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(54) DEVICE FOR DETERMINING AT LEAST ONE CHARACTERISTIC OF A RAILWAY RESONANT CIRCUIT, AND TRACKSIDE TRAIN PROTECTION SYSTEM INCLUDING SUCH A DEVICE

(57) An electronic determination device (14) is configured for determining at least one characteristic of a railway resonant circuit (12), the resonant circuit being included in a trackside train protection system and configured for transmitting information to an on-board train protection system.

The determination device (14) is adapted to be connected between two terminals (16) of the resonant circuit and comprises an injection module (24) configured for injecting at least one input alternating voltage between said terminals; a measuring module (26) configured for measuring at least one resulting voltage between said terminals after injection of a respective input alternating voltage; a determination module (28) configured for determining at least one characteristic of the resonant circuit from the at least one measured resulting voltage; a radio-transmission module (30) for radio-transmitting the at least one determined characteristic to a remote electronic apparatus.

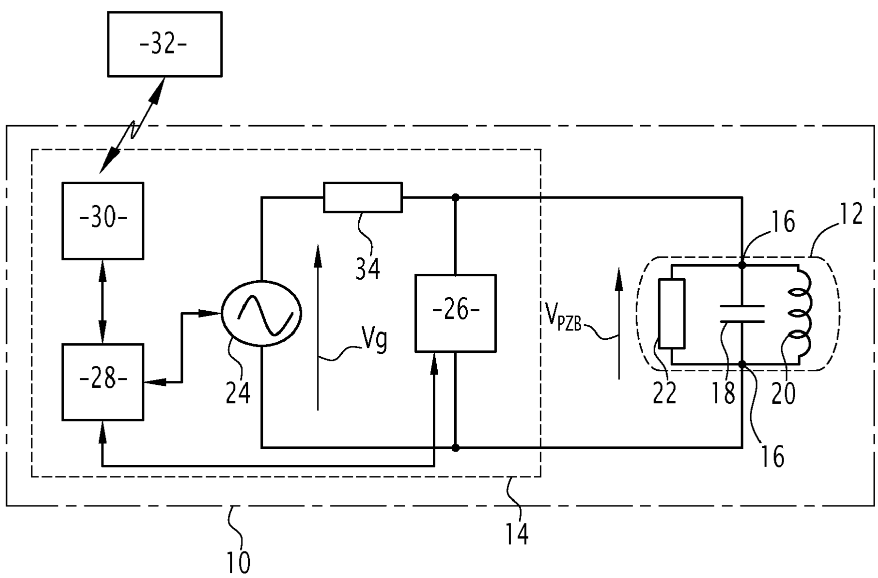

FIG.1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to an electronic determination device for determining at least one characteristic of a railway resonant circuit.

[0002] The resonant circuit being included in a trackside train protection system and being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system.

[0003] The invention also relates to a trackside train protection system comprising such a railway resonant circuit and such an electronic determination device, the determination device being connected between two terminals of the resonant circuit.

[0004] The invention concerns the field of automatic railway protection installations with a trackside train protection system including several railway resonant circuits intended to be arranged along a railway track and an on-board train protection system. The on-board train protection system is embedded on board a railway vehicle and communicates successively with the railway resonant circuits arranged along the railway track in order to ensure protection of the railway vehicle.

BACKGROUND OF THE INVENTION

[0005] The railway resonant circuit is for example a PZB magnet, where PZB is the abbreviation of German expression *Punktförmige ZugBeeinflussung,* officially translated as intermittent automatic train running control. The PZB magnet is also called PZB/INDUSI magnet.

[0006] For example, a train front operating vehicle is equipped with an onboard transmitter coil, i.e. an antenna, in which superimposed frequencies of 500 Hz, 1000 Hz and 2000 Hz are injected. The railway resonant circuits are installed along the railway track, for example at specific distance from a signal or speed position of a trackside signaling system to be protected by the automatic railway protection installation. Each railway resonant circuit resonates for at least one of the three frequencies (none, 500 Hz, 1000 Hz and 2000 Hz), depending on the information (one information corresponding to the selection of given frequency) to be transmitted by the trackside train protection system to the on-board train protection system.

[0007] When the on-board train protection system with the antenna passes over a corresponding railway resonant circuit, the presence of the resonant circuit is detected by the on-board train protection system through a change in magnetic flux created via a resonance frequency of the specific resonant circuit. This activates an appropriate onboard circuit and triggers whatever action is required based on the location (e.g., an audible/visual warning, enforced speed limit, or enforced stop by brakes application). The configuration of the resonant circuit via frequency selection is either permanent or selected by the trackside signaling system.

[0008] A correct operation of this automatic railway protection installation strongly depends on the correct resonance frequency defined by the resonant circuit composition. Consequently, to ensure safety and availability of the installation, the resonant circuit characteristics (resonance frequencies and quality factor) have to remain within defined tolerances.

[0009] Checking compliance with these tolerances is generally performed by periodical checks using a dedicated tool. The tool manually operated by an operator performs the measurement of the resonance frequency and quality factor parameters of the resonant circuit. Resonant circuits with characteristics outside the allowed limits are replaced.

[0010] Accordingly, EP 2 810 848 A2 discloses a method for periodically testing a PZB magnet using a specific device detecting a phase difference between an injected current and a read back voltage. When the phase difference is at its minimum, the injected frequency is the resonance frequency of the PZB magnet. Cut-off frequencies are detected similarly by comparing -45° and +45° signals.

SUMMARY OF THE INVENTION

[0011] However such a method is costly and not optimal.

[0012] A goal of the present invention is therefore to propose an electronic determination device for determining at least one characteristic of a railway resonant circuit in a more efficient and less costly manner.

