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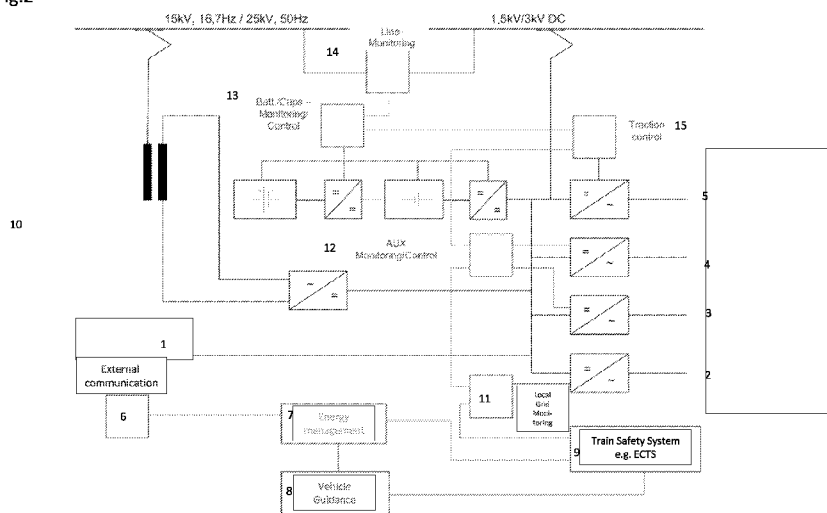
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Fig.2



(57) Abstract: The present invention relates to a method for converting a diesel-electric, or diesel hydraulic rail vehicle to an all-electric rail vehicle capable of moving on partially electrified railway tracks, comprising providing the vehicle a storage and autonomous supply electric power system comprising an electric traction unit, if not present in the vehicle prior to the conversion, or if the existing electric traction unit is to be replaced; an accumulator unit comprising one or more electricity accumulators, and a super capacitor unit comprising one or more super-capacitive assemblies; a power supply device for supplying external power when available to the traction and the storage and supply system, and a control and distribution system for distributing electric power between the traction system, the power supply device and the electric power storage and autonomous supply system according to the traction operation and availability of external power.

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Technical field

The present invention relates to a method and to a device for controlling the electrical power supply of an electric traction vehicle intended to operate in an external supply mode or in an autonomous supply mode depending on the presence or the absence of an external power supply infrastructure along the vehicle's trajectory. The invention relates in particular to the supply of electrical energy to rail vehicles, and to a power and a propulsion system for electric rail vehicles.

Background of the Invention

Most of the European countries offer very good railroad infrastructure, the majority of which are electrified. However, electrification of the non-grid served network represents a major investment, which in particular for tracks that are not frequently used may be considered as too expensive, as rail transport competes with road and shipping transport, and thus get sub-optimal volume streams that do normally not permit the required investment due to higher than necessary unit costs due to lack of economies of scale with regard to asset utilisation. Also, presently there is a shortage of adequate rolling stock, which cannot easily be replaced.

Direct Diesel engine drive are presently the standard propulsion vehicles for railway transport of goods on track trajectories with interrupted, or no electric grid connection available, as they can operate autonomously from grid electricity, thereby propelling rail cars for goods and/or passengers. Despite their widespread commercial use, such locomotives or otherwise rail vehicles have clear disadvantages. They produce air pollution, especially particulate soot suspected to cause a variety of illnesses; they are noisy, and their fuel sources are limited due to their dependence on fossil fuels.

In recent years, Diesel-electric locomotives have been developed, which run a Diesel engine as a stationary electric generator, producing electrical power for an electric propulsion system and auxiliary functionality. While such engine-generator couplings may permit to run the Diesel engine often at a

constant optimal operational window, the concept suffers from the high weight of the doubly functional propulsion system.

In comparison to diesel-powered vehicles, electric rail vehicles offer substantially better energy efficiency, lower emissions and lower operating costs. Electric locomotives are also usually quieter, more powerful, and more responsive and reliable than diesels. They have no local emissions, an important advantage in tunnels and urban areas. Some electric traction systems provide regenerative braking that turns the train's kinetic energy back into electricity and returns it to the supply system to be used by other trains or the general utility grid. Accordingly, it would be desirable to operate all-electric rail vehicles even on non-electrified rail tracks, in particular in urban centres and industrial areas.

Independently from a direct or an indirect drive, combustion engines are complex, with many moving parts subject to wear, and require lubrication and lubrication and regular maintenance. Also, such engines are comparatively inefficient due to the inherent limitations of thermodynamic engines. Hence, it would be particularly helpful if Diesel-electric locomotives and trains could be converted to become emission-free, i.e. without producing soot particles, CO, CO₂ and NO_x, or be replaced by emission-free vehicles.

The present invention relates to railway propulsion systems with no direct emissions, which can be used on grid-connected and off-grid connected railway lines.

Summary

According to a first aspect there is provided an electrically-powered traction vehicle for moving on railway partially electrified tracks using externally or internally stored electrical power, the device comprising:

- a. an electrically powered traction system;
- b. an electric power storage and autonomous supply system comprising
 - i. an accumulator unit comprising one or more electricity accumulators, and
 - ii. a super capacitor unit comprising one or more super-capacitive assemblies;

- c. a power supply device for supplying external power when available to the traction and the storage and supply system, and
 - d. a control and distribution system for distributing electric power between the traction system, the power supply device and the electric power storage and autonomous supply system according to the traction operation and availability of external power,
- 5 wherein the vehicle has been converted from a diesel electric or diesel hydraulic vehicle.

The vehicles according to the present invention comprise an autonomous power supply system on board. The entire system thus comprises an all-electric power train, i.e. an electrically powered traction and propulsion system, such as e.g. an electric motor connected directly, or through gearing to the traction wheels of the vehicle in such manner as to propel the vehicle on the rail tracks.

15 In a second aspect, the present invention also relates to a method of operating a vehicle according to the invention in an external power mode or an autonomous power-supply mode, depending on the presence or absence of an external power source infrastructure along the trajectory of the vehicle.

