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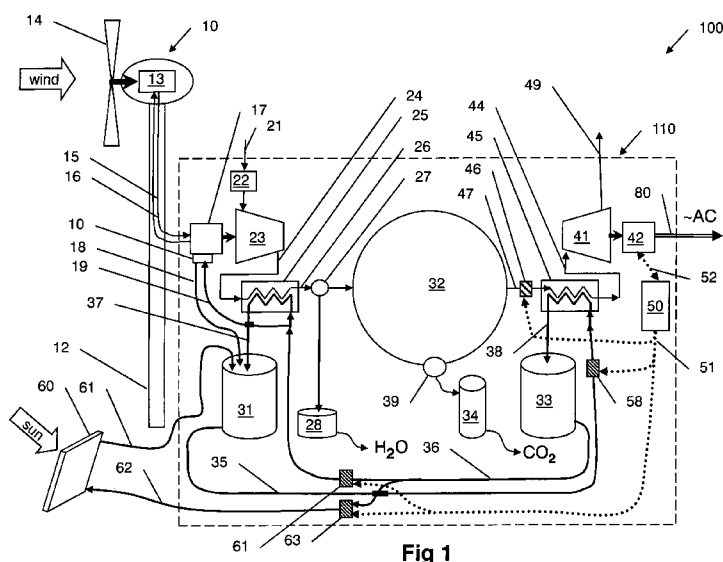


Fig 1

(57) Abstract: A small to medium size system for wing energy harvesting, storing and generating electricity is disclosed. The system uses a wind turbine situated on a mast to capture wind energy and hydraulic power transmission to transmit the energy to a compressor which compresses atmospheric air. Heat generated by the compressing of air is removed by heat exchanging with water and stored in hot water container. The cooled compressed air is stored in a compressed air tank. On demand, the compressed air is released and heated by the stored hot water, then used to power a generator using a pneumatic motor. Solar heater is used to further heat the water. Water and liquefied CO₂ are removed from the compressed air. Hydrostatic, variable displacement power transmission system allows the wind turbine to rotate at speeds proportional to wind velocity and to capture the maximum possible energy from light and fast winds.

A SYSTEM FOR WIND ENERGY HARVESTING AND STORAGE USING COMPRESSED AIR AND HOT WATER

5

FIELD OF THE INVENTION

The present invention relates to a system and method for wind energy harvesting, storage of harvested energy in compressed air and hot water, and
10 controlled conversion of the energy to grid rated electric power using modified turbines.

BACKGROUND OF THE INVENTION

15

An increasing number of people in developed economies convert their home energy consumption from non-renewable energy sources to sustainable, clean ones. Three main technologies offer home-based renewable energy source: solar photovoltaic (PV) cells, solar thermal electricity, and wind
20 turbines.

However, the cost of residential solar PV energy (40¢/KWh, excluding incentives) is roughly twice the retail price of electricity in London, and 5-times the average price in the US. While wind-powered electricity may cost less, in the range of 10-15 ¢/KWh in current small-wind (1-100KW) systems, its
25 popularity is still behind that of solar PV, in part because wind is an intermittent, less predictable power resource, which compromises customers' ability to take full advantage of total wind power available, and sell electricity to the main power grid during demand spikes. Moreover, not all winds are suitable for direct generation of electricity: winds that are too strong or too
30 weak cannot be harnessed towards electricity production because they cannot be readily converted into electricity. Clearly, an efficient energy storing mechanism is needed.

Wind turbines technology is one of the most mature technologies for capturing wind energy and conversion to electric power. It is also one of the leading technologies in installed capacity and production costs, compared to other renewable energy sources. Wind turbines technology is competing
5 successfully with more conventional electric power sources such as gas, coal or oil fired electric power stations.

The rate of growth of installed capacity of wind turbines is globally more than 20% per annum. Growth rate is limited by the ability of wind turbines producers to supply systems, and not by the demand. The potential energy
10 from wind worldwide is far higher than the total global demand for electric power. Theoretically it is possible for the whole world to rely on wind power for electricity. However, the uneven distribution of wind sources, geographically and seasonally, makes total reliance on wind energy not feasible.