[0013] To this end, the invention relates to an electronic determination device for determining at least one characteristic of a railway resonant circuit, the resonant circuit being included in a trackside train protection system and being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system,

the determination device being adapted to be connected between two terminals of the resonant circuit and comprising:

- an injection module configured for injecting at least one input alternating voltage between the terminals of the resonant circuit;
- a measuring module configured for measuring at least one resulting voltage between the terminals of the resonant circuit after injection of a respective input alternating voltage;
- a determination module configured for determining at least one characteristic of the resonant circuit from the at least one measured resulting voltage;
- a radio-transmission module for radio-transmitting the at least one determined characteristic to a remote electronic apparatus.

[0014] Thanks to the invention, the electronic determination device is configured for determining at least one characteristic of a railway resonant circuit and for automatically radio-transmitting the at least one determined characteristic to a remote electronic apparatus via the radio-transmission module.

[0015] Further, the determination of the at least one characteristic of the resonant circuit is preferably carried out in a transparent manner during time slot(s) where the resonant circuit is not excited by the antenna of a corresponding on-board train protection system.

[0016] According to other advantageous aspects of the invention, the determination device comprises one or more of the following features taken alone or according to all technically possible combinations:

- the injection module is configured for injecting at least two input alternating voltages successively between the terminals of the resonant circuit, the measuring module being configured for measuring successively at least two resulting voltages between the terminals of the resonant circuit, each one after injection of a respective input alternating voltage, and the determination module being configured for determining the at least one characteristic from the at least two measured resulting voltages;
- two characteristics to be determined are a resonance frequency of the resonant circuit and a half-bandwidth of a frequency response of the resonant circuit and the injection module is configured for injecting first, second and third input alternating voltages successively between the terminals of the resonant circuit, the first input alternating voltage having a first frequency equal to a reference frequency minus a reference half-bandwidth, the second input alternating voltage having a second frequency equal to a reference frequency plus a reference half-bandwidth and the third input alternating voltage having a third frequency equal to the reference frequency, the measuring module being configured for measuring a first resulting voltage corresponding to the first input alternating voltage, a second resulting voltage corresponding to the second input alternating voltage and respectively a third resulting voltage corresponding to the third input alternating voltage, and the determination module being configured for determining the resonance frequency from a first difference between the first resulting voltage and the second resulting voltage and respectively the half-bandwidth from a second difference between the second resulting voltage and the third resulting voltage multiplied by a factor, the factor being substantially equal to $\sqrt{2}$;
- if the first difference is equal to 0 within a first predefined margin of error, the determined resonance frequency is equal to the reference frequency; if said first difference is lower than minus the first predefined margin of error, the reference frequency is increased and the injection module is configured for injecting new first and second input alternating voltages successively with the increased reference frequency, the measuring module being configured for measuring corresponding new first and second resulting voltages, and the determination module being configured for calculating a new first difference between the new first resulting voltage and the new second resulting voltage; and if said first difference is greater than the first predefined margin of error, the reference frequency is decreased and the injection module is configured for injecting new first and second input alternating voltages successively with the decreased reference frequency, the measuring module being configured for measuring corresponding new first and second resulting voltages, and the determination module being configured for calculating a new first difference between the new first resulting voltage and the new second resulting voltage;
- if the second difference is equal to 0 within a second predefined margin of error, the determined half-bandwidth is equal to the reference half-bandwidth; if said second difference is lower than minus the second predefined margin of error, the reference half-bandwidth is increased and the injection module is configured for injecting new second and third input alternating voltages successively with the increased reference half-bandwidth, the measuring module being configured for measuring corresponding new second and third resulting voltages, and the determination module being configured for calculating a new second difference between the new second resulting voltage and the new third resulting voltage multiplied by the factor; and - if said second difference is greater than the second predefined margin of error, the reference half-bandwidth is decreased and the injection module is configured for injecting new second and third input alternating voltages successively with the decreased reference half-bandwidth, the measuring module being configured for measuring corresponding new second and third resulting voltages, and the determination module being configured for calculating a new second difference between the new second resulting voltage and the new third resulting voltage multiplied by the factor.
- a characteristic to be determined is a resonance frequency of the resonant circuit and the injection module is configured for injecting first and second input alternating voltages successively between the terminals of the resonant circuit, the first input alternating voltage having a first frequency equal to a reference frequency minus a predefined delta and the second input alternating voltage having a second frequency equal to the reference frequency plus the predefined delta, the measuring module being configured for measuring a first resulting voltage corre-

sponding to the first input alternating voltage and respectively a second resulting voltage corresponding to the second input alternating voltage, and the determination module being configured for determining the resonance frequency from a difference between the first resulting voltage and the second resulting voltage;

- if the difference is equal to 0 within a predefined margin of error, the determined resonance frequency is equal to the reference frequency; if said difference is lower than minus the predefined margin of error, the reference frequency is increased and the injection module is configured for injecting new first and second input alternating voltages successively with the increased reference frequency, the measuring module being configured for measuring corresponding new first and second resulting voltages, and the determination module being configured for calculating a new difference between the new first resulting voltage and the new second resulting voltage; and if said difference is greater than the predefined margin of error, the reference frequency is decreased and the injection module is configured for injecting new first and second input alternating voltages successively with the decreased reference frequency, the measuring module being configured for measuring corresponding new first and second resulting voltages, and the determination module being configured for calculating a new difference between the new first resulting voltage and the new second resulting voltage;
- a characteristic to be determined is a half-bandwidth of a frequency response of the resonant circuit and the injection module is configured for injecting former and latter input alternating voltages successively between the terminals of the resonant circuit, the former input alternating voltage having a former frequency equal to a predefined frequency plus a reference half-bandwidth and the latter input alternating voltage having a latter frequency equal to the predefined frequency, the measuring module being configured for measuring a former resulting voltage corresponding to the former input alternating voltage and respectively a latter resulting voltage corresponding to the latter input alternating voltage, and the determination module being configured for determining the half-bandwidth from a difference between the former resulting voltage and the latter resulting voltage multiplied by a factor, the factor being substantially equal to $\sqrt{2}$;
- if the difference is equal to 0 within a predefined margin of error, the determined half-bandwidth is equal to the reference half-bandwidth; if said difference is lower than minus the predefined margin of error, the reference half-bandwidth is increased and the injection module is configured for injecting new former and latter input alternating voltages successively with the increased reference half-bandwidth, the measuring module being configured for measuring corresponding new former and latter resulting voltages, and the determination module being configured for calculating a new difference between the new former resulting voltage and the new latter resulting voltage multiplied by the factor; and if said difference is greater than the predefined margin of error, the reference half-bandwidth is decreased and the injection module is configured for injecting new former and latter input alternating voltages successively with the decreased reference half-bandwidth, the measuring module being configured for measuring corresponding new former and latter resulting voltages, and the determination module being configured for calculating a new difference between the new former resulting voltage and the new latter resulting voltage multiplied by the factor; and
- the determination device is configured for being permanently connected between the terminals of the resonant circuit.

