

Method for detecting faults on a power supply line for railway vehicles

The present invention relates to a method for detecting faults on an electrical power supply line for railway vehicles, said line extending between at least a first and a second reversible substation able to supply an electrical current circulating on the electrical power supply line, the first substation being controlled in a current supply mode, to supply electrical current to the electrical power supply line and the second substation being controlled in a current recovery mode, to recover the electrical current from the power supply line and return it on an electrical power distribution network.

In order to be supplied with electrical current, railway vehicles include a pantograph, which rubs on an electrical power supply line on which a current circulates coming from the electric network. This repeated friction creates, during the lifetime of the electrical power supply line, mechanical wear of that line, leading to a reduction in its section.

The electrical power supply lines can also wear under the effect of weather conditions, for example.

This wear can, in the longer or shorter term, lead to a break in the electrical power supply line if these faults are not detected and repaired promptly, or to malfunctions in the electrical power supply of the railway vehicles.

Under extraordinary circumstances, such as, for example, during heavy snowfall or storms, the electrical power line can also break abruptly.

However, such a power supply line break leads to substantial disruptions in railway traffic if it is not detected promptly, since the railway vehicles can then no longer travel on the line and the railway vehicles already engaged on the line remain blocked and must be towed by special vehicles.

It is possible, in order to detect faults on an electrical power supply line, to measure the mechanical tension of the power supply line by adding mechanical means to its ends, which are able to measure the mechanical tension of the power supply line. A substantial tension drop then indicates a catenary system break.

Such a method is not fully satisfactory. Indeed, it requires the addition of extra equipment, specific to the detection of a potential break in the power supply line and that is not useful under normal circumstances.. Furthermore, it only allows detecting breaks in the line and does not provide indications relative to the wear of the line, which can lead to a break over time.

One aim of the invention is therefore to obtain a method for detecting faults in electrical power supply lines that is simple and inexpensive to use and that makes it possible to detect the wear of power supply lines before any break thereof.

To that end, the invention relates to a method for detecting faults of the
aforementioned type, characterized in that it comprises a step of establishing a voltage
difference between the output terminals of the first and second substations such that a
current circulates on the electrical power supply line between the first substation and the
5 second substation;

a step of determining the impedance value of the power supply line at a nominal
temperature; and

a step of comparing the value of the determined impedance of the power supply
line at the nominal temperature with an expected nominal impedance of the power supply
10 line at the nominal temperature.

This method can be carried out without specific equipment and controlled
remotely, which limits costs and makes maintenance easier on the line.

The method according to the invention can comprise one or more of the following
features, considered alone or according to all technically possible combinations:

15 - the method comprises a step of measuring the current circulating on the power
supply line, the determined value of the impedance of the power supply line at the nominal
temperature being determined as a function of the measured current;

- the method comprises a step of measuring the temperature of the power supply
line, the value of the determined impedance of the power supply line at the nominal
20 temperature being determined as a function of the measured temperature;

- the method comprises a step of choosing and controlling the voltage difference
between the output terminals of the first and second substations;

- the first substation and the second substation each comprise a reversible power
converter, such that the first substation and the second substation can operate in current
25 supply mode or in current recovery mode and the method comprises a step of controlling
the operating mode of the first and the second substation, in current supply mode and in
current recovery mode, respectively;

- the reversible power converter comprises a rectifier and an inverter, connected to
the rectifier in anti-parallel, and the first or the second substation operates in inverter
30 mode when it is controlled in current recovery mode and in rectifier mode when it is
controlled in current supply mode;

- each substation is connected to the power supply line and to a rail such that the
current circulates in a loop passing successively through the substation controlled in
current supply mode, then through the power supply line, then through the substation
35 controlled in current recovery mode, then through the rail to return to the substation
controlled in current supply mode;

- the method comprises a step of checking if a railway vehicle circulates between the first and second substations, the voltage difference being established if no vehicle is circulating between the first and second substations ;

- the power supply line extending between more than two substations, the method comprises a step of choosing two substations to be controlled in current supply mode and current recovery mode, respectively, and a step of establishing a voltage difference between the output terminals of said substations depending on the portion of the line to be tested; and

- the method comprises a step of emitting an alarm if the ratio:

$$\frac{Z_{det}}{Z_L}$$

is below a threshold value.

