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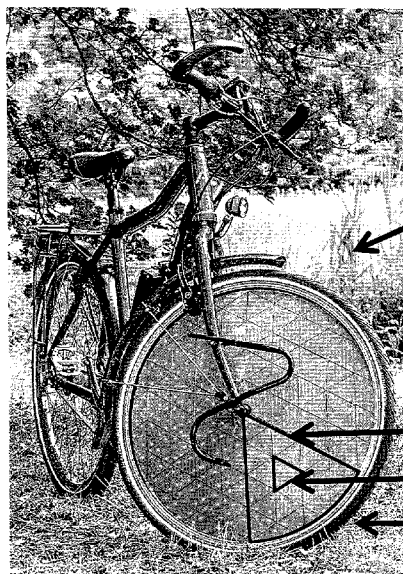
(54) **Title:** PV-WHEEL

Fig. 4

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(57) **Abstract:** The present invention is in the field of an electric bicycle, also known as an e-bike or booster bike. The present e- bike relates to a bicycle with an integrated electric motor which can if required be used for propulsion. A variety of types of e-bikes exist, from e-bikes that only assist a rider to more powerful e-bikes which may fully support motion. The present e- bike, comprising a PV-elements is also referred to as an s-bike.

PV-wheel

Field of the invention

The present invention is in the field of an electric bicycle, also known as an e-bike or booster bike.

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Background of the invention

10 The present e-bike relates to a bicycle with an integrated electric motor which can if required be used for propulsion. A variety of types of e-bikes exist, from e-bikes that only assist a rider to more powerful e-bikes which may fully support motion. All e-bikes still have the ability to be pedalled by a rider, contrary to electric motorcycles. E-bikes therefore may provide power on demand. With power-on-demand an e-bike rider can ride by pedal power alone, i.e. fully human-powered, can ride by electric motor alone by operating the
15 throttle manually, and can ride using both together at the same time. E-bikes may use rechargeable batteries. Newer models generally used NiMH, NiCd, Li-ion batteries, such as LiFePO₄, LiMnCo, and Li-ion polymer. Velocities reached are from about 25 to 45 km/h. E-bikes are alternatives for conventional bicycles, and for fossil fuel-powered mopeds and small motorcycles. E-bikes are the electric motor-powered versions of motorized bicycles, which have been around since the late 19th century; however as early as 1895 patents were filed relating to e-bikes.

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A disadvantage with most e-bikes is their limit operational range, typically from 30-60 km. Adding batteries and/or increasing the size thereof may improve the range somewhat, but typically the range is still rather limited. After use (or during use) the batteries need to be recharged, which is at least
30 time-consuming, typically 8 hours for the above range.

The power of the motor is for regular e-bikes up to 250 W, and for fast e-bikes (so-called S-pedelecs [pedal electric cycle]) above 250 W. For regular use a power of around 80-100 W is regarded sufficient.

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E-bikes are considered zero-emissions vehicles, as they emit no combustion by-products directly. However, the environmental effects of electricity generation and power distribution and of manufacturing and disposing of high storage density batteries must be taken into account. The environmental

effects involved in recharging the batteries can be minimised, such as by charging via solar power or other renewable energy resources. Therewith e-bike riders can charge their vehicles with energy of photovoltaic panels, such as at home.

5 A problem when using solar cells, such as PV-cells, is that these are very sensitive to breakage, to penetration of oxygen and water, and to heating. The sensitivity of the solar cells to breakage makes it also difficult to apply the cells on surfaces, even under well-defined conditions. Also it is difficult to harvest energy, especially under cloudy circumstance, 10 in case of partly shaded cells, such as by object in a direct vicinity of the wheel, in case of defective cells, etc. Typically the yield (or power output) of solar cells is still to a large extent limited due to electrically non-optimal conditions, such as a gap-voltage, too low power generation, heating, a desire to maintain voltage at a constant level, non-functioning cells disturbing performance of all cells in a chain comprising said cell, etc. Under optimal sunny conditions these problems are less important, apart from shading effects. 15 Hence application of solar cells is limited to well defined boundary conditions, such as on top of roofs or in solar power plants and on relative flat and typically non-curved surfaces, and in situations where no or very limited shading occurs; and even there performance is hampered by e.g. incidental shading and heating. Also electrically contacting of solar cells is 20 difficult.

Some solutions to providing solar energy to an e-bike relate to relatively complex structures, such as a trailer, a construction attached to the e-bike comprising solar panels, 30 etc. All of these solutions are impractical, limit an action radius and (maximum) speed of the bike, are not at all integrated with the concept of the vehicle, and are typically voluminous.

Recent developments are indicated below.

35 US2011/174554 A1 recites a solar powered wheel apparatus, typically a car, comprising one or more photovoltaic cells housed on a rotatable element connected to a rotary object such as a wheel, an electric motor, and an axial shaft, is provided. The electric motor is in electric communication with 40 the photovoltaic cells that power the electric motor and is

rigidly connected to the rotatable element that houses the photovoltaic cells. The axial shaft is rotatably connected to the electric motor and rigidly connected to a support structure of the rotary object. The electric motor converts electrical energy produced by the photovoltaic cells into mechanical energy causing the electric motor to rotate about the axial shaft. The rotation of the electric motor rotates the rigidly connected rotatable element that houses the photovoltaic cells. The rotation of the rotatable element housing the photovoltaic cells removes heat from the photovoltaic cells and causes rotation of the connected rotary object.

EP 1 820 727 A1 recites a wheel comprising a shaft adapted to be secured to a bearing structure of the vehicle and about which the wheel is mounted to rotate, a reversible rotary electrical machine mounted coaxially about the shaft (2) and adapted selectively to act as an electrical generator and as an electric motor actuating the wheel, energy storage means which may be coupled to the electrical machine, electronic control means adapted to control the electrical machine and the energy storage means according to predetermined methods, and solar energy converters connected to at least one lateral portion of the wheel and adapted to convert the incident solar energy into electrical energy, and which may be coupled to the energy storage means. The energy storage means comprise at least one substantially planar or film rechargeable battery applied to at least one lateral portion of the wheel and rotating rigidly with this wheel.

It is noted that car wheels are substantially in the same position all the time. In terms of power consumption wheels of a car generating solar energy can never match the required amount of energy. Also in view of the speed of a car and potential damage PV_wheels are impractical for a car and hence would only theoretically be considered. These documents are totally silent on harvesting energy at a very low power; most likely these systems are not suited for this purpose and as it is not explicitly mentioned the inventors of these systems must have overlooked this phenomenon and concentrated on full radiation circumstances.

The above two documents relate to simple design ideas which are difficult to implement in practice. For instance some

of the designs are prone to damage, e.g. by hitting a side walk, if damaged the total design has to be replaced, there is no optimization for sub-optimal light circumstances, defective individual solar cells effect the whole design in terms of output, and replacement seems difficult.

US 5,389,158 A recites a photovoltaic (PV) cell with a single pn-junction is disclosed that is capable of functioning as both a current source and a bypass diode. The photovoltaic cell is made of material that has a low bandgap energy, 1.0 eV, or less. One version of the PV cell is formed of a GaSb wafer doped with Te to form an n-region. Multiple PV cells of this invention can be connected in series or in parallel or in tandem in a primary-booster tandem pair to form a circuit without the requirement of protecting the individual cells of the circuit with a separate bypass diode. So this documents describes a way to circumvent specific PV cells that are defective.