According to a third aspect according to the present invention, the present invention relates to a method for converting an diesel-electric or diesel-hydraulic rail vehicle to an all-electric rail vehicle capable of moving on railway partially electrified tracks, comprising providing the vehicle a storage and autonomous supply electric power system comprising

- a. Optionally, where necessary, an electric traction unit;
 - b. an accumulator unit comprising one or more electricity accumulators, and
 - c. a super capacitor unit comprising one or more super-capacitive assemblies;
 - d. a power supply device for supplying external power when available to the traction and the storage and supply system, and
 - e. a control and distribution system for distributing electric power between the traction system, the power supply device and the electric power storage and autonomous supply system
- 25
- 30

according to the traction operation and availability of external power.

Brief description of the drawings

These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a view of an electrical power system according to a first example, including a schematic overview circuit diagram; wherein Energy Transfer from On-board Energy System (1) and Energy Transfer from train line electricity net, e.g. a catenary is received (2) are show, as well as auxiliary electricity with variable Frequency (3) auxiliary electricity at 50Hz (4) and energy provision for traction (5),

Figure 2 is a view of an electrical power system according to a first example, including a schematic overview circuit diagram;

Figure 3 is an overhead plan view of an auxiliary electrical power system layout of a electrified locomotive according to the first example;

Figure 4 is an overhead plan showing a possible arrangement of containers on a train;

Figure 5 is an overhead plan view showing a possible positioning of wagons and power and control units in lang-haul and autonomous mode.

Recently, new locomotives have been developed that allow electric propulsion and – albeit brief- autonomous operation on non-electrified railway stretches, such as for instance disclosed in DE102008037661; WO2016/084043, WO2006/008391; US 2008/0021602 and US 2002/0174798.

These however represent novel and purpose-designed drive units, and only slowly will enter the market where adequate. Also, this does not allow an immediate replacement of existing rolling stock, and usually takes several years until such locomotives or traction units are permitted access to public rails systems based on the respective applicable homologation procedures in the respective countries.

“Partially electrified railway tracks” herein refers to railway tracks comprising track sections equipped with external power supply infrastructure, and track sections not equipped with external power supply infrastructure. Typically, railway electrification systems supply electric power to railway

vehicles such as locomotives, trains and trams and without an on-board energy supply. Power is typically supplied to trains with a continuous conductor running along the track that usually takes one of two forms, namely an overhead line that is suspended from poles or structures along or atop the rail track; or from
5 a third rail mounted at track level and contacted by a sliding 'pick-up shoe'. Both overhead wire and third-rail systems usually use the running rails as the return conductor, with the exception of some systems using a separate, fourth rail for this purpose.

When running on the external power supply, the vehicle receives the
10 electrical current needed to run the electrically powered traction and propulsion system by way of a power supply system, including a connector such as e.g. a pantograph carried by the vehicle.

Preferably, the connector is retractable, and may be automatically connected when power and lines are available. Preferably, the connection of
15 the pantograph to the overhead line or third rail is detected in order to best manage switching from one power supply mode to the other, and thus to optimize the performance of the system power. Moreover, in order to optimize the performance of the vehicle, it is necessary that the vehicle is continuously supplied with electrical energy by either the autonomous power supply system,
20 or the external power source, e.g. the catenary, which leads to having transitions during which the vehicle is at both connected to the stand-alone power supply and to the catenary.

During these transitions, the autonomous power supply device may be active, i.e. supplying energy, with an output voltage matching the catenary
25 voltage, thereby avoiding a loss of energy from the autonomous power supply device to the catenary.

The invention also provides for method for controlling the electrical power supply of an all-electrically-powered vehicle operating in stand-alone power supply mode or in external power supply mode, the detection of the
30 connection of the vehicle to an external power supply infrastructure, and may advantageously optimize the management of the transition between the two power supply modes, while being simple and economical.

According to a preferred embodiment of the method according to the invention, when the vehicle is in a transient supply phase during which the

power supply unit is simultaneously powered by the autonomous power supply system and connected to the power supply infrastructure, the output voltage of the autonomous power supply system is controlled so that the current passing through the external power supply line is substantially zero, thereby avoiding
5 flow of energy from the autonomous power unit to the grid.

According to another preferred embodiment of the method according to the invention, when during circulation on the rail network the vehicle is powered by the autonomous power supply system and reaches an area equipped with an external power supply, the following steps are carried out:

10 Detection of the presence of an external supply infrastructure for connection with the connecting member, visually by the train chauffeur, or automatically by an indication signal given by e.g. the train safety system, or another automatic means;

Externally connecting the connection member with the external supply
15 infrastructure, controlling the output voltage of the autonomous power supply system so as to substantially cancel the current to the external power supply line; and

Stopping the supply of power from the autonomous power supply unit to the power supply unit for traction, and optionally auxiliary energy.

20 According to yet another characteristic of the method according to the invention, when the vehicle is circulated by being supplied by the external supply line only and reaches an area not equipped with an external supply infrastructure, the disconnection of the connecting member with the external power supply infrastructure in the following steps:

25 Switching on the autonomous power supply system in such a way that the latter supplies energy to the power supply unit;

Controlling the output voltage of the autonomous power supply system so as to substantially match the current of the external power supply line.

The present invention also relates to a modular use of the vehicle,
30 whereby units are present in one or more different sub-units, such as attraction and power unit and a traction and control unit.

Ideally, such subunits may be coupled automatically, coupling at the centre of the train in order to separate the traction parts quickly and without the need for personnel.

In addition, a train bus bar (known also as ETS, Zugsammelschiene, or TBB, "Train Bus Bar") may be provided for electricity supply for the traction and control vehicle, as well as the individual wagons.

5 By this power supply to wagons, it is possible to install electrically operated brakes as well as to have power supply for refrigerated or heated containers, or people carriers available. With this conversion, a previously diesel engined vehicle becomes an economical and environmentally-friendly traction variant for both route operation and shunting and connection operation, and with a strongly reduced noise level.

10 Due to their mechanical design, previous generation diesel-electric locomotives are ideal for the conversion to vehicles, which combine the advantages of electric vehicles with the autonomy that so far was afforded by Diesel engines (or steam engines).

15 In order to be able to use the vehicles both environmentally and commercially, it is necessary to modernize or rebuild existing vehicles, which on a carbon footprint basis should be more beneficial than the provision of entirely novel vehicles. Also, such a refurbishment could have an immediate effect on the overall fleet emissions, while not requiring a full electrification of the rail lines.