Storing wind-powered electricity in batteries, however, eliminates the
15 energetic gain in efficiency, because of the power adjustment required (DC to AC conversion). Also, expensive and pollution creating batteries spoil the utterly-green halo of wind-powered electricity. In a market largely putting ecology before economy, this could prove a problematic setback.

Additionally, there is no known and effective solution for using wind
20 which is too light or too strong.

Theoretical efficiency of wind turbine may reach 59%, but in practice only about 25% of the wind energy is actually used.

Application WO09144737; titled "wind turbine system with steady
25 electric power output using air battery"; to Patel Madhusudan Purshottam ; discloses a design of wind turbine system with steady electric output using air battery regardless the rotating speed of the rotor. More particularly the system delivers constant voltage and constant frequency with controllable parameters. the major modules of the system incorporates, a wind powered rotor, air pump
30 to charge air battery, air battery, air motor, electric generator driven by air motor, control components and interface controllers to deliver the power to utility grid or for use as stand alone power station.

Publication number: WO2009061209 (A1); titled "wind turbine with electrical swivel" to Haarberg Per Olav; discloses a wind turbine power production system with a closed loop hydrostatic transmission system for the transfer of mechanical energy from a wind turbine rotor to an electric generator arranged on the ground.

US2006210406A; titled "Wind turbine with hydraulic transmission"; to David McConnell et.al.; discloses a wind turbine includes a closed loop hydrostatic transmission. The rotor is directly coupled to a low-speed high torque hydraulic motor, which is pressure-reversible to act as a pump. A variable displacement, pressure compensated hydrostatic transmission receives the hydraulic fluid output and drives a generator. The hydrostatic transmission and the generator may be compactly located in the nacelle of wind turbine tower.

Application US2009021012A; titled "integrated wind-power electrical generation and compressed air energy storage system "; to Muckle Thomas A and Stull Mark A; discloses a method and apparatus for using wind energy to compress air or pressurize a fluid as a means of storing energy. Compressed air or pressurized fluid is generated directly by the wind turbines, thereby avoiding the energy losses that occur when wind power is used first to generate electricity to run an electrically powered air compressor. The compressed air or pressurized fluid is stored by means of expanding a volume at constant or nearly constant pressure. This method avoids energy losses that would otherwise result from compressional heating; while also allowing lower pressures to be employed, reducing the cost of the containment facility and avoiding the need to locate facilities in geographically favored locations where underground storage is available. The invention permits both large and small-scale storage at low cost per unit of energy stored, thereby avoiding the difficulty of using a highly variable and unreliable source of energy such as the wind for electrical power generation. The invention can be used for generation and storage on land, in shallow near-shore waters and in deep-water locations far from shore.

United States Patent Application 20080047271 ; To Ingersoll Eric; titled "Wind turbine system"; discloses a wind turbine system for producing compressed air from wind energy. The wind turbine harvests energy from wind to produce mechanical energy. A compressor receives mechanical energy from the wind turbine to compress air to an elevated pressure. Thermal energy may be removed from the air, and the air is stored in a storage device, such that the air may be released from the storage device on demand.

SUMMARY OF THE INVENTION

Wind turbines technology is one of the most mature technologies for capturing wind energy and conversion to electric power. It is also one of the leading sources in installed capacity and production costs, compared to other renewable energy sources. Wind turbines technology is competing successfully with more conventional electric power sources such as gas, coal or oil fired electric power stations.

The main obstacle in increasing the extent to which the national or international grid can depend on wind as a source of electric energy is the lack of a built in, cheap and flexible technology to store the energy captured from available wind, and to supply it to the grid according to the demand from users.

One of the potential technologies to store energy from fluctuating sources is Compressed Air Energy Storage (CAES). Using CAES, air is compressed while collecting heat created by the air compression and storing the compressed air and accumulated heat. On demand, the stored compressed air and stored heat are converted to electric energy. However CAES is currently limited to large scale energy production, and depends on the availability of enormous natural or man made cavities, such as abandoned mines.

