



(43) International Publication Date
17 November 2016 (17.11.2016)

- (51) International Patent Classification:
H02M 7/06 (2006.01) *H02H 7/122* (2006.01)
- (21) International Application Number:
PCT/EP2016/060865
- (22) International Filing Date:
13 May 2016 (13.05.2016)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
15167582.4 13 May 2015 (13.05.2015) EP
- (71) Applicant: ASSA ABLOY AB [SE/SE]; P.O. Box 70340,
107 23 Stockholm (SE).
- (72) Inventor: ARBEGARD, Bernt; Råfsvägen 5, 175 43 Jär-
fälla (SE).
- (74) Agent: KRANSELL & WENNBORG KB; P.O. Box
27834, 115 93 Stockholm (SE).
- (81) Designated States (*unless otherwise indicated, for every
kind of national protection available*): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM,
DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR,
KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG,
MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM,
PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,
SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN,
TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States (*unless otherwise indicated, for every
kind of regional protection available*): ARIPO (BW, GH,
GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ,
TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU,
TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE,
DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,
LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK,
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: MECHANICAL TO ELECTRIC POWER CONVERTER

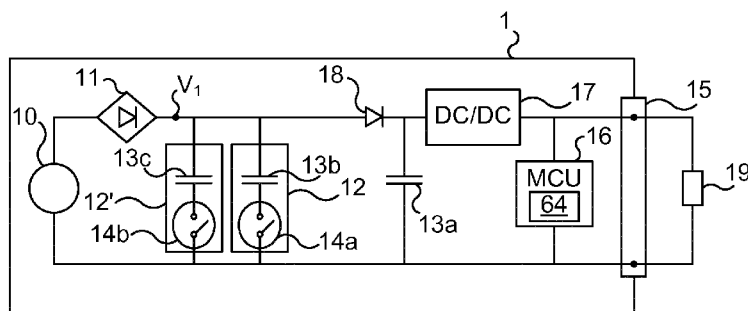


Fig. 3

(57) Abstract: It is provided a mechanical to electric power converter comprising: an electric generator configured to convert a mechanical motion to an electric generator signal; a DC, direct current, output; a rectifier configured to convert the electric generator signal to a rectified signal; a first energy storage element provided between the rectifier and the DC output; a secondary string comprising a second energy storage element and a first switch, the secondary string being provided between the rectifier and the DC output; and a controller configured to close the first switch to enable the rectified signal to charge the second energy storage element when a first switching condition is true.

MECHANICAL TO ELECTRIC POWER CONVERTER

TECHNICAL FIELD

The invention relates to a mechanical to electric power converter, lock device and method for converting power, especially for converting mechanical
5 power to electric power.

BACKGROUND

Energy harvesting can be used to convert mechanical energy to electric energy. For instance, in locks, the energy of inserting a key can be harvested to supply electric energy. The electric energy can then be used to perform
10 electronic access control and, when access is granted, energise an actuator (such as a motor or solenoid) to unlock the lock.

However, the efficiency of such energy harvesting is critical. If more electric energy could be made available, reliability would be improved and more activities could be performed in the lock, such as powering LEDs (Light
15 Emitting Diodes), displays, keypads, more powerful motors, etc. Hence, it is always beneficial to be able to more efficiently convert mechanical energy of a limited mechanical movement (such as when inserting a key) to electric energy.

SUMMARY

20 It is an object to improve the efficiency of converting mechanical power to electric power.

According to a first aspect, it is provided a mechanical to electric power converter comprising: an electric generator configured to convert a mechanical motion to an electric generator signal; a DC, direct current,
25 output; a rectifier configured to convert the electric generator signal to a rectified signal; a first energy storage element provided between the rectifier and the DC output; a secondary string comprising a second energy storage element and a first switch, the secondary string being provided between the rectifier and the DC output; and a controller configured to close the first

switch to enable the rectified signal to charge the second energy storage element when a first switching condition is true.

The first switching condition may be a condition which indicates that the first capacitor is sufficiently charged.

- 5 The first switching condition may comprise that a measured voltage is greater than a first threshold voltage.

The measured voltage may be a voltage across the first energy storage element.

- 10 The first switching condition may comprise that a rate of change of a voltage is less than a first rate threshold.

The first switching condition may comprise that a certain time has elapsed from when the electric generator starts to provide the electric generator signal.

- 15 The mechanical to electric power converter may further comprise a diode between the first energy storage element and the second energy storage element, preventing an electric current from flowing from the first energy storage element to the second energy storage element.

- 20 The mechanical to electric power converter according to any one of the preceding claims may further comprise a tertiary string comprising a third energy storage element and a second switch. The tertiary string is provided between the rectifier and the DC output. The controller is then configured to close the second switch to enable the rectified signal to charge the third energy storage element when a second switching condition is true.

The second threshold voltage may be less than the first threshold voltage.

- 25 The mechanical to electric power converter may further comprise a DC/DC converter configured to supply a suitable DC voltage on the DC output.

A capacitance of the second energy storage element may be at least twice the capacitance of the first energy storage element.

The mechanical to electric power converter may further comprise: a memory storing instructions that, when executed by the processor, cause the
5 controller to close the first switch to enable the rectified signal to charge the second energy storage element when a first switching condition is true.

According to a second aspect, it is provided a lock device comprising the mechanical to electric power converter according to any one of the preceding claims.

