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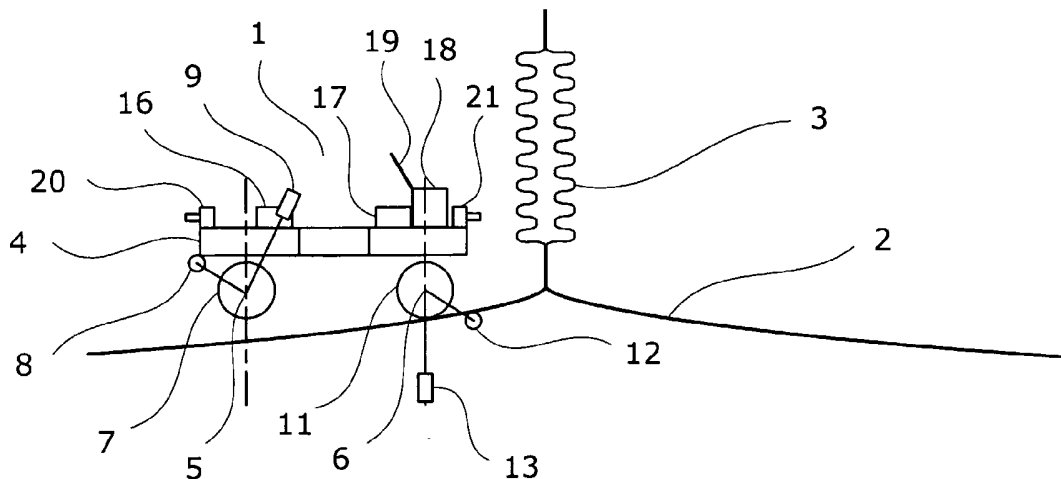
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(54) Title: LINE INSPECTION



(57) Abstract: A system for electric power line (2) inspection comprises a remotely controlled robot (1) for movement on the electric power line, and a communication unit (18) for remote operation and communication of sensed parameter values.

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## **Line inspection**

### TECHNICAL FIELD

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The present invention concerns inspection of electric power lines. Especially the invention concerns inspection of airborne electric lines which are suspended in insulators from a framework supported by a load carrying structure.

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### BACKGROUND OF THE INVENTION

It is of great interest for a network owner to be able to guarantee a fail free electric power delivery. It is therefore also of great interest to have the transmission lines inspected. Not only the condition of the line itself and its junctions but also the conditions of insulators, towers and transmission line corridors are of great interest. The most common way of such inspections is using personal on site. The personal travels along the line either by foot or vehicle to inspect the lines. In some occasions the lines may be inspected by an aircraft. Such aircraft may be operated remotely or by a pilot.

From AU 2001 100 302 a system for electric power transmission line inspection is previously known. The object of the system is to avoid the drawbacks with man operated or remotely operated flying vehicles which are hazardous and difficult to operate. The known system thus provide an unmanned airship with a balloon body that carries appropriate sensors, control and communication equipment. The airship is carrying out its tasks autonomously and communicating with a mobile ground control station.

As by all flying vehicles it is very difficult to achieve a moving path along the lines. Such vehicle is depending not only on the wind but also weather conditions like rain, fog and temperature. Thus a flying vehicle  
5 is not only power consuming and costly to produce, it also needs an operator. The operator may be a pilot that controls the flying vehicle directly or remotely or an operator on the ground for maintenance of the vehicle.

10 From US 5,901,651 a self-powered trolley for stringing lines between utility poles is known. The object of the trolley is to provide a method and a device for restringing lines between poles. Thus the trolley is self powered and configured with two wheels to be hooked on the remaining wire between two poles. The trolley has a bump contact at  
15 its front line and light to be used at night.

The known trolley is not remotely operated and do not carry any equipment for inspecting the line. Its only object is to restring the line between two poles. Thus the trolley is hung at a first end of a wire,  
20 supplied with the end of a new wire and just started. By its self power the trolley travels on the existing wire to the other pole where it stops by opening the bumper contact. The inspection of a line or remote control is not discussed in the known document.

25 From US 6,494,141 a remotely operated vehicle for inspection and intervention of a live line is previously known. The object of the vehicle is to provide a traction force sufficient for operation on a live line covered with ice. Accordingly a remotely operated vehicle is provided which comprises three driving wheels and two opposite pressure wheels  
30 squeezing between them the live line. Although having its main object to de-icing the line the vehicle can be equipped with a camera, a

microphone and instruments for measuring resistivity, voltage and current. The known vehicle has no equipment for passing a position where the line is hung or supported by an insulator.

