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- (54) **Title:** SYSTEM FOR TRANSFERRING ENERGY TO A VEHICLE AND VEHICLE-ROUTE ARRANGEMENT

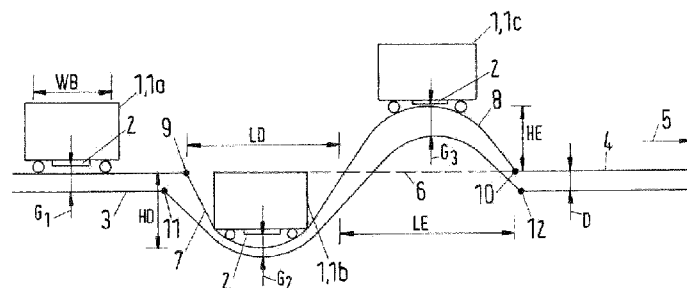


Fig.2

- (57) **Abstract:** The invention relates to a system for transferring energy to a vehicle (1), in particular a track-bound vehicle, such as a light rail vehicle, and a vehicle-route arrangement wherein - the system comprises an electric conductor arrangement adapted to produce an electromagnetic field which can be received by the vehicle (1) thereby transferring the energy to the vehicle, - wherein the conductor arrangement comprises at least one electric line (3), - wherein the electric line (3) is integrated in the ground at the path of travel of the vehicle (1), and wherein - a distance (D) of the electric line (3) of the conductor arrangement to a driving surface (4) of the ground varies. The invention further relates to a method of building such a system.

System for transferring energy to a vehicle and vehicle-route arrangement

The invention relates to a system for transferring energy to a vehicle, in particular a track-bound vehicle, such as a light rail vehicle. Furthermore, the invention relates to a vehicle-route-arrangement. The invention further relates to a method of building such a system.

While travelling on a route vehicles require energy for driving (i.e. propulsion) and for auxiliary equipment which does not produce propulsion of the vehicle. Such auxiliary equipment includes, for example, lighting systems, heating and/or air-conditioning systems, ventilation and passenger information systems. Not only track-bound vehicles (such as trams), but also road automobiles can be operated using electric energy. If continuous electric contact between the travelling vehicle and an electric rail or wire along the route is not desired, electric energy can be either withdrawn from an on-board energy storage or can be received by induction from an arrangement of electric lines of the route.

Generally speaking, the vehicle may be, for example, a vehicle having an electrically operated drive motor. However, the vehicle may also be a vehicle having a hybrid drive system, e.g. a system which can be operated by electric energy or by other energy, such as energy provided using fuel (e.g. natural gas, diesel fuel, petrol or hydrogen).

In particular, the vehicle can be a track-bound vehicle. Track-bound vehicles such as trams can be provided with electric energy via a pantograph which contacts a conductor like an overhead line or a live rail. However, under specific circumstances such as within the historic centre of a city such conductors are undesired for aesthetic reasons. On the other hand, live rails which are varied in the ground cause safety problems.

To overcome this problem, energy can be transferred inductively to the vehicle. In this case, a track-sided conductor arrangement produces an electromagnetic field. The field is

received by a coil on board of the vehicle so that the field produces an electric voltage by induction.

The transfer of electric energy to the vehicle by induction forms a background of the invention. A route-sided (primary side) conductor arrangement (primary winding) produces an electromagnetic field. The field is received by at least one inductance on a secondary side, e.g. a coil, on board of the vehicle so that the field produces an electric voltage by induction. The expression "pick-up" has been used for a vehicle-sided device which comprises at least one inductance. The transferred energy may be used for propulsion of the vehicle and/or for other purposes such as providing the auxiliary equipment of the vehicle with energy. The conductor arrangement on the primary side can also be referred to as transmitter and the pick-up arrangement on the secondary side can also be referred to as receiver.

The inductive transfer of energy depends, among other things, on the distance between the route-sided conductor arrangement and the vehicle-sided pick-up arrangement, i.e. the gap between the primary side and the secondary side. A variation of the distance between the transmitter and the receiver, i.e. the gap, can cause undesirable changes or variations of a voltage on the secondary side which can e.g. exceed acceptable voltage limits.

A variation of the distance between the transmitter and the receiver can be caused by vertical curves, e.g. deepenings or elevations, of a driving surface provided by the route. The route can be a road or a track. Different approaches to compensate such undesired variations exist.

One solution explored is a dynamic positioning of the pick-up arrangement. An example is described in US 3,914,562. The document describes an electrically driven vehicle having suitable batteries to drive the vehicle on conventional roads. The vehicle has means for receiving power from a conductor embedded in a prepared roadway for driving the vehicle and for charging the batteries. The power receiving means on-board the vehicle, i.e. the pick-up, which are mounted at the bottom of the vehicle, can be lowered towards the surface of the road in order to reduce the size of the air gap between the pick-up and the conductor embedded in the roadway. The pick-up comprises a pick-up core including a central elevated section and a pair of lateral sections disposed closer to the road which

serve as magnetic poles. A pick-up coil is wound about the central core section. A pick-up position control automatically or manually adjusts the position of the pick-up relative to the roadway. The pick-up position control comprises a pair of relays for energizing an electric motor of the means for raising and lowering the pick-up. These raising and lowering means include a linkage connecting the framework of the vehicle to suitable bracing elements secured to the pick-up core. Two sets of bell crank arms are connected to the bracing elements and to a double ended reciprocating output member provided by the motor. The arms are mounted by pivot pins to the vehicle framework.

The raising and lowering means described in US 3,914,562 require a large space with respect to a vertical direction. Therefore, the pick-up and the raising and lowering means need to be taken into account in the conceptual design of the vehicle. Alteration of an existing vehicle, i.e. mounting a pick-up and a corresponding lifting device, requires extensive effort or is impossible, if the vehicle is not yet designed to be operated using such a pick-up.

Another solution is to modify electric elements on the secondary side in order to handle a larger range of voltages being input to the system. Such a solution, however, is costly and the respective electric elements usually require a large installation space.