The invention will be better understood upon reading the following description, provided solely as an example, and done in reference to the appended drawings, in which:

- figure 1 is a diagrammatic illustration of a railway network equipped with substations able to carry out the method for detecting faults according to the invention; and

- figure 2 is a diagrammatic illustration of the implementation of the inventive method by the railway network of figure 1.

The invention is applicable to a direct current or an alternating current power supply line. In the rest of the description, the described embodiment relates to a direct current power supply line.

The direct current railway network 5 shown in figure 1 includes an electrical power supply line 10, connected to an electrical power supply network 15 via reversible substations 20.

"Reversible substation" refers to a substation able, in a current supply mode, to provide current to the electrical supply line 10 and also able, in a current recovery mode, to recover current from the electrical supply line 10, the recovered current for example coming from the braking of a railway vehicle connected to the power supply line 10, and to send it back on the electrical power supply network 15.

The railway network 5 includes a number n of reversible substations 20, distributed at regular intervals along the electrical power supply line 10. To simplify figures 1 and 2, only two reversible substations 20 have been shown. The substations 20 are able to make a current I circulate on the power supply line 10.

The railway network 5 also includes one or more temperature sensors (not shown), adapted to measure the temperature T_{mes} of the electrical power supply line 10, as well as sensors (not shown) adapted to measure the intensity I_{mes} of the current circulating on the power supply line 10. Such temperature and intensity sensors are for example arranged at each substation 20.

The railway network 5 also comprises rails 22, on which a railway vehicle is able to travel. The rails 22 have a nominal linear impedance Z_R , for example equal to 18 m Ω /km for a standard track with two parallel rails. These rails 22 are electrically connected to the reversible substations 20.

The electrical power supply line 10 has a nominal linear impedance Z_L calculated at a nominal temperature. The nominal linear impedance Z_L is for example 0.05 Ω /km for direct current overhead contact lines and 0.02 Ω /km for direct current ground contact lines of the 3rd rail type. These values differ for an alternating current power supply line. The value of the nominal linear impedance Z_L of the electrical power supply line 10 is given by the specifications of the power supply line 10.

The electrical power supply network 15 is a wide area electrical power distribution network. It is for example a high-voltage three-phase alternating voltage network.

The substations 20 are identical to each other and only one of these substations 20 will be described in detail.

The substation 20 includes a four-quadrant reversible converter 25 connected on one side to the electrical power supply network 15 and on the other side to the power supply line 10.

A traction transformer 30 is arranged between the converter 25 and the power supply network 15, so as to lower the alternating voltage coming from the power supply network 15 to an alternating voltage accepted at the input of the converter 25.

The converter 25 is a reversible converter that can, for example, be made up of a rectifier 35, connected in anti-parallel to an inverter 40. The converter 25 can operate in rectifier mode or inverter mode.

In rectifier mode, the converter 25 is able to rectify the three-phase alternating voltage coming from the traction transformer 30 to deliver, at its output, a rectified direct voltage. The converter 25 is thus in current supply mode.

In inverter mode, the converter 25 is able to invert the direct voltage coming from the power supply line 10 to deliver an alternating three-phase voltage. The converter 25 is thus in current recovery mode.

The converter 25 is a controllable converter. To that end, the substation 20 includes a control module 45 able to control the switching of the converter 25 from the

current recovery mode towards the current supply mode, i.e. from the inverter mode to the rectifier mode and vice versa.