[0017] The invention also relates to a trackside train protection system comprising:

- a railway resonant circuit, the resonant circuit being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system; and
- an electronic determination device for determining at least one characteristic the resonant circuit, the determination device being connected between two terminals of the resonant circuit, wherein the determination device is as defined above.

[0018] According to another advantageous aspect of the invention, the trackside train protection system comprises the following feature:

- the resonant circuit has a resonance frequency and includes at least a component among a capacitor and a coil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The invention will be better understood upon reading of the following description, which is given solely by way of example and with reference to the appended drawings, in which:

- Figure 1 is a schematic view of a trackside train protection system according to the invention, comprising a railway resonant circuit, the resonant circuit being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system, and an electronic determination device for determining at least one characteristic of a resonant circuit, the determination device being connected between two terminals of the resonant circuit;

- Figure 2 is a curve representing a frequency response of the resonant circuit of Figure 1 and illustrating the calculation of a first difference for determining a resonance frequency of said resonant circuit; and
- Figure 3 is a view similar to the view of Figure 2 and illustrating the calculation of a second difference for determining a half-bandwidth of a frequency response of said resonant circuit.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0020] In the following, the expression "substantially equal to" defines an equality relation to more or less 10%.

[0021] In Figure 1, a trackside train protection system 10 comprises a railway resonant circuit 12, the resonant circuit 12 being configured for transmitting information to an on-board train protection system, not shown, by resonating in response to a signal emitted by the on-board train protection system.

[0022] The trackside train protection system 10 comprises an electronic determination device 14 for determining at least one characteristic of the resonant circuit 12, the determination device 14 being connected between two terminals 16 of the resonant circuit 12.

[0023] The resonant circuit 12 has a resonance frequency F_0 and a half-bandwidth df_0 of its frequency response. The resonant circuit 12 has therefore a quality factor Q verifying the following equation:

$$Q = \frac{F_0}{2 \times df_0} \quad (1)$$

where F_0 represents the resonance frequency, and df_0 represents the half-bandwidth of the frequency response of the resonant circuit 12.

[0024] The resonance frequency F_0 is for example a frequency substantially equal to one of the following frequencies: 500 Hz, 1000 Hz and 2000 Hz.

[0025] The resonant circuit 12 includes at least a component among a capacitor 18 and a coil 20. In the example of Figure 1, the resonant circuit 12 includes both the capacitor 18 and the coil 20, and also a resistor 22, each one of the capacitor 18, the coil 20 and the resistor 22 being connected in parallel.

[0026] The determination device 14 is adapted to be connected between two terminals 16 of the resonant circuit 12 and comprises an injection module 24 configured for injecting at least one input alternating voltage Vg between the terminals 16 of the resonant circuit 12 and a measuring module 26 configured for measuring at least one resulting voltage V_{PZB} between the terminals 16 of the resonant circuit 12 after injection of a respective input alternating voltage Vg.

[0027] The determination device 14 also comprises a determination module 28 configured for determining at least one characteristic F_0, df_0 of the resonant circuit 12 from the at least one measured resulting voltage V_{PZB} and a radio-transmission module 30 for radio-transmitting the at least one determined characteristic F_0, df_0 to a remote electronic apparatus 32.

[0028] In the example of Figure 1, the determination device 14 also comprises a measure resistor 34 connected to the injection module 24 and being intended to be connected to one of the terminals 16 of the resonant circuit 12.

[0029] The determination device 14 is preferably configured for being permanently connected between the two terminals 16 of the resonant circuit 12.

[0030] In the example of Figure 1, the injection module 24 is an alternating voltage source and the measuring module 26 is an alternating voltmeter.

[0031] In the example of Figure 1, the injection module 24, the measuring module 26, the determination module 28 and the radio-transmission module 30 are respective electronic modules.

[0032] The injection module 24 is for example configured for injecting at least two input alternating voltages Vg_1, Vg_2 successively between the terminals 16 of the resonant circuit 12. The measuring module 26 is accordingly configured for measuring successively at least two resulting voltages V_{PZB1}, V_{PZB2} between the terminals 16 of the resonant circuit 12, each one after injection of a respective input alternating voltage Vg_1, Vg_2, and the determination module 28 is configured for determining the at least one characteristic F_0, df_0 from the at least two measured resulting voltages V_{PZB1}, V_{PZB2}.

[0033] The injection module 24 is for example configured for injecting a voltage Vg with amplitude substantially equal to 20 V and a current substantially equal to 100 μA. Vg is a general notation for the voltage injected by the injection module 24; first, second and third alternating voltages injected by the injection module 24 with specific first, second and third frequencies F_1, F_2 and F_3 are further denoted Vg_1, Vg_2 and respectively Vg_3.

[0034] The determination module 28 is linked via respective data links to the injection module 24, to the measuring module 26 and respectively to the radio-transmission module 30, as shown in Figure 1.

[0035] The radio-transmission module 30 is preferably a low-power radio-transmission module and is for example compliant with at least one of the following standards: SigFox, LoRa, Meshed Bluetooth 5.

[0036] The value of the measure resistor 34 is much higher than an impedance Z of the resonant circuit 12 so as avoiding disturbing the operation of the resonant circuit 12 when resonating in response to a signal emitted by the on-board train protection system. The value of the measure resistor 34 is for example substantially equal to

200 kΩ.