5

## SUMMARY OF THE INVENTION

A primary object of the present invention is to provide a system for power line inspection that include a remotely operated robot moving  
10 along the line for sensing a maintenance need of the power line and its surroundings.

This object is achieved according to the invention by a system comprising a control robot characterized by the features in the  
15 independent claim 1, or by a method characterized by the steps in the independent claim 6. Preferred embodiments are described in the dependent claims.

According to the invention a remotely operated robot is provided for  
20 movement along the power line, the robot being capable to pass a suspension structure. The robot comprises a frame and a first and second bogie attached moveably to the frame. Each bogie comprises a first wheel for driving the robot on the line, a second wheel arranged on the opposite side of the line for forming between the wheels a torque  
25 arm. Each bogie also comprises a stabilizer containing a first and second counterweight, which are moveable in two degrees of freedom (DOF).

For passing a suspension point such as an insulator the robot lifts its  
30 second bogie, swing the frame around the insulator, and then swings over also the first bogie. The frame contains for this reason a bent

structure for receiving the insulator. Thus, in a first step the second bogie is disengaged from the line by moving the counterweights above the line and by loosens the grip of the second wheel. In the next step the frame with its second bogie is lifted and swung around the first bogie to pass the insulator, whereby first wheel of the second bogie is placed in contact with the line on the other side of the insulator. During this movement the counterweights of the first bogie is moved sideways to compensate the torque of the out hanging frame. In a next step the counterweight of the second bogie is lowered and the first and second wheel of the second bogie is engaged with the line. In a next step, which is equivalent to the first step, the first bogie is disengaged from the line by moving the counterweights above the line and by loosening its grip of the second wheel. Then frame with its first bogie is lifted and swung around the second bogie to pass the insulator, whereby first wheel of the first bogie is placed in contact with the line on the other side of the insulator. Now the whole robot is on the other side of the insulator.

The robot also comprises a plurality of communicable sensor units. Each sensor unit comprises sensing means for temperature, sound and vibration as well as a communication unit and a power unit. The sound sensor may be connected to an analyzing devise for detecting corona phenomenon. In an embodiment of the invention the sensor unit also comprises a video camera and a global positioning sensing (GPS) unit. In an embodiment of the invention the robot comprises an autonomous robot that moves along the lines for long distances. In another embodiment of the invention the system comprises a data logger positioned on even distances which receives all information for transmission to a main controller. This communication may involve any ordinary communication system available, such as a telecom system or an optical fiber.

In each time period of desire the sensor unit communicate its sensed values along with an identification signal to a data logger. Such data logger may either be positioned on one of the poles along the power line or positioned in a moveable vehicle. In order to reduce the amount of communication each sensing unit compares the latest sensed information with the prior sensed information.

In a first aspect of the invention the object is achieved by a system for power line inspection comprising a remotely operated robot containing a frame and a first and second bogie for passing a suspension insulator. In an embodiment the robot comprises a plurality of sensing units. Each sensing unit comprises sensing means, a power source and communication means.

In a second aspect of the invention the objects are achieved by a method for inspection of a electric power line, comprising, moving a remotely operated robot comprising a frame and a first and second bogie along the power line, sensing the parameter values by way of a plurality of sensors carried by the robot, storing the values in a computer means, and sending information from a communication unit located on the robot to a receiving unit on the ground.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the present invention will become more apparent to a person skilled in the art from the following detailed description in conjunction with the appended drawing in which:

Fig 1 is a side view of a remotely operated robot on a power line according to the invention,

Fig 2 is a plan view of the robot,

Fig 3 is a side view of the robot in a second position on the line,

Fig 4 is a principal outline of a power line with an inspection robot system according to the invention, and

5 Fig 5 is a principal sketch of a sensor unit.

## DESCRIPTION OF PREFERRED EMBODIMENTS

10 According to fig 1 a remotely operated robot 1 according to the invention is illustrated for operation on a power line 2, which is suspended by an insulator 3. The robot comprises a frame 4, a first bogie 5 and a second bogie 6. The first bogie comprises a first wheel 7 for engagement with the line, and a second wheel 8 for forming a  
15 moment arm across the line. The first bogie also comprises a first counterweight 9 and a second counterweight 10 as shown in fig 2. The second bogie 6 comprises a first wheel 11 for engagement with the line, and a second wheel 12 for forming a moment arm across the line. The second bogie also comprises a first counterweight 13 and a second  
20 counterweight 14 as shown in fig 2.