20 In order to cover the original task area of the diesel engines, an alternative energy source is thus installed in the form of a accumulator-supercapacitors combination, and where necessary, electric traction units.

The supercapacitors provide the starting energy necessary for start-up, the accumulator supplies the necessary energy of persistence.

25 Likewise, in this "diesel replacement" operation, an electric regenerative brake is implemented via the feed back into the supercapacitors and accumulator. Excess energy may be stored, or may be used for the production of pressurized air, whereby the energy management system distributes the power preferably in line with train trajectory.

30 Preferably, the accumulators or supercapacitors are charged via the current collector / conductor wire on electrified lines or sections of the track. The accumulator and supercapacitors can be charged under the driving wire during normal operation, whereby a choice can be made between gentle normal load and full charge. However, since the charging process may have a negative

effect on the accumulator life, an intelligent energy management system (IEMS) capable of automatically selecting between the different charging variants due to the journey data is preferably employed, which results in an optimization of the charging status and lifetime.

5 The IEMS hence not only optimizes the load of the accumulators alone, but also optimizes starting traction, acceleration and energy consumption during the journey due to the available stretch or rail trajectory data.

 Particularly suitable diesel-electric donor vehicles are already equipped with a current collector, e.g. a pantograph, for driving wire operation, and the
10 necessary electrical equipment (disconnecter, high voltage main switch for AC operation, High Speed Circuit Breaker for DC operation, earthing disconnecter). However, these unit may however be added or refurbished.

 Thanks to their mechanical design, previous generation diesel engine electric rail vehicles are ideal for the conversion to CO₂-free E-hybrid vehicles,
15 which combine the advantages of a diesel engine- generator combination as autonomous power source, and electric traction.

 In order to be able to use the vehicles both environmentally and commercially, it is necessary to modernize or rebuild the existing vehicles. In order to cover the original task of the diesel engines, an alternative energy
20 source is installed in the form of an accumulator – supercapacitor combination. The supercapacitor element provides the energy peak required for propulsion start-up, whereby the accumulator element supplies the necessary energy of persistence. Ideally, it may thus only be required to add the autonomous power source units, and remove the diesel engine and the generator unit, however it
25 may be advantageous to replace also the electric traction unit.

 Accordingly, in a preferred embodiment, the present invention relates to a method for converting a vehicle, having a diesel-powered source of electric power and an electric traction unit powered by the diesel-powered source, to a vehicle capable of powering the electric traction unit by externally provided
30 and/or internally stored electric power from partially electrified tracks of a railway, comprising providing the vehicle with a storage and autonomous supply system of electric power comprising:

 a. an accumulator unit comprising one or more electricity accumulators, and

b. a super capacitor unit comprising one or more super-capacitive assemblies;

c. a device for supplying the external electric power, when available, to the storage and autonomous supply system, and

5 d. a control and distribution system for distributing electric power between the diesel-powered source of electric power, the electric traction unit, the device for supplying the external electric power and the storage and autonomous supply system according to the traction operation and availability of external electric power.

10 Suitable traction motors used in locomotives according to the invention may include the existing electric drive motors or engines. Preferably, the existing electric engines are replaced by preferably brushless AC induction motors including an annular stator inside of which a cylindrical rotor is rotatably provided. The rotor may include a plurality of conductive bars arranged along
15 the length of the rotor in a "squirrel-cage" structure. The stator may include a ring of electromagnets that produce a rotating magnetic field when power is supplied to the stator, and the rotating magnetic field may lead to rotation of the rotor and the flow of current along the conductive bars of the rotor. In accordance with an aspect of the present disclosure, several electric motors
20 are employed operatively associated to a plurality of axles driving a rotation of wheels, more particularly including traction motors configured to drive rotation of the axles.

Each of the traction motors may be associated with a respective one of the axles and may include a stator and a rotor inside of the stator.

25 Preferably, an electric regenerative brake is implemented via the feed back into the supercapacitor element and accumulator element, whereby excess energy may be stored for later usage or to provide traction, or used for the production of pressurized air to support braking procedures.

The accumulator element and/or supercapacitor element are charged
30 via the current collector / conductor wire on electrified lines or sections of the track and may be charged under the driving wire during normal operation.

The permanent charging discharging process has a negative effect on the accumulator life. An intelligent energy management system (IEMS) is capable of automatically selecting between the different charging variants due

to the stretch data, which of course implies an optimization of the charging status and lifetime.

The IEMS not only optimizes the load of the accumulators alone, but also optimizes starting traction, acceleration and energy consumption during the
5 journey due to the available stretch data.

The accumulator assembly preferably comprises accumulator modules selected from lead-acid batteries, lead-carbon batteries, lithium-titanate batteries, zinc-bromine batteries, nickel-zinc batteries, nickel metal hydride (NiMH) batteries, lithium-ion (Li-ion) batteries, lithium polymer (Li-poly)
10 batteries, lithium sulfur (Li-S) batteries, preferably, Lithium-iron-phosphate (LiFePO), polymer electrolyte, solid state batteries or any suitable combination thereof due to the comparatively low fire risk at high energy density. Other rechargeable batteries include sodium ion batteries, magnesium ion batteries, and combinations thereof.

15 The capacitor assembly may be provided as any suitable capacitor adapted for storing the surplus electrical energy of the rail transportation system. Capacitors have long been known and used in electronic circuitry for the storage of electrical energy. In its simplest form, the capacitor includes a pair of electrically conductive plates, typically constructed of metal,
20 separated by air or a dielectric material. The size or area of the conductive plates as well as the permittivity and thickness of the dielectric material between the plates determines the magnitude of the capacitance of the capacitor. Super-capacitor electrodes include a conductive plate, known as a current collector, which is coated with a carbon derivative material, such as activated carbon or
25 graphene. These electrodes are typically separated from each other by an intervening separator made from a porous insulating material that prevents the electrical shorting of the electrodes but allows electrolyte ions to move between the electrodes. In use, when subjected to a voltage, ion flow between the electrodes results in energy storage within the electrodes through the charge
30 separation at the electrode surface with positive charges in one electrode attracting negative ions to that electrode's surface and with negative charges in the other electrode attracting positive ions to that electrode's surface.