[0037] In a first embodiment, two characteristics of the resonant circuit 12 are determined by the determination device 14: the resonance frequency F_0 and the half-bandwidth df_0 of a frequency response of the resonant circuit 12, shown in Figures 2 and 3 with the curve 100.

[0038] According to this first embodiment, the injection module 24 is configured for injecting first Vg_1, second Vg_2 and third Vg_3 input alternating voltages successively between the terminals 16 of the resonant circuit 12, the first input alternating voltage Vg_1 having a first frequency F_1 equal to a reference frequency F_m minus a reference half-bandwidth df, the second input alternating voltage Vg_2 having a second frequency F_2 equal to a reference frequency F_m plus a reference half-bandwidth df and the third input alternating voltage Vg_3 having a third frequency F_3 equal to the reference frequency F_m.

[0039] The first, second and third frequencies F_1, F_2, F_3 therefore follow respectively the following equations:

$$F_1 = F_m - df \quad (2)$$

$$F_2 = F_m + df \quad (3)$$

$$F_3 = F_m \quad (4)$$

[0040] The measuring module 26 is configured for measuring a first resulting voltage $V_{PZB}(F_1)$, i.e. $V_{PZB}(F_m\text{-}df)$, corresponding to the first input alternating voltage Vg_1, a second resulting voltage $V_{PZB}(F_2)$, i.e. $V_{PZB}(F_m\text{+}df)$, corresponding to the second input alternating voltage Vg_2 and respectively a third resulting voltage $V_{PZB}(F_3)$, i.e. $V_{PZB}(F_m)$, corresponding to the third input alternating voltage Vg_3.

[0041] Further, the determination module 28 is configured for determining the resonance frequency F_0 from a first difference α between the first resulting voltage $V_{PZB}(F_1)$ and the second resulting voltage $V_{PZB}(F_2)$, and respectively the half-bandwidth df from a second difference β between the second resulting voltage $V_{PZB}(F_2)$ and the third resulting voltage $V_{PZB}(F_3)$ multiplied by a factor K, the factor K being substantially equal to $\sqrt{2}$.

[0042] The first and second differences α, β therefore follow respectively the following equations:

$$\alpha = V_{PZB}(F_m - df) - V_{PZB}(F_m + df) \quad (5)$$

$$\beta = V_{PZB}(F_m) - K * V_{PZB}(F_m + df) \quad (6)$$

[0043] Then, if the first difference α is equal to 0 within a first predefined margin of error ε_1, the determined resonance frequency F_0 is equal to the reference frequency F_m. The value of first predefined margin of error ε_1 is for example substantially equal to 50 mV, or preferably substantially equal to 20 mV.

[0044] If said first difference α is lower than minus the first predefined margin of error ε_1, the reference frequency F_m is increased and the injection module 24 is configured for injecting new first and second input alternating voltages Vg_1, Vg_2 successively with the increased reference frequency, and the measuring module 26 is further configured for measuring corresponding new first and second resulting voltages $V_{PZB}(F_1)$, $V_{PZB}(F_2)$. Then, the determination module 28 is configured for calculating a new first difference α between the new first resulting voltage $V_{PZB}(F_1)$ and the new second resulting voltage $V_{PZB}(F_2)$.

[0045] If said first difference α is greater than the first predefined margin of error ε_1, the reference frequency F_m is decreased and the injection module 24 is configured for injecting new first and second input alternating voltages Vg_1, Vg_2 successively with the decreased reference frequency F_m, and the measuring module 26 is further configured for measuring corresponding new first and second resulting voltages $V_{PZB}(F_1)$, $V_{PZB}(F_2)$. The determination module 28 is then configured for calculating a new first difference α between the new first resulting voltage $V_{PZB}(F_1)$ and the new second resulting voltage.

[0046] If the second difference β is equal to 0 within a second predefined margin of error ε_2, the determined half-bandwidth is equal to the reference half-bandwidth df. The value of second predefined margin of error ε_2 is for example substantially equal to 50 mV, or preferably substantially equal to 20 mV.

[0047] If said second difference β is lower than minus the second predefined margin of error ε_2, the reference half-bandwidth df is increased and the injection module 24 is configured for injecting new second and third input alternating voltages successively with the increased reference half-bandwidth df, the measuring module 26 being configured for measuring corresponding new second and third resulting voltages, and the determination module 28 being configured for calculating a new second difference β between the new second resulting voltage $V_{PZB}(F_2)$ and the new third resulting voltage $V_{PZB}(F_3)$ multiplied by the factor K.

[0048] If said second difference β is greater than the second predefined margin of error ε_2, the reference half-bandwidth df is decreased and the injection module 24 is configured for injecting new second and third input alternating voltages successively with the decreased reference half-bandwidth df, the measuring module 26 being configured for measuring corresponding new second and third resulting voltages, and the determination module 28 being configured for calculating a new second difference β between the new second resulting voltage $V_{PZB}(F_2)$ and the new third resulting voltage $V_{PZB}(F_3)$ multiplied by the factor K.

[0049] In other words, in this first embodiment, the injection module 24 is configured for injecting new input alternating voltages in a next analysis cycle according to the following rules:

- if $\alpha > \varepsilon_1$, then the reference frequency F_m is reduced for the next analysis cycle;
- if $\alpha < -\varepsilon_1$, then the reference frequency F_m is increased for the next analysis cycle;
- if $\beta > \varepsilon_2$, then the reference half-bandwidth df is reduced for the next analysis cycle; and
- if $\beta < -\varepsilon_2$, then the reference half-bandwidth df is increased for the next analysis cycle.

[0050] Thus, after one or several analysis cycles, the first and the second differences α, β respectively converge progressively to the null value and the resonance frequency F_0 and the half-bandwidth df_0 are then determined by the determination module 28. Further, the quality factor Q is also calculated according to equation (1).