The present invention provides a system for energy storage that is a complete and stand alone system, which captures stores and converts wind energy to electrical energy. The claimed invention may be designed for small

to medium scale use, although it can be upgraded to larger systems with relevant modifications.

According to one exemplary embodiment of the present invention, the system comprises a wind turbine, typically 4m in diameter on a 10m mast, and is able to produce an annual average of 2.5 kW captured energy, under an average annual wind speed of 8.5 m/sec. with peak capturing capacity up to 60 kW. The system is able to store energy equivalent to 150 kWh of power, or 540 MJ and to supply electricity up to a peak demand of 10kW. This energy is stored for example in a 1.2 cubic m compressed air tank capable of holding pressures up to 300 bars, and water tanks of 1.4 cubic m.

The inventive system efficiently stores wind power as compressed air, thus it renders wind power predictable and reliable. Customers can always tell the amount of energy at their disposal by reading the pressure. For example, the system allows customers use the power stored on a windy night to cool a sultry afternoon.

The invention provides small to medium wind turbine for on-grid and off-grid applications.

The process for converting wind energy to electricity is similar to an adiabatic process, by the fact that heat, which is created in the process of transferring and converting kinetic wind energy to compressed air, is kept separately in water and is used to heat the compressed air at during its expansion. Capturing lost heat, which is created during transfer of energy from the blades and during air compression, and reusing that heat to heat up the air at the expansion phase of the compressed air increases efficiency.

The system can produce small amounts of liquid CO₂, as an additional high value product.

By desiccating the compressed air, the system produces small amounts of water, which can be used to supplement water lost in the process, and remove the need to continuously supply the system with water. Excess water could be used, in arid locations, for small agriculture or nature protection applications.

The system according to the claimed invention can be installed in any location, with favorable wind conditions. For example, the system according to the claimed invention can be installed on rooftops, or in the vicinity of small electric power users to supply local demand for electricity. The system
5 according to the claimed invention can also be installed independent of the grid, to supply electric power to remote locations. The system according to the claimed invention can also be installed by small entrepreneurs, who will sell electricity to the grid .

10 In some embodiments, energy utilization efficiency may be close to the theoretical value of 59%.

According to one aspect of the current invention, a system for harvesting and storing wind energy is provided, the system comprising : a wind turbine powered by the atmospheric wind; a compressor, powered by said
15 wind turbine, compressing atmospheric air; a first heat exchanger, removing heat generated by said compressing of atmospheric air and heating cold water; a hot water container, storing said heated water; a compressed air tank, holding said compressed, cooled air; an air demand valve, releasing said cold compressed air from said compressed air tank to a second heat exchanger; a
20 second heat exchanger, receiving hot water from said hot water container, heating said released cold compressed air and cooling said hot water; a cold water container, storing said cooled water; a pneumatic motor, powered by said heated compressed air; and a generator; powered by said pneumatic motor and generating electric power.

25 In some embodiments the wind turbine is a multi-blade wind turbine situated on a mast .

In some embodiments the system further comprising a power transmission, transmitting power from said wind turbine to said compressor .

In some embodiments the power transmission comprises: a hydraulic
30 pump powered by said wind turbine; a hydraulic motor powering said compressor; and hydraulic pipes connecting said hydraulic pump and said hydraulic motor

In some embodiments the hydraulic pump is directly connected to the shaft of said wind turbine.

In some embodiments the hydraulic pump is a hydraulic variable displacement pump.

5 In some embodiments the air compressor is directly attached said wind turbine, and said air compressor is a variable displacement compressor capable of changing the specific volume of air it compressed per cycle.

In some embodiments the system further comprises an additional water heater, heating water to be stored in said hot water container.

10 In some embodiments the additional water heater is a solar heat trap.

In some embodiments the heat generated by at least one of: said hydraulic pump; said hydraulic motor; said compressor; and said generator is used for heating water to be stored in said hot water container.