EP 2 200 151 A1 recites a photovoltaic system for generating an output voltage which is essentially uninfluenced by varying irradiation, the photovoltaic system comprising at least one photovoltaic unit comprising two photovoltaic sources, each comprising an input terminal and an output terminal. The system is characterized amongst others in that the photovoltaic unit comprises two voltage adding arrangements each having a first route comprising a voltage source and a second route constituting a voltage source bypass. Therein only one battery is used per current converter, which is considered a voltage source. Such does not relate to a voltage adder. Further the system does not describe a comparator, only a means for comparing output power to an instantaneous need. The system further suffers from typical prior art problems and does not provide the advantages of the present invention. The above system is not capable of storing small amounts of energy (in this respect only the impractical use of a battery is recited, wherein a battery is not suited for storing small amounts of energy as the losses are already much higher), to balance energy input and energy output, and to optimize output in terms of electrical energy. The above system is at the best only capable of generating an output voltage which is essentially uninfluenced by varying irradiation; by keeping the output voltage constant, this comes with the expense of reducing energy con-

version as part of the energy is used to keep the voltage constant. In view of energy conversion optimization such is considered to put the horse behind the wagon.

US2012/223583 A1 recites a switched capacitor multi-level output DC-DC converters can be used as panel integrated modules in a solar maximum power point tracking system. The system can also include a central input current-controlled ripple port inverter. The system can implement per panel MPPT without inter-panel communication, electrolytic capacitors or per panel magnetics. A Marx converter implementation of the switched capacitor module is studied. Average total efficiencies (tracking conversion) greater than 93% can be achieved for a simulated 510 W, 3 panel, DC-DC system. The DC-DC converters are not applied per individual cell. As a consequence the system can e.g. not compensate for shading of (a part of) the panel.

It is an object of the present invention to overcome one or more of the disadvantages of the prior art, and to provide an improve e-bike, without jeopardizing functionality and advantages.

Summary of the invention

In a first aspect, the present invention relates to a wheel for a vehicle, wherein the vehicle is a bicycle, comprising on each side at least one PV-element, an electrical power connection and a rigid support for the at least one PV-element, and in a second aspect to a bicycle comprising at least one wheel according to the invention, having an improved topology, resolution, robustness, modularity and energy efficiency.

The PV-element comprises at least two voltaic units (VU1, VU2), the voltaic units being electrically coupled, wherein each voltaic unit is capable of operating at one first voltage and at one or more first current.

In order to harvest energy generated by the PV-element the present invention relies partly on an ultra-low voltage harvester. The ultra-low voltage harvester is capable of operating at low voltages and/or low currents, and still optimizes a power output. The ultra-low voltage harvester is therefore also capable to operate or function on an individual cell basis, or typically on a group of cells basis, which overcomes for instance a shading effect or otherwise partly func-

tioning of a cell. The harvesting technology is aimed at optimizing output in terms of electrical energy, by upgrading energy provided by e.g. a PV-system, wherein the upgraded power can be harvested at a higher efficiency, that is with fewer losses. The technology is aimed at maximizing power output and at harvesting power starting at very low levels. Typically a voltaic system is not optimised in terms of power output en power generation. Such is especially important as many voltaic units operate at sub-optimal conditions, thereby not generating any power or at the most a very low amount. Amongst others the present system collects all generated power and converts generated power into usable power, and makes use of a comparator for optimizing output. The present circuit makes PV systems insensitive for shading effects, causing detrimental effects in e.g. a series of cells, apart from cells not providing a current due to lack of solar radiation. Furthermore at low light conditions the present circuit electronics converts non-usable power in usable power. By using the circuit electronics the power generation of a PV system increases 10-20% in comparison to the conventional PV systems and 5-15% in comparison to PV systems with micro-inverters. In an example charge siphon devices, typically a capacitor, are not fully loaded, but partly. Typically the present charge siphon device is loaded to about 63% of its maximal loading capacity. The present circuit is very efficient > 95%, typical 98% under all conditions. The present circuit electronics can be produced at low cost for economy of scale quantities. The present circuit is very robust since it uses conventional electrical components with a proven stability at extreme climate conditions over time (>20 years). As indicated throughout the description the present circuit is applicable to in principle any voltaic system, such as a PV-system. An example of such a circuit is given in Dutch Patent Application NL2010197 and subsequent PCT application PCT/ NL2014/050046, of which the disclosure and teachings are incorporated herein by reference. The present circuit is not aimed at keeping an output voltage constant, or for that matter keeping an output current constant, but at maximizing power output.

The IC³ circuit may comprise at least two charge

siphon devices per unit, such as a capacitor, preferably having a relatively small capacitance of e.g. 1 - 100 nF, such as 2-50 nF. The module preferably operates at a power of less than 1 mW, more preferably less than 0.5 mW, even
5 more preferably less than 0.25 mW, such as at about 0.1 mW. In an example the IC3 circuit has a power usage of less than 400 μ W and a shutdown current of 400 μ A.

Therewith e.g. parasitic power losses are reduced significantly to about 10^{-6} - 10^{-2} of the output, depending on
10 operating conditions.

The present invention provides as a consequence a system with a relatively high internal capacitance. Therewith in principle a relatively high storage capacity is provided as well.

15 Contrary to many prior art systems energy can now be harvested at a PV-cell level. Such provides huge advantages, at minimal extra costs.

In this respect it is noted that typical power consumption of an e-bike, such as the present solar, or s-bike, is
20 typically from 65-125 W, or around 80 W. With one wheel according to the invention under optimal conditions a power in that order of magnitude may be provided, such as about 75-100 W. In case of two wheels the energy generation is close to sufficient for an intended use or better. It is noted that also power is
25 generated when the s-bike is not used, such as when parked in the sun.

The present electrical power connection is for connecting the at least one PV-element to a charge storing device and/or to an electrical motor. Generated power may be used di-
30 rectly, may be stored, and e.g. in case of surplus may be used and stored.

It has been found important to provide a rigid support for the PV-element. The PV-element may be attached directly to the rigid support, such as by adhering, or indirectly. The rig-
35 id support is sufficiently stiff, or non-flexible. To that end the support may be reinforced, such as by providing fibres thereto. The support is also preferably capable of withstanding rotational forces. The support is also preferably durable, in that properties remain largely unaffected over time.

40 The present bicycle is compared to prior art embodi-

ments simple and effective. For instance it has been proposed to build a cage-like structure, as a carriage, or on top of the vehicle. The present wheel is relatively insensitive to shading, such as caused by pedalling, by a support of a carrier, by a front or back fork, by other constructional elements, etc.

Thereby the present invention provides a solution to one or more of the above mentioned problems.

Advantages of the present description are detailed throughout the description.

Detailed description of the invention

In an exemplary embodiment the present wheel comprises an electrical motor. The motor is preferably located in the axis of the wheel. An integrated motor is relatively easy to produce. Examples of motors are direct-drive and geared motor. The motor is preferably operated at direct current (DC).