A preferred diesel donor vehicle is preferably already equipped with a current collector for driving wire operation and the necessary electrical

equipment (disconnecter, high voltage main switch for AC operation, High Speed Circuit Breaker for DC operation, earthing disconnecter).

By removing the combustion engine and the generator / gearbox, it was found that sufficient space is created for installing the components required for the E-hybrid operation in the traction vehicle, while maintaining the technical features that are required for the vehicle operation, ideally therefore maintaining the use permissions already in place prior to the conversion.

As set out above, also the electric traction engines present may be replaced, preferably replacing DC engines with brushless Alternating Current (AC) motors. Not only can such motors provide the same torques as the existing motors, but applying suitable converter technology permit an easier recovery of energy upon braking, and back-feeding energy to the system, thereby reducing train energy use.

Preferred are asynchronous motors with alternating current, which permit the use of a brushless engine, which is needing considerably less maintenance, and permitting an easier back-feeding of recovered energy during braking processes.

Preferably, the weight in a bogie remains essentially identical compared to pre-refurbishment stage, as well as the force attack points. In this manner a motor in a bogie has essentially an identical weight and the same attack points to the motor it replaces. Driving torques need to be essentially identical, such that friction loss and departure torques are mimicked to allow for the same driving and shunting capacity and behavior.

Obviously, electric motor development implies that a power increase is easily possible without requiring significant changes in the thus transformed, refurbished vehicle.

When employed as a regenerative brake, braking resistance in the range of from 0,2 to 3,5 MW, preferably of from 0,5 to 2,5, more preferably of from 1 to 2 MW are required, for suitable effectivity, which may be part of the power supply and control system, and depending on the required deceleration of the vehicle.

A regenerative brake and back-feeding system allows to charge the accumulator and/or the supercapacitor, in particular when running independently from external power supply, whereby the power management

unit may distribute the actual back-fed energy between accumulator or supercapacitor units. This is preferably in line with the required energy components in line with the rail trajectory to be covered, and the thus required drive energy, e.g. taking into account gradients and turns.

5 The train may comprise a freight train. The auxiliary electrical system may comprise a goods-related electrical system. The electrical power system may comprise at least one electrical power supply unit for providing electrical power to a wagon or train car, or multiple wagons or train cars. Can also be valid for passenger trains.

10 The electrical power supply unit may provide electrical power to a plurality of wagons. The electrical power supply unit may provide an electrical power output. The electrical power output may be for providing primary, i.e. for the propulsion and for charging of the autonomous power supply devices, or auxiliary electrical power, e.g. for refrigeration, heating or light, to a plurality of
15 wagons or train cars. Preferred is a single electrical power output may provide electrical power for the plurality of wagons or train cars. The electrical power output from the electrical power supply unit may be.

 The primary, and the auxiliary electrical system may comprise a power supply unit that is powered by electricity that is drawn from a rail power line, such as drawn from a catenary or overhead line. The electrical system's power
20 supply unit may comprise a convertor. Preferably, the electrical system may comprise a convertor for converting electricity from a standard electrical train bus bar ("Zugsammelschiene", Train Bus Bar), which allows to connect the power supply units by standardised plug and socket connections. The train-line
25 may be for providing train operational power, such as for the locomotion of the train. The train-line may provide traction and/or braking power/s for the train. The train-line may comprise a standard electrical train bus bar for supplying power along the train, such as with connections between wagons of the train. The power output may provide an additional or alternative power output to a
30 train's bus bar. For example, the power output may provide an additional power output, such as with a different power and/or voltage and/or current rating to the train's bus bar.

 The power system comprises an entirely electrical power system. In contrast to a power system whereby electricity may be indirectly generated,

such as via a generator (e.g. diesel or associated with locomotion, such as a dynamo), an entirely electrical power system may be advantageous. Preferably, the electrical power system may power the vehicle or train independently of movement of the railway vehicle, such as when the railway vehicle is, or has been, stationary. The electrical power system according to the invention is operational without generation such as without a dynamo; and/or without a generator, and hence may not provide or demand any extra resistance or friction on the train wheel.

The electrical power from and to the power supply unit in the vehicle assembly may be supplied through the standard electrical train line, or through a separate, discrete electrical power network. Preferably, the standard electrical train bus bar is employed. Applicants found that the standard electrical train bus bar (ETBB or 'Zugsammelschiene') has a sufficiently large capacity, as it permits currents of up to 3.000 Volt and 800 Ampere, which suffices for traction and charging/recharging operations.

This approach thus permits provision of traction, even if the power supply module is in a separate wagon, e.g. in the form of a standardized container that is tendered after, or pushed by a locomotive, to which it is connected by the ETBB. In an alternative embodiment, the power supply modules and a traction unit are based in a power supply tender, and are controlled and connected to a separate traction module, e.g. an all-electric or diesel-hydraulic locomotive that forms the traction unit.

The benefit of using a modular power supply unit without traction permits the use of normal, standard e-locomotives in combination with a power supply container, thereby effectively converting a standard vehicle assembly to an all-electric hybrid assembly.

Beneficially, the containers may be used to harness and store other forms of energy, such as wind and solar power, and be coupled charged to a standard train, to make it independent from external power grid.

The electrical power output may comprise 3-phase AC. The electrical power output may comprise a voltage in a range of about 100V to about 3000V. The electrical power output may supply a voltage in a range of about 300V to about 1500V. In at least some examples, the convertor is configured to supply an electrical power output of about 360V to about 460V, 50HZ. In at least some

examples, the convertor is configured to supply an electrical power output of about 400V to about 500V, 60HZ. In at least one example, the electrical power output is about 400V, 50Hz.

5 The vehicle preferably comprises a DC/DC converter with 900-1600V entry voltage and a stabilised exit voltage to ensure accumulator and supercapacitor stability.

The drive train usually requires air or liquid cooling. Preferably during stationary use or when in a station, the air flow and power supply level can be reduced to reduce the overall noise.

10 The present power supply system may advantageously also provide auxiliary power, for e.g. for use of a refrigeration system; an air-conditioning system; a heating system; a circulation system, such as incorporating a fan and/or a vent. The auxiliary electrical system may be for supplying the output power to a plurality of appliances.