15 In some embodiments the system further comprises an air desiccator removing water from said compressed air .

In some embodiments the system further comprises carbon dioxide removing unit removing liquefied carbon dioxide from said compressed air .

20 In some embodiments the power transmission comprises a transfer system based on a hydrostatic, variable displacement pump attached directly to the main shaft of the wind turbine, which reaches pick performance ratios at very low rotation speeds and retains that high ratio up to very high rotations speeds and reduces the need for expensive mechanical reduction transfer system.

25 In some embodiments the power transmission comprises a power transfer system based on a hydrostatic, variable displacement which produces an output of variable volume and fixed pressure per revolution, allowing said wind turbine to rotate at speeds in direct proportion to wind velocity and at the same time to capture the maximum possible energy from the wind.

30 In some embodiments the generated electric power is supplied to the main electric grid .

In some embodiments the system is a stand-alone system .

In some embodiments the system is capable of storing up to 300 kWh of power .

In some embodiments the compressed air tank is capable of storing up to three cubic meter of compressed air .

5 In some embodiments the water containers are capable of storing up to four cubic meter of water .

In some embodiments the system is capable of peak power capturing capacity of up to 120 kW, and to supply electricity up to a peak demand of 20kW .

10 In some embodiments the system is having peak power output capacity substantially larger than its peak power capturing capacity .

In some embodiments the power transmission comprises a corner gear and a vertical shaft.

15 It is another aspect of the current invention to provide a method for harvesting and storing wind energy, the method comprising the steps of:
a) storing energy derived from wind by: capturing wind power by a wind turbine; using said captured wind power to compress atmospheric air, generating compressed air and heat; storing said compressed air; heating
20 water by utilizing said generated heat; storing said heated water; and
b) Generating electricity from said stored energy by: releasing some of said stored compressed air; heating said released compressed air by said stored hot water; powering a pneumatic motor with said heated compressed air; and generating electrical power by powering a generator by said pneumatic motor.

25 In some embodiments the step of heating water further comprises heating said water by solar power.

In some embodiments the step of heating said compressed air further comprises cooling said hot water and storing said cooled water.

30 Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials

similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods and materials are described below. In case of conflict, the patent specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only
5 and not intended to be limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Some embodiments of the invention are herein described, by way of
10 example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily
15 understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be
20 embodied in practice.

In the drawings:

Figure 1 schematically depicts a block diagram of the wind harvesting and
25 storage system according to an exemplary embodiment of the current invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

30

Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application

to the details set forth in the following description or exemplified by the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

The terms "comprises", "comprising", "includes", "including", and
5 "having" together with their conjugates mean "including but not limited to".

The term "consisting of" has the same meaning as "including and limited to".

The term "consisting essentially of" means that the composition, method or structure may include additional ingredients, steps and/or parts,
10 but only if the additional ingredients, steps and/or parts do not materially alter the basic and novel characteristics of the claimed composition, method or structure.

As used herein, the singular form "a", "an" and "the" include plural references unless the context clearly dictates otherwise. For example, the
15 term "a compound" or "at least one compound" may include a plurality of compounds, including mixtures thereof.

Throughout this application, various embodiments of this invention may be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be
20 construed as an inflexible limitation on the scope of the invention. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within that range.

It is appreciated that certain features of the invention, which are, for
25 clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination or as suitable in any other described embodiment of the invention.
30 Certain features described in the context of various embodiments are not to be considered essential features of those embodiments, unless the embodiment is inoperative without those elements.

The drawings are generally not to scale. For clarity, non-essential elements were omitted from the drawing.

Figure 1 schematically depicts a block diagram of the wind harvesting and storage system according to an exemplary embodiment of the current invention.

In this figure, thin arrows represent air flow directions, heavy arrows represent liquid flow, solid heavy arrows represent mechanical transfer of rotational motion in a shaft, double lined arrow represent flow of electric AC power, and doted arrows represent sensing, control and command channels.