In an exemplary embodiment the present ultra-low harvester comprises at least one Intelligent cell current converter circuit (50), the circuit multiplying the first voltage by a first factor and dividing the one or more first currents by the first factor, and one or more of a wireless power transmitter (WiPoT) (60) and an electrical accumulator (A3), preferably at least one circuit and at least one wireless transmitter per unit, the Intelligent cell current converter circuits comprising

(i) one or more (n) voltage adders (V1, V2) and optionally one or more current adders (C3), the one or more current adders being adapted to be in electrical connection to the one or more voltage adders,

(ii) two or more first charge siphon devices (72) per voltage adder, preferably 2-100 siphon devices per voltage adder, such as 4-50 siphon devices per voltage adder, wherein the two or more first siphon devices are electrically connected in series to one and another. Therewith a voltage is multiplied by a first factor being in the example above from 2-100, assuming the same charge siphon devices are used. It is noted that by switching, e.g. by using more or less charge siphon device, per IC3 circuit a different multiplying factor may be obtained, the factor being from 2-100. In an idle mode the first factor may also be 1. The two or more first charge siphon devices are adapted to be in electrical connection with the one or more

voltage adders, and are capacitors. The IC³ further comprises
(iii) one or more switches for electrically connecting or
disconnecting components of the voltaic system, and
(iv) a comparator (U4),

5 the wireless power transmitter (60) comprising

a primary winding (Tr1), a secondary winding (Tr2),
and optionally a generator/oscillator (U6),

wherein the primary winding is adapted to be electrically coupled to the one or more voltaic units,

10 wherein the secondary winding is adapted to be electrically coupled to one or more of a load device and power grid, and

wherein the one or more voltaic units, the at least one Intelligent cell current converter circuit, and wireless power transmitter are adapted to be in electrical contact with one and another. An example of such a circuit is given in figures 1-3.

In an exemplary embodiment the present wheel comprises a material of the support that is selected from carbon, a light weight metal, such as aluminium, titanium, a polymer, and combinations thereof. The material is preferably further reinforced, such as by fibres, to further increase a stiffness thereof. The material may further relate to a composite material, in order to tune various parameters optimally, such as stiffness, thermal expansion (coefficient), durability, electrical behaviour, such as electrical discharge behaviour, and electrical conductivity, etc. It has been found that by a proper selection the efficiency of the present wheel may increase by 5-10% (relatively) over time.

30 In an exemplary embodiment the present wheel support is curved, such as forming a section of a sphere, or of a rounded object, or is multi-faceted. In view of a shape of the PV-elements the support may be multi-faceted, such as having triangular facets, hexagonal facets, and pentagonal facets.
35 Therewith a curved surface is provided closely following contours of the PV-element. As such durability of the PV-element is improved, as well as performance thereof.

In an exemplary embodiment the present wheel comprises a charge storing device, such as a battery. The charge storing device is integrated in the wheel. It is noted that inte-

grating various (further) elements in the wheel makes the wheel more stable when rotating, which is advantageous especially for elderly people and kids, at the expense of a reduction in steering performance. Further a string inverter may be present, typically a standard string inverter is used. In addition to the string inverter, or as an alternative, a micro inverter may be present.

In an exemplary embodiment the present wheel comprises one or more of a cooling element, such as a passive cooling element, such as a grid, a wireless power transferor, a carbon based power transferor, such as carbon brushes, and a metal slip power contact, such as metal brushes. For better efficiency the PV-element is preferably provided with a cooling element, such as a grid. It is noted that when cycling the wind cools the present wheel to some extent. As such external cooling elements, e.g. fins, may be provided as well. The external elements may further direct air towards the present wheel. It is considered best to keep a temperature of the PV-element below 80 °C, even better below 60 °C.

The power generated may be transferred using a wireless power transferor, having low losses. As an alternative more conventional measures as a carbon based power transferor, and a metal slip power contact may be provided, preferably in a brush like form or slip contact like form.

In an exemplary embodiment the present wheel comprises at least one PV-element that is selected from back-side contacted PV-elements, III-V PV-cells, Si-based PV-cells, and combinations thereof. It is preferred to use relatively high yielding cells. It is further preferred to add further measures, such as an anti-reflective coating, to use back side contacted PV-elements, to use a bottom reflective layer, to use further optical measures to confine light in the PV-element, etc. It is further preferred to use a foil or thin-film type PV-element.

In an exemplary embodiment of the present wheel the PV-elements form sections of a wheel, such as triangular section, and/or wherein PV-elements are triangular shaped. Preferably the shape of the PV-elements and support largely coincide, e.g. in terms of efficiency, durability, etc. For instance the sections may relate to pie point (of cake point) shaped ele-

ments. It is [referred to use 6-48, such as 12-24 point shaped elements. The elements are preferably also replaceable on an individual basis. In case of failure first of all only a small fraction of the potential power is lost; second the failing element can be replaced easily, such as by a click system. The elements preferably comprise many small PV-cells, preferably 100-10,000 cells, more preferably 1000-5000 cells, e.g. 1500-2500 cells. The cells may have a length of 1-100 mm, preferably 2-50 mm, more preferably 3-25 mm, such as 5-10 mm, and a similar width. Such small cells offer the advantage of an improved resolution towards varying light conditions, insensitivity towards damage, form free design, and full integration. Each individual PV-element may function as such, on an individual basis, or partly or fully integrated. The energy harvested is preferably transferred wirelessly, from the PV-cell to the power harvester, from the power harvester towards the frame of the vehicle, or both.

In an exemplary embodiment of the present wheel the PV-elements are covered with an optically transparent coating, the coating providing protection to the PV-elements, such as protection to the environment, protection against scratches and wear, etc. The coating preferably has a high hardness (Mho), of e.g. > 5 Mho. The coating is preferably not permeable to water and oxygen, such as good as 10^{-3} (g/m²/day). The coating may be a stack of layers of two or more of SiO₂, TiO₂, and Al₂O₃, preferably 5-50 layers, each layer having a thickness of 1-50 nm, with a total layer stack of 10-500 nm. Such a layer can be deposited on the PV-elements, such as by Atomic Layer Deposition.

In an example the coating may be a thin SiO₂ layer, such as an 0.5-1500 µm thick layer. The layer may be attached, such as by adhering to the PV-element, and may be deposited thereon. The coating may be an integral part, to be attached as one part

In an exemplary embodiment the present wheel the ultra-low voltage harvester and/or optional motor are located in an axis of the wheel. In a further example each individual PV-cell, or a group of cells comprising 2-4 cells, comprises an ultra-low voltage harvester. In this way the energy of each small group of cells or each individual cell having optionally different light conditions or varying light conditions can be

harvested optimally, typically for more than 95%, compared to no energy for prior art systems under shady or sub-optimal light conditions.

In an exemplary embodiment of the present wheel the PV-cell and ultra-low voltage harvester are integrated, such as into an application specific integrated circuit. At one side of the integrated element or circuit the PV-cell is present. The ultra-low voltage harvester is typically integrated at another side thereof. Typically wireless power transfer is used from the PV-cell towards the harvester. Thereto a primary coil, having 1-3 windings, preferably 1, and a secondary coil, having 1-3 windings, preferably 1, is provided at either side. The couple factor is therewith close to 1 and virtually no energy is lost when transferring the energy. A similar energy transfer is provided from the wheel to e.g. a frame.