[0051] Therefore, the determination device 14 allows continuous monitoring of the characteristics F_0 and Q of the resonant circuit 12, such as the PZB magnet, and this continuous monitoring is performed in parallel of the resonant circuit state acquisition by the on-board train protection system.

[0052] The monitoring of the resonant circuit 12, such as the PZB magnet, is performed during a given time slot where an alternating voltage V_g with a selectable frequency can be generated by the injection module 24 without impact on the resonant circuit state acquisition.

[0053] In a second embodiment, the characteristic of the resonant circuit 12 to be determined by the determination device 14 is the resonance frequency F_0.

[0054] According to this second embodiment, the injection module 24 is configured for injecting first and second input alternating voltages successively between the terminals 16 of the resonant circuit 12, the first input alternating voltage having a first frequency equal to a reference frequency minus a predefined delta and the second input alternating voltage having a second frequency equal to the reference frequency plus the predefined delta, the measuring module 26 being configured for measuring a first resulting voltage $V_{PZB}(F_1)$ corresponding to the first input alternating voltage and respectively a second resulting voltage $V_{PZB}(F_2)$ corresponding to the second input alternating voltage, and the determination module 28 being configured for determining the resonance frequency F_0 from a difference α between the first resulting voltage $V_{PZB}(F_1)$ and the second resulting voltage.

[0055] Then, if the difference α is equal to 0 within a predefined margin of error ε_1, the determined resonance frequency F_0 is equal to the reference frequency.

[0056] If said difference α is lower than minus the predefined margin of error ε_1, the reference frequency is increased and the injection module 24 is configured for injecting new first and second input alternating voltages successively with the increased reference frequency, the measuring module 26 being configured for measuring corresponding new first and second resulting voltages $V_{PZB}(F_1)$, $V_{PZB}(F_2)$, and the determination module 28 being configured for calculating a new difference α between the new first resulting voltage $V_{PZB}(F_1)$ and the new second resulting voltage.

[0057] If said difference α is greater than the predefined margin of error ε_1, the reference frequency is decreased and the injection module 24 is configured for injecting new first and second input alternating voltages successively with the decreased reference frequency, the measuring module 26 being configured for measuring corresponding new first and second resulting voltages $V_{PZB}(F_1)$, $V_{PZB}(F_2)$, and the determination module 28 being configured for calculating a new difference α between the new first resulting voltage $V_{PZB}(F_1)$ and the new second resulting voltage $V_{PZB}(F_2)$.

[0058] In other words, in this second embodiment, the injection module 24 is configured for injecting new input alternating voltages in a next analysis cycle according to the following rules:

- if $\alpha > \varepsilon_1$, then the reference frequency F_m is reduced for the next analysis cycle; and
- if $\alpha < -\varepsilon_1$, then the reference frequency F_m is increased for the next analysis cycle.

[0059] In a third embodiment, the characteristic of the resonant circuit 12 to be determined by the determination device 14 is the half-bandwidth df_0 of the frequency response of the resonant circuit 12 (curve 100 in Figures 2 and 3).

[0060] According to this third embodiment, the injection module 24 is configured for injecting former and latter input alternating voltages successively between the terminals 16 of the resonant circuit 12, the former input alternating voltage having a former frequency equal to a predefined frequency plus a reference half-bandwidth df and the latter input alternating voltage having a latter frequency equal to the predefined frequency, the measuring module 26 being configured for measuring a former resulting voltage $V_{PZB}(F_2)$ corresponding to the former input alternating voltage and respectively a latter resulting voltage $V_{PZB}(F_3)$ corresponding to the latter input alternating voltage, and the determination module 28 being configured for determining the half-bandwidth df from a difference β between the former resulting voltage $V_{PZB}(F_2)$ and the latter resulting voltage $V_{PZB}(F_3)$ multiplied by a factor K, the factor K being substantially equal to $\sqrt{2}$.

[0061] Then, if the difference β is equal to 0 within a predefined margin of error ε_2, the determined half-bandwidth is equal to the reference half-bandwidth df.

[0062] If said difference β is lower than minus the predefined margin of error ε_2, the reference half-bandwidth df is increased and the injection module 24 is configured for injecting new former and latter input alternating voltages successively with the increased reference half-bandwidth df, the measuring module 26 being configured for measuring corresponding new former and latter resulting voltages, and the determination module 28 being configured for calculating a new difference β between the new former resulting voltage $V_{PZB}(F_2)$ and the new latter resulting voltage $V_{PZB}(F_3)$ multiplied by the factor K.

[0063] If said difference β is greater than the predefined margin of error ε_2, the reference half-bandwidth df is decreased and the injection module 24 is configured for injecting new former and latter input alternating voltages successively with the decreased reference half-bandwidth df, the measuring module 26 being configured for measuring corresponding new former and latter resulting voltages, and the determination module 28 being configured for calculating a new difference β between the new former resulting voltage $V_{PZB}(F_2)$ and the new latter resulting voltage $V_{PZB}(F_3)$ multiplied by the factor K.

[0064] In other words, in this third embodiment, the injection module 24 is configured for injecting new input alternating voltages in a next analysis cycle according to the following rules:

- if $\beta > \varepsilon_2$, then the reference half-bandwidth df is reduced for the next analysis cycle; and
- if $\beta < -\varepsilon_2$, then the reference half-bandwidth df is increased for the next analysis cycle.

[0065] The determination device 14 according to the invention therefore allows determining at least one characteristic of a railway resonant circuit 12 in a more efficient and less costly manner.

Claims

1. An electronic determination device (14) for determining at least one characteristic (F_0, df_0, Q) of a railway resonant circuit (12), the resonant circuit (12) being included in a trackside train protection system and being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system,
the determination device (14) being adapted to be connected between two terminals (16) of the resonant circuit (12) and comprising:

   - an injection module (24) configured for injecting at least one input alternating voltage between the terminals (16) of the resonant circuit (12);
   - a measuring module (26) configured for measuring at least one resulting voltage between the terminals (16) of the resonant circuit (12) after injection of a respective input alternating voltage;
   - a determination module (28) configured for determining at least one characteristic (F_0, df_0, Q) of the resonant circuit (12) from the at least one measured resulting voltage;
   - a radio-transmission module (30) for radio-transmitting the at least one determined characteristic (F_0, df_0, Q) to a remote electronic apparatus.