The system 100 comprise wind turbine 11 situated on a tower 12 and a housing 110, housing the energy conversion and storage machinery.

The Turbine and air compressor subsystem

Wind turbine 10 comprises a plurality of blades 14 which rotates due to wind pressure and power a hydrostatic transmission for transferring the wind generated energy to housing 110. The hydrostatic transmission comprises a hydrostatic pump 13 connected to the shaft of the wind turbine 10, a hydraulic motor 17, and hydraulic pipes 15 and 16. Hydraulic motor 17 is connected to air compressor 23 which receives atmospheric air through intake 21 and produces hot compressed air at its output 24.

Optionally and alternatively, hydrostatic transmission is replaced with a mechanical transmission, for example based on a corner gear and vertical shaft connects to the compressor 23.

Optionally or alternatively air compressor 23 is directly attached to the shaft of wind turbine 10. In this option a dedicated air compressor is attached directly to the wind turbine shaft, with the ability to compress air at variable rotation speeds and ability to change the specific volume of air it compressed per cycle (a variable displacement compressor).

The wind turbine may be designed to operate in winds up to 100 km/h, with insignificant changes in efficiency. It is possible to allow the wind turbine to operate at higher winds, employing more robust blades & mast.

In the depicted exemplary embodiment, the wind turbine drives a hydrostatic transmission. Preferably, the hydrostatic pump 13 is directly connected to the wind turbine shaft, without reduction gear, and is of variable displacement type.

5 Preferably, the wind turbine is driving a hydraulic variable displacement pump, instead of an electric generator. This changes the behavior of the wind turbine, since a hydraulic pump, which produces an output of variable volume and fixed pressure per revolution, and this fact allows the wind turbine blades
10 14 to rotate at speeds in direct proportion to wind velocity and at the same time to capture the maximum possible energy from the wind. Since kinetic energy of the wind relates to wind velocity to the third power, the rotation of the blades changes directly with wind velocity, and energy output of the wind turbine with wind velocity at the third power.

 Therefore, the wind turbine operates at almost any wind velocity
15 beginning with very low wind velocities, once the moment created by the wind can overcome the static resistance created by the hydraulic pump, and if the blades can survive the axial forces, up to very high wind velocities, up to a point when blade tips reach a velocity of about 0.6 Mach.

 At high wind velocities the wind turbine will rotate faster, reaching very
20 high blade edge velocities, which will cause high centrifugal acceleration of the blades that could result in high noise and high strain to the blades. A solution to this problem may be to have a variable displacement hydrostatic pump that will have a nearly zero displacement at low wind velocities, and very high displacement at very high velocities .

25 Since at high wind velocities the turbine blades will rotate at a fixed, high ratio to wind velocity, centrifugal forces would stiffen the blades and reduce bending effects, that alone can allow the wind turbine to continue operating at very high wind velocities, and reduce fatigue effects in the blades, increasing average energy output of the system, life span and also allowing
30 installation of wind turbines at areas with occasional high winds.

 Pitch control of the turbine blade or variable gear between the turbine and load is used in electricity generating wind turbine to accommodate the

variability of the wind on the one hand and the requirements of a nearly fixed velocity required by the electric generator. That feature complicates the design of wind turbines and constitutes a significant part of the cost of wind turbines. It also reduces the efficiency of wind turbines when wind velocity falls beyond
5 the designed range of velocities. The system according to the current invention preferably avoids using pitch control and gears between the blades and the compressor. This could be achieved by selecting a variable displacement hydraulic pump which can operate at a wide range of rotation speeds, and could also modify its specific volume, as described above. The hydraulic pump
10 is preferably selected so as to be connected to the turbine shaft without any reduction gear. In addition, allowing the turbine blades to rotate at speeds in fixed ratio to wind velocity removes the need for pitch, or drag control of the blades.

The use of a variable velocity and variable output per cycle transfer
15 system between the wind turbine blades and the air compression system, allows the blades to rotate at variable speed, which allows capturing energy from the wind at higher efficiency and wider range of wind velocities.