The rectifier 35 is for example formed by a controlled rectifier bridge made from thyristors or power transistors such as IGBT transistors (Insulated Gate Bipolar Transistor).

The converter 25 is able to generate, at its output terminal, i.e. at the electrical connection point of the substation 20 to the power supply line 10, a desired voltage U_C .

Such a substation 20 is for example described in document EP-1 985 490.

According to one embodiment, the railway network 5 also includes, at each substation 20, a sensor able to measure the voltage U_C actually applied to the output of each substation 20 so as to verify that this voltage corresponds to the control voltage U_C .

The inventive method for detecting faults on the power supply line 10 will now be explained in reference to figure 2.

In a first step, the operator chooses a segment T of the power supply line 10 on which he wishes to detect the existence of faults.

He then determines, in a second step, the first substation 20A and the second substation 20B between which the segment T of the power supply line 10 selected in the first step extends. The first substation 20A and the second substation 20B are separated by a distance d_{AB} . The first substation 20A and the second substation 20B are for example substations adjacent along the power supply line 10. They may, however, also be substations that are not adjacent and are separated from each other by a number of substations smaller than or equal to $n-2$. Thus, the first substation 20A and the second substation 20B can for example be the end substations of the electrical power supply line 10.

The operator then ensures that no railway vehicle is traveling on the segment T between the first substation 20A and the second substation 20B or is about to arrive at the first or second substation 20A, 20B.

In a third step, the operator chooses a current I for detecting faults that he wishes to make circulate on the segment T of the power supply line 10. This current I is below a threshold value I_{max} above which the power supply line 10 and/or the related equipment may be damaged.

He then deduces, from the selected value of the current I, the values of the desired output voltages U_{CA} and U_{CB} to be applied to the output of a first converter 25A of the first substation 20A and of a second converter 25B of the second substation 20B, respectively. The output voltages U_{CA} and U_{CB} are different from each other. The voltage U_{CA} is higher than the voltage U_{CB} .

In a fourth step, the operator controls, via a control module 45A of the first substation 20A, the operation of the converter 25A in current supply mode, i.e. in rectifier mode. At the same time, he controls, via a control module 45B of the second substation 20B, the operation of the converter 25B in current recovery mode, i.e. in inverter mode.

5 A voltage difference D is thus established between the outputs of the first substation 20A and of the second substation 20B. This voltage difference D is equal to $U_{CA} - U_{CB}$. This voltage difference D is positive. It causes the circulation of a current I for detecting faults on the power supply line 10 on the segment T between the first substation 20A and the second substation 20B.

10 Due to the electrical connection between the first and second substations 20A, 20B and the rails 22, the current I describes a loop passing through the power supply line 10 from the first substation 20A towards the second substation 20B, i.e. over the segment T and through the rail 22 from the second substation 20B towards the first substation 20A.

In a fifth step, the operator controls the measurement, by the current sensor, of the value I_{mes} of the electrical current circulating on the segment T, as well as the measurement, by the temperature sensor, of the temperature T_{mes} of the power supply line 10.

According to one embodiment, these measurements are done at a single location on the segment T. According to another embodiment, they are done at the first and second substations 20A, 20B.

According to one embodiment, the operator also controls the measurement, by the voltage sensor, of the voltages U_{CA} and U_{CB} actually applied to the output of the substations 20A and 20B, respectively, and compares these values to the control values.

In a sixth step, the operator determines a value Z_{det} of the linear impedance of the power supply line 10 at a nominal temperature.

To that end, he determines the impedance $Z(T_{mes})$ of the power supply line 10 at the temperature T_{mes} of the line 10, measured using the temperature sensor, using the following formula:

$$Z(T_{mes}) = \frac{(U_{CA} - U_{CB}) - Z_R(T_{mes}) \times I_{mes} \times d_{AB}}{I_{mes} \times d_{AB}} = \frac{D - Z_R(T_{mes}) \times I_{mes} \times d_{AB}}{I_{mes} \times d_{AB}}$$

30 In this formula, $Z_R(T_{mes})$ is the value of the linear impedance of the rail 22 at the temperature T_{mes} .

In this formula, U_{CA} and U_{CB} can be the control values or, for a more subtle estimation, the values actually applied measured by the voltage sensor.