2. The determination device (14) according to claim 1, wherein the injection module (24) is configured for injecting at least two input alternating voltages successively between the terminals (16) of the resonant circuit (12), the measuring module (26) being configured for measuring successively at least two resulting voltages between the terminals (16) of the resonant circuit (12), each one after injection of a respective input alternating voltage, and the determination module (28) being configured for determining the at least one characteristic (F_0, df_0) from the at least two measured resulting voltages.

3. The determination device (14) according to claim 2, wherein two characteristics to be determined are a resonance frequency (F_0) of the resonant circuit (12) and a half-bandwidth (df_0) of a frequency response of the resonant circuit (12) and the injection module (24) is configured for injecting first, second and third input alternating voltages successively between the terminals (16) of the resonant circuit (12), the first input alternating voltage having a first frequency equal to a reference frequency minus a reference half-bandwidth (df), the second input alternating voltage having a second frequency equal to a reference frequency plus a reference half-bandwidth (df) and the third input alternating voltage having a third frequency equal to the reference frequency, the measuring module (26) being configured for measuring a first resulting voltage ($V_{PZB}(F_1)$) corresponding to the first input alternating voltage, a second resulting voltage ($V_{PZB}(F_2)$) corresponding to the second input alternating voltage and respectively a third resulting voltage ($V_{PZB}(F_3)$) corresponding to the third input alternating voltage, and the determination module (28) being configured for determining the resonance frequency (F_0) from a first difference (α) between the first resulting voltage ($V_{PZB}(F_1)$) and the second resulting voltage ($V_{PZB}(F_2)$) and respectively the half-bandwidth (df) from a second difference (β) between the second resulting voltage ($V_{PZB}(F_2)$) and the third resulting voltage ($V_{PZB}(F_3)$) multiplied by a factor (K), the factor (K) being substantially equal to $\sqrt{2}$.

4. The determination device (14) according to claim 3, wherein:

- if the first difference (α) is equal to 0 within a first predefined margin of error (ε_1), the determined resonance frequency (F_0) is equal to the reference frequency;
- if said first difference (α) is lower than minus the first predefined margin of error (ε_1), the reference frequency is increased and the injection module (24) is configured for injecting new first and second input alternating voltages successively with the increased reference frequency, the measuring module (26) being configured for measuring corresponding new first and second resulting voltages ($V_{PZB}(F_1)$, $V_{PZB}(F_2)$), and the determination module (28) being configured for calculating a new first difference (α) between the new first resulting voltage ($V_{PZB}(F_1)$) and the new second resulting voltage; and
- if said first difference (α) is greater than the first predefined margin of error (ε_1), the reference frequency is decreased and the injection module (24) is configured for injecting new first and second input alternating voltages successively with the decreased reference frequency, the measuring module (26) being configured for measuring corresponding new first and second resulting voltages ($V_{PZB}(F_1)$, $V_{PZB}(F_2)$), and the determination module (28) being configured for calculating a new first difference (α) between the new first resulting voltage ($V_{PZB}(F_1)$) and the new second resulting voltage.

5. The determination device (14) according to claim 3 or 4, wherein:

- if the second difference (β) is equal to 0 within a second predefined margin of error (ε_2), the determined half-bandwidth is equal to the reference half-bandwidth (df);
- if said second difference (β) is lower than minus the second predefined margin of error (ε_2), the reference half-bandwidth (df) is increased and the injection module (24) is configured for injecting new second and third input alternating voltages successively with the increased reference half-bandwidth (df), the measuring module (26) being configured for measuring corresponding new second and third resulting voltages, and the determination module (28) being configured for calculating a new second difference (β) between the new second resulting voltage ($V_{PZB}(F_2)$) and the new third resulting voltage ($V_{PZB}(F_3)$) multiplied by the factor (K); and
- if said second difference (β) is greater than the second predefined margin of error (ε_2), the reference half-bandwidth (df) is decreased and the injection module (24) is configured for injecting new second and third input alternating voltages successively with the decreased reference half-bandwidth (df), the measuring module (26) being configured for measuring corresponding new second and third resulting voltages, and the determination module (28) being configured for calculating a new second difference (β) between the new second resulting voltage ($V_{PZB}(F_2)$) and the new third resulting voltage ($V_{PZB}(F_3)$) multiplied by the factor (K).

6. The determination device (14) according to claim 2, wherein a characteristic to be determined is a resonance frequency (F_0) of the resonant circuit (12) and the injection module (24) is configured for injecting first and second input alternating voltages successively between the terminals (16) of the resonant circuit (12), the first input alternating voltage having a first frequency equal to a reference frequency minus a predefined delta and the second input alternating voltage having a second frequency equal to the reference frequency plus the predefined delta, the measuring module (26) being configured for measuring a first resulting voltage ($V_{PZB}(F_1)$) corresponding to the first input alternating voltage and respectively a second resulting voltage ($V_{PZB}(F_2)$) corresponding to the second input alternating voltage, and the determination module (28) being configured for determining the resonance frequency (F_0) from a difference (α) between the first resulting voltage ($V_{PZB}(F_1)$) and the second resulting voltage.