The transfer system, based on a hydrostatic, variable displacement
20 pump attached directly to the main shaft of the wind turbine, which reaches pick performance ratios at very low rotation speeds and retains that high ratio up to very high rotations speeds, reduces the need for expensive mechanical reduction transfer system.

Compressed air subsystem

25 In the exemplary embodiment of the current invention atmospheric air is used. Atmospheric air may contain some elements that may be detrimental to the system and others that could become a source of additional income to the proposed system. Dust and other solids in the air could damage the mechanical parts of the compressor and pneumatic motor, so the air is
30 preferably be filtered of solids by filter 22 before compression. For example, a suitable dry filter system, preferably self cleaning filter may be used.

Heat is removed from the hot compressed air 24 at the output of compressor 23 in heat exchanger 25. Heat exchanger 25 receives cold water from cold water line 36 and produces hot water 37 and cold compressed air 26.

5 Water in the compressed air is preferably removed before the compressed air 26 is stored in pressure tank 32. This is a standard procedure with air compressors. A desiccation system 27 which removed water from the compressed air may be installed before pressure tank 32. The amount of water is relatively small, however if larger wind turbines are used to compress
10 air, the amount of water could become significant, especially in waterless areas. In such cases the water could be added to the heat storage tank, stored in water tank 28, or provided for local use.

Carbon dioxide (CO₂) exists naturally in air, and when compressed above 12 Bar, will liquefy. If that CO₂ is stored in the compressed air tank, it
15 may gradually accumulate and reduce the free volume of the tank. However, liquid CO₂ is of commercial value, and could be removed occasionally from the compressed air tank 32 by CO₂ removing unit 39 to a CO₂ container 34 and sold separately. It was estimated that at the current value of CO₂ this alone could increase income from the system by about 10%. Alternatively, liquefied
20 CO₂ may be expanded to further cool water in cold water line 36 or in cold water tank 33.

Water from the cold water container 33 may optionally be used to cool the hydrostatic transmission and the air compressor; the resulting hot water is stored in the hot water container 31. The depicted exemplary embodiment
25 shows cold water line 19 branching from cold water line 36 leading to hydraulic motor cooler 10 which cools hydraulic motor 17. Hot water from motor cooler 10 flows through pipe 18 and collects in hot water container 31. For clarity, optional or alternative cooling of other systems such as: the compressor 23, hydraulic pump 13, and generator 42 were omitted from this drawing.

30 Preferably, a cold water pump 61, preferably controlled by controller 50 via control line 51, regulates the flow of cooling water in response to the wind velocity and the generated heat. Optional sensors may be used to sense the

temperature in one or a plurality of locations and adjust the flow of cooling water through the various coolers such as motor cooler 10 and heat exchanger 25. Alternatively, cold water pump 61 may be powered by the hydraulic motor 17 (or mechanical transmission) such that the amount of cooling water is in proportion to the rate of heat production, and when no wind is blowing - cold water flow stops.

Electricity generation subsystem

Upon demand for electricity, air valve 46, controlled by controller 50 via control line 51, opens and allow compressed air to exit the compressed air tank 32 through compressed air exit pipe 47. The compressed air is heated in heat exchanger 45 which receives hot water from hot water container 31 through hot water line 35. The resulting cold water exit the heat exchanger 45 through cold water pipe 38 and collects in cold water container 33.

Water pump 59, preferably controlled by controller 50 via control line 51, is used for circulating and controlling hot water flow through heat exchanger 45.

Cold compressed air is 44 expanded in air turbine or pneumatic motor 41 which turns generator 42 producing electric power 80. Sensing and control line 52 connected to controller 50 is used for example for sensing the demand for electricity, and the rate of rotation of generator 42. These sensors signals may be used for example for controlling valve 46, the water pumps etc. For clarity, other optional sensors such as water level sensors and temperature sensors in the hot and cold water containers were omitted from this figure.