10 According to a third aspect, it is provided a method for converting energy from a mechanical motion to a DC, direct current, output signal on a DC output of a mechanical to electric power converter. The method is performed in the mechanical to electric power converter and comprises the steps of:
converting a mechanical motion to an electric generator signal in an AC
15 generator; converting the electric generator signal to a rectified signal in a rectifier; storing energy in a first energy storage element provided between the rectifier and the DC output; when a first switching condition is true, closing a first switch to enable the rectified signal to charge a second energy storage element, the first switch and the second energy storage element
20 forming part of a secondary string being provided between the rectifier and the DC output.

The step of closing the first switch may comprise dynamically controlling the first switch according to a target duty cycle. This can e.g. be implemented using pulse width modulation (PWM) or pulse frequency modulation (PFM).

25 The method may further comprise the step of: when a second switching condition is true, closing a second switch to enable the rectified signal to charge a third energy storage element, the second switch and the third energy storage element forming part of a tertiary string being provided between the rectifier and the DC output.

The method may further comprise the step of: supplying a suitable DC voltage on the DC output using a DC/DC converter.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated.

10 BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic diagram illustrating a mechanical to electric power converter using only one energy storage element;

15 Fig 2 is a schematic graph illustrating the operation of the mechanical to electric power converter of Fig 1;

Fig 3 is a schematic diagram illustrating a mechanical to electric power converter using a plurality of energy storage elements;

20 Fig 4 is a schematic graph illustrating the operation of the mechanical to electric power converter of Fig 3;

Fig 5 is a flow chart illustrating the operation of the mechanical to electric power converter of Fig 3; and

Fig 6 is a schematic diagram illustrating the mechanical to electric power converter of Fig 3 forming part of a lock device.

25 DETAILED DESCRIPTION

The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention

are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope
5 of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

Fig 1 is a schematic diagram illustrating a mechanical to electric power converter 1 using only one energy storage element. An electric generator 10 comprises mechanical and electrical components to convert a mechanical
10 motion to a generator signal in the form of an AC (Alternating Current) or DC (Direct Current) signal. For instance, when deployed in a lock device, the motion of inserting a key, turning a key or turning a handle/knob is converted to a voltage. When the electric generator 10 is implemented using an AC generator, a rectifier 11 converts the AC of the generator signal to a
15 rectified signal at point v1. The rectifier 11 is of any suitable type providing an output voltage of only one sign. For instance the rectifier 11 can be a diode bridge rectifier. When the electric generator 10 is implemented using a DC generator, the rectifier can be replaced with a diode to prevent a reverse DC current to the generator 10.

20 A first energy storage element 13a is charged by the rectified signal. The energy storage element can be of any suitable type, e.g. a capacitor, a battery, a super capacitor, etc. For simplicity, any reference to this or other energy storage elements is simply referred to as a capacitor in the text below. The electric energy from the first capacitor 13a energy is converted by a DC/DC
25 converter 17 to a suitable output voltage for powering a controller 16 and to be provided on a DC output 15 of the mechanical to electric power converter 1. The DC/DC converter 17 can be a buck converter, a boost converter or a buck/boost converter as needed, to provide the suitable voltage on the DC output 15.

30 The controller 16 can be implemented using a processor (e.g. MCU (microcontroller unit), a CPU (central processing unit) or DSP (digital signal

processor)), executing software instructions. Alternatively or additionally, the controller is implemented using any combination of one or more application specific integrated circuits, field programmable gate arrays, discrete logical components, etc. When the controller 16 executes software instructions, the software instructions are stored in a memory 64, which can be provided as part of the controller 16 (as shown) or externally to the controller 16 (not shown). The memory 64 can be any combination of read and write memory (RAM) and read only memory (ROM). The memory 64 comprises persistent storage, which, for example, can be any single one or combination of magnetic memory, optical memory, solid state memory, etc.

The DC output 15 provides a suitable DC voltage for powering a load 19, such as an access control device and other electrical components of a lock device. The controller 16 can optionally also be used for functions, such as the access control, of the lock device.

Fig 2 is a schematic graph illustrating the operation of the mechanical to electric power converter of Fig 1 when a mechanical action is applied to the mechanical to electric power converter, e.g. by inserting a key. The vertical axis represents voltage and the horizontal axis represents time.

The rectified signal 21 is here shown as a rectified generator signal in the form of an AC signal and an upper line 20 shows the voltage across the first capacitor 13a.

The generator signal increases in amplitude over time to a point after which it decreases again. As long as the rectified generator signal is greater than the current voltage of the first capacitor 13a, the first capacitor 13a is charged. In other words, the capacitor voltage 20 increases with (in this case) the rectified signal 21 when this is at a higher voltage, as indicated by charging periods 22a-c at the lower section of Fig 2.

Fig 3 is a schematic diagram illustrating a mechanical to electric power converter 1 using a plurality of capacitors. Here there is a secondary string 12 provided with one end between the rectifier 11 and the DC output 15 and one

end at ground. In other words, the secondary string 12 is provided in parallel to the first capacitor 13a. The secondary string 12 comprises a second capacitor 13b, hereinafter denoted second capacitor 13b, and a first switch 14a. Optionally, a tertiary string 12' is provided in parallel to the secondary string 12.. The tertiary string 12' comprises a third capacitor 13c, hereinafter denoted third capacitor 13c, and a second switch 14b. More strings with respective capacitors and switches can optionally be provided if desired. The switches 14a-b can e.g. be implemented using transistors.