7. The determination device (14) according to claim 6, wherein:

- if the difference (α) is equal to 0 within a predefined margin of error (ε_1), the determined resonance frequency (F_0) is equal to the reference frequency;
- if said difference (α) is lower than minus the predefined margin of error (ε_1), the reference frequency is increased and the injection module (24) is configured for injecting new first and second input alternating voltages successively with the increased reference frequency, the measuring module (26) being configured for measuring corresponding new first and second resulting voltages ($V_{PZB}(F_1)$, $V_{PZB}(F_2)$), and the determination module (28) being configured for calculating a new difference (α) between the new first resulting voltage ($V_{PZB}(F_1)$) and the new second resulting voltage; and
- if said difference (α) is greater than the predefined margin of error (ε_1), the reference frequency is decreased and the injection module (24) is configured for injecting new first and second input alternating voltages successively with the decreased reference frequency, the measuring module (26) being configured for measuring cor-

responding new first and second resulting voltages ($V_{PZB}(F_1)$, $V_{PZB}(F_2)$), and the determination module (28) being configured for calculating a new difference (α) between the new first resulting voltage ($V_{PZB}(F_1)$) and the new second resulting voltage ($V_{PZB}(F_2)$).

8. The determination device (14) according to claim 2, wherein a characteristic to be determined is a half-bandwidth (df_0) of a frequency response of the resonant circuit (12) and the injection module (24) is configured for injecting former and latter input alternating voltages successively between the terminals (16) of the resonant circuit (12), the former input alternating voltage having a former frequency equal to a predefined frequency plus a reference half-bandwidth (df) and the latter input alternating voltage having a latter frequency equal to the predefined frequency, the measuring module (26) being configured for measuring a former resulting voltage ($V_{PZB}(F_2)$) corresponding to the former input alternating voltage and respectively a latter resulting voltage ($V_{PZB}(F_3)$) corresponding to the latter input alternating voltage, and the determination module (28) being configured for determining the half-bandwidth (df) from a difference (β) between the former resulting voltage ($V_{PZB}(F_2)$) and the latter resulting voltage ($V_{PZB}(F_3)$) multiplied by a factor (K), the factor (K) being substantially equal to $\sqrt{2}$.

9. The determination device (14) according to claim 8, wherein:

- if the difference (β) is equal to 0 within a predefined margin of error (ε_2), the determined half-bandwidth is equal to the reference half-bandwidth (df);
- if said difference (β) is lower than minus the predefined margin of error (ε_2), the reference half-bandwidth (df) is increased and the injection module (24) is configured for injecting new former and latter input alternating voltages successively with the increased reference half-bandwidth (df), the measuring module (26) being configured for measuring corresponding new former and latter resulting voltages, and the determination module (28) being configured for calculating a new difference (β) between the new former resulting voltage ($V_{PZB}(F_2)$) and the new latter resulting voltage ($V_{PZB}(F_3)$) multiplied by the factor (K); and
- if said difference (β) is greater than the predefined margin of error (ε_2), the reference half-bandwidth (df) is decreased and the injection module (24) is configured for injecting new former and latter input alternating voltages successively with the decreased reference half-bandwidth (df), the measuring module (26) being configured for measuring corresponding new former and latter resulting voltages, and the determination module (28) being configured for calculating a new difference (β) between the new former resulting voltage ($V_{PZB}(F_2)$) and the new latter resulting voltage ($V_{PZB}(F_3)$) multiplied by the factor (K).

10. The determination device (14) according to any one of the preceding claims, wherein the determination device (14) is configured for being permanently connected between the terminals (16) of the resonant circuit (12).

11. A trackside train protection system (10) comprising:

- a railway resonant circuit (12), the resonant circuit (12) being configured for transmitting information to an on-board train protection system by resonating in response to a signal emitted by the on-board train protection system; and
- an electronic determination device (14) for determining at least one characteristic (F_0, df_0, Q) the resonant circuit (12), the determination device (14) being connected between two terminals (16) of the resonant circuit (12),

wherein the determination device (14) is according to any one of the preceding claims.

12. The trackside train protection system (10) according to claim 11 wherein the resonant circuit (12) has a resonance frequency (F_0) and includes at least a component among a capacitor (24) and a coil (26).

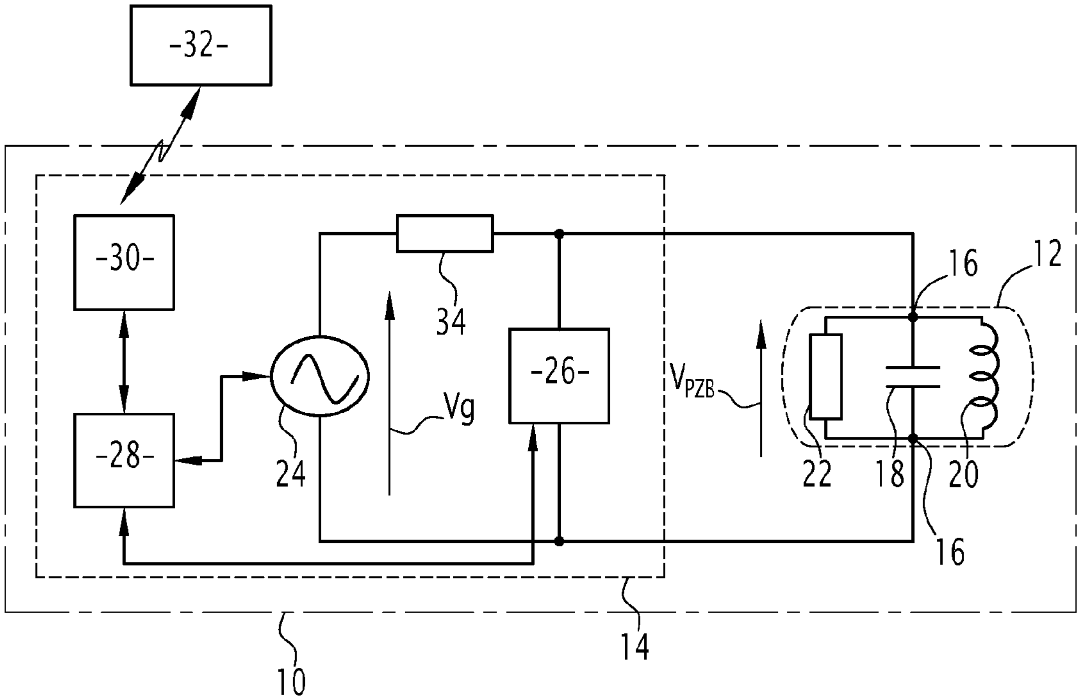
-32-
-30-
-28-
-26-
34
24
Vg
V_{PZB}
16
12
22
18
20
16
14
10

