). The individual members can be formed, as an example, from metal sheets bent into the hexagonal shape. The members can be joined on-site, as an example. In some applications, a suitable tower base can be formed with hexagonal members formed of ½" or 1" thick bent and welded steel, joined together on-site, with flanges or other fittings appropriate to the foundation and the remainder of the tower. In each example, a ladder for access to the generator can be provided in any of the open spaces in the cross-section. Also, electrical conductors for transmission of power from the generator to the transmission line or to a stepup transformer can be routed through any of the open spaces in the cross-section. Access ladders and electrical conductors can be routed outside the cross-section if desired, although routing inside the cross-section can allow the tower base section to provide a measure of safety and security to the access ladder and electrical conductor. Other cross-sections can be suitable for use with the present invention, depending on considerations such as weight, cost, strength, and material availability.

[0033] The end of the tower base section that mounts with a foundation can be configured based on the requirements of the foundation, for example by welding or otherwise attaching a circular flange to the tower base section with holes spaced as is conventionally done in utility towers, or for example by forming other attachment or embedment features specific to the foundation system used. The end of the tower base section that mounts with the upper portion of the tower can be configured based on the requirements of the generator. Some generators have tower systems
designed for use with the generator; the upper end of the tower base section can be configured with flanges or other mounting features that interface with appropriate features of the middle or upper portions of the existing generator tower system.

[0034] The tower base section can also have mounting features to accommodate electrical conductors of the transmission line. Such supports can be, as one example, formed as part of the tower base section itself. As another example, supports can be formed with a keyed end that can be mounted in a corresponding feature (e.g., a tapered slot or keyhole) in the tower base section in the field. As another example, supports can be formed offsite and welded to the tower base section on site. As another example, supports can be welded to the tower base section or inserted into corresponding features of the tower base section and then suspended at their ends from cables attached higher up on the tower base section. Other means of supporting electrical wires from such towers can be adapted from those described in Transmission Line Reference Book, 345 kv and above/Second Edition; Electric Power Research Institute; Copyright 1982 by the Electric Power Research Institute, Inc.; and Overhead Power Lines. Planning, Designing, Construction; Springer-Verlag Berlin Heidelberg 2003; Printed in Germany; each of which is incorporated herein by reference.

[0035] In the example of Fig. 4e, a truss structure is configured to mount with or surrounding a base section like those described herein, or like those currently available for use with generators such as wind turbines. The truss frame, unlike those in current use in transmission lines, can wrap around the tower base and derive a portion of its strength therefrom. The combination of the wrap-around truss frame with the bottom tower section can provide a composite tower base section suitable for use in a linear generator according to the present invention. While the figure shows a truss that is wider at the base than the top, when combined with a turbine tower the truss can be narrower at the base than at the top since the turbine tower and turbine tower foundation can provide additional support. The truss can be made to lock to the tower foundation. Such add-on truss structures can be readily adapted to mount with a variety of different turbine towers and turbine tower foundations.

[0036] Fig. 5 is a schematic illustration of some design considerations associated with linear generator and associated towers according to the present invention. A tower base section interfaces with a foundation that anchors the tower to the ground. The tower base section must effectively withstand (or, transmit to the foundation) loads such as the weight of the electrical conductors in the transmission lines, for example on the order of 250,000 pounds for double circuit 500kV lines; dynamic loads such as wind from the transmission lines; dynamic loads such as wind impinging on the towers and the generator; the weight of the generator (e.g., wind turbine or photovoltaic
system) and the upper sections of the tower, for example on the order of 120 tons; and, with a wind
generator, the wind load associated with the turbine itself. Accordingly, the foundation and tower
base section must satisfy more demanding requirements than are required for towers that need only
support either a transmission line or a generator. The greater overall strength of a tower such as
those described as compared with conventional towers (e.g., truss-type towers, or towers
conventionally used with wind turbines) can provide increased resistance to damage from
environmental hazards. As an example, an embodiment with hexagonal elements as in Fig. 4d can be
designed to withstand a 6.2 magnitude earthquake.