15 The power output may comprise an AC voltage/s. The power output may provide an electrical power supply suitable for an electrical goods-related system, without requiring further or additional adaptation to be fed in or connected to the goods-related system. In at least some examples, the electrical power output may be configured for or suitable for direct connection
20 to a goods container, such as a reefer.

The power supply unit may comprise a convertor. The convertor may comprise a transformer. The convertor may convert an AC voltage into an AC voltage. Additionally or alternatively, the convertor may convert a DC voltage into an AC voltage. Additionally or alternatively, the convertor may convert an
25 AC voltage into a DC voltage. Additionally, or alternatively, the convertor may convert a DC voltage into a DC voltage. The convertor may provide a voltage step-down.

The control unit may comprise an accumulator and supercapacitors management system monitoring and equalizing the accumulators/ and
30 supercapacitors to maintain a desired state of charge and depth of discharge for each accumulator. A motor control circuitry may operate in coordination with the accumulator management system to draw currents from the accumulator assembly to drive the plurality of traction motors according to desired throttle levels. The accumulator management system may further monitor the

accumulator assembly with temperature sensors and may cause cooling or air-circulation equipment to equalize accumulator temperatures. A brake system may comprise both a regenerative braking mechanism and an air braking mechanism wherein the former is prioritized over the latter so that brake energy
5 can be recovered to recharge the accumulator assembly.

In another particular exemplary embodiment, two or more accumulator-powered, all-electric locomotives according to the invention may be coupled together or in the same train and operate in tandem.

In yet another embodiment, one or more accumulator-powered
10 locomotives may be coupled with one or more other types of locomotives such as diesel-electric locomotives. An accumulator assembly carried on the accumulator-powered or accumulator-carrying locomotive(s) may be recharged with energy generated from regenerative braking and/or from engine(s) on the diesel-electric locomotive(s). The accumulator assembly may also supply
15 electric power to drive traction motors on the accumulator-powered locomotive(s) and/or the diesel-electric locomotive(s).

According to a further aspect, there is provided a railway vehicle, such as a train, comprising at least one vehicle of any other aspect, example, embodiment or claim and at least one different railway vehicle of any other
20 aspect, example, embodiment or claim.

The train may comprise a single vehicle, such as in rail busses, or multiple wagons. The train thus formed may be configured to move up to one or more of: 10 wagons; 15 wagons; 20 wagons; 25 wagons; 30; 35 or 40 wagons. In at least some examples, a single locomotive may be configured to
25 provide the motion of more than 25 wagons. The train may comprise a plurality of power supply units. Accordingly, in at least some example trains, two or more locomotives or drive train vehicles may provide motion, to 50 or more wagons.

According to a further aspect there is provided a method of powering a railway-based propulsion system, such as powering a freight train. The method
30 may comprise supplying auxiliary electrical power to a goods-related electrical system.

The method may comprise monitoring a status. The status may comprise an electrical status of a locomotive. For example, the method may comprise checking electrical supply connection.

The method may comprise sending a signal when or whenever the propulsion mode is changed, using the data for the presence or absence of infrastructure as available in the train safety system. For example, the power supply unit may be controlled or managed by a controller that identifies energy use for the locomotive. The method may also providing tracking capabilities to verify the amount of energy consumed by the locomotive, and preferably certify this use, e.g. using a certification system, that certifies the use of energy per locomotive, or per train. An example for such certification is the use of a block chain method encrypting and certifying an attached energy use file.

The method may comprise performing one or more actions in response to electrical (dis)connecting, such as one or more of: sending a signal, measuring the amount of electrical current, and recharging the accumulator and the supercapacitor units, a queuing the container in a power management system.

The action or actions may be predetermined, and/or automated. Additionally, or alternatively the actions may be selectable and/or manual. Sending the signal may comprise sending the signal within the train. Additionally, or alternatively, sending the signal may comprise sending the signal remotely from the train, such as remotely to a control or logging centre (e.g. at a fixed location, such as via satellite or telecommunication link).

During operation, when the vehicle is about to leave a zone equipped with a catenary to enter a zone that is not such equipped, the autonomous power supply system is switched back to active mode either on command of the driver or automatically, for example by interaction with a beacon arranged along the track or else by estimation of the position by a computer or via train safety management systems. During this phase, the power supply system is briefly simultaneously powered by the autonomous power supply system and the external power supply line. At this point in time, the control unit then regulates the output voltage of the autonomous power supply system as to match essentially the current in the external power supply line, and thus avoids a discharge of the autonomous power supply system to the catenary.

The method further comprises locally collecting, buffering and/or storing electrical power, such on or at a container that can be conveniently be tendered in a train, further referred to as Container Power Pack (CPP).

For example, between a wagon's auxiliary electrical connector/s and the container, there may be provided an accumulator or for a discontinuity in electrical supply. For example, the local buffer may enable a wagon to perform one or more actions such when disconnected or upon disconnection, such as to send signal indicative of disconnection or prolonged disconnection.

Another aspect of the present disclosure provides a computer program comprising instructions arranged, when executed, to implement a method in accordance with any other aspect, example or embodiment. A further aspect provides machine-readable storage storing such a program.

The invention includes one or more corresponding aspects, embodiments or features in isolation or in various combinations whether or not specifically stated (including claimed) in that combination or in isolation. For example, it will readily be appreciated that features recited as optional with respect to the first aspect may be additionally applicable with respect to the other aspects without the need to explicitly and unnecessarily list those various combinations and permutations here (e.g. the device of one aspect may comprise features of any other aspect). Optional features as recited in respect of a method may be additionally applicable to an apparatus or device; and vice versa.

In addition, corresponding means for performing one or more of the discussed functions are also within the present disclosure.

It will be appreciated that one or more embodiments/aspects may be useful in at least partially powering a railway-associated system. The above summary is intended to be merely exemplary and non-limiting.

Various respective aspects and features of the present disclosure are defined in the appended claims.

It may be an aim of certain embodiments of the present disclosure to solve, mitigate or obviate, at least partly, at least one of the problems and/or disadvantages associated with the prior art. Certain embodiments or examples may aim to provide at least one of the advantages described herein.