It is an object of the present invention to provide a system for transferring energy to a vehicle, in particular a track-bound vehicle, such as a light rail vehicle, and a route-vehicle-arrangement, wherein undesirable changes or variations of an induced voltage on a secondary side of an inductive power transfer system, e.g. due to vertical curves of a driving surface, are reduced or minimized. Furthermore, it is an object of the invention to provide a method of building such a system.

It is a basic idea of the invention to adapt the course of an electric line providing a primary winding for an inductive power transfer to a vehicle to a topology, in particular to unevennesses or irregularities, of a route or a driving surface of the route such that a distance between the electric line and a vehicle-sided receiver is constant or within a predetermined distance interval if the vehicle travels on the driving surface.

A system for transferring energy to a vehicle, in particular a track-bound vehicle, such as a light rail vehicle, is proposed. The system can also be referred to as route-conductor-arrangement.

The system comprises an electric conductor arrangement adapted to produce an electromagnetic field which can be received by the vehicle thereby transferring the energy to the vehicle. The electric conductor arrangement provides a primary winding of a transformer for inductive power transfer to the vehicle. The electric conductor arrangement is adapted to produce an electromagnetic field which can be received by a vehicle, in particular a track-bound vehicle, such as a light rail vehicle, or a road automobile. The vehicle can travel on a driving surface of a route, in particular the driving surface provided by a road or a track, and energy is transferred to the vehicle by the aforementioned electromagnetic field. Energy can be transferred while the vehicle is moving (dynamic transfer, e.g. dynamic charging) or at a halt (static transfer, e.g. static charging). The electric conductor arrangement can also be referred to as transmitter.

The conductor arrangement comprises at least one electric line which is integrated in the ground at the path of travel of the vehicle. In particular, the conductor arrangement or at least one electric line of the conductor arrangement can be integrated into one or more base layers of a roadway or track, wherein a base layer is a layer below the driving surface provided by the roadway or track. In case of a track, the driving surface is provided by the rail track.

Thus, the system or the route-conductor-arrangement comprises the conductor arrangement and the driving surface or elements providing the driving surface of the route. The conductor arrangement or the electric line of the conductor arrangement is arranged below or under the driving surface of the route. The electric line extends along a direction of travel of the vehicle on the driving surface.

According to the invention, a distance of the conductor arrangement or the electric line of the conductor arrangement to a driving surface of the ground varies, in particular along the extension of the electric line in the direction of travel. The distance can be a vertical distance. The vertical direction can be defined as a direction which is perpendicular to the driving surface or which is perpendicular to a reference plane comprising a substantial part of the driving surface. Vehicles can travel on the driving surface in a direction of

travel. The driving surface, along a course of the driving surface, can have vertical curves, e.g. deepenings or elevations. The deepenings and elevations can be deepenings and elevations with respect to the reference plane. In case of a deepening, for example, the driving surface, with respect to the reference plane, descends or lowers into the deepening and ascends to the reference plane along the course of the driving surface in the direction of travel. In case of a deepening, the driving surface is deflected or deviated such that the driving surface within the deepening is located below or under the reference plane. In case of an elevation, the driving surface is deflected or deviated such that the driving surface of the elevation is located above the reference plane. Thus, the driving surface, along the course of the driving surface in the direction of travel, can be deflected vertically with respect to a reference plane. If the vehicle travels on the driving surface, the vertical curves of the driving surface, e.g. the elevations or deepenings, can cause a variation of an air gap between a vehicle-sided receiver (e.g. a pick-up arrangement of the vehicle) and the transmitter provided by the conductor arrangement or the electric line of the conductor arrangement. These variations can cause undesirable voltage changes or variations of the induced voltage on the secondary side, e.g. of the output voltage of the receiver. By varying the distance of the conductor arrangement or the electric line of the conductor arrangement to the driving surface, the variation of the aforementioned gap can be eliminated or reduced. This, in turn, eliminates or reduces the undesired voltage variations or changes. In particular, the conductor arrangement or the electric line of the conductor arrangement can be designed and/or arranged with respect to the driving surface such that a distance of a pick-up arrangement of a vehicle travelling on the driving surface, in particular a receiving coil of the pick-up arrangement, to the conductor arrangement or the electric line of the conductor arrangement is constant or varies within a predetermined minimal distance and a predetermined maximal distance if the vehicle travels on the driving surface in the direction of travel. The distance can be measured in a direction perpendicular to the driving surface, e.g. along the course of the driving surface, or in a direction perpendicular to the reference plane.

This advantageously provides a system or a route-conductor-arrangement which reduces or even eliminates undesired voltage variations of the induced voltage.

In another embodiment, the system comprises a conductor arrangement adapted to produce an electromagnetic field which can be received by a vehicle, in particular a track-bound vehicle, such as a light rail vehicle, travelling on a driving surface of a route thereby

transferring energy to the vehicle, wherein the electric conductor arrangement comprises at least one electric line, wherein at least one section of the electric line along a course of the electric line is deflected vertically. Additionally, at least one section of the electric line along the course of the electric line can be deflected such that a meandering line is provided. In particular, the section can be deflected horizontally in order to form a meandering line. The vertical direction of deflection of the electric line is oriented perpendicular to a reference plane which is provided by substantial portion of the driving surface or comprises a substantial portion of the driving surface. As already mentioned before, the driving surface can also be deflected vertically with respect to the reference plane, wherein vertical deflections generate the aforementioned deepenings or elevations of the driving surface.

Thus, the distances of the electric line of the conductor arrangement to the reference plane can be varied depending on a distance of the driving surface or portions of the driving surface to the reference plane, wherein the distance of the electric line to the reference plane, along the course of the electric line, is varied such that the distance of the electric line to the driving surface varies. This advantageously provides a system (or route-conductor-arrangement) wherein a design and/or arrangement of the electric line can effectively be adapted to a course of the driving surface with respect to a reference plane which, in turn, results in an effective elimination or reduction of undesired voltage changes on the secondary side.