[0037] Fig. 6(a-g) are schematic illustrations of example linear generator embodiments according to
the present invention. The illustrations are meant as examples only; other arrangements of
generators, transformers, types of generators, and connection patterns can also be realized within
the present invention. In the example of Fig. 6a, a plurality of wind turbine generators (4 in the
figure) mount each with a tower as described herein. The towers also provide a transmission line
capability that is continued via a conventional tower (at the right of the figure). The wind turbine
generators are connected such that their combined output matches the requirements of the
transmission line so that no step up transformer is needed.

[0038] In the example of Fig. 6b, a plurality (4 in the figure) of wind turbine generators mount each
with a tower as described herein. The towers also provide transmission line capability that is
continued via a conventional tower (at the right of the figure). The wind turbine generators are
connected together via a second electrical line and share a transformer, which then connects the
power output from the wind turbine generators to the main transmission line.

[0039] In the example of Fig. 6c, a plurality of different generators (in the figure, two wind turbine
generators and two photovoltaic arrays, although various types of generators can be suitable) each
mount with a tower as described herein. Different generators can utilize different tower designs,
recognizing different weight, wind, and other design characteristics. Each generator has its own step
up transformer to interface the generator output to a transmission line carried by the towers. The
transmission line is continued via a conventional tower (at the right of the figure).

[0040] In the example of Fig. 6d, two wind turbine generators mount with towers as described
herein, and, together with a plurality of conventional towers, provide a transmission line. Additional
generators (wind turbines in the figure, although various other types of generators can be suitable)
are disposed off the main transmission line route. These additional generators can mount with
towers as described herein, or with towers as previously used with such generators. The additional
generators connect with shared transformers local to the generators along the transmission line,
allowing the power output from all the generators to be interfaced to the transmission line.
[0041] In the example of Fig. 6e, a plurality of generators (wind turbine generators in the figure, although various types of generators can be suitable) each mount with a tower as described herein. The generators are grouped (groups of three in the figure), with a single transformer shared among each group. The generators each connect to one of the group transformers, which then interface the generated power to the transmission line.

[0042] In the example of Fig. 6f, a plurality of generators each mount with a tower as described herein. Each generator has its own transformer for interface to a transmission line carried by the towers and by conventional towers. A second generator, in the figure a photovoltaic array although various other types of generators can be suitable, mounts off the main transmission line, and connects via a second electrical line to the transmission line. The combination of generators and transmission line provided by the present invention allows electrical power from the remote photovoltaic array to be economically brought to consumers.

[0043] In the example of Fig. 6g, a linear generator is disposed between two cities. The linear generator comprises a plurality of wind turbine towers with truss-type towers disposed therebetween. In regions close to the cities, smaller wind turbines (e.g., 1.5MW turbines) can be used to reduce any disadvantages of the turbines such as visual impact, airflow disturbance, interference with aircraft, noise, etc. In regions away from the cities, larger turbines (e.g., 3MW turbines) are used since the relatively low adjacent population density does not require the smaller turbines.

[0044] Fig. 7 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water such as a river, canal, or ocean, for example across a river or between two islands. A plurality of generators each mount with a tower as described herein. Note that the tower and foundation for such applications will also require ability to withstand hydraulic forces in the water, and provide additional height above the base to clear the water surface. The added generation capacity provided by the present invention can help justify the cost of the foundations and towers, making such transmission lines more cost-effective than conventional undersea lines.

[0045] Fig. 8 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water such as a river, canal, or ocean, for example across a river or between two islands. A plurality of generators each mount with a tower as described herein. Note that the tower and foundation for such applications will also require ability to withstand hydraulic forces in the water, and provide additional height above the base to clear the water surface. The added generation capacity provided by the present invention can help justify the cost of the foundations and towers, making such
transmission lines more cost-effective than conventional undersea lines. A portion of the line crossing the water is implemented as an underwater transmission line, such as those currently in use, to facilitate boat traffic.

[0046] Fig. 9 is a schematic illustration of an example linear generator according to the present invention implemented in an application where the transmission line is used to cross a body of water such as a river, canal, or ocean, for example across a river or between two islands. The figure illustrates several different types of generator stations; in some applications a specific type of generator might be best suited for the local conditions. In the figure, an undersea generator station is mounted proximal the foundation of an above-water transmission tower. Such an undersea generator can be, for example, tidal, temperature, or current driven. Next, a generator on the surface of the water mounts with its own foundation and provides a link in the transmission line. Such a surface generator can be, for example, tidal or current driven. Next, an undersea transmission line connects with another undersea generator. The transmission line then connects with a land-based transmission line.