Detailed description

Referring initially to Figure 1, there is shown an electrical power system, generally referenced by numeral 10, according to a first example. According to a first aspect there is provided an electrical power system for a railway or

railroad vehicle. Figure 1 is a view of an electrical power system including a schematic overview circuit diagram; showing the energy transfer from the on-board autonomous energy system (1) and from the external source, such as train line electricity net, e.g. via a catenary (2), as well as provision of auxiliary electricity with variable frequency (3) auxiliary electricity at 50Hz (4) and energy provision for traction (5).

Figure 2 shows the system depicted in Figure 1, but with the control system depicted as well. Numerals 1 to 5 are as in Figure 1; the system further has an external communication unit (6), energy management system (7), vehicle control (8), train safety system (8), such as e.g. ETCS; local electricity net monitoring unit (11); auxiliary power monitoring and control unit (12), accumulator and supercapacitor monitoring and control unit (13), Line monitoring and control unit (14), and traction control (15).

Figure 3 shows an exemplary freight train combination according to the subject invention. Herein, train 10 comprises a freight train, whereby power modules are based in the middle of the train, whereas traction units with cabin are based at each end of the train.

Figure 4 shows a modular construction of a freight train combination according to the subject invention. Herein, train 40 comprises a power modules (40a, 40b) that may be based in the middle of the train, whereas traction units with cabin (41a, 41b) are based at each end of the train, and wagons (43a, 43b) maybe queued between the traction and power units; for maritime transports (i.e. coupling ship and train transport), a set up with 5 shortened 80' wagons and one 60' wagon per module is found particularly useful, as it permits main line operations on the areas with catenary wire, which permits performance sufficient for operating speed 140km/h, while shunting operations at railway sidings without catenary wire are possible via accumulator modules with speeds typically up to 25km/h.

Due to the centrally located traction units, for „Push – Pull“ operations, traction units equipped with a small propulsion unit as well as small driver cab for train control during long distance as well as shunting operations were found particularly useful.

Figure 5 illustrates that preferably in this modular deployment, long-haul train units run on catenary electricity for the longer distances may

advantageously be separated into two train segments via automated coupling/uncoupling between the power modules. Accordingly, this permits multiple unit operations with two train units on long-haul operations, while the flexible train units can be decoupled and can be coupled for shunting and maneuvering, eliminating additional shunting maneuvers with separate locomotive, which is cost advantageous due to the low maintenance/higher up time and lower energy consumption, Since this is also achieving a zero emission, this is automatically guaranteed, and removes the need for separately accounting, but can be automatically incorporated into CO₂ avoidance schemes, as will be set out below. Single unit (50a), double unit (50b); Part of a train used in shunting operation (no catenary, 50c).

The present vehicle and its power system comprise an entirely electrical power system. In contrast to a power system whereby electricity is indirectly generated, such as via a generator, for instance a wheel dynamo, an entirely electrical power system is advantageous.

For example, the autonomous power supply system can power not only the locomotive, but also provide auxiliary power to the plurality of wagons independently of movement of the train, such as when the train is, or has been, stationary; or is moving slowly.

The auxiliary electrical power system is then operational independently if the train is connected to a railway powerline, or not. Also, preferably, the auxiliary electrical power system can thus be operated without generation, thus not needing a dynamo or a separate diesel or otherwise generator. Also, for the auxiliary electrical power, no additional accumulator providing electrical power directly to the wagons is required, reducing both costs and complexity.

Particularly compared to a generator-based system, the present electrical autonomous power system comprises a minimum of, or no parts subject to wear.

Preferably, the auxiliary electrical power is provided from the autonomous power system through standard cable connections between wagons, and thus does not provide or demand any extra resistance on wheels of the train; and is generally insensitive to weather and train speed.

The locomotive comprises standard electrical train bus bar (Zugsammelschiene, ETBB) for connection to wagons, preferably using standards presently in use.

5 It will be appreciated that any of the aforementioned apparatus may have other functions in addition to the mentioned functions, and that these functions is performed by the same apparatus.

10 The applicant hereby discloses in isolation each individual feature described herein and any combination of two or more such features, to the extent that such features or combinations are capable of being carried out based on the present specification as a whole in the light of the common general knowledge of a person skilled in the art, irrespective of whether such features or combinations of features solve any problems disclosed herein, and without limitation to the scope of the claims.

15 The applicant indicates that aspects of the present invention may consist of any such individual feature or combination of features. It should be understood that the embodiments described herein are merely exemplary and that various modifications are made thereto without departing from the scope or spirit of the invention.

Claims

1. A method for converting a diesel-electric, or diesel hydraulic rail vehicle to an all-electric rail vehicle capable of moving on partially electrified railway tracks, comprising providing the vehicle a storage and autonomous supply electric power system comprising
 - a. an electric traction unit, if not present in the vehicle prior to the conversion, or if the existing electric traction unit is to be replaced;
 - b. an accumulator unit comprising one or more electricity accumulators, and
 - c. a super capacitor unit comprising one or more super-capacitive assemblies;
 - d. a power supply device for supplying external power when available to the traction and the storage and supply system, and
 - e. a control and distribution system for distributing electric power between the traction system, the power supply device and the electric power storage and autonomous supply system according to the traction operation and availability of external power.
2. The method according to claim 1, wherein a diesel engine and, where applicable, gear box and mechanical and/or hydraulic transmission, and/or electric traction unit are removed to increase space and reduce weight.
3. The method of claim 2, wherein the overall weight and weight distribution per axle is identical to the original weight and weight distribution per axle of the rail vehicle prior to conversion.
4. A method according to any one of claims 1 to 3, wherein the axle load of each axle is essentially identical to the original axle load of the rail vehicle prior to conversion.
5. A method according to any one of the previous claims, wherein the weight per bogie is essentially identical to the vehicle prior to conversion.

6. A method according to claim 5, wherein an engine in a bogie essentially has an identical weight to, and wherein it is configured such that it essentially uses the same force attack points, as an engine prior to the conversion.

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7. A method according to any one of the previous claims, wherein a convertor is present to convert DC to AC.

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8. A method according to any one of the previous claims, wherein the power and driving torques provided to the converted vehicle by the electric traction unit is equal to, or higher than of the drive train of the original vehicle prior to conversion.

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9. A method according to any one of the previous claims, comprising the step of equipping the electric traction unit with asynchronous engines.