The electric conductor arrangement can be manufactured by providing at least one electric line and deflecting at least one section of the electric line along course of the electric line vertically. Deflecting the electric line can e.g. be achieved by bending the electric line. Additionally, at least one section of the electric line along the course of the electric line can be deflected, for example horizontally, in order to form a meandering line.

In another embodiment, the electric line of the conductor arrangement is arranged such that the distance of the electric line to the driving surface decreases while the driving surface descends into a deepening or to a bottom of the deepening and increases while the driving surface ascends from the deepening or from the bottom of the deepening. In the following, a descent or ascent is defined with respect to a direction of travel of the vehicle on the driving surface. The driving surface, for example, can descend into a deepening with respect to a reference plane until the driving surface reaches a bottom of

the deepening. From this bottom or bottom part of the deepening, the driving surface, with respect to a direction of travel, ascends from the bottom or bottom part to the reference plane. With an increasing distance from the driving surface to the reference plane, the distance from the electric line to the driving surface decreases. With a decreasing distance of the driving surface to the reference plane, the distance of the electric line to the driving surface increases.

Alternatively or in addition, the distance of the electric line to the driving surface increases while the driving surface ascends to an elevation or to a peak of the elevation and decreases while the driving surface descends from the elevation or from the peak of the elevation. According to the deepening case, a distance of the electric line to the driving surface can increase while a distance of the driving surface to a reference plane increases while passing an elevation in the direction of travel. Also, a distance from the electric line to the driving surface can decrease while the distance of the driving surface to the reference plane decreases while passing the elevation.

In total, if a sign-sensitive analysis of the distance of the driving surface to the reference plane is chosen and a distance of the driving surface to the reference plane is negative while the driving surface runs through a deepening, the distance of the electric line to the driving surface (which is always considered positive) decreases while the distance of the driving surface to the reference plane decreases. Correspondingly, the distance of the electric line to the driving surface increases while the distance of the driving surface to the reference plane increases.

The proposed arrangement of the electric line with respect to the driving surface reduces or eliminates a variation of the air gap between the electric line (transmitter) and a vehicle-sided receiver on a vehicle while the vehicle passes or drives through the deepening or across the elevation. While passing a deepening in the direction of travel, the distance of the receiver, which can e.g. be a pick-up arrangement installed at a bottom side of the vehicle, to the driving surface can increase. To compensate this increase, the electric line has to be arranged such that the electric line is located closer to the driving surface. Correspondingly, the distance of a vehicle-sided receiver, e.g. a pick-up arrangement installed at the bottom side of the vehicle, to the driving surface can decrease while the vehicle passes an elevation in the direction of travel. Thus, to compensate this decrease, the electric line has to be arranged such that it is located deeper under the driving surface.

In another embodiment, the electric line is arranged such that the distance of the electric line to the driving surface is minimal at a bottom part of a deepening.

In another embodiment, the electric line is arranged such that the distance of the electric line to the driving surface is maximal at a peak part of an elevation.

At the bottom or bottom part of the deepening, the distance of a vehicle-sided receiver, e.g. a pick-up arrangement of the vehicle, to the driving surface can become maximal. Therefore, to compensate this maximal distance, the distance of the electric line to the driving surface has to become minimal to provide a constant or nearly constant distance of the electric line to the vehicle-sided receiver. Correspondingly, the distance of the electric line to the driving surface has to become maximal in order to provide a constant or nearly constant distance of the electric line to the vehicle-sided receiver, as the distance of the vehicle-sided receiver to the driving surface can become minimal at a peak or peak part of an elevation.

This arrangement of the electric line advantageously provides a constant or nearly constant distance of the electric line to the receiver also while the vehicle passes deepenings and elevations of the driving surface.

In another embodiment, the electric line is arranged such that the distance of the electric line to the driving surface increases before the driving surface descends to a deepening and/or increases after the driving surfaces ascends from the deepening.

In the direction of travel, the driving surface descends into a deepening, if a distance of the driving surface to a reference plane decreases (sign-sensitive observation). The driving surface can also descend into a deepening if a distance of the driving surface to the reference plane decreases and is additionally negative (sign-sensitive observation). Before or ahead of a beginning of the descent, the distance of the electric line to the driving surface increases. The term "before" or "ahead" is defined relative to the course of the driving surface in the direction of travel. Correspondingly, an end of an ascent of the driving surface from a deepening is reached, if the distance of the driving surface to the reference plane becomes zero or reaches the same distance as before or at the beginning of the descent. After that end of the ascent from the bottom of the deepening, the distance

of the electric line to the driving surface can also increase, e.g. until a predetermined distance is reached.

This arrangement of the electric line serves to compensate an air gap variation between a vehicle-sided receiver and the electric line, when only a part of the vehicle, e.g. a front part of the vehicle, descends into the deepening. If only a part, e.g. the front part of the vehicle, descends into the deepening, the distance between the vehicle-sided receiver and the driving surface can decrease. In order to compensate this decrease, the distance between the driving surface and the electric line has to increase. The same observation holds if another part of the vehicle, e.g. a rear part or tail part of the vehicle, ascends from the deepening while the front part travels on the driving surface which can e.g. be located within the reference plane.

This arrangement of the electric line with respect to the driving surface along the direction of travel further enhances the elimination or reduction of undesired voltage variations caused by a variation of the air gap between the receiver and the electric line due to vertical curves of the driving surface.

In another embodiment, the electric line is arranged such that the distance of the electric line to the driving surfaces decreases before the driving surface ascends to an elevation or after the driving surface descends from the elevation. Along the driving surface in the direction of travel, an ascent of an elevation begins when the distance of the driving surface to the reference plane increases. Before or ahead of this beginning of the ascent, the distance of the electric line to the driving surface is decreased. If only a part of the vehicle, in particular a front part of the vehicle, passes or drives on the ascent to a peak or a peak part of the elevation, the distance of a vehicle-sided receiver to the driving surface can increase. To compensate this increase, the distance of the electric line to the driving surface has to decrease. The same observation holds for the end of a descent from the peak or peak part of the elevation.