To be able to receive the structure of the insulator 3 when the robot is swung around the insulator the frame of the robot comprises a bent portion 15. The robot comprises a first motor 16 arranged on the frame  
25 for moving the first bogie 5, and a second motor 17 arranged on the frame for moving the second bogie 6. The robot also comprises a remote control 18 with an antenna 19 for the remote operation of the robot. For inspecting the line including the insulators the robot comprises a plurality of sensor units. In the embodiment shown the

robot comprise a first sensor unit 20 in the form of a video camera and a second sensor unit 21.

In operation the robot stops close to an insulator as in fig 1 and the  
5 frame 4 including the first bogie 5 raises by the force of a withholding  
moment created by the first wheel and the second wheel of the second  
bogie 6. Thereafter the frame 4 is swung 180 degrees in a horizontal  
plane, to a position illustrated by fig 2. During this movement the  
balance is controlled by adjusting the counterweights of the second  
10 bogie. A gyro controls the lifting mechanism so that the robot is always  
is in horizontal position before, and during turning the 180 degree.  
When the first bogie is in engagement with the line on the other side of  
the insulator the frame including the second bogie is raised by the force  
of a withholding moment created by the first wheel and the second  
15 wheel of the first bogie 5. Thereafter the frame 4 is swung 180 degrees  
in a horizontal plane, to a position illustrated by fig 3.

In a further embodiment of the invention the robot comprises an  
autonomous robot that given a certain task controls itself along a power  
20 line. Thus it passes itself the suspension insulators, collect information  
and communicate this information to the data loggers. In case of  
malfunction it communicates this information together with a  
geographic position. Thereby the operator may localize the robot and  
arrange for the robot to be repaired or replaced.

25

An airborne electric power line is shown in fig 4, where only one line is  
shown owing to simplicity. The line 1 is supported by a first and second  
tower, each comprising a framework column 22 and a framework beam  
23 carrying the lines via insulators 3. The left tower in the figure has  
30 only one insulator. The right tower in the figure has two insulators  
indicating that the tower is located at a position where the power line

changes its direction. According to the invention the inspection system comprises a remotely operated robot 1 carrying a plurality of sensor units 20, 21 having a common antenna 19 for a cordless communication. In the embodiment shown the system comprises on  
5 even distances data logger units 24 with antennas 25. The distance may be in the region of 2 to 5 km. In the embodiment shown the data logger 24 is positioned in one of the supporting towers. It may, however be positioned anywhere along the line and may even comprise a mobile data logger.

10

An embodiment of the sensor unit 18 is shown in fig 5. The sensor unit comprises a sound sensor 26, a temperature sensor 27 and a vibration sensor 28. By arranging a suitable analyzer connected to the sound sensor, phenomenon like corona may be detected. The sound sensor is  
15 also capable to detect the sound and rain. I rare occasions it may also pick up the sound of a falling tree. In the embodiment shown the sensor unit also comprise a camera module 29 and a GPS positioning unit 30 with an antenna 31. The sensor unit further comprises an electric power source 32 with an energy transforming unit 33. The  
20 electric power source comprises battery means and may comprise a fuel cell. The energy transforming unit 33 may comprise a solar cell or any means for receiving power from the power line on which the robot travels. The sensing unit also comprises computer means 34 having memory means 35 for data collection and comparison. The sensor unit  
25 also comprises a communication unit 36 having connection to the antenna 19. The communication unit may comprise any transmitter/receiver available. Favorable would, however, be a lightweight, low power consuming communication unit for medium or distances. The supporting towers are usually displaced some 250 m and  
30 an even multiple of desire of such distances would be an appropriate transmitting reach for the communication unit.

In operation a sensor unit senses a plurality of parameter values and periodically communicates this information to a data logger. The data logger collects all information for a longer period and may deliver its  
5 information on request from a main controller. The main controller may comprise the network operation main control, and could be located at any distance from the line to be inspected. The communication between the data logger and the main controller may comprise any feasible communication facility available. It may thus comprise a direct  
10 connection, an electromagnetic system or an optical fiber.