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10. A method according to any one of the previous claims, wherein the converted vehicle is equipped with, and configured to reconvert kinetic energy to electric energy when reducing the speed.

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11. A method according to any one of the previous claims, wherein the electric traction unit operates as a regenerative brake providing a braking resistor power of in the range of from 0,2 to 3,5 MW, preferably at least 1.5 MW.

12. A converted railway locomotive or vehicle obtainable according to the method of any one of claims 1 to 11.

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13. A converted railway locomotive or vehicle according to claim 12, wherein the accumulator assembly comprises batteries selected from a group consisting of: lead-acid batteries, lead-carbon batteries, lithium-titanate batteries, zinc-bromine batteries, nickel-zinc batteries, nickel metal hydride (NiMH) batteries, lithium-ion (Li-ion) batteries, lithium polymer (Li-poly)

batteries, lithium sulfur (Li-S) batteries, Lithium-Iron phosphate (LiFePO) batteries, sodium- or magnesium-ion , polymer electrolyte, solid state batteries, or any combination thereof suitable for battery applications.

- 5 14. A converted railway locomotive or vehicle for moving on partially electrified railway tracks, the converted railway locomotive or vehicle comprising:
- a. an electrically powered traction system;
 - b. a storage and autonomous electric power supply system comprising
 - 10 i. an accumulator unit comprising one or more electricity accumulators, preferably a lithium or lithium iron phosphate assembly, and
 - ii. a super capacitor unit comprising one or more super-capacitive assemblies;
 - c. a power supply device for supplying external power when available
 - 15 d. to the traction and the storage and supply system, and
 - d. a control and distribution system for distributing electric power between the traction system, the power supply device and the electric power storage and autonomous supply system according to the traction operation and availability of external power, preferably
 - 20 obtained from conversion of a Diesel-electric or Diesel hydraulic vehicle, more preferably by any one of claims 1 to 13.
15. A converted railway locomotive or vehicle according to claim 14, wherein the vehicle is adapted to operate in a stand-alone mode or in an external
- 25 power supply mode, depending on whether or not an external power supply is available along the rail track of the vehicle.
16. A converted railway locomotive or vehicle according to any one of claims 14 or 15, wherein components (a) to (d) are combined in one vehicle.
- 30 17. A converted railway locomotive or vehicle according to any one of claims 1 to 13, wherein the super-capacitive assemblies comprise a plurality of supercapacitors connected in series and/or in parallel, with a combined capacity sufficient to power the traction device for an initial operational

phase on autonomous power supply, and/or when the operational mode is switched between autonomous and external power supply.

5 18. A converted railway locomotive or vehicle according to any one of the previous claims, wherein the power supply device comprises at least one retractable connection member, preferably a catenary collection device, more preferably a least one pantograph, for collecting power from a catenary power line.

10 19. A converted railway locomotive or vehicle according to any one of the claims 3 to 9, wherein the control and distribution system is adapted to provide and to control recharging of the accumulators and/or super-capacitive assemblies by at least part of the external power available during externally powered operation.

15 20. A converted railway locomotive or vehicle according to any one of the claims 3 to 10, wherein the control and distribution system is adapted to control re- and discharging of the accumulator assembly and the one or more super-capacitive assemblies with the available power not used for
20 traction of the vehicle, and/or with the power regained regeneratively, preferably in line with the power requirement for the rail trajectory.

25 21. A converted railway locomotive or vehicle according to any one of the claims 15 to 20, wherein the power supply unit is adapted to be connected to both the power supply and storage system on board of the vehicle, and the power supply means connectable to an external power supply
30 structure by means of a retractable connection member; the power supply system further adapted to actively and automatically control the connection of the connection member by a logic to retract the connection member in absence of an external power supply structure, or in absence of a current in the external power supply infrastructure, and logic to extend the connection member in the presence of an external power supply infrastructure, and/or the presence of a current in the external power supply infrastructure, to connect to the power supply.

22. A converted railway locomotive or vehicle according to any one of claims 15 to 21, being connected to an external power supply infrastructure by means of a connection member, characterized in that it comprises a current sensor for measuring the current flowing through in order to detect the connection of the connecting member to the external supply infrastructure.
23. A converted railway locomotive or vehicle according to any one of claims 15 to 23, wherein the control and distribution system is adapted to balance power surges provided by the external catenary and power drainage peaks in the power supply system or by the traction system through use of the supercapacitor unit and/or accumulator unit.
24. A converted railway locomotive or vehicle according to any one of claims 15 to 24, wherein the power supply device is adapted to maintain dynamic traction performance of the vehicle during transition between operating phases, wherein the vehicle is switching power provision between the available external and internal sources.
25. A converted railway locomotive or vehicle according to any one of claims 15 to 24, wherein the control module is provided for modifying the output voltage of the system power supply unit.
26. A converted railway locomotive or vehicle according to any one of claims 15 to 25, wherein the connecting member consists of a pantograph carried by the vehicle, and adapted for cooperating with a catenary as external power supply.
27. A converted railway locomotive or vehicle according to any one of claims 15 to 26, wherein the control unit and the autonomous power system are adapted to match the supplied voltage to the energy storage module according to the state of charge of the storage module of energy, in which the power supply unit and the control unit are adapted to cooperate during

a power transfer by the external power source to the on-board energy storage system.

28. A converted railway locomotive or vehicle according to any one of claims 5 15 to 27, wherein the control unit comprises a sensor and logic to monitor the state of the energy storage module, and to control the operation of the energy converter according to the monitored state, to optimize useful accumulator and/or supercapacitor lifetime.
- 10 29. A train comprising one or more converted railway locomotive or vehicle according to any one of claims 15 to 28, and a plurality of wagons.
- 15 30. A method of operating a converted railway locomotive or vehicle according to any one of claims 15 to 28 or a train according to claim 29 in an external power mode or an autonomous power-supply mode, depending on the presence or absence of an external power source infrastructure along the trajectory of the vehicle.
- 20 31. A method according to claim 30, wherein the converted railway locomotive or vehicle comprises a power supply system connected to both the power supply and storage system on board of the vehicle and the power supply system connectable to the external power supply structure by means of a retractable connection member, wherein the connection of the connection member is controlled by measuring the current flowing through the 25 external power supply line, wherein the presence of a current in the external power supply structure signals the presence of an external power supply infrastructure when connected by the retractable connection member.
- 30 32. A method according to claim 31, wherein when the converted railway locomotive or vehicle is in a transient supply phase during which the power supply system is simultaneously supplied with power from the on-board power supply and connected to the external power supply infrastructure, the output voltage of the autonomous power supply system is controlled in

such a way that the current flowing through the power line is essentially zero.