The controller 16 is here configured to close the first switch 14a when a first switching condition is fulfilled. The first switching condition is a condition which indicates (directly or indirectly) that the first capacitor is sufficiently charged. Sufficiently charged is here to be interpreted as a charge level at which it is reasonable to start charging the second capacitor. The first condition could e.g. comprise that the measured voltage is greater than a first threshold voltage to thereby enable the rectified signal to charge the second capacitor 13b. This threshold voltage indicates that the first capacitor is sufficiently charged. Alternatively or additionally, the first switching condition comprises that a rate of change of the voltage is less than a first rate threshold. When the rate of change decreases below this threshold, this indicates that the capacitor is sufficiently charged. In other words, when the voltage flattens out, this can be part of the first switching condition. The rate of change of the voltage can be expressed as a time derivative (dV/dt) of the measured voltage. Alternatively or additionally, the first switching condition comprises that a certain time has elapsed time since activation, e.g. by key insertion. It is thus assumed that the first capacitor has been sufficiently charged after this elapsed time. This activation can e.g. be indicated by the start of the provision of the electric generator signal. The first switching condition can be defined also or alternatively using other voltages, currents or other physical parameters within the system.

Optionally, a diode 18 is provided between the first capacitor 13a and the second capacitor 13b to thereby prevent an electric current from flowing from the first capacitor 13a to the second capacitor 13b. In this way, a stable output

voltage is provided on the DC output 15. In such a case, the secondary string 12 is still considered to be connected in parallel to the first capacitor 13a, albeit via the diode 18.

Looking now to Fig 4, this is a schematic graph illustrating the operation of the mechanical to electric power converter 1 of Fig 3. As in Fig 2, the vertical axis represents voltage and the horizontal axis represents time. Here there are ten charging periods 22a-j.

At time t_0 , the first switch is open (in a non-conducting state), whereby the rectified signal charges the first capacitor 13a in the first to five complete charging periods 22a-e and in an initial section of the sixth charging period 22f.

At time t_1 , the first switching condition is fulfilled, whereby the first switch 14a is closed (to a conducting state). In the example shown here, the first switching condition is that the voltage is greater than a first threshold value th_1 . However, as explained above, any other one or combination of conditions can make up the first switching condition. The second capacitor 13b then starts to charge in the sixth charging period 22f. Since, at time t_1 , the second capacitor 13b is uncharged, the rectifier signal v_1 drops to zero and charging can start at an earlier point in time than if only the first capacitor was charged, thus utilising more electric energy of the rectified signal to charge a capacitor (the second capacitor in this case). Optionally, the first switch 14a can be dynamically closed using e.g. a Pulse Width Modulated (PWM) or Pulse Frequency Modulated (PFM) signal instead of being statically closed. When the dynamic closing (e.g. PWM/PFM) is utilised, the amount of mechanical resistance experienced by the user can be controlled, e.g. when inserting a key or turning a door handle. For instance, if a duty cycle is controlled to be low, the mechanical resistance becomes low. On the other hand, if the duty cycle is controlled to be high, the mechanical resistance becomes high. The duty cycle can be controlled to vary over time to achieve a desired profile of mechanical resistance to thereby achieve a high quality user experience. The dynamic control can also be used to optimise power transfer

over time during the entire mechanical motion. The type of switching mode, static or dynamic, can also be selected depending on different parameters in the system.

At time t_2 , the second switching condition is fulfilled, whereby the second
5 switch 14b is closed. The second switching condition can be of the same type as the first switching condition or it can be of a different type. In this example, the second switching condition is that the voltage is greater than a second threshold th_2 . The second threshold th_2 can be less than the first threshold th_1 to allow more energy to be utilised for charging the third
10 capacitor 13c when the amplitude of the rectified signal 21 decreases. The third capacitor 13c then starts to charge in the ninth charging period 22i. Optionally the first switch 14a can be opened at time t_2 . Because the third capacitor 13c is then uncharged, the rectifier signal v_1 drops to zero and charging occurs. In fact, charging of the first and second capacitors 13a-13b is
15 not possible at this stage, but using the second switch, the third capacitor can be charged, utilising electric energy which would otherwise be wasted. In one embodiment, the first switch 14a is kept closed at time t_2 , whereby, the second capacitor 13b and the third capacitor 13c are charged in parallel starting from a voltage v_1 which depends on the previous charge level of the
20 second capacitor 13b. The first and second switches 14a and 14b can in this charging phase be connected either dynamically (e.g. using PWM/PFM) or statically, independently of each other in the same way as described at time t_1 above.

Hence, by using the secondary string 12 and the tertiary string 12', more
25 electric energy is stored which can be used to power the controller 16 and the load 19. In other words, more power is harvested, converting mechanical power to electric power. Moreover, the second capacitor 13b and the third capacitor 13c are selected to achieve the desired characteristics of charging. This gives much more flexibility, e.g. compared to using a single non-linear
30 capacitor.

The diode 18 prevents the voltage supplied to the DC/DC converter 17 from dropping when the first switch 14a and the second switch 14b are statically or dynamically closed. In this way, the voltage level provided to the DC/DC converter 17 can be kept at a high level, allowing the load 19 to be powered
5 also at time t1 and t2.

In one embodiment, the capacitance of the second storage element 13b is considerably larger than the capacitance of the first storage element 13a. For instance, the capacitance of the second storage element 13b can be at least twice the capacitance of the first storage element 13a. In this way, the voltage
10 of the first (smaller) capacitor 13a quickly reaches a level which can be utilised for powering the load, while additional power is collected in the second and third capacitors 13b-c. This can be particularly useful when response times need to be short, e.g. when powering electronic access control where short response time greatly benefit the user experience.

15 Fig 5 is a flow chart illustrating the operation of the mechanical to electric power converter of Fig 3. The method is performed in the mechanical to electric power converter 1 e.g. of Fig 3, with or without optional components as described above. The method can be started when a suitable mechanical motion is performed, e.g. by a user. For instance, when the mechanical to
20 electric power converter is powered by the insertion of a key, the method is started when the key is inserted.