Although favorable the scope of the invention must not be limited by the embodiments presented but contain also embodiments obvious to a person skilled in the art. Thus, the bogie construction may comprise  
15 two wheels on one side of the line and a single wheel on the other side. This would not only stabilize the robot but also increase the moving performance when the lines are slippery. Thus, a better friction would be accomplished between the wheels and the wire of the power line. Also a three wheel construction would prevent the robot to loosen its  
20 grip of the wire. Within the inventive scope is also included that the robot comprises a hanging robot. This includes the robot frame being positioned under the power line to be inspected. In such embodiment the counter weights may be excluded. However arrangements have to be made to position at least some of the sensors on the upper side of  
25 the power line.

## CLAIMS

1. System for electric power line (2) inspection comprising a remotely controlled robot (1) for movement on the electric power line, and a communication unit (18) for remote operation and communication of sensed parameter values, **characterized in** that the robot comprises a frame (4), a first bogie (5) and a second bogie (6), the bogies being moveable attached to the frame, and that the sensing unit 18 comprises a video camera (29).
2. System according to claim 1, wherein each bogie comprises a first wheel (7, 11) and a second wheel (8, 12) arranged on opposite sides of the power line to form a moment arm.
3. System according to claim 1 or 2, wherein each bogie comprises a first (9, 13) and second (10, 14) counterweight, which are moveable in 2 DOF.
4. System according to any of the preceding claims, wherein the frame (4) comprises a bent portion (15) for receiving the structure of an insulator (3).
5. System according to any of the preceding claims, wherein the communication unit comprises communication means (36), electric power means (32), computer means (34) and sensor means (26, 27, and 28).
6. Method for inspection of a electric power line (2) comprising, sensing parameter values from the power line (2), and communicating the values, **characterized by**, moving a remotely operated robot (1) comprising a frame (4) and a first (5) and second (6) bogie along the power line (2), sensing the parameter values by way of a

plurality of sensors (26, 27, 28) carried by the robot, storing the values in a computer means (34), and sending information from a communication unit (18) located on the robot (1) to a receiving unit (24) on the ground.

7. Method according to claim 6, wherein sensed values comprises information from a camera (29), a microphone (26), a thermometer (27) and a vibration sensing means (28).
8. Computer program product storable on a computer usable medium containing instructions for a processor to evaluate the method of claim 6 to 7.
9. Computer program product according to claims 8 provided at least in part over a network, such as the Internet.
10. Computer readable medium, characterized in that it contains a computer program product according to claim 8.

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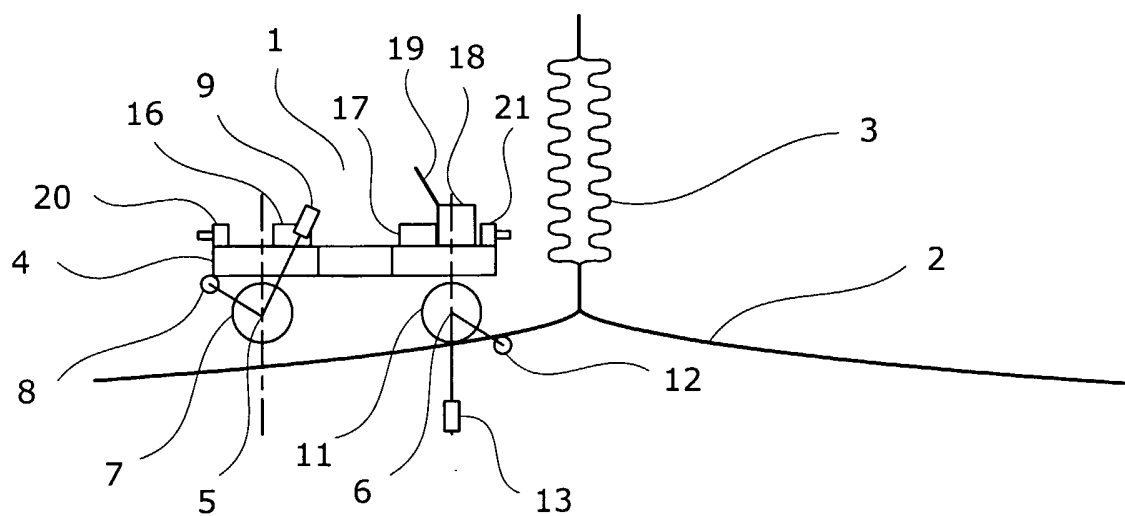