FIG.1

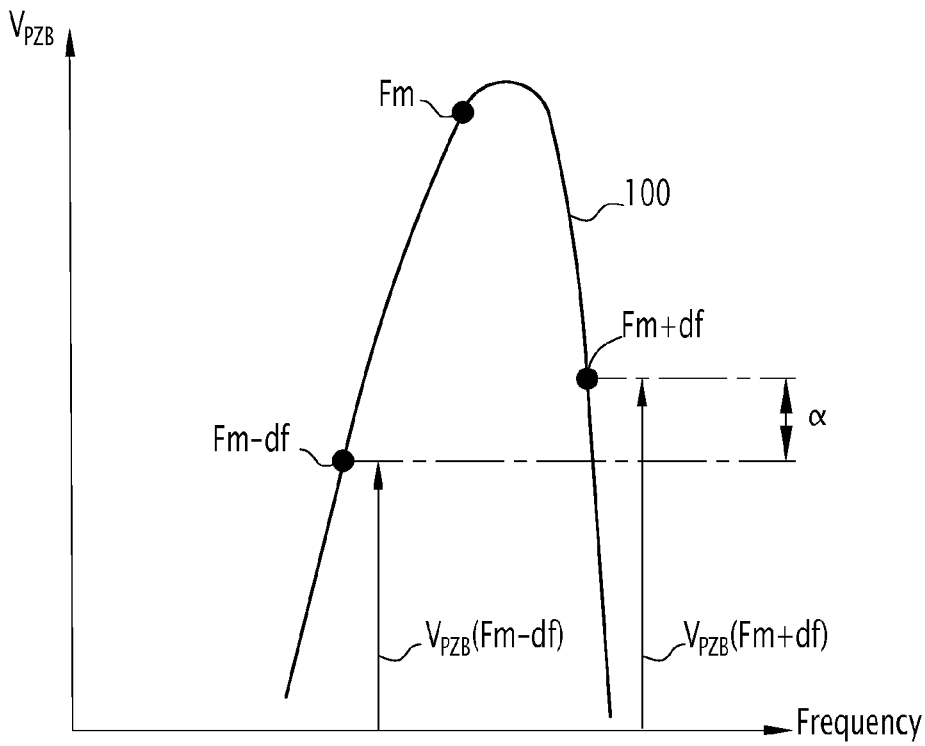
V_{PZB}
Fm
100
Fm+df
α
Fm-df
V_{PZB}(Fm-df)
V_{PZB}(Fm+df)
Frequency

FIG.2

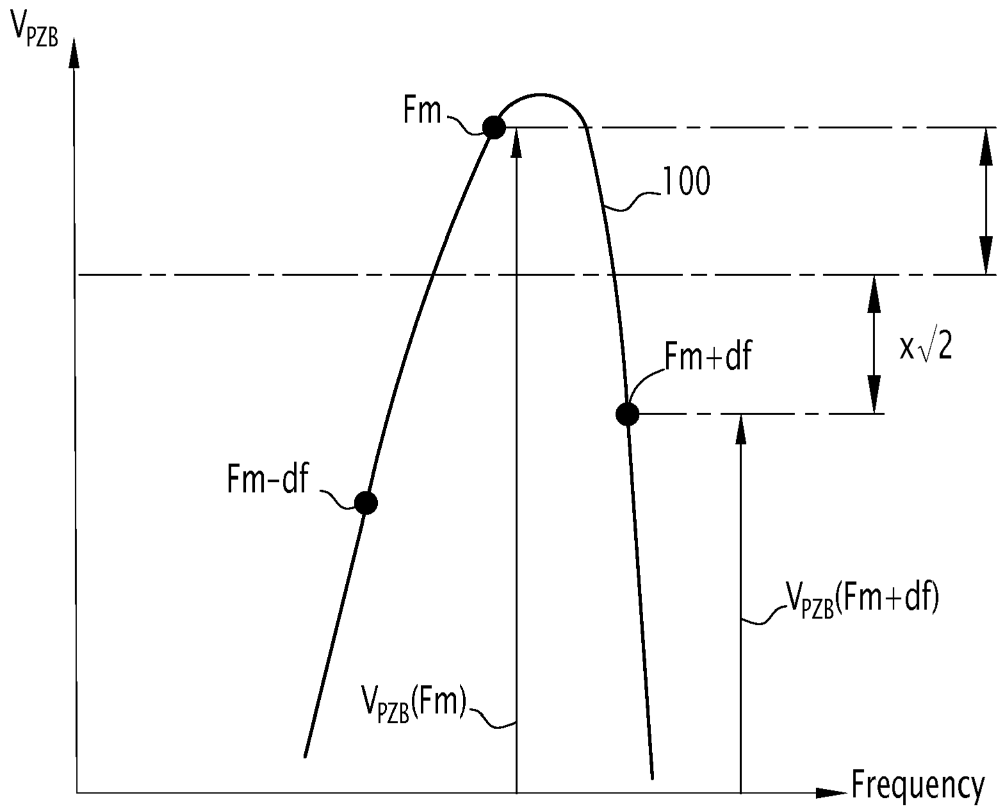

FIG.3

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EUROPEAN SEARCH REPORT

Application Number
EP 17 30 5875

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	EP 2 960 922 A1 (ALSTOM TRANSP TECH [FR]) 30 December 2015 (2015-12-30) * paragraph [0020] - paragraph [0075]; figure 1 * -----	1,2,6,7, 10-12	INV. B61L3/12
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TECHNICAL FIELDS SEARCHED (IPC)

B61L

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	12 December 2017	Mäki-Mantila, M

CATEGORY OF CITED DOCUMENTS

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12-12-2017

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REFERENCES CITED IN THE DESCRIPTION

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