As explained before, this arrangement of the electric line further enhances the reduction or elimination of an undesired voltage variation on the secondary side.

In another embodiment, the distance of the electric line to the driving surface is varied according to a predetermined wheelbase of vehicle and/or a length of the deepening

and/or a length of an elevation. The length of a deepening or elevation is defined with respect to the direction of travel. It can be also defined as a length in the direction of travel with respect to the reference plane. Depending on a relationship between the wheelbase and the length of a deepening or the length of an elevation, the distance of a vehicle-sided receiver, e.g. a pick-up arrangement installed at the bottom side of the vehicle, to the driving surface varies. If the wheelbase is smaller than the length of the deepening, all wheels of the vehicle may be located within the deepening at one point in time. If the wheelbase is larger than the length of the deepening, only one wheel or one axis of the vehicle carrying two wheels will be located within the deepening if the vehicle travels in the direction of travel along the driving surface. These parameters can define or influence the distance of a vehicle-sided receiver to the driving surface. The electric line has to be arranged such that the distance of the electric line to the receiver is constant or nearly constant or within a predefined distance interval.

The predetermined wheelbase of the vehicle can be an average wheelbase or representative wheelbase if vehicles with different wheelbases travel on the driving surface. Accordingly, the length of the deepening and the length of an elevation may be an average length of multiple deepenings or an average length of multiple elevations. In the case of vehicles with different wheelbases and/or different lengths of elevations or deepenings, the distance of the electric line to the receiver cannot be constant for all vehicles and/or for all deepenings/elevations. By arranging the electric line depending on an average wheelbase and/or an average length, undesired voltage variations can be reduced for vehicles with different wheelbases.

In another embodiment, the distance of the electric line to the driving surface is varied according to a pick-up height and/or a pick-up displacement and/or a depth of a deepening and/or a height of an elevation. The pick-up height is a distance of the pick-up arrangement, e.g. one or more multiple coil(s) installed at a bottom side of the vehicle, from the driving surface if the driving surface is a plane, e.g. the reference plane. Also, the depth of the deepening and the height of an elevation can be defined with respect to a reference plane and can be the distance of the bottom or peak of the deepening/elevation to the reference plane. Depending on the pick-up height and the depth of a deepening or the height of an elevation, the distance of the driving surface to the pick-up arrangement is varied when the vehicle passes deepenings or elevations. Thus, the distance of the

electric line to the driving surface has to be arranged such that the aforementioned distances of the pick-up arrangement to the driving surface are compensated for.

A pick-up displacement is referred to as a displacement of the pick-up arrangement from a longitudinal centre of the vehicle in a longitudinal direction of the vehicle which can correspond to the direction of travel if the vehicle travels forward. The pick-up displacement in the longitudinal direction of the vehicle from the longitudinal centre of the vehicle can influence the distance of the pick-up arrangement to the driving surface in case that only a part of the vehicle, e.g. a front part or a rear part of the vehicle, passes an elevation or deepening. If the electric line is arranged such that the distance of the electric line to the driving surface increases before the driving surface descends into a deepening, the distance of the beginning of the increase of the distance of the electric line to the driving surface to the beginning of the descent of the driving surface into the deepening can be chosen depending on the aforementioned pick-up displacement. Correspondingly, the distance between an end of the ascent of the deepening to the point where an increase of the distance of the electric line to the driving surface becomes zero after the driving surface ascends from the deepening can also depend on the aforementioned pick-up displacement. The same observation holds for an elevation of the driving surface.

Also, the pick-up height can depend on a wheel circumference.

It is possible, that a cable bearing element or support element which is used to provide a mechanical guidance for the conductor arrangement or the at least one electric line of the conductor arrangement is adapted such that a desired arrangement of the electric line to the driving surface is provided. It is further possible, that a cooling arrangement is designed and/or arranged such that the at least one electric line of the conductor arrangement can be cooled effectively along the course of the electric line.

In another embodiment, the conductor arrangement comprises a plurality of primary segments, in particular a plurality of consecutive segments, wherein each segment extends along a different section of a path of travel of the vehicle. Each of the consecutive segments comprises a section of the electric line, wherein corresponding sections of the electric line of neighbouring consecutive segments are connected in series to each other. Furthermore, the segments are arranged such that a distance of the electric line or the section of the electric line of the conductor arrangement to the driving surface of the

ground varies. This advantageously allows building the conductor arrangement of multiple and discontinuous sections which can be beneficial from the production cost perspective.

Furthermore, a vehicle-route-arrangement is proposed. The arrangement comprises one of the previously described systems. The vehicle comprises a pick-up arrangement, e.g. comprising a coil. The electric line of the system is arranged such that the distance of the electric line to the pick-up arrangement of the vehicle is constant or varies within a predetermined minimal distance and a predetermined maximal distance if the vehicle travels on the driving surface. In this case, the driving surface is the driving surface of the system. In particular, a track-bound vehicle-track-arrangement is proposed, wherein the electric line is arranged such that the distance of the electric line to the pick-up arrangement of the track-bound vehicle is constant or varies within a predetermined minimal distance and maximal distance if the track-bound vehicle, e.g. a light rail vehicle, travels on the driving surface of the rail track. In this case, the conductor arrangement or the electric line of the conductor arrangement can be integrated into a ground on which the rail track is installed.

This vehicle-road-arrangement advantageously reduces or eliminated undesired voltage variations on the secondary side while the vehicle travels on the driving surface in the direction of travel.

Furthermore, a method of building a system for transferring energy to a vehicle, in particular to a track-bound vehicle, such as a light rail vehicle, is proposed. The method comprises the steps of providing an electric conductor arrangement adapted to produce an electromagnetic field which can be received by the vehicle thereby transferring the energy to the vehicle. The electric conductor arrangement comprises at least one electric line. Furthermore, the at least one electric line is integrated in the ground at the path of travel of the vehicle.