The electric generator is driven by the pneumatic motor 41, thus, electric output may be produced according to grid demand, as long as there is compressed air and preferably also hot water in the tanks.

Optionally, produced electricity 80 is conditioned before it is united with main grid electricity, for example to maintain exact frequency, desired voltage and phase, etc. For clarity, the conditioning circuitry was omitted from the drawing. In some embodiments, the conditioning circuitry comprises an inverter or DC to AC convertor. When the system is used as "stand alone" unit,

the conditioning circuitry may not be needed and proper voltage and frequency may be achieved by regulating the compressed air supply and the generator.

Temperature control and optional additional solar heating

5 The temperature of the air at the expander unit 45 is related to the power output. It is simpler, from control aspects, to heat the air before or during expansion to more or less a set temperature. Using heat exchanger 45 with controlled flow of hot water 35, or mixing water from the two water containers 31 and 33 enables flexible temperature control

10 Output of the system could be further increased by additional and optional solar thermal heating of the water in the hot water container 31.

 It would be beneficial to add heat to the system to increase hot water temperature by heating the water by solar thermal heat trap, since it increases the potential energy of the complete system in direct proportion to the added
15 energy in the water.

 In the depicted embodiment, solar thermal heat trap 60 receives cold water via cold water heater intake line 62 branching from cold water line 36. Heated water from heat trap 60 is collected in hot water container 31 via heated water line 61. In the depicted embodiment, pump 63, preferably
20 controlled by controller 50 via control line 51 ensures that water will flow through the solar heat trap 60 only when the sun is shining. It should be noted that other water flow configurations may be used, for example, solar heat trap 60 may be in line with the heat exchanger 25, or hot water may be circulating from hot water container 31 and back. It should also be noted that in some
25 embodiments water is heated even while the wind is low or the air is still. It should also be noted that solar heat trap 60 may be replaced or supplemented with other sources of heat which may be available, for example left-over or exhaust heat from optional combustion-powered backup generator (not seen in the figure) used when electricity demand exhausted the stored compressed
30 air.

 Thermal heating, with a supply of fresh water, could also allow using the system as a hot water source, for example for industrial or residential use

Safety precautions and regulations

The system according to the claimed invention preferably includes means for reducing the risk involved. These means may comprise means to
5 prevent the air tank from exploding or being ejected due to a breach and escaping compressed air. Additionally, an automatic identification of a hazardous damage to the air container and activation of an automatic air release valve may be added to the system. Further reduction of potential risk from high pressure air containers may be achieved by anchoring such
10 containers to weights, or to the water containers, thus avoiding the phenomenon of such containers flying if a hole is created on the surface of the compressed air containers.

It should be noted that although tanks 32, 31, 33, 34 and 33 are seen housed within the housing 110, some or all may be placed outside housing, for
15 example underground, in a near by separate housing or outdoors. In some embodiments composite material is used for the containers such as compressed air container 32.

Although the invention has been described in conjunction with specific
20 embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents and patent applications mentioned in this specification are herein incorporated
25 in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the
30 present invention.

CLAIMS

1. A system for harvesting and storing wind energy comprising:
a wind turbine powered by the atmospheric wind;
5 a compressor, powered by said wind turbine, compressing atmospheric air;
a first heat exchanger, removing heat generated by said compressing of atmospheric air and heating cold water;
a hot water container, storing said heated water;
10 a compressed air tank, holding said compressed, cooled air;
an air demand valve, releasing said cold compressed air from said compressed air tank to a second heat exchanger;
a second heat exchanger, receiving hot water from said hot water container, heating said released cold compressed air and cooling said
15 hot water;
a cold water container, storing said cooled water;
a pneumatic motor, powered by said heated compressed air; and
a generator; powered by said pneumatic motor and generating electric power.
20
2. The system for harvesting and storing wind energy of claim 1, wherein said wind turbine is a multi-blade wind turbine situated on a mast.
- 25 3. The system for harvesting and storing wind energy of claim 2, and further comprising a power transmission, transmitting power from said wind turbine to said compressor.
- 30 4. The system for harvesting and storing wind energy of claim 3, wherein said power transmission comprises:
a hydraulic pump powered by said wind turbine;
a hydraulic motor powering said compressor; and

hydraulic pipes connecting said hydraulic pump and said hydraulic motor.