The method is illustrated in two paths. The path on the left hand side converts power and the path on the right hand side controls the switches. The two paths can be performed in parallel in the mechanical to electric power
25 converter. First the power conversion is described.

In a *convert to electric* step 40, a mechanical motion is converted to an electric generator signal in the electric generator. As explained above, the electric generator signal can be an AC signal or a DC signal. The mechanical motion can e.g. be a linear motion, a rotary motion or any other motion
30 which can be used to drive the electric generator.

In an optional *rectify* step 42, when the generator signal is an AC signal, the generator signal is rectified to a rectified signal in the rectifier. If a DC generator is used, this step can be omitted. A single diode can however be provided to avoid discharge of the second capacitor 13b and the third
5 capacitor 13c through the DC generator.

In a *store energy* step 44, energy is stored in the first capacitor provided between the rectifier and the DC output. The second capacitor is also charged in this step when activated using the first switch. Additional capacitors can also be charged in this step when activated using respective switches.

10 In a *supply suitable voltage* step 48, a suitable DC voltage is supplied on the DC output using the DC/DC converter.

In a conditional *end* step 54, the left hand path ends if appropriate. Otherwise, the left hand path continues with the *convert to electric* step 40. This determination can be an active determination e.g. by considering the
15 voltage of the first capacitor. Alternatively, this is a passive determination, i.e. the path ends when there is no power conversion to be performed.

It is to be noted that the steps 40, 42, 44, 48, 54 of the left path can be performed independently in parallel to ensure that the power supply occurs without interruption.

20 Now, the switch control path on the right side of the flow chart is described. Optionally, this path is started when the mechanical to electric power converter supplies sufficient electric power to power the controller 16.

In a conditional *first switching condition* step 45, it is determined whether the first switching condition is fulfilled. If this is the case, the method
25 proceeds to a *control first switch* step 46. Otherwise, the path re-executes the conditional *first switching condition* step 45, optionally after a delay. As explained above, the first switching condition can be any single or combination of relevant sub-conditions, e.g. related to voltage, rate of change of voltage (dV/dt), time, etc. When several sub-conditions are combined,

these can be combined using AND logic, i.e. that all sub-conditions need to be true to fulfil the first switching condition. Alternatively, the sub-conditions are combined using OR logic, i.e. that any one or more of the sub-conditions need to be true to fulfil the first switching condition.

- 5 In a *control 1st switch* step 46, the first switch is statically or dynamically (e.g. using PWM/PFM) closed to enable the rectified signal to charge the second capacitor. As described above, the first switch and the second capacitor form part of a secondary string provided between the rectifier and the DC output.

- 10 In a conditional *second switching condition* step 47, it is determined whether the second switching condition is fulfilled. If this is the case, the method proceeds to a *control second switch* step 48. Otherwise, the path re-executes the conditional *second switching condition* step 47, optionally after a delay.

- 15 As explained above, the second switching condition can be any single or combination of relevant sub-conditions, e.g. related to voltage, rate of change of voltage (dV/dt), time, etc. When several sub-conditions are combined, these can be combined using AND logic, i.e. that all sub-conditions need to be true to fulfil the first switching condition. Alternatively, the sub-conditions are combined using OR logic, i.e. that any one or more of the sub-conditions need to be true to fulfil the first switching condition. The second switching
- 20 condition can be of the same type (and the same or different value) as the first switching condition, or the second switching condition can be of a different type to the first switching condition. In a *control 2nd switch* step 48, the second switch is statically or dynamically (e.g. using PWM/PFM) closed to enable the rectified signal to charge the third capacitor. As described
- 25 above, the second switch and the third capacitor form part of a tertiary string provided between the rectifier and the DC output.

The third capacitor can be connected alone, i.e. while disconnecting the second capacitor, or in parallel with the second capacitor. Each of the two capacitors can be individually closed or opened in a static or dynamic way.

In a conditional *end* step 50, it is determined whether the right hand path is to end. This determination can be an active determination e.g. by considering the voltage of the first capacitor. Alternatively, this is a passive determination, i.e. the path ends when no power is supplied anymore. If the
5 right hand path is to end, the method proceeds to an *open switch(es)* step 52. Otherwise, the path re-executes the conditional *end* step 50, optionally after a delay.

In the *open switch(es)* step 52, the first switch and the second switch, when deployed, are opened. In this way, the mechanical to electric power converter
10 is in a state where the method can be performed again. Optionally, the switches are such that they open when not provided with a control signal. In such a case, when the power conversion ends, the controller becomes unpowered and ends sending a control signal to the second switch (and any other switches), thus opening the switch(es) when there is no more electric
15 power left.

Fig 6 is a schematic diagram illustrating the mechanical to electric power converter of Fig 3 forming part of a lock device 3.

The lock device 3 then comprises the mechanical to electric power converter 1 of Fig 3 (with or without optional components) and a load 19 powered by the
20 mechanical to electric power converter. The load 19 can e.g. comprise one or more access control circuitries, LEDs, displays, keypads, solenoids, motors, etc. Using the more efficient mechanical to electric power converter 1 as described above, the load 19 can consume more power which is harvested from the mechanical motion, such as inserting a key. In this way, power
25 harvesting can be used in cases which would otherwise require external power supply, such as a mains connection or cell batteries.

Here now follows a set of embodiments enumerated with roman numerals.