The operator then deduces, from the value $Z(T_{mes})$ of the impedance of the line 10 thus determined and the temperature T_{mes} of the power supply line 10, the value Z_{det} of the

impedance of the power supply line 10 at the nominal temperature, at which the nominal value Z_L of the impedance of the power supply line 10 indicated in the specifications was calculated. This deduction is for example done using a conversion table.

5 Lastly, he compares the value Z_{det} of the impedance of the line 10 determined in the sixth step to the nominal value Z_L of the expected linear impedance at the nominal temperature and deduces, from this comparison, a value C characteristic of the faults in the power supply line 10.

Thus, the value C for example corresponds to the quotient of Z_{det} by Z_L according to the formula

$$10 \quad C = \frac{Z_{det}}{Z_L}$$

This value C corresponds to the reduction of the section of the power supply line 10 relative to its nominal section.

15 In a seventh step, according to one embodiment, the operator compares this value C to a threshold value C_S . The value C_S corresponds to the maximum admissible reduction of the section of the power supply line 10, i.e. for which it is still possible to make railway vehicles pass safely on the line 10.

If the value C is below the threshold value C_S , the operator triggers an alarm, which indicates that a fault has been observed on the power supply line 10.

20 Reparatory measures are then taken, for example to consolidate the line 10 at the location where it is worn and to thereby prevent the line 10 from breaking due to wear.

In the case where the power supply line 10 is broken, no current I circulates on the line 10 and Z_{det} tends towards infinity. In this case, in one embodiment, the operator controls the stop of the travel of the railway vehicles along the power supply line 10.

25 This method is implemented remotely by an operator, who controls each step of the method.

According to another embodiment, this method can also be implemented in an automated manner. In that case, the railway network alternatively comprises a control module able to control each of the steps of the method listed above, so as to detect faults on the power supply line.

30 The method for detecting faults according to the invention has the advantage of not requiring that specific additional equipment be provided to detect faults on the power supply line. In fact, the method only uses the reversible substations, which are permanently present along the power supply line, since they are used to supply the supply line.

The method according to the invention is also particularly simple to carry out, since one need only select adapted output voltages of the converters of certain substations to detect any faults on the power supply line between those substations.

Furthermore, this method is very safe to use, since it can be implemented remotely
5 without needing maintenance staff at the segment itself.

Lastly, this method makes it possible to detect not only a break of the power supply line, but also wear of the power supply line resulting in a localized or distributed reduction of its section. Thus, preventive repair or consolidation measures on the line can be taken and the risk of a break of the line is decreased.

10 It is possible to implement this method first on a long segment T and then, if faults are detected, to implement the method on different shorter sub-segments T' included in the initial segment T so as to more precisely determine the geographic location of the fault.

According to one alternative of the converter 25, the latter is a two-quadrant
15 converter.

According to another embodiment, the power supply line 10 is an alternating current power supply line. In this embodiment, the reversible power converter 25 of the substation 20, arranged between the transformer 30 and the power supply line 10, is a reversible alternating current-alternating current converter (AC-AC converter).

20 The substation 20 also includes a control module 45 able to control the switching of the reversible alternating current-alternating current converter 25 in the electrical current supply mode or the electrical current recovery mode.

As described above, for an electrical power supply line 10 extending between a first and a second reversible substation 20A, 20B, the first substation 20A is controlled in
25 electrical current supply mode, while the second substation 20B is controlled in electrical current recovery mode.