In addition to the above example a high efficiency solar battery charger may be used, e.g. a charger with embedded maximum power point tracking, e.g. operable at 100 kHz, having an 120 m Ω internal power active switch a 140 m Ω internal synchronous rectifier, and a 0.3-5.5 V operating input voltage; therewith up to 95% energy efficiency in this part of the chain is achieved.

In a second aspect the present invention relates to a bicycle comprising at least one wheel according to the invention.

The present bicycle relates to a very simple structure, adding no further constructional elements to the bicycle. The solution is very practical, increases an action radius and (maximum) speed of the bike, is fully integrated with the concept of the bicycle, and does not consume further volume.

In an exemplary embodiment the present bicycle is selected from a bicycle, such as an e-bike, and a solar bike or s-bike.

In an exemplary embodiment the present bicycle further comprises one or more of a power supply, such as a USB-port, a battery, such as a Li-ion battery, and a (mains) power grid inlet. The power supply is for connecting modern devices, such as multi-media devices. The battery is for charging and providing power. The inlet is for attaching the bicycle c.q. battery to a main power grid. The inlet preferably also comprises a trans-

former.

For the bicycle, comprising the present wheel a further type of motor may be considered, such as a motor supporting pedal cycling, a chain drive or belt drive to support the chain or belt motion, etc. Such a motor need not be located in the wheel.

The invention will hereafter be further elucidated with reference to the Example and Drawings which are exemplary and explanatory of nature and are not limiting the scope of the invention. To the person skilled in the art it may be clear that many variants, being obvious or not, may be conceivable falling within the scope of protection, defined by the present claims.

Brief description of the Figures

SUMMARY OF THE FIGURES

Fig. 1a-g show schematical lay-outs of a VMC2 module and IC3 technology.

Fig. 2 shows a schematical lay-out of a VMC2 module and a WiPoT.

Fig. 3 shows an example of the present WiPoT.

Fig. 4 shows an s-bike.

DETAILED DESCRIPTION OF THE FIGURES

In figure 1a two PV-cells are provided forming one PV-unit (VU1, VU2). The PV-unit is connected to a first series of switches (V1,V2,V3). The switch may be in one of three positions, indicated with A, 0 (neutral) and B. By alternating setting of these switches capacitors (721,722) are loaded. In figure 1a further a controller U4 is provided. Communication with switches (V1,V2,V3) can be provided by a bus or the like. Communication can be wireless, by electrical current and by magnetic field, and a combination thereof. In the example, relating to the present invention, two capacitors are shown. In principle two or more capacitors may be used, such as 3-10 in series. It is preferred to use 2 capacitors, in view of optimal yield. The present system increases power and reduces current, therewith reducing losses during transport. The present system uses preferably Maximum PowerPoint Tracking, preferably at a chosen voltage of e.g. 0.5V. Preferably the VMC2 is provided in a chip. As such one chip per PV-cell may be provided. The chips may be interconnected, either in series, preferably in paral-

1el. An advantage of the present invention is that if one PV-cell does not provide output or a significantly reduced output, the system as a whole provides almost the same output as before, contrary to prior art systems.

5 In figure 1b a VMC2 module (50) comprises a series of $1, \dots, i, \dots, n$ switches ($V1, V2, V3; V_i, V_j, V_k; V_a, V_b, V_c$) and capacitors ($721, 722; 72x, 72y; 72q, 72r$). The example shows only three ($1, i, n$) out of n switches and capacitors.

10 In figure 1c four voltaic units (VU1-VU4) are shown connected in series. The three units on the right are not functioning fully, e.g. due to shading. As a consequence the output is in the example limited to about 50% to 4A (second unit), 75% to 2A (third unit), and 12.5% to 1A (fourth unit) (compared to 8A for the unit on the left). All units operate in the example at about 0.5 V. By providing IC3 (50) technology to each voltaic unit the current is kept constant (to 1A in the example), whereas the voltage is added, from 4V towards 6V, 7V and 7.5V on the right, respectively. The most right unit is considered limiting, e.g. providing only 1A. The IC3-4 provides a (1 step) multiplication/division of 1 (equal). The output voltage $U_{04}=U_{i4} \times 1$ (0.5V) and the output current is $I_{04}=I_{i4}/1$ (1A). As a consequence the IC3-3 provides a (2 step) multiplication/division of 2. The output voltage $U_{03}=U_{i3} \times 2$ (1.0V) and the output current is $I_{03}=I_{i3}/2$ (1A). As a consequence the IC3-2 provides a (4 step) multiplication/division of 4. The output voltage $U_{02}=U_{i2} \times 4$ (2.0V) and the output current is $I_{02}=I_{i2}/4$ (1A). As a consequence the IC3-1 provides a (8 step) multiplication/division of 8. The output voltage $U_{01}=U_{i1} \times 8$ (4.0V) and the output current is $I_{01}=I_{i1}/8$ (1A). The summed voltages Σ_i are from left to right 4.0V, 6.0V, 7.0V and 7.5V, respectively, at a constant current of 1A. Therewith the system as a whole is electrically balanced. Herein power is collected per cell and bundled in series.

35 In figure 1d the present n voltaic units having each one IC3 circuit further comprise a module for converting a constant current and variable voltage $\Sigma 1$ to a variable current and a constant voltage $\Sigma 2$, such as a low drop out (LDO) module (91), and an inverter (92).

40 In figure 1e three voltaic units (VU) are connected in parallel. One (the lower) voltaic unit is partly shaded, and as

a consequence providing less current (I_{ij} ; 4A compared to 8A for the top two), all at 0.5V (U_{ij}). Each voltaic unit has a series of IC3's, (50) in the example 3. The IC3 1a,b,c multiply the voltage by a factor 4 and divide the current by a factor 4, providing an output $U_{o1a}=U_{i1a} \times 4$ (same for b,c), and a output $I_{o1a}=I_{i1a}/4$ (same for b,c), whereas for IC3 2a,b,c and IC3 3a,b,c the factor is 2, providing an output $U_{o2a}=U_{i2a} \times 2$ (same for b,c), and a output $I_{o2a}=I_{i2a}/2$ (same for b,c) (and same for IC3 3a,b,c). The final output is 8V and 1,25 A ($\square 3$). It is noted that in principle any factor may be chosen, the factor typically being an integer, such as 2, 3, 4, 5, 6, 8 etc. Typically a factor 2^n is chosen, n typically being $\in [1,10]$. It is preferred to optimise a maximal power output. In a preferred example the factor is 2. Herein power is collected per cell and bundled in parallel. As a result a constant voltage and a variable output are provided.

In figure 1f figure 1e is presented somewhat different. Therein each VMC2 (52) comprises in the example 3 IC3's. The number of IC3's per VMC2 may vary from a minimum of 1 to about 10, such as 2-8, preferably 3 or 4.

As such the present options of connecting cells in series or in parallel provide a possibility of generating constant current or constant voltage and collecting power fully. Of course combinations of parallel and series are envisaged. As a consequence not fully functioning voltaic units do not hinder power harvesting; in fact all or almost all energy is harvested. Even further also at very low power output energy is harvested, contrary to prior art systems.

In figure 1g a principle of the present IC3 circuit is presented. Therein current is divided and voltage is multiplied in n steps. As a consequence $U_{o1}=U_{i1} \times n$ and $I_{o1}=I_{i1}/n$, the multiplication/division factor being n. For instance n may be 2, the factor as a consequence being 2, etc.