[0047] In such across-water applications, the various transmission stations can also be used to provide power directly. For example, electric boat recharging stations can be implemented at such a tower. As another example, sonar systems, scientific projects, and industrial equipment can be powered directly by such towers, reducing the need for fossil fuel engines and batteries. In land-based systems, similar benefits can be obtained, for example by implementing charging stations for electric vehicles, or by powering railroad or other transportation systems from the transmission line and the corresponding nearby generators.

[0048] Fig. 10 is a schematic illustration of an embodiment of the present invention including energy storage capability. A linear generator such as those described elsewhere herein is disposed between two cities, as an example. Along the linear generator is placed an energy storage system, allowing energy generated during certain periods (i.e., periods of high generation relative to demand) to be stored for use during other periods (i.e., periods of low generation relative to demand). In the figure, the storage facility comprises an electrically powered hydrogen generator coupled to a hydrogen storage system, which is in turn coupled to a hydrogen powered electricity generator. During net storage conditions, surplus electricity is used to drive the hydrogen generator to produce hydrogen which is stored in the storage system. During net consumption periods, the stored hydrogen is used to drive the electricity generator to produce additional electricity as required. The hydrogen generation system can comprise an electrolysis system as an example. The electrical generator can comprise an internal combustion generator or a fuel cell, as examples. Other energy storage systems can be used, for example compressed gas storage, mechanical energy
storage such as flywheels, and batteries. The energy storage facility can be located in a region best suited to its needs, for example remote from population areas or near beneficial natural features, since the linear generator according to the present invention provides cost effective energy transport.

[0049] Embodiments of the present invention can also provide increased resistance to damage due to lightning. Lightning strikes are a principal cause of damage to conventional truss towers in current transmission lines. Wind turbines, on the other hand, can be designed to accommodate lightning strikes. Lightning strikes with the present invention are likely to hit the turbines (due to their greater height relative to the transmission line); the regular spacing makes it more likely that any particular lightning event will involve a wind turbine rather than the transmission line or an intermediate truss-type tower. Lightning strikes are therefore accommodated safely with less chance of damage to the transmission line.

[0050] Embodiments of the present invention can provide remote monitoring of the system along with fault detection and tolerance. Each tower (turbine or truss, although the greater height of the turbine tower can be advantageous) can have monitoring equipment mounted with it, for example cameras that allow remote visual inspection of the tower and the transmission lines extending therefrom. As another example, each turbine tower can have monitoring systems that allow remote monitoring of the performance of (and maintenance requirements of) the turbine or other generator, the transmission line, or both. Faults or sabotage can thereby be prevented or detected, and required maintenance can be optimally performed. Embodiments of the present invention can also provide for fault tolerant operation, since loss of any single generator doesn't necessarily cause the rest of the system to fail. As an example, consider the example in Fig. 6g assuming the 3MW turbine in the center of the figure fails or is attacked. The transmission line between the two cities can be disrupted, and the total generating capacity of the linear generator is reduced. However, each city still has the benefit of the portion of the linear generator still in operation that lies between the failed turbine and the city. So, the city at the top right still has the benefit of the two 1.5MW turbines; the city at the lower left still has benefit of the 3MW and 1.5MW turbines nearest it.