A voltage difference D is then established between the output terminals of the first and second substations 20A, 20B so that a current I circulates on the electrical power supply line 10 between the first substation 20A and the second substation 20B. The value
30 of the impedance Z_{det} of the power supply line 10 at a nominal temperature is then determined in the same way as in the first embodiment and this value Z_{det} is compared to the nominal impedance Z_L of the power supply line 10 expected at the nominal temperature.

CLAIMS

1.- A method for detecting faults on a power supply line (10) for railway vehicles, said line (10) extending between at least a first and a second reversible substation (20A, 20B) able to supply an electrical current (I) circulating on the electrical power supply line (10), the first substation (20A) being controlled in a current supply mode, to supply electrical current to the electrical power supply line (10), and the second substation (20B) being controlled in a current recovery mode, to recover the electrical current from the power supply line (10) and return it on an electrical power distribution network (15), said method being characterized in that it successively comprises:

a step of establishing a voltage difference (D) between the output terminals of the first and second substations (20A, 20B) such that a current (I) circulates on the electrical power supply line (10) between the first substation (20A) and the second substation (20B);
a step of determining the impedance value (Z_{det}) of the power supply line (10) at a nominal temperature; and

a step of comparing the value (Z_{det}) of the determined impedance of the power supply line (10) at the nominal temperature with an expected nominal impedance (Z_L) of the power supply line (10) at the nominal temperature.

2.- The method for detecting faults according to claim 1, characterized in that it comprises a step of measuring the current (I_{mes}) circulating on the power supply line (10), the determined value of the impedance (Z_{det}) of the power supply line (10) at the nominal temperature being determined as a function of the measured current (I_{mes}).

3.- The method for detecting faults according to claim 1 or 2, characterized in that it comprises a step of measuring the temperature (T_{mes}) of the power supply line (10), the determined value of the impedance (Z_{det}) of the power supply line (10) at the nominal temperature being determined as a function of the measured temperature (T_{mes}).

4.- The method for detecting faults according to one of claims 1 to 3, characterized in that it comprises a step of choosing and controlling the voltage difference (D) between the output terminals of the first and second substations (20A, 20B).

5. The method for detecting faults according to one of claims 1 to 4, characterized in that the first substation (20A) and the second substation each (20B) comprise a reversible power converter (25), such that the first substation (20A) and the second substation (20B) can operate in current supply mode or current recovery mode and in that the method comprises a step of controlling the operating mode of the first and second substation (20A, 20B), in current supply mode and in current recovery mode, respectively.

6.- The method for detecting faults according to claim 5, characterized in that the reversible power converter (25) comprises a rectifier (35) and an inverter (40), connected to the rectifier (35) in anti-parallel, and in that the first or second substation (20A, 20B) operates in inverter mode when it is controlled in current recovery mode and in rectifier mode when it is controlled in current supply mode.

7. The method for detecting faults according to any one of claims 1 to 6, characterized in that each substation (20A, 20B) is connected to the power supply line (10) and to a rail (22) such that the current (I) circulates in a loop passing successively through the substation (20A) controlled in current supply mode, then through the power supply line (10), then through the substation (20B) controlled in current recovery mode, then through the rail (22) to return to the substation (20A) controlled in current supply mode.

8. The method for detecting faults according to any one of claims 1 to 7, comprising a step of checking if a railway vehicle circulates between the first and second substations (20A, 20B), the voltage difference (D) being established if no vehicle is circulating between the first and second substations (20A, 20B).

9. The method for detecting faults according to any one of claims 1 to 8, the power supply line (10) extending between more than two substations (20), the method comprising a step of choosing two substations (20A, 20B) to be controlled in current supply mode and current recovery mode, respectively, and a step of establishing a voltage difference (D) between the output terminals of said substations (20A, 20B) depending on the portion (T) of the line (10) to be tested.

10. The method for detecting faults according to one of claims 1 to 9, further comprising a step of emitting an alarm if the ratio:

$$\frac{Z_{\text{det}}}{Z_L}$$

is below a threshold value (C_s).