In figure 2 two PV-cells are provided forming one PV-unit (VU1, VU2). A current in maximum power point for VU1 is $I_{mpp1}=U_{mpp1}/R_x$, and for VU2 is $I_{mpp2}=U_{mpp2}/R_x$. The cells are connected to an optional voltaic multiplying current converter module (50). A voltage adder (V1, V2) connects the PV-cell to two or more harvesting capacitors (72), or is switched off (open). The output current of the voltage adder U1 is $I_{out1}=n \times U_{mpp1}/R_x$, for

U2 is $I_{out2} = n \times U_{mpp2} / R_y$, wherein n is the number of capacitances, taking all capacitances are equal. Also a microcontroller (U4) is provided, typically comprising a processor. Switching and harvesting can be optimised by using a modulated frequency. As such every cell can be treated as a unique cell, having specific characteristics. When switching preferably also the ground is switched at the same time. The capacitance of the harvesting capacitor is preferably about 10% smaller than the capacitance of the PV-cell. When switching the capacitance of a PV-cell is connected to the capacitance of one of the harvesting capacitors, and typically then switched to an-other harvesting capacitance. Further a current adder (C3), providing a current $I_{out1} + I_{out2}$, connects the voltage adders to a wireless power transmitter (60). Optionally a Li-ion accumulator (A3) is provided, e.g. a 3.7 V 650 mA battery, as well as a VMC2-power supply (U5). A current of $I_{chrg} = U_{accu} / R_z$ is provided to the WiPoT. The wireless power transmitter comprises a primary (Tr1) and a secondary (Tr2) winding. Optionally a WiPoT generator (U6) is provided. Further the secondary winding is connected to a load resistance (41), or to the power grid, or to a further accumulator, such as a battery pack, e.g. having a 3-5 kW storage capacity. Optionally the WiPoT is idle.

In an example a coil is used with an inductance of < 4000 nH, preferably 400-600 nH. In an example a gap in the transformer is smaller than 250 μm , preferably smaller than 50 μm , such as smaller than 10 μm . As such magnetic field lines have been found to be trapped inside the transformer.

Fig. 3 shows an example of the present WiPoT. Therein at a left side a voltage V_{cell} is provided, such as by a solar cell. Two oscillators, O1 and O2, such as voltage controlled oscillators, are used to control the two transformers Tr1 and Tr2. In an example a first transformer, e.g. Tr1, may be used to transform a positive part of the sinusoidal signal, whereas a second transformer, e.g. Tr2, may be used to transform a negative part of the sinusoidal signal. The transformers have a multiplication factor of n , such as 2, 4, 8 etc. Two rectifiers, R1 and R2, are used to provide a direct current. As a result an output potential of n times the cell potential is provided.

Figure 4 shows an s-bike 100 according to the inven-

tion. Therein a wheel 200 is shown, having a series of triangular formed PV-cells (210). These PV-cells are grouped in larger triangular sections 220. The PV-elements 220 form sections of a wheel.

5 The invention although described in detailed explanatory context may be best understood in conjunction with the accompanying examples and figures.

 It should be appreciated that for commercial application it may be preferable to use one or more variations of the present system, which would similar be to the ones disclosed in the present application and are within the spirit of the invention.

CLAIMS

1. Bicycle heel (200) comprising on each side

(a) at least one PV-element, the PV-element comprising

at least two voltaic units (VU1, VU2), the voltaic
5 units being electrically coupled, each VU comprising at least
one cell, wherein each voltaic unit is capable of operating at
one first voltage and at one or more first currents, and

an ultra-low voltage harvester per cell for optimizing
output in terms of electrical energy,

10 (b) an electrical power connection for connecting the
at least one PV-element to a charge storing device and/or to an
electrical motor, and

(c) a rigid support for the at least one PV-element.

2. Wheel according to claim 1, further comprising an
15 electrical motor.

3. Wheel according to any of the preceding claims,
wherein the ultra-low harvester comprises at least one Intelli-
gent cell current converter circuit (50), the circuit multiply-
ing the first voltage by a first factor and dividing the one or
20 more first currents by the first factor, and one or more of a
wireless power transmitter (WiPoT) (60) and an electrical accu-
mulator (A3), preferably at least one circuit and at least one
wireless transmitter per unit,

the Intelligent cell current converter circuits com-
25 prising

(i) one or more (n) voltage adders (V1, V2) and optionally
one or more current adders (C3), the one or more current adders
being adapted to be in electrical connection to the one or more
voltage adders,

30 (ii) two or more first charge siphon devices (72) per volt-
age adder, preferably 2-100 siphon devices per voltage adder,
such as 4-50 siphon devices per voltage adder, wherein the two
or more first siphon devices are electrically connected in se-
ries to one and another, wherein the two or more first charge
35 siphon devices are adapted to be in electrical connection with
the one or more volt-age adders, wherein the one or more charge
siphon devices comprise one or more capacitors,

(iii) one or more switches for electrically connecting or disconnecting components of the voltaic system, and

(iv) a comparator (U4),

the wireless power transmitter (60) comprising

5 a primary winding (Tr1), a secondary winding (Tr2), and optionally a generator/oscillator (U6),

wherein the primary winding is adapted to be electrically coupled to the one or more voltaic units,

10 wherein the secondary winding is adapted to be electrically coupled to one or more of a load device and power grid, and

15 wherein the one or more voltaic units, the at least one Intelligent cell current converter circuit, and wireless power transmitter are adapted to be in electrical contact with one and another.

4. Wheel according to any of the preceding claims, wherein a material of the support is selected from carbon, a light weight metal, such as aluminium, titanium, a polymer, and combinations thereof, and

20 wherein the support is curved, such as forming a section of a sphere, or of a rounded object.

5. Wheel according to any of the preceding claims, further comprising at least one of a charge storing device, such as a battery, a string inverter, a micro inverter, and a

25 high efficiency solar battery charger.

6. Wheel according to any of the preceding claims, further comprising one or more of

a cooling element, such as a passive cooling element, such as a grid,

30 a wireless power transferor,

a carbon based power transferor, such as carbon brushes, and

a metal slip power contact, such as metal brushes.

7. Wheel according to any of the preceding claims,

35 wherein the at least one PV-element is selected from back-side contacted PV-elements, III-V PV-cells, Si-based PV-cells, preferably having a bottom reflective layer, and combinations thereof.

8. Wheel according to any of the preceding claims,

40 wherein the PV-elements form sections of a wheel, such as tri-

angular sections (220), and/or wherein PV-elements are triangular shaped (210).

5 9. Wheel according to any of the preceding claims, wherein the ultra-low voltage harvester and/or optional motor are located in an axis of the wheel, or wherein each individual PV-cell, or a group of cells comprising 2-4 cells, comprises an ultra-low voltage harvester.