- i. A power converter (1) comprising:
 - an electric generator (10) configured to convert a mechanical motion to
30 an electric generator signal;

- a DC, direct current, output (15);
a rectifier (11) configured to convert the electric generator signal to a rectified signal;
a first energy storage element (13a) provided between the rectifier (11)
5 and the DC output (15);
a secondary string (12) comprising a second energy storage element (13b) and a first switch (14a), the secondary string being provided between the rectifier (11) and the DC output (15); and
a controller (16) configured to close the first switch (14a) to enable the
10 rectified signal to charge the second energy storage element (13b) when a first switching condition is true.
- ii. The power converter (1) according to embodiment i, wherein the first switching condition comprises that a measured voltage is greater than a first threshold voltage.
- 15 iii. The power converter (1) according to embodiment ii, wherein the measured voltage is a voltage across the first energy storage element (13a).
- iv. The power converter (1) according to any one of the preceding embodiments, wherein the first switching condition comprises that a rate of change of a voltage is less than a first rate threshold.
- 20 v. The power converter (1) according to any one of the preceding embodiments, wherein the first switching condition comprises that a certain time has elapsed from when the electric generator (10) starts to provide the electric generator signal.
- vi. The power converter (1) according to any one of the preceding
25 embodiments, further comprising a diode (18) between the first energy storage element (13a) and the second energy storage element (13b), preventing an electric current from flowing from the first energy storage element (13a) to the second energy storage element.

- vii. The power converter (1) according to any one of the preceding embodiments, further comprising a tertiary string (12') comprising a third energy storage element (13b) and a second switch (14b), the tertiary string being provided between the rectifier (11) and the DC output (15); and
- 5 wherein the controller (16) is configured to close the second switch (14b) to enable the rectified signal to charge the third energy storage element (13b) when a second switching condition is true.
- viii. The power converter (1) according to embodiment vii, wherein the second threshold voltage is less than the first threshold voltage.
- 10 ix. The power converter (1) according to any one of the preceding embodiments, further comprising a DC/DC converter (17) configured to supply a suitable DC voltage on the DC output (15).
- x. The power converter (1) according to any one of the preceding embodiments, wherein a capacitance of the second energy storage element
- 15 (13b) is at least twice the capacitance of the first energy storage element (13a).
- xi. The power converter (1) according to any one of the preceding embodiments, further comprising: a memory (64) storing instructions (66) that, when executed by the processor, cause the controller to close the first
- 20 switch (14a) to enable the rectified signal to charge the second energy storage element (13b) when a first switching condition is true.
- xii. A lock device (3) comprising the power converter (1) according to any one of the preceding embodiments.
- xiii. A method for converting energy from a mechanical motion to a DC,
- 25 direct current, output signal on a DC output (15) of a power converter (1), the method being performed in the power converter (1) and comprising the steps of:
- converting (40) a mechanical motion to an electric generator signal in an AC generator (10);

converting (42) the electric generator signal to a rectified signal in a rectifier (11);

storing (44) energy in a first energy storage element (13a) provided between the rectifier (11) and the DC output (15);

5 when a first switching condition is true, closing (46) a first switch (14a) to enable the rectified signal to charge a second energy storage element (13b), the first switch (14a) and the second energy storage element (13b) forming part of a secondary string (12) being provided between the rectifier (11) and the DC output (15).

10 xiv. The method according to embodiment xiii, wherein the step of closing (46) the first switch comprises dynamically controlling the first switch according to a target duty cycle.

xv. The method according to embodiment xiii, further comprising the step of:

15 when a second switching condition is true, closing (48) a second switch (14b) to enable the rectified signal to charge a third energy storage element (13c), the second switch (14b) and the third energy storage element (13c) forming part of a tertiary string (12') being provided between the rectifier (11) and the DC output (15).

20 The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

CLAIMS

1. A mechanical to electric power converter (1) comprising:
 - an electric generator (10) configured to convert a mechanical motion to an electric generator signal;
 - 5 a DC, direct current, output (15);
 - a rectifier (11) configured to convert the electric generator signal to a rectified signal;
 - a first energy storage element (13a) provided between the rectifier (11) and the DC output (15);
 - 10 a secondary string (12) comprising a second energy storage element (13b) and a first switch (14a), the secondary string being provided in parallel to the first energy storage element; and
 - a controller (16) configured to close the first switch (14a) to enable the rectified signal to charge the second energy storage element (13b) when a first
 - 15 switching condition is true.
2. The mechanical to electric power converter (1) according to claim 1, wherein the first switching condition is a condition which indicates that the first capacitor is sufficiently charged.
3. The mechanical to electric power converter (1) according to claim 1 or 2,
20 wherein the first switching condition comprises that a measured voltage is greater than a first threshold voltage.
4. The mechanical to electric power converter (1) according to claim 3, wherein the measured voltage is a voltage across the first energy storage element (13a).
- 25 5. The mechanical to electric power converter (1) according to any one of the preceding claims, wherein the first switching condition comprises that a rate of change of a voltage is less than a first rate threshold.
6. The mechanical to electric power converter (1) according to any one of the preceding claims, wherein the first switching condition comprises that a

certain time has elapsed from when the electric generator (10) starts to provide the electric generator signal.

7. The mechanical to electric power converter (1) according to any one of the preceding claims, further comprising a diode (18) between the first
5 energy storage element (13a) and the second energy storage element (13b), preventing an electric current from flowing from the first energy storage element (13a) to the second energy storage element.
8. The mechanical to electric power converter (1) according to any one of the preceding claims, further comprising a tertiary string (12') comprising a
10 third energy storage element (13b) and a second switch (14b), the tertiary string being provided in parallel to the secondary string (12); and
wherein the controller (16) is configured to close the second switch (14b) to enable the rectified signal to charge the third energy storage element (13b) when a second switching condition is true.
- 15 9. The mechanical to electric power converter (1) according to claim 8 when dependent on claim 3, wherein the second threshold voltage is less than the first threshold voltage.
10. The mechanical to electric power converter (1) according to any one of the preceding claims, further comprising a DC/DC converter (17) configured
20 to supply a suitable DC voltage on the DC output (15).
11. The mechanical to electric power converter (1) according to any one of the preceding claims, wherein a capacitance of the second energy storage element (13b) is at least twice the capacitance of the first energy storage element (13a).
- 25 12. The mechanical to electric power converter (1) according to any one of the preceding claims, further comprising: a memory (64) storing instructions (66) that, when executed by the processor, cause the controller to close the first switch (14a) to enable the rectified signal to charge the second energy storage element (13b) when a first switching condition is true.