According to the invention, the method further comprises the step of arranging the electric line of the conductor arrangement such that a distance of the electric line of the conductor arrangement to a driving surface of the ground varies. The distance of the electric line of the conductor arrangement to the driving surface can be varied within a minimal distance and a maximal distance.

In another embodiment, the method comprises the step of building a route for vehicles, wherein the electric line of the conductor arrangement is integrated into the ground while the route is being built. In this case, the electric line is integrated into the ground during the process of building the route. In contrast to an installation the electric line after the route has being built (which can be complex, costly and may require destruction of the driving surface), the proposed method allows a simple and effective installation of the electric line, wherein a desired variation of distances of the electric line to the driving surface can be provided. The proposed method in particular relates to building a track for track-bound vehicles, in particular for light rail vehicles.

Examples for track-bound vehicles are conventional rail vehicles, mono-rail vehicles, metros and busses (which may be guided on the track by optical means or mechanical means other than rails).

An arrangement of electrical conductors or lines along the track or driving surface can be realized in a variety of ways. In principle, the electric lines can be cables laid in the ground as usual in road constructions or underground engineering. The opening in the ground is then filled and provided with a suitable covering over which the vehicle can travel. For example, in the case of railways, the conductor arrangement can be first laid and then the rails providing the rail track can be installed there upon.

Also proposed is the previously described conductor arrangement and a method of manufacturing such a conductor arrangement.

Examples will be described with reference to the attached figures. The figures show:

- Fig. 1 a schematic side view of a system for transferring energy to a vehicle according to the state of the art,
- Fig. 2 a schematic side view of a proposed system for transferring energy to a vehicle and
- Fig. 3 a schematic side view of a vehicle with a pick-up arrangement.

Fig. 1 shows a schematic side view of a system for transferring energy to a vehicle 1, which is a light rail vehicle, by means of inductive power transfer. The system comprises an electric conductor arrangement adapted to produce an electromagnetic field which can

be received by a pick-up arrangement 2 of the vehicle 1. The conductor arrangement comprises electric lines 3 which are integrated in the ground at the path of travel of the vehicle 1. Also shown is a driving surface 4 of the system on which the vehicle 1 travels in a direction of travel which is symbolized by an arrow 5. Shown is a reference plane 6 of the driving surface 4 which comprises substantial parts of the driving surface 4. Furthermore, a deepening 7 and an elevation 8 of the driving surface 4 with respect to the reference plane 6 is shown. The deepening 7 has a length LD and depth HD. Accordingly, the elevation 8 has a length LE and a height HE. Also shown is a wheelbase WB of the vehicle 1.

At least one section of the electric line 3 of the conductor arrangement along a course of the electric line 3 is deflected vertically. This means that at least one section of the electric line 3 along a routing of the electric line 3 is deflected in a vertical direction. The vertical direction is defined with respect to a global coordinate system, i.e. a global coordinate system given by the route or driving surface 4 the vehicle 1 travels on. In particular, the vertical direction can be oriented perpendicular to the driving surface 4 or the reference plane 6 of the driving surface 4.

The deflection of the electric line 3 is given with respect to a straight course or routing of the electric line 3. Thus, the electric line 3 has a curvature or at least one curved section, wherein the curvature is designed such that the electric line 3 is deflected vertically. A radius of the curvature, e.g. a bending radius of the electric line 3, can be larger than a predetermined minimal radius to prevent the electric line from being damaged. In particular, the electric line 3 can have a wave-like form with wave crests and wave troughs with respect to a straight reference course of the electric line 3.

In Fig. 1, the deflection or curvature of the electric line 3 is chosen such that a distance of the electric line 3 to the driving surface 4 is constant. With respect to Fig. 2, the deflection or the curvature of the electric line 3 is chosen such that a distance of the electric line 3 to the driving surface 4 of the route the vehicle 1 travels on is varied along the course of the electric line 3. Preferably, the electric conductor arrangement comprises three electric lines to carry a three-phase electric current and produce a corresponding electromagnetic field which can be received by the vehicle. In this case, corresponding sections of the electric lines along a course of the electric lines are deflected vertically in the same

manner.

It is also possible that at least one section of the electric line 3, along the course of the electric line 3, deflects horizontally in order to form a meandering line. Thus, the electric line 3 extends in a meandering manner, wherein sections of the electric line 3 are deflected horizontally to form a meandering path of the electric line 3. The expression "meandering" covers both, the laying of an electric line 3 with smoothly curved transitions (having large radii of curvature) between straight electric line 3 section as well as configurations with sharp, angular transition regions between adjacent straight sections. Thus, the electric line 3, with regard to the course of the electric line, can deflect horizontally and vertically. In this case, a direction of the vertical deflection is perpendicular to a direction of a deflection in a horizontal direction. In the case of the electric conductor arrangement comprising three electric lines, each of the electric lines 3, along the course of the respective electric line 3, can form a meandering line.

The vehicle 1 is shown in different configurations or settings 1a, 1b, 1c when the vehicle 1 travels on the driving surface 4. In a first setting 1a, the vehicle 1 travels on the driving surface 4 which corresponds to the reference plane 6. In a second setting 1b the vehicle 1 travels through the deepening 7. In a third configuration 1c, the vehicle 1 travels on or across the elevation 8.

In Fig. 1 a distance D between the electric lines 3 and the driving surface 4 is constant for all sections of the driving surface 4 along the direction of travel (see arrow 5). This means that the distance D is constant for the settings 1a, 1b, 1c. As shown in Fig. 1, a distance G1 of the electric lines 3 to the pick-up arrangement 2, which is installed at a bottom of the vehicle 1, in the first setting 1a of the vehicle 1 is smaller than a distance G2 of the electric lines 3 to the pick-up arrangement 2 in the second setting 1b and larger than a distance G3 of the electric lines 3 to the pick-up arrangement 2 in the third setting 1c. This variation of the distances G1, G2, G3 causes undesired voltage variations of the voltage produced by the pick-up arrangement 2 during inductive power transfer.