Fig 1

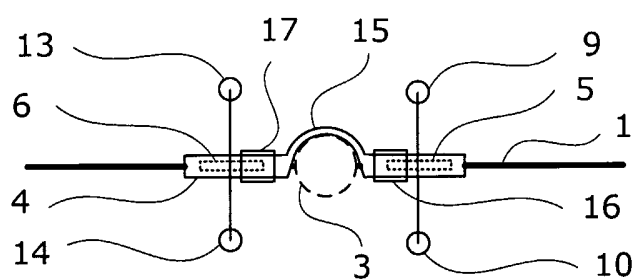


Fig 2

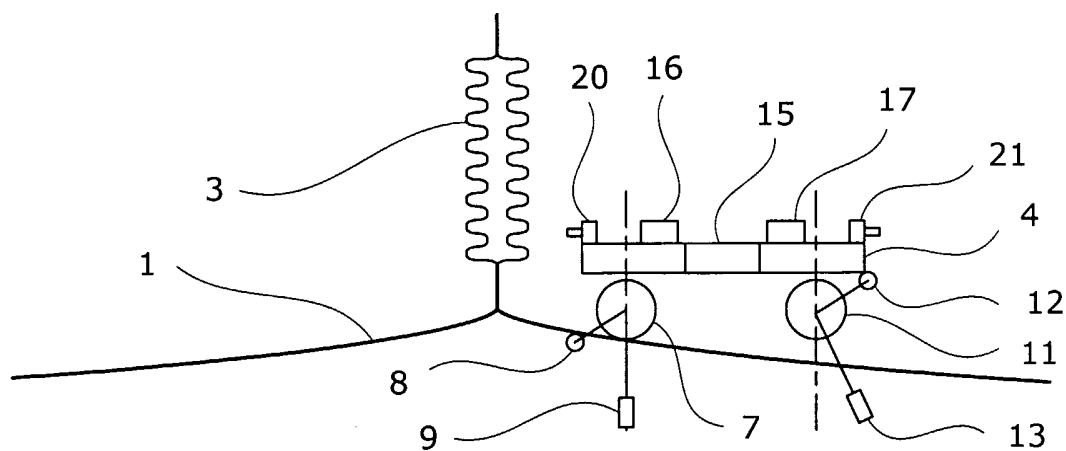


Fig 3

2/2

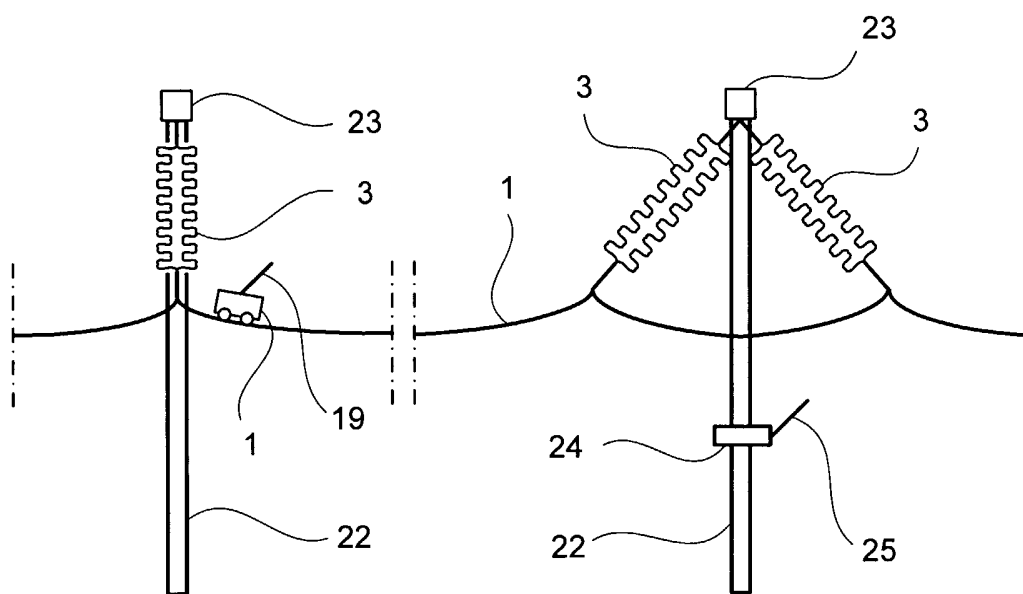


Fig 4

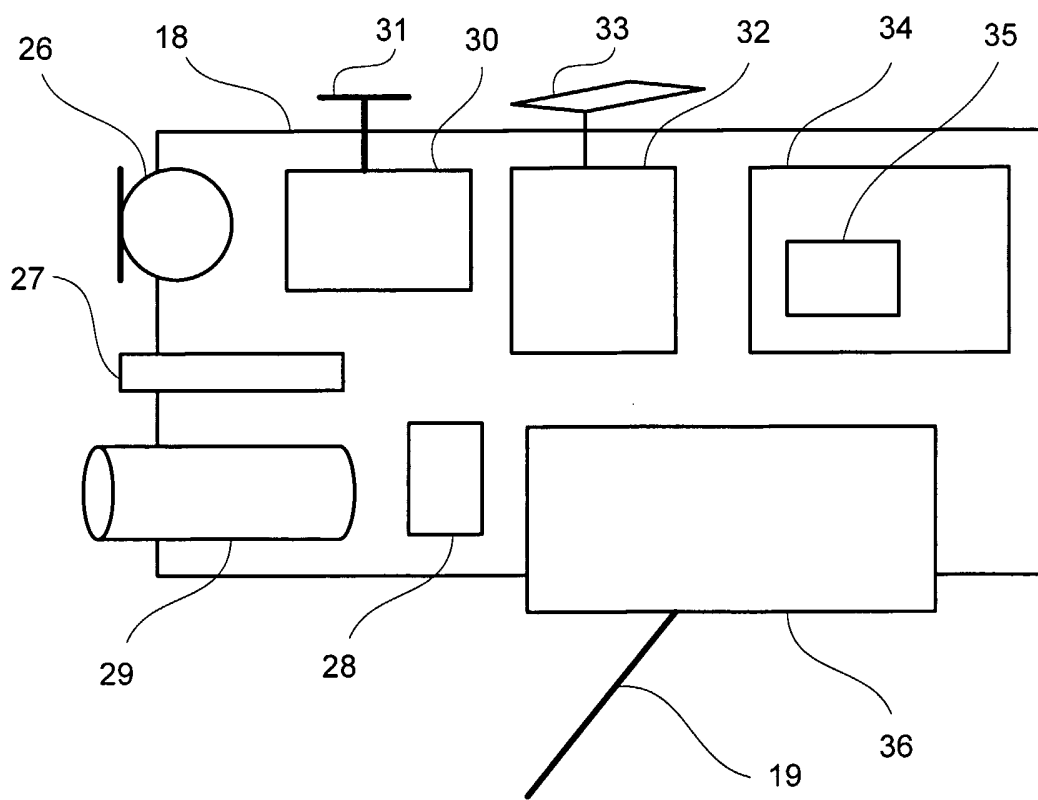


Fig 5

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/SE 2005/000200

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H02G 1/02  
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)

IPC7: H02G

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                        | Relevant to claim No. |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| Y         | US 4904996 A (R.A. FERNANDES), 27 February 1990<br>(27.02.1990), column 4, line 19 - column 6,<br>line 68, figures 1-5, abstract<br>--                                                                    | 1,2,5-10              |
| Y         | DATABASE WPI<br>Week 199809<br>Derwent Publications Ltd., London, GB;<br>Class X12, AN 1998-094311<br>& JP 9322344 A (HITACHI CABLE LTD),<br>12 December 1997 (1997-12-12)<br>abstract, figures 1,2<br>-- | 1,2,5-10              |
| A         | WO 2004070902 A1 (HYDRO-QUEBEC), 19 August 2004<br>(19.08.2004), figures 1-20, abstract<br>--                                                                                                             | 1-10                  |

☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                                                   | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | <p>DATABASE WPI<br/> Week 198930<br/> Derwent Publications Ltd., London, GB;<br/> Class X12, AN 1989-217955<br/> &amp; JP 1157208 A (NIPPON TELEGRAPH &amp; TELEPHONE CORP),<br/> 20 June 1989 (1989-06-20)<br/> abstract, figures 1-9</p> <p>--</p> | 1-10                  |
| A         | <p>DATABASE WPI<br/> Week 199403<br/> Derwent Publications Ltd.; London, GB;<br/> Class T01, AN 1994-021601<br/> &amp; JP 5328555 A (KANDEN KOGYO KK),<br/> 10 December 1993 (1993-12-10)<br/> abstract, figures 1-4</p> <p>--<br/> -----</p>        | 1-10                  |

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International application No.

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