5. The system for harvesting and storing wind energy of claim 4,
5 wherein hydraulic pump is directly connected to the shaft of said wind turbine.
6. The system for harvesting and storing wind energy of claim 3,
wherein hydraulic pump is a hydraulic variable displacement pump.
- 10 7. The system for harvesting and storing wind energy of claim 1,
wherein said air compressor is directly attached said wind turbine,
and said air compressor is a variable displacement compressor
capable of changing the specific volume of air it compressed per
15 cycle.
8. The system for harvesting and storing wind energy of claim 1, and
further comprising an additional water heater, heating water to be
stored in said hot water container.
- 20 9. The system for harvesting and storing wind energy of claim 8,
wherein said additional water heater is a solar heat trap.
10. The system for harvesting and storing wind energy of claim 4,
25 wherein heat generated by at least one of: said hydraulic pump;
said hydraulic motor; said compressor; and said generator is used
for heating water to be stored in said hot water container.
11. The system for harvesting and storing wind energy of claim 1, and
30 further comprising an air desiccator removing water from said
compressed air.

12. The system for harvesting and storing wind energy of claim 1, and further comprising carbon dioxide removing unit removing liquefied carbon dioxide from said compressed air.

5 13. The system for harvesting and storing wind energy of claim 3, wherein said power transmission comprises a transfer system based on a hydrostatic, variable displacement pump attached directly to the main shaft of the wind turbine, which reaches pick performance ratios at very low rotation speeds and retains that high
10 ratio up to very high rotations speeds and reduces the need for expensive mechanical reduction transfer system.

14. The system for harvesting and storing wind energy of claim 3, wherein said power transmission comprises a power transfer
15 system based on a hydrostatic, variable displacement which produces an output of variable volume and fixed pressure per revolution, allowing said wind turbine to rotate at speeds in direct proportion to wind velocity and at the same time to capture the maximum possible energy from the wind.

20 15. The system for harvesting and storing wind energy of claim 1, wherein said generated electric power is supplied to the main electric grid.

25 16. The system for harvesting and storing wind energy of claim 1, wherein said system is a stand-alone system.

17. The system for harvesting and storing wind energy of claim 1, wherein said system is capable of storing up to 300 kWh of power.

18. The system for harvesting and storing wind energy of claim 1, and wherein said compressed air tank is capable of storing up to three cubic meter of compressed air.
- 5 19. The system for harvesting and storing wind energy of claim 1, and wherein said water containers are capable of storing up to four cubic meter of water.
- 10 20. The system for harvesting and storing wind energy of claim 1, wherein said system is capable of peak power capturing capacity of up to 120 kW, and to supply electricity up to a peak demand of 20kW.
- 15 21. The system for harvesting and storing wind energy of claim 1, wherein said system is having peak power output capacity substantially larger than its peak power capturing capacity.
- 20 22. The system for harvesting and storing wind energy of claim 3, wherein said power transmission comprises a corner gear and a vertical shaft.
23. The method for harvesting and storing wind energy comprising:
storing energy derived from wind by:
capturing wind power by a wind turbine;
25 using said captured wind power to compress
atmospheric air, generating compressed air and heat;
storing said compressed air;
heating water by utilizing said generated heat;
storing said heated water; and
30 generating electricity from said stored energy:
releasing some of said stored compressed air;

heating said released compressed air by said stored hot water;

powering a pneumatic motor with said heated compressed air; and

generating electrical power by powering a generator by said pneumatic motor.

24. The method for harvesting and storing wind energy of claim 23, wherein the step of heating water further comprising heating said water by solar power.

25. The method for harvesting and storing wind energy of claim 23, wherein the step of heating said compressed air further comprising cooling said hot water and storing said cooled water.