Fig. 2 shows a schematic side view of a system for transferring energy to a vehicle 1 according to the invention. The vehicle 1 is shown in three settings 1a, 1b, 1c. The vehicle 1 travels on a driving surface 4, which can e.g. be provided by rails of a railway track. The driving surface has unevennesses or irregularities which are provided by a deepening 7

and an elevation 8. Also shown is a reference plane 6 of the driving surface 4 which comprises substantial part of the driving surface 4. The deepening 7 has a depth HD and a length LD. Accordingly, the elevation 8 has a height HE and a length LE.

In a first setting 1a, the vehicle 1 travels along a plane driving surface 4, which, in this case, corresponds to the reference plane 6. As can be seen in Fig. 2, a distance of the pick-up arrangement 2 of the vehicle 1 to the driving surface 4 in the first setting 1a is smaller than the corresponding distance in the second setting 1b and larger than the corresponding distance in the third setting 1c. Also shown is a distance D of the electric lines 3 to the driving surface 4. The electric lines 3 are arranged such that the distance D of the electric lines 3 to the driving surface 4 decreases while the driving surface 4 descends to a bottom of the deepening 7 and increases while the driving surface 4 ascends from the bottom of the deepening 7. Also, the distance D of the electric lines 3 to the driving surfaces 4 increases while the driving surface 4 ascends to a peak of the elevation 8 and decreases while the driving surface 4 descends from the peak of the elevation 8.

Furthermore, it is shown in Fig. 2, that the electric lines 3 are arranged such that the distances G1, G2, G3 are constant in the different settings 1a, 1b, 1c. Thus, there is no voltage variation due to variations of an air gap between the pick-up arrangement 2 and the electric lines 3.

It can be also seen from Fig. 2 that the distance D from the electric lines 3 to the driving surface 4 increases before the driving surface 4 descends into the deepening 7. In Fig. 2, the beginning 9 of the deepening 7 is shown. Also shown is an end 10 of the elevation 8. It can be seen from Fig. 2, that the electric lines 3 are arranged such that the increase of the distance D begins at a point 11 which is located before or ahead the beginning 9 of the deepening 7 with respect to the direction of travel (see arrow 5). Also, the decrease of the distance D after the elevation 8 (with respect to the direction of travel (see arrow 5)) ends after or beyond the end 10 of the elevation 8. The distances between the beginning 9 and the point 11 and the distance between the end 10 and the point 12 can be chosen depending on the wheelbase WB of the vehicle 1 or an average wheelbase of vehicles travelling on the driving surface 4. Also, the distance D of the electric lines 3 to the driving surface 4 can be varied according to the wheelbase WB of the vehicle 1, a length LD of

the deepening 7, the length LE of the elevation 8, the depth HD of the deepening 7, and the height HE of the elevation 8.

It is also possible that the conductor arrangement comprises a plurality of primary segments, in particular a plurality of consecutive segments. Each segment can extend along a different section of a path of travel of the vehicle 1. Within each section, the electric line(s) 3 may follow a straight course or straight routing with respect to a vertical direction. This can be referred to as a flat course of the electric line(s) 3, wherein such a segment can be referred to as flat segment. Thus, there is no vertical bending or vertical deflection of the electric line(s) 3 within the respective segment. Within each section, the electric line(s) 3, however, can be shaped such that each electric line(s) 3 form (a) meandering line(s).

Each of the consecutive segments can comprise the electric lines 3 or a section of the electric lines 3, wherein each electric line can carry a phase of an alternating current for producing the alternating electromagnetic field. Corresponding electric lines of neighbouring consecutive segments for carrying the same phase of the alternating current can be connected in series to each other.

The different segments can be arranged at different depths along the direction of travel (see arrow 5). This means that a distance of the segments to a driving surface 4 of the ground varies. In particular, the segments can be arranged such that a distance D of the electric lines 3 or a distance of the respective section of the electric lines 3 comprised by the segment to the driving surface 4 of the ground varies. The depth of each segment can be adapted to a vertical radius of the driving surface 4 or guide-way. As shown in Fig. 2, a grade of the driving surface 4 can change up or down which results in a varying distance between a pick-up arrangement 2 and the driving surface 4 or guide-way, i.e. between the pick-up arrangement 2 and the electric lines 3. This grade can be associated with a vertical radius. In particular, it is possible that the different segments can be arranged at different depths along the direction of travel (see arrow 5) such that a distance of a pick-up arrangement 2 of a vehicle 1 travelling on the driving surface 4, in particular a receiving coil of the pick-up arrangement 2, to the conductor arrangement or the electric lines 3 of the conductor arrangement is constant or varies within a predetermined minimal distance and a predetermined maximal distance if the vehicle 1 travels on the driving surface 4 in the direction of travel (see arrow 5).

In this way, the course of the electric lines 3 with respect to the direction of travel (see arrow 5) is provided by the consecutive arrangement of the segments, in particular flat segments. Preferably, the segments are arranged such that the continuous arrangement of the electric lines 3 shown in Fig. 2 is tracked.

A segment can be arranged such that the aforementioned straight course of the electric line(s) 3 of the segment along the direction of travel (see arrow 5) is parallel to the direction of travel or the aforementioned reference plane 6. It is, however, also possible that a segment is arranged such that the aforementioned straight course of the electric line(s) 3 of the segment and the direction of travel or the reference plane 6 draw a predetermined angle. The predetermined angle can be larger than 0° and smaller than 90° . Such a segment can be referred to as a skewed segment, wherein "skewed" is related to the direction of travel (see arrow 5) or the reference plane 6.

Furthermore, the system can comprise a power supply line for supplying electric energy to the segments. A switching device for producing the alternating current of the conductor arrangement from the current carried by the power supply line can be connected to each interface between two neighbouring consecutive segments, thereby connecting the power supply line with the electric lines 3 of the neighbouring consecutive segments. The system can further comprise a control device for controlling the operation of the switching device.