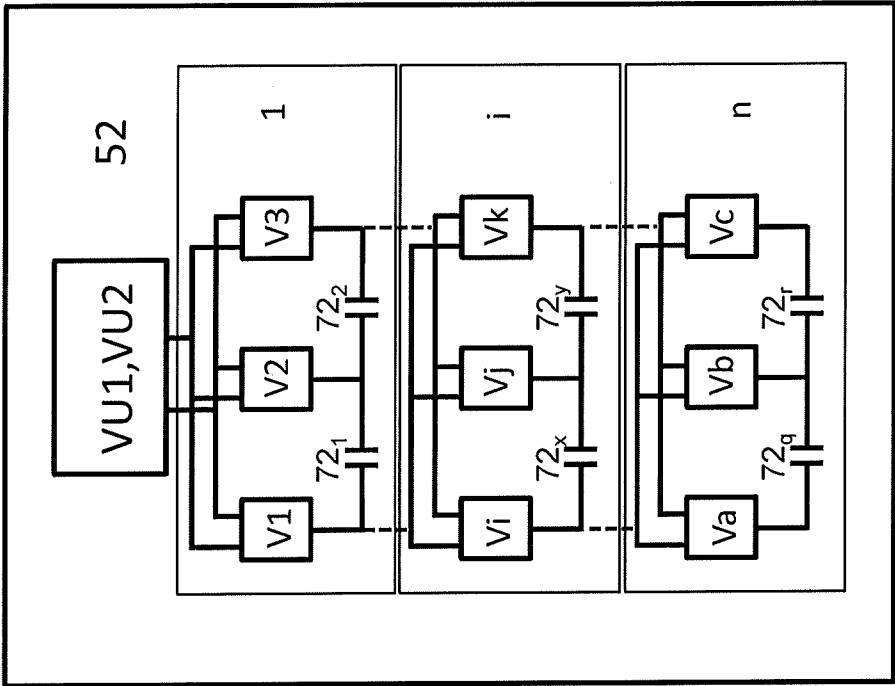
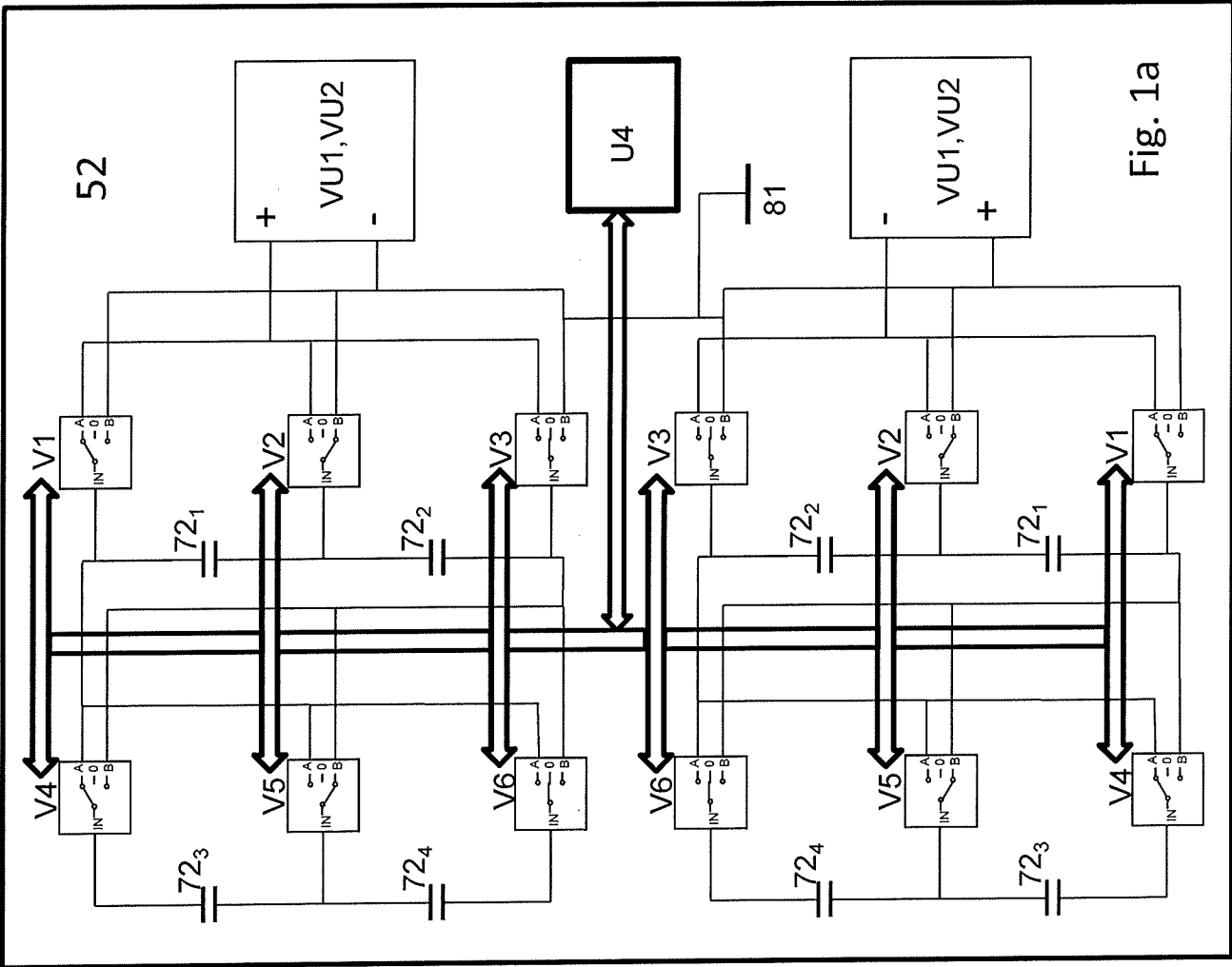
10 10. Wheel according to any of the preceding claims, wherein the PV-elements are covered with an optically transparent coating.

11. Wheel according to any of the preceding claims, wherein the PV-cell and ultra-low voltage harvester are integrated.

15 12. Bicycle comprising at least one wheel according to any of the preceding claims.

13. Bicycle according to claim 12, wherein the bicycle is selected from a bicycle, such as an e-bike, and a solar bike.

20 14. Bicycle according to any of claims 12-13, further comprising one or more of a power supply, such as a USB-port, a battery, such as a Li-ion battery, and a (mains) power grid inlet.