33. A method according to any one of claims 30 to 32, wherein when the converted railway locomotive is moving under autonomous power alone and reaches an area equipped with an external power infrastructure, the following steps are carried out:

- a. detection of the connection of the connection member with the external supply infrastructure;
- b. controlling the output voltage of the autonomous power supply system so as to substantially cancel the current of the external supply line;
- c. stopping the supply of energy by the autonomous power supply system in the direction of the power supply unit, and
- d. matching the voltage and current required for the traction system to ascertain continued operation, and, optionally,
- e. recharging the autonomous power supply unit.

34. A method according to claim 33, wherein a stationary external supply structure is present, and wherein the converted railway locomotive or vehicle is charged when stationary.

35. A method according to claim 34, wherein a feedback loop between the power supply system and the traction module disables traction while connected to the stationary charger.

36. A method according to any one of claims 31 to 35, wherein when the converted railway locomotive or vehicle is moving under external power and reaches an area not equipped with an external power infrastructure, the following steps are carried out:

- a. detection of the connection of the connection member with the external supply infrastructure;

- b. controlling the output voltage of the autonomous power supply system so as to substantially match the current of the external supply line;
 - c. stopping the supply of energy by the external power supply system in the direction of the power supply unit; and, optionally,
 - d. retracting the collection device, and, optionally separating the train into several smaller train parts for shunting, wherein each train part is capable of autonomously moving.
- 5
- 10 37. The method according to claim 36, wherein when the converted railway locomotive or vehicle is powered by an external supply line and reaches an area not equipped with an external supply infrastructure, the autonomous power supply system is started in such a way that the latter supplies power to the power supply system; and wherein the output
- 15 voltage of the autonomous power supply system is balanced between the supercapacitor and accumulator units to substantially replace the current provided by of the external power supply line to the traction system.
- 20 38. The method according to any one of claims 30 to 37, wherein when the converted railway locomotive or vehicle is regeneratively generating electrical energy during braking, the output voltage of the autonomous power supply system is balanced between the supercapacitor and accumulator units, substantially in line with the envisaged rail trajectory.
- 25

Fig.1

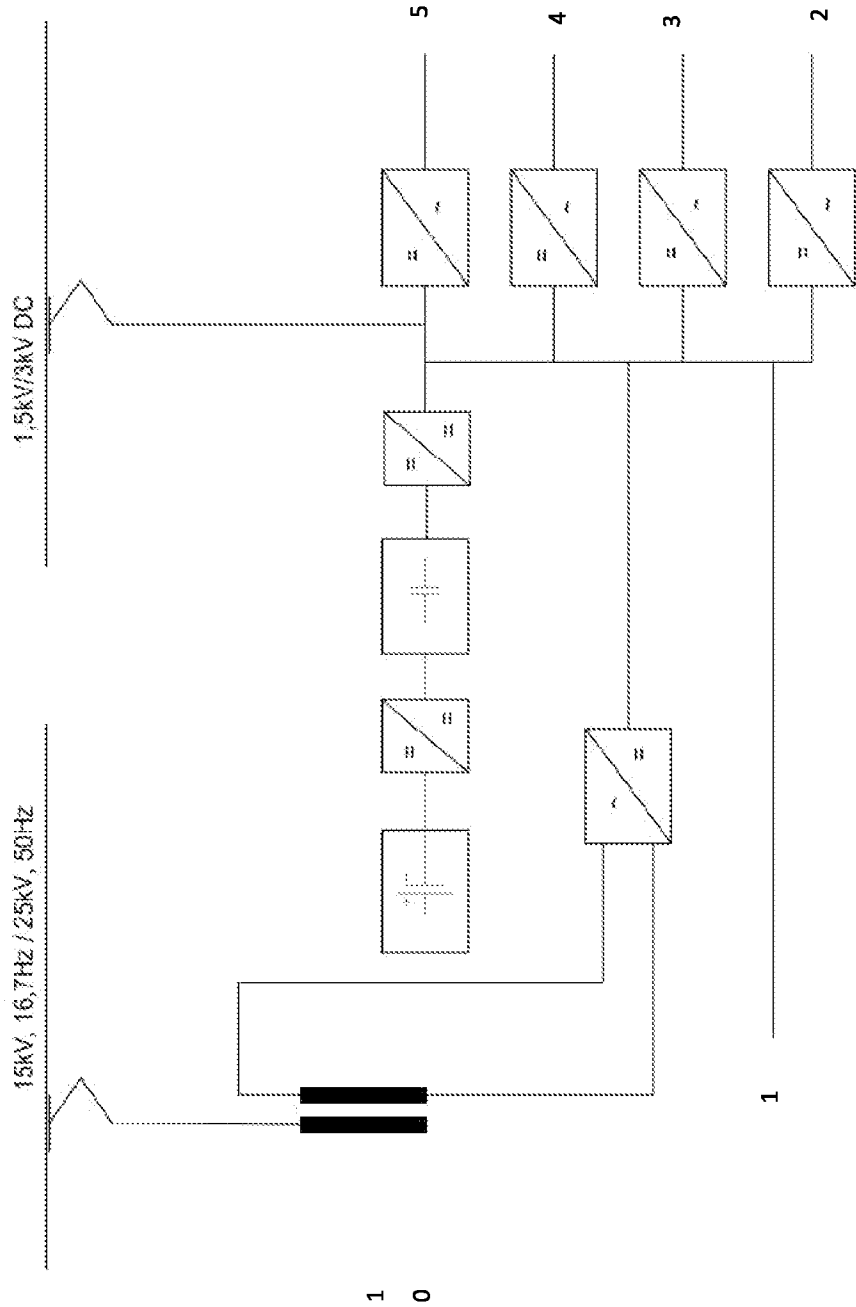


Fig.2