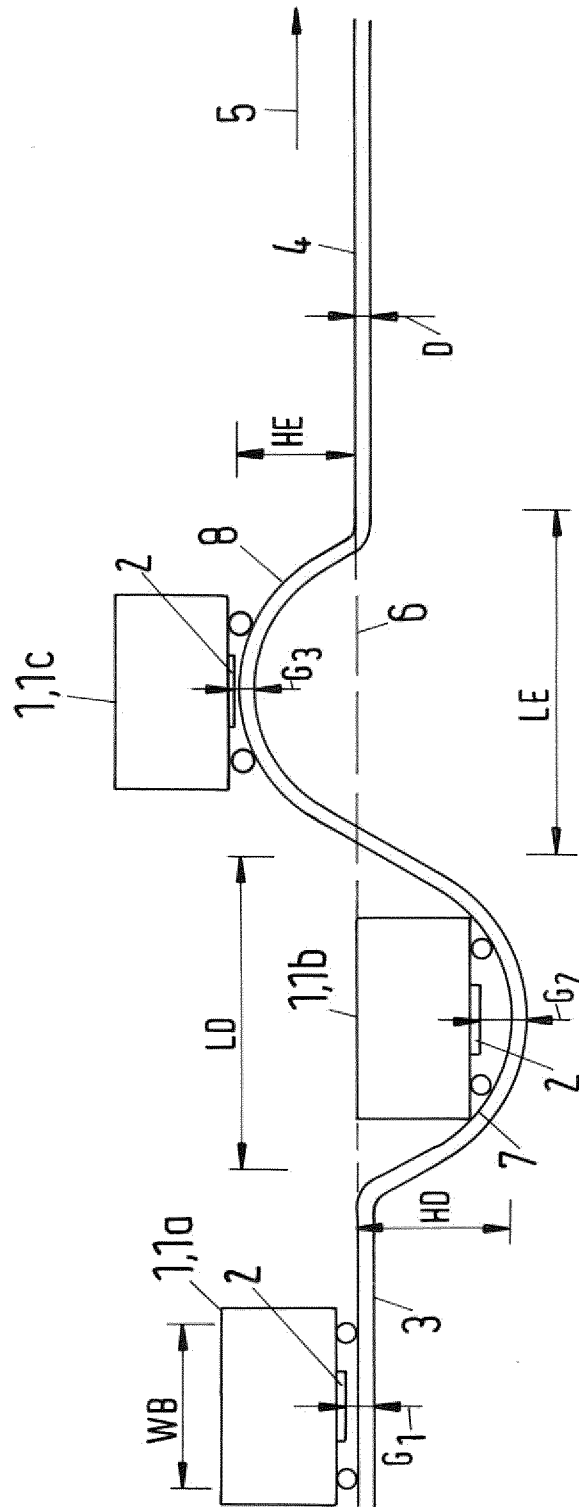
Fig. 3 shows a schematic side view of a vehicle 1. The vehicle 1 travels on a driving surface 4. In Fig. 3, a pick-up arrangement 2 of the vehicle 1 is located at a predetermined pick-up height PH, which is defined as a distance from the pick-up arrangement 2 to the driving surface 4 if the vehicle 1 travels on a plane driving surface 4. In Fig. 3, the pick-up arrangement 2 is displaced from a longitudinal centre C of the vehicle 1 by a pick-up displacement PD. A longitudinal direction is symbolized by an arrow 13. In this case, the distance D of the electric lines 3 (see Fig. 2) can be varied depending on the shown pick-up displacement PD.

Claims

1. A system for transferring energy to a vehicle (1), in particular a track-bound vehicle, such as a light rail vehicle, wherein
 - the system comprises an electric conductor arrangement adapted to produce an electromagnetic field which can be received by the vehicle (1) thereby transferring the energy to the vehicle,
 - wherein the conductor arrangement comprises at least one electric line (3),
 - wherein the electric line (3) is integrated in the ground at the path of travel of the vehicle (1),characterized in that
 - a distance (D) of the electric line (3) of the conductor arrangement to a driving surface (4) of the ground varies.
2. A system according to claim 1, wherein at least one section of the electric line (3) along a course of the electric line (3) is deflected vertically, wherein a vertical direction of deflection is oriented perpendicular to a reference plane (6) which is provided by a substantial portion of the driving surface (4) or comprises a substantial portion of the driving surface (4).
3. A system according to one of the claims 1 or 2, wherein the electric line (3) of the conductor arrangement is arranged such that the distance (D) of the electric line (3) to the driving surface (4) decreases while the driving surface (4) descends into a deepening (7) and increases while the driving surface (4) ascends from the deepening (7) and/or the distance (D) of the electric line (3) to the driving surface (4) increases while the driving surface (4) ascends to an elevation (8) and decreases while the driving surface (4) descends from the elevation (8).
4. A system according to one of the claims 1 to 3, wherein the electric line (4) is arranged such that the distance (D) of the electric line (4) to the driving surface (4) is minimal at a bottom part of a deepening (7).

5. A system according to one of the claims 1 to 4, wherein the electric line (3) is arranged such that the distance (D) of the electric line (3) to the driving surface (4) is maximal at a peak part of an elevation (8).
6. A system according to one of the claims 1 to 5, wherein the electric line (3) is arranged such that the distance (D) of the electric line (3) to the driving surface (4) increases before the driving surface (4) descends into a deepening (7) and/or after the driving surface (4) ascends from the deepening (7).
7. A system according to one of the claims 1 to 6, wherein the electric line (3) is arranged such that the distance (D) of the electric line (3) to the driving surface (4) decreases before the driving surface (4) ascends to an elevation (8) and/or after the driving surface (4) descends from the elevation (8).
8. A system according to one of the claims 1 to 7, wherein the distance (D) of the electric line (3) to the driving surface (4) is varied according to a predetermined wheelbase (WB) of the vehicle (1) and/or a length (LD) of a deepening (7) and/or a length (LE) of an elevation (8).
9. A system according to one of the claims 1 to 8, wherein the distance (D) of the electric line (3) to the driving surface (4) is varied according to a pick-up height (PH) and/or a pick-up displacement (PD) and/or a depth (HD) of a deepening (7) and/or a height (HE) of an elevation (8).
10. A system according to one of the claims 1 to 9, wherein the conductor arrangement comprises a plurality of primary segments, in particular a plurality of consecutive segments, wherein each segment extends along a different section of a path of travel of the vehicle (1), wherein each of the consecutive segments comprises a section of the electric line (3), wherein corresponding sections of the electric line (3) of neighbouring consecutive segments are connected in series to each other, wherein the segments are arranged such that a distance (D) of the electric line (3) of the conductor arrangement to the driving surface (4) of the ground varies.