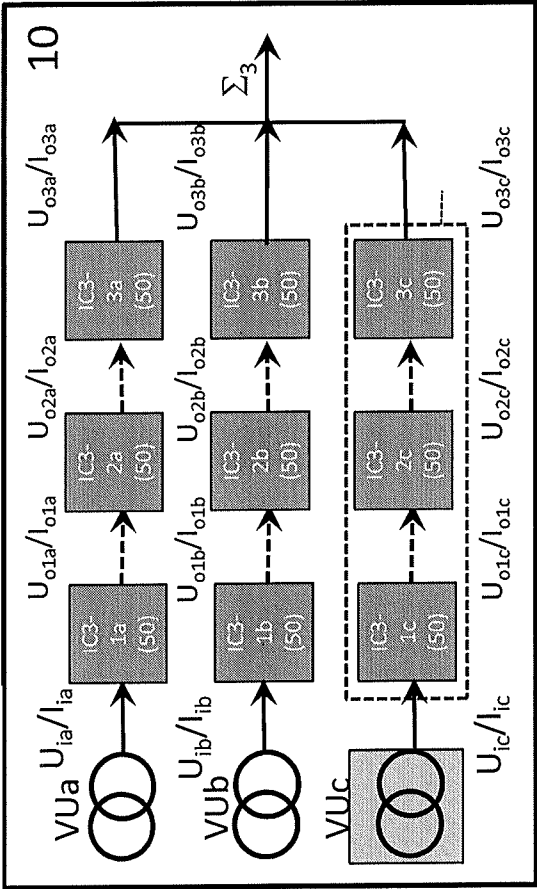


Fig. 1e

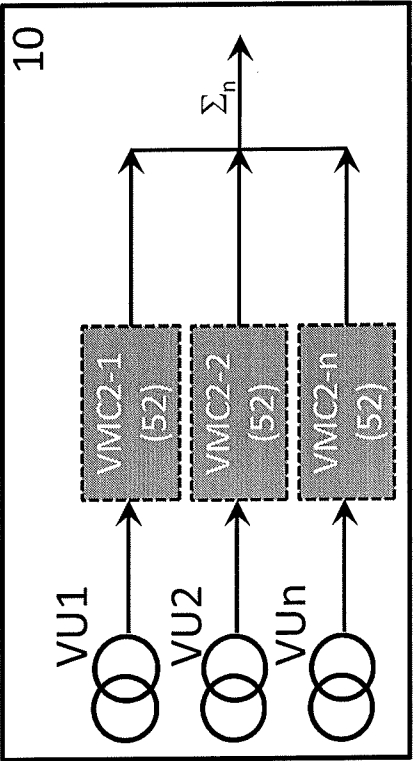


Fig. 1f

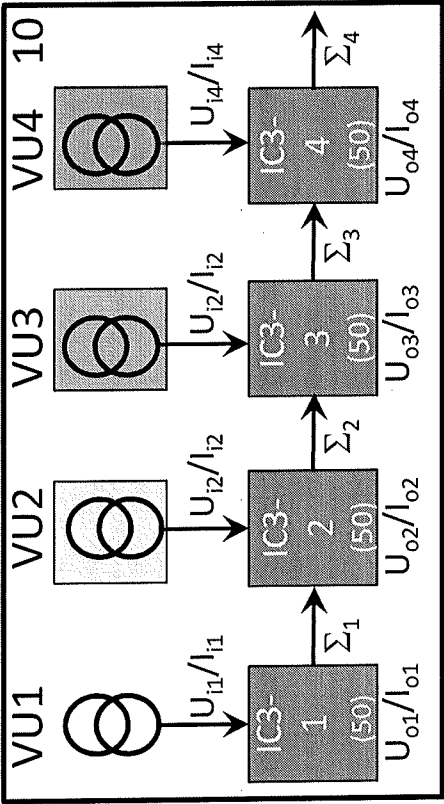


Fig. 1c

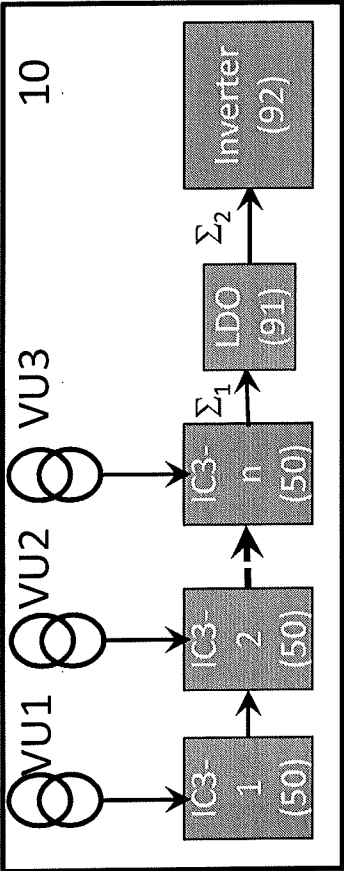


Fig. 1d

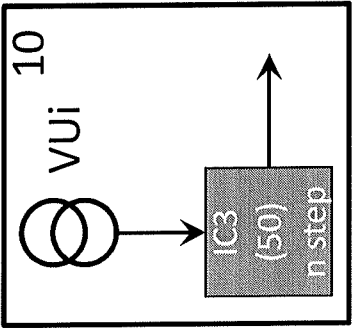


Fig. 1g

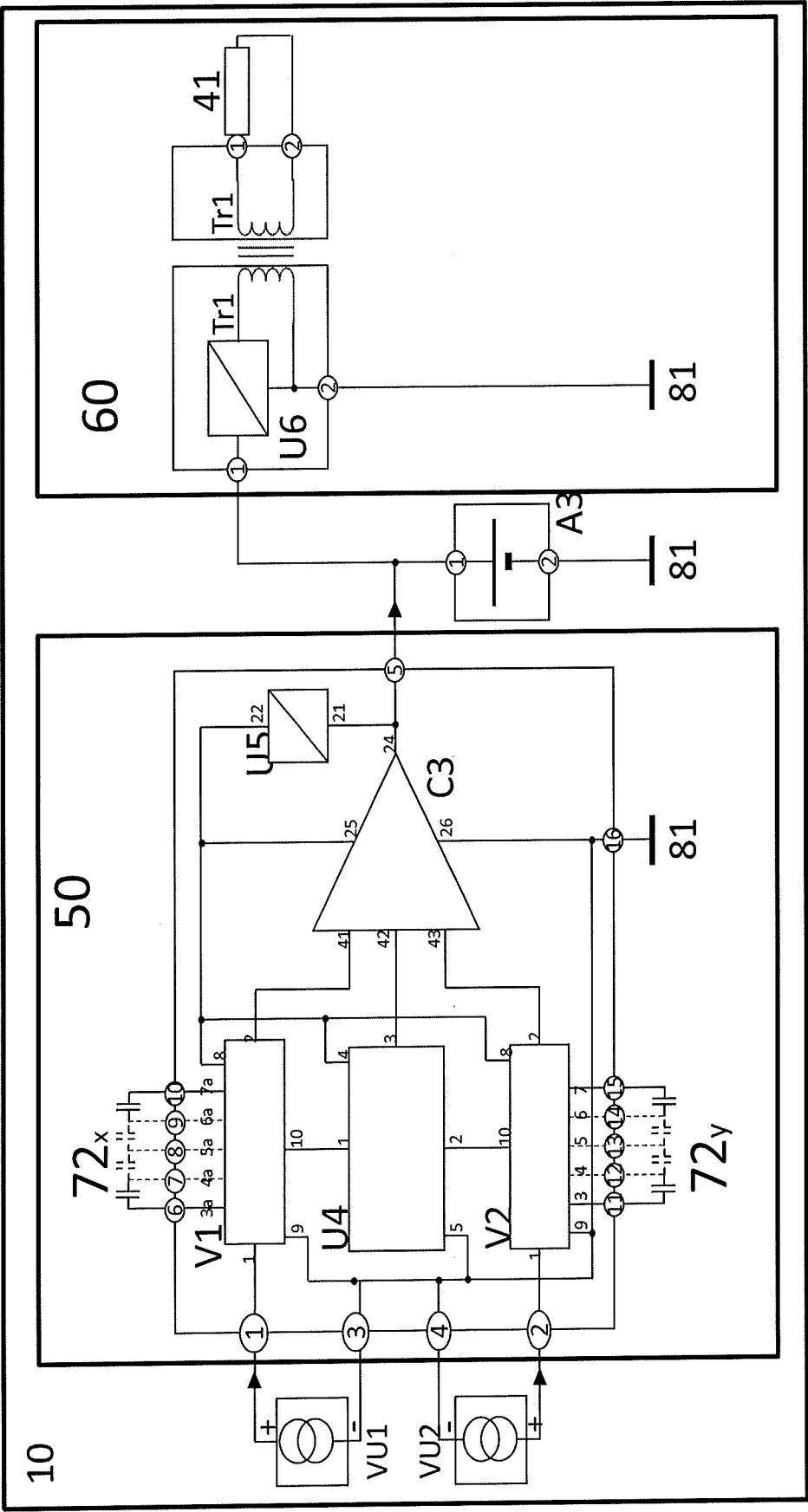
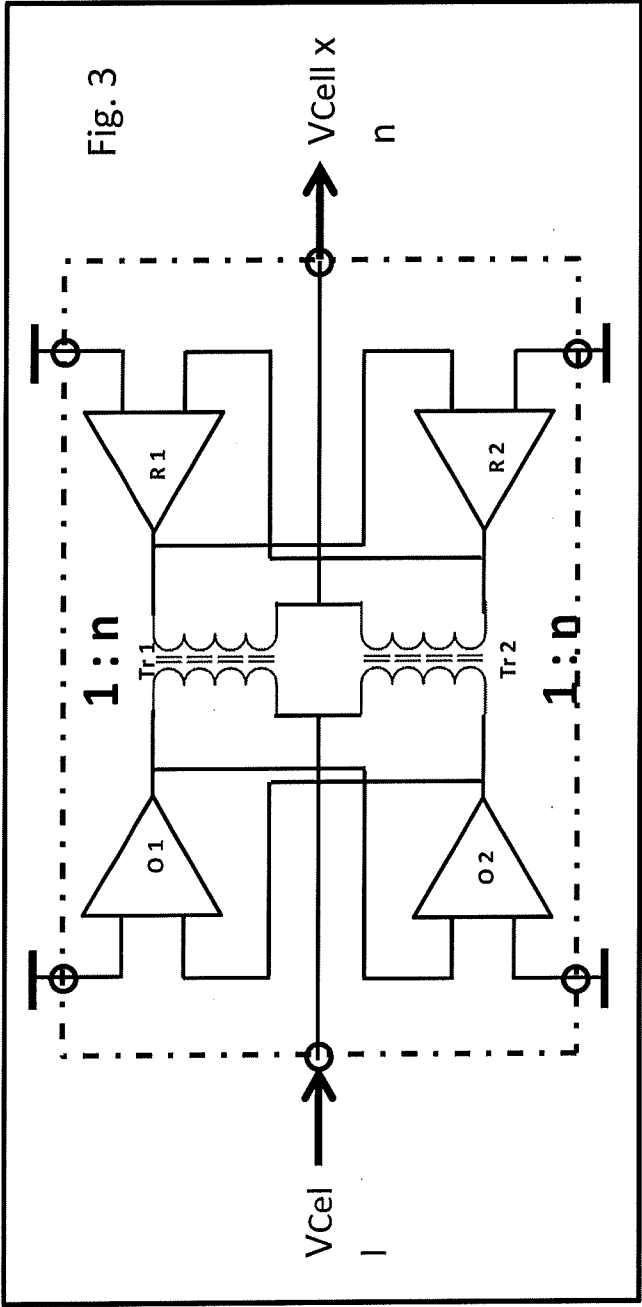
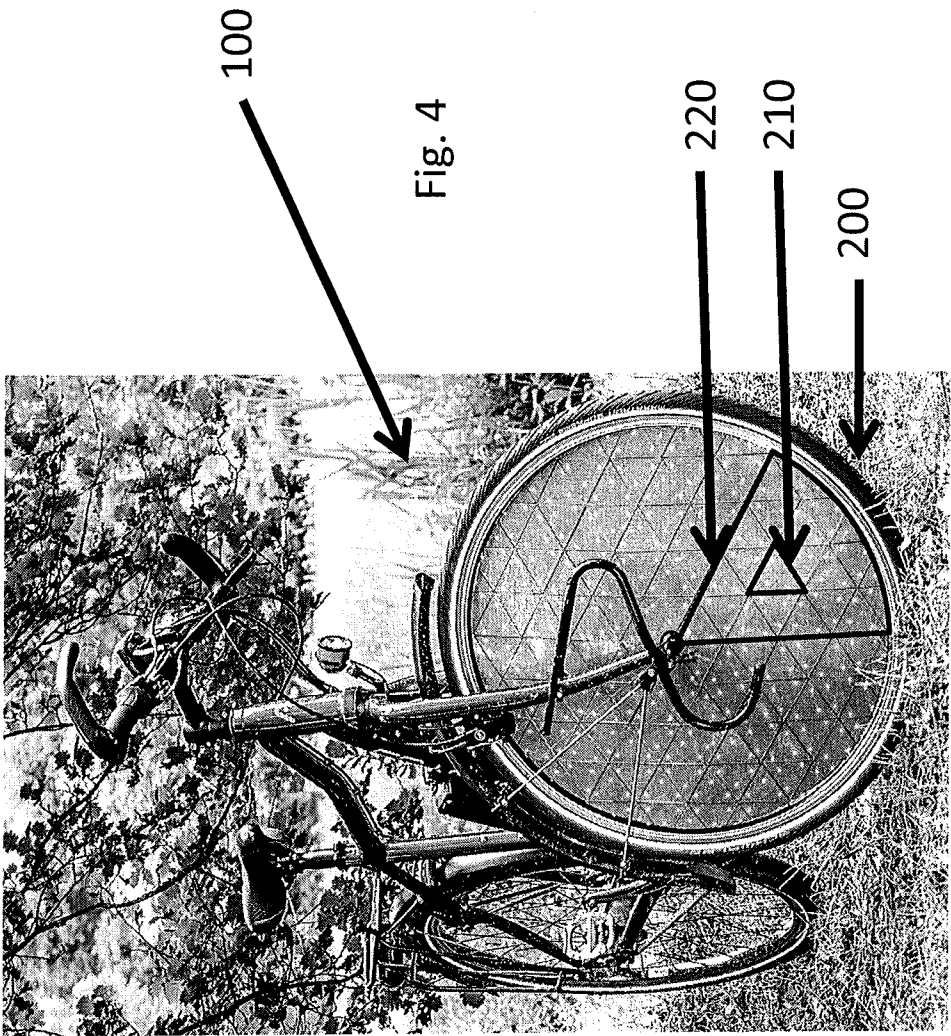


Fig. 2





INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2015/050554

A. CLASSIFICATION OF SUBJECT MATTER

INV. B62M6/85 H01L31/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B62M H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

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X	EP 1 820 727 A1 (FIAT RICERCHE [IT]) 22 August 2007 (2007-08-22) cited in the application paragraph [0020]; figure 1 -----	1-14
Y	WO 2010/081746 A2 (BERGER HUBERT [AT]) 22 July 2010 (2010-07-22) page 21, line 18 - line 24; figure 4 -----	1-14
A	US 2012/043923 A1 (IKRIANNIKOV ALEXANDR [US] ET AL) 23 February 2012 (2012-02-23) figure 6 ----- -/-	1,3,5-7, 10,11,14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

6 January 2016

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INTERNATIONAL SEARCH REPORT

International application No

PCT/NL2015/050554

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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International application No

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