[0051] The particular sizes and equipment discussed above are cited merely to illustrate particular embodiments of the invention. It is contemplated that the use of the invention can involve components having different sizes and characteristics. It is intended that the scope of the invention be defined by the claims appended hereto. The above description discloses several methods and materials of the present invention. This invention is susceptible to modifications in the methods and materials, as well as alterations in the fabrication methods and equipment. Such modifications will
become apparent to those skilled in the art from a consideration of this disclosure or practice of the
invention disclosed herein. Consequently, it is not intended that this invention be limited to the
specific embodiments disclosed herein, but that it cover all modifications and alternatives coming
within the true scope and spirit of the invention.
Claims
What is claimed is:
1. Methods and apparatuses substantially as described herein.
2. Linear generators substantially as described herein.
3. Towers and tower base sections substantially as described herein.
4. Methods of transmitting and generating electrical power substantially as described herein.
5. An electrical generation and transmission system, comprising one or more electricity generators, each configured to support and interface electrical power with an electrical transmission line.
6. An electrical generation and transmission system, comprising two or more wind turbine systems, each comprising a tower configured to support a wind turbine generator and to support electrical transmission lines, and a wind turbine generator mounted with the tower; and an electrical power transmission line mounted with the towers and configured to transmit electrical power along the transmission line and to interface electrical power with the wind turbine generators.
7. An electrical generator and transmission system, comprising a support tower as in any of figures 4a through e, an electrical generator mounted with the support tower, an interface between the electrical generator and an electrical transmission line mounted with the tower.
8. A support tower for an electrical generator, comprising 6 elongated members each having a roughly hexagonal cross-section, wherein the 6 members are mounted with each other such that an inner section is formed having a roughly hexagonal cross-section, and a mounting interface at one end of the 6 elongated members when mounted with each other suitable for interfacing with a foundation, and a mounting interface at another end of the 6 elongated members when mounted with each other suitable for interfacing with an electrical generator.
9. A support tower for an electrical generator, comprising an elongated member having a roughly hexagonal cross-section, and 6 reinforcing members mounted internal to the hexagonal cross-section and extending from a vertex on the hexagonal cross-section to an axis roughly in the center of the hexagonal cross-section; and a mounting interface at one end of the elongated member suitable for interfacing with a foundation, and a mounting interface at another end of the elongated member suitable for interfacing with an electrical generator.
10. A support tower for an electrical generator, comprising a plurality of roughly cylindrical members, mounted with each other to form an elongated member; and a mounting interface at one end of the elongated member suitable for interfacing with a foundation, and a mounting interface at another end of the elongated member suitable for interfacing with an electrical generator.
11. An electrical generation and transmission system, comprising:
   a. A plurality of electrical generator stations each comprising an electrical generator mounted with a generator tower, wherein the generator tower comprises features adapted to support an electrical transmission line;
   b. A plurality of transmission towers, each comprising features adapted to support an electrical transmission line;
   c. Wherein the electrical generation stations and transmission towers are disposed in an arrangement extending from a start location to an end location;
   d. An electrical transmission line mounted with the generator towers and the transmission towers such that electricity can be communicated between the start and end locations.

12. An electrical generation and transmission system as in claim 11, further comprising one or more transformers, each in electrical communication with one or more electrical generator stations and in electrical communication with the electrical transmission line, and adapted to interface electrical power from the electrical generator stations to the electrical transmission line.

13. An electrical generation and transmission system as in claim 12, wherein each transformer is in electrical communication with exactly one electrical generator station.

14. An electrical generation and transmission system as in claim 12, wherein each transformer is in electrical communication with more than one electrical generator station.

15. An electrical generation and transmission system as in claim 11, wherein at least one electrical generator comprises a wind turbine generator.

16. An electrical generation and transmission system as in claim 11, wherein at least one electrical generator comprises a photovoltaic generator.

17. An electrical generation and transmission system as in claim 11, wherein at least one electrical generator comprises a biomass generator.

18. An electrical generation and transmission system as in claim 11, further comprising an energy storage facility in electrical communication with the electrical transmission line, or an electrical generator station, or a combination thereof.

19. An electrical generation and transmission system as in claim 11, wherein at least one electrical generator station comprises a foundation and generator tower configured to mount within a body of water and extend upward therefrom such that the electrical generator and electrical transmission line are disposed above the surface of the water.

20. An electrical generation and transmission system as in claim 11, further comprising one or more electrical energy dispensing outlets in electrical communication with an electrical generator, the electrical transmission line, or a combination thereof.
21. A method of producing and transmitting energy, comprising providing an electrical generation and transmission system as in claim 11, accepting electrical energy input at the start location, and communicating electrical energy from the start location and from the electrical generators with the end location.
Typical Pylons in a 400kV Route

Fig. 2