11. A vehicle-route-arrangement, wherein the arrangement comprises a system according to one of the claims 1 to 10, wherein the vehicle (1) comprises a pick-up arrangement (2), wherein the electric line (3) is arranged such that the distance (G1, G2, G3) of the electric line (3) to the pick-up arrangement (2) is constant or varies within a predetermined minimal distance and a predetermined maximal distance if the vehicle (1) travels on the driving surface (4).
12. A method of building a system for transferring energy to a vehicle (1), in particular to a track-bound vehicle, such as a light rail vehicle, the method comprising the steps of:
- providing an electric conductor arrangement adapted to produce an electromagnetic field which can be received by the vehicle (1) thereby transferring the energy to the vehicle (1),
 - integrating at least one electric line (3) of the conductor arrangement in the ground at the path of travel of the vehicle (1),
- characterized in that the method further comprises the step of
- arranging the electric line (1) of the conductor arrangement such that a distance (D) of the electric line (3) of the conductor arrangement to a driving surface (4) of the ground varies.
13. A method according to claim 12, wherein the method comprises the step of:
- building a route for vehicles (1), wherein the electric line (3) of the conductor arrangement is integrated into the ground while the route is being built.



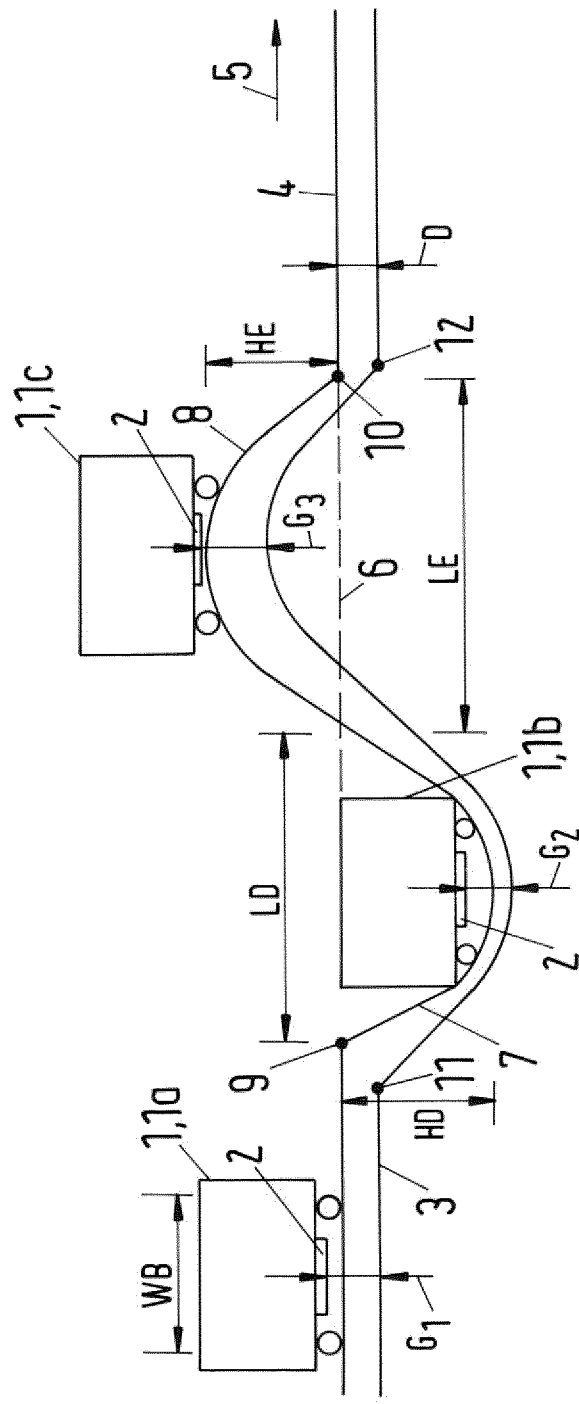


Fig.2

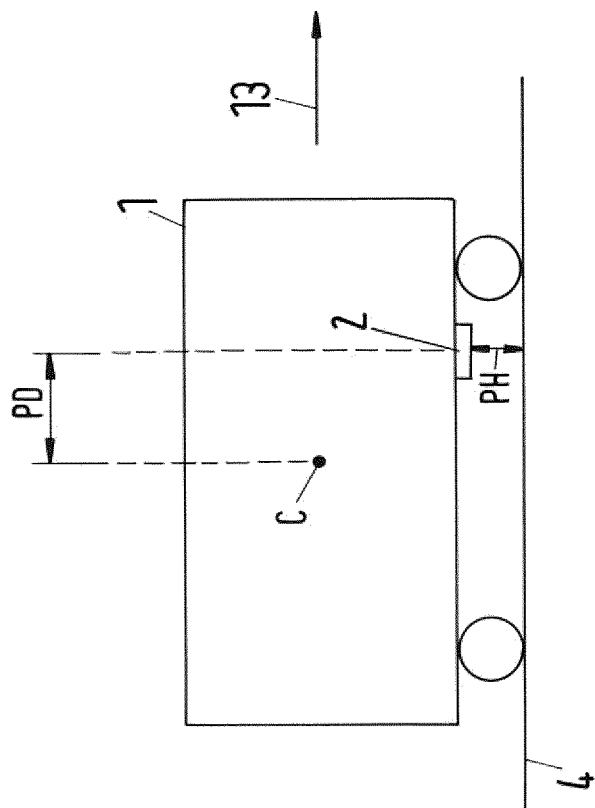


Fig.3