13. A lock device (3) comprising the mechanical to electric power converter (1) according to any one of the preceding claims.

14. A method for converting energy from a mechanical motion to a DC, direct current, output signal on a DC output (15) of a mechanical to electric power converter (1), the method being performed in the mechanical to electric power converter (1) and comprising the steps of:

5 converting (40) a mechanical motion to an electric generator signal in an AC generator (10);

10 converting (42) the electric generator signal to a rectified signal in a rectifier (11);

storing (44) energy in a first energy storage element (13a) provided between the rectifier (11) and the DC output (15);

when a first switching condition is true, closing (46) a first switch (14a) to enable the rectified signal to charge a second energy storage element (13b),

15 the first switch (14a) and the second energy storage element (13b) forming part of a secondary string (12) being provided between the rectifier (11) and the DC output (15).

15. The method according to claim 14, wherein the step of closing (46) the first switch comprises dynamically controlling the first switch according to a target duty cycle.

20

16. The method according to claim 14 or 15, further comprising the step of:

when a second switching condition is true, closing (48) a second switch (14b) to enable the rectified signal to charge a third energy storage element (13c), the second switch (14b) and the third energy storage element (13c)

25 forming part of a tertiary string (12') being provided between the rectifier (11) and the DC output (15).

1/3

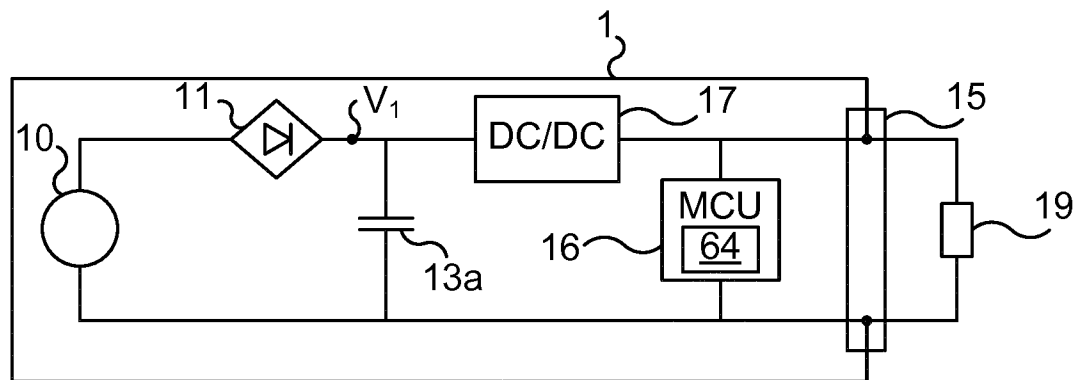


Fig. 1

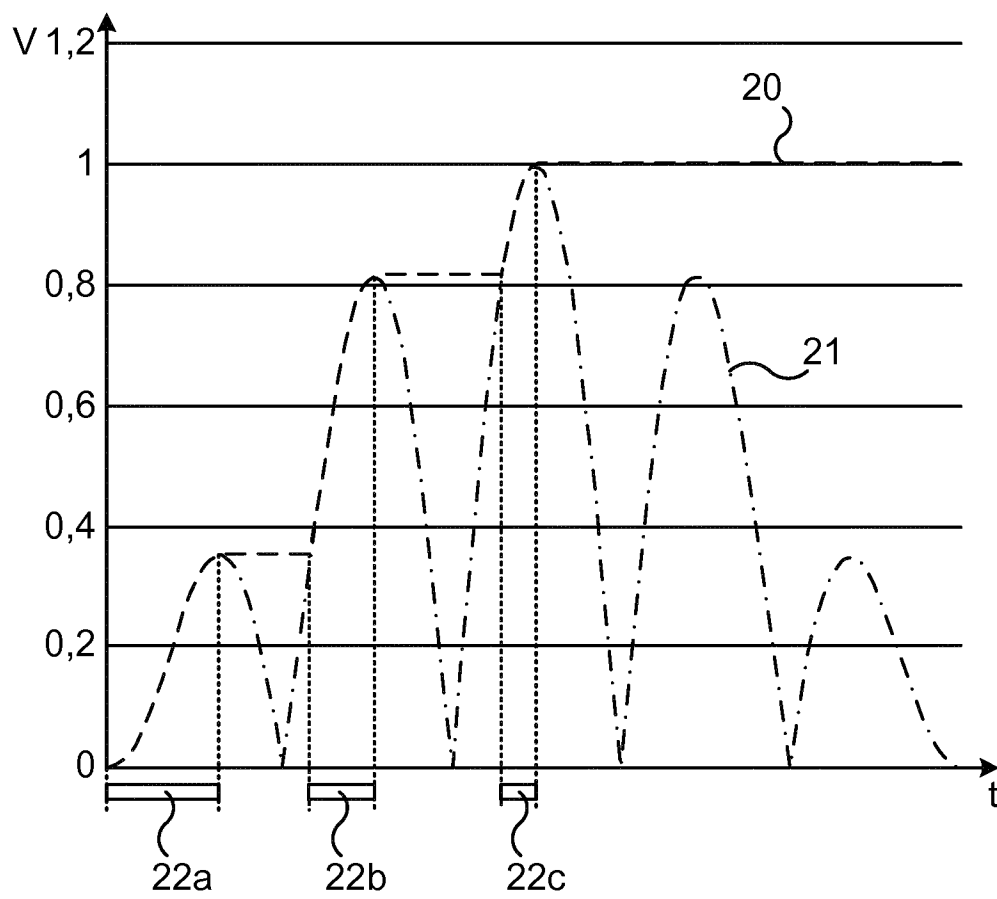


Fig. 2

2/3

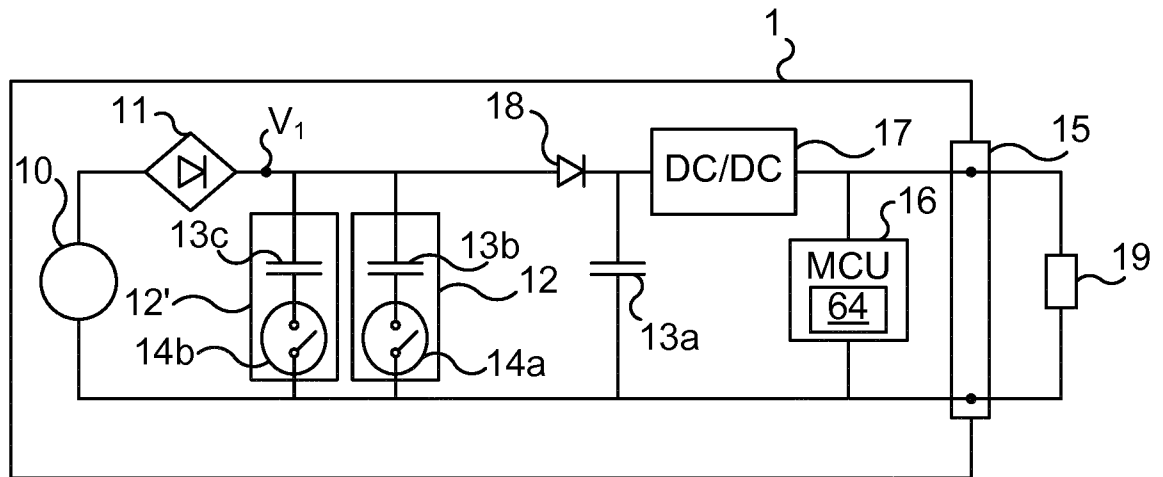


Fig. 3

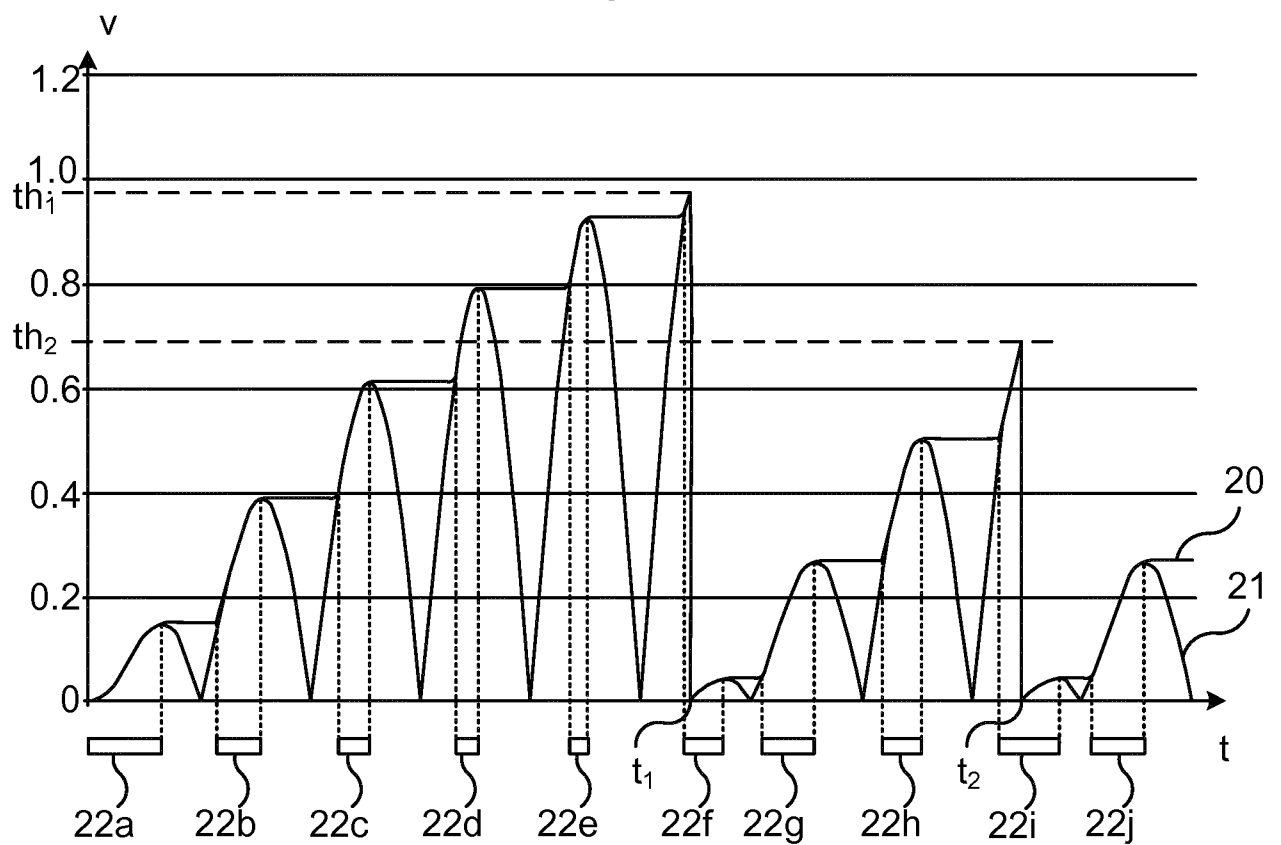


Fig. 4

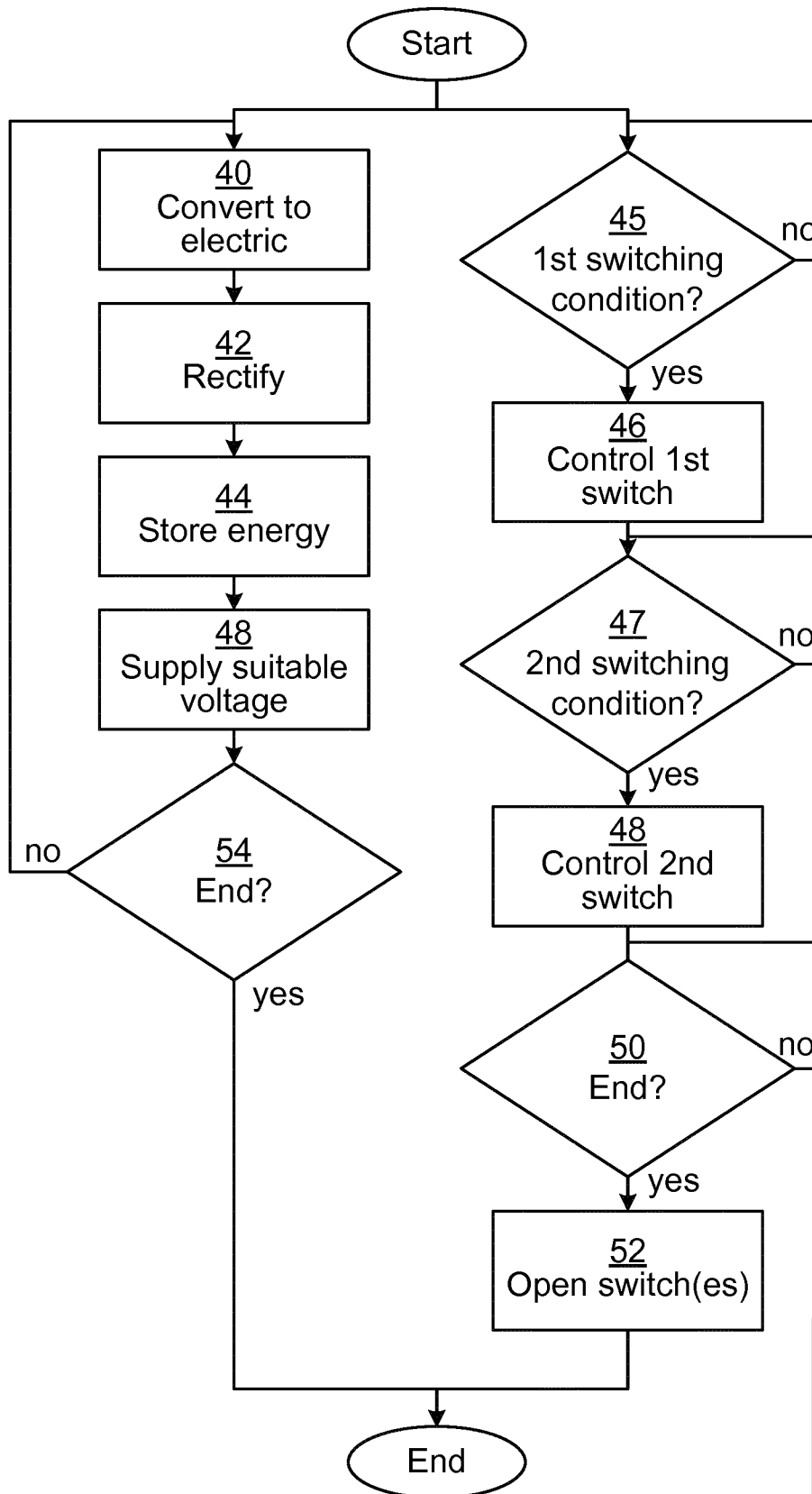


Fig. 5

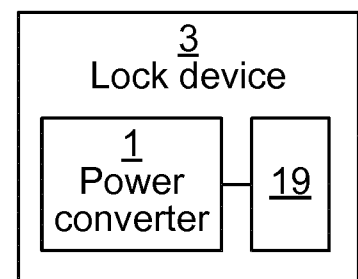


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/060865

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02M7/06 H02H7/122
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)
H02M H02H G07C

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/074361 A1 (TAO FENG FENG [US] ET AL) 31 March 2011 (2011-03-31) paragraphs [0029], [0030], [0034] - [0036]; figures 1,2 -----	1-16
A	EP 2 775 604 A1 (NXP BV [NL]) 10 September 2014 (2014-09-10) claim 8 -----	13
A	JP 2005 080456 A (TOYOTA MOTOR CORP) 24 March 2005 (2005-03-24) abstract; figure 1 -----	1,14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

10 August 2016

Date of mailing of the international search report

19/08/2016

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Speiser, Pierre

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2016/060865

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011074361	A1	31-03-2011	NONE
EP 2775604	A1	10-09-2014	NONE
JP 2005080456	A	24-03-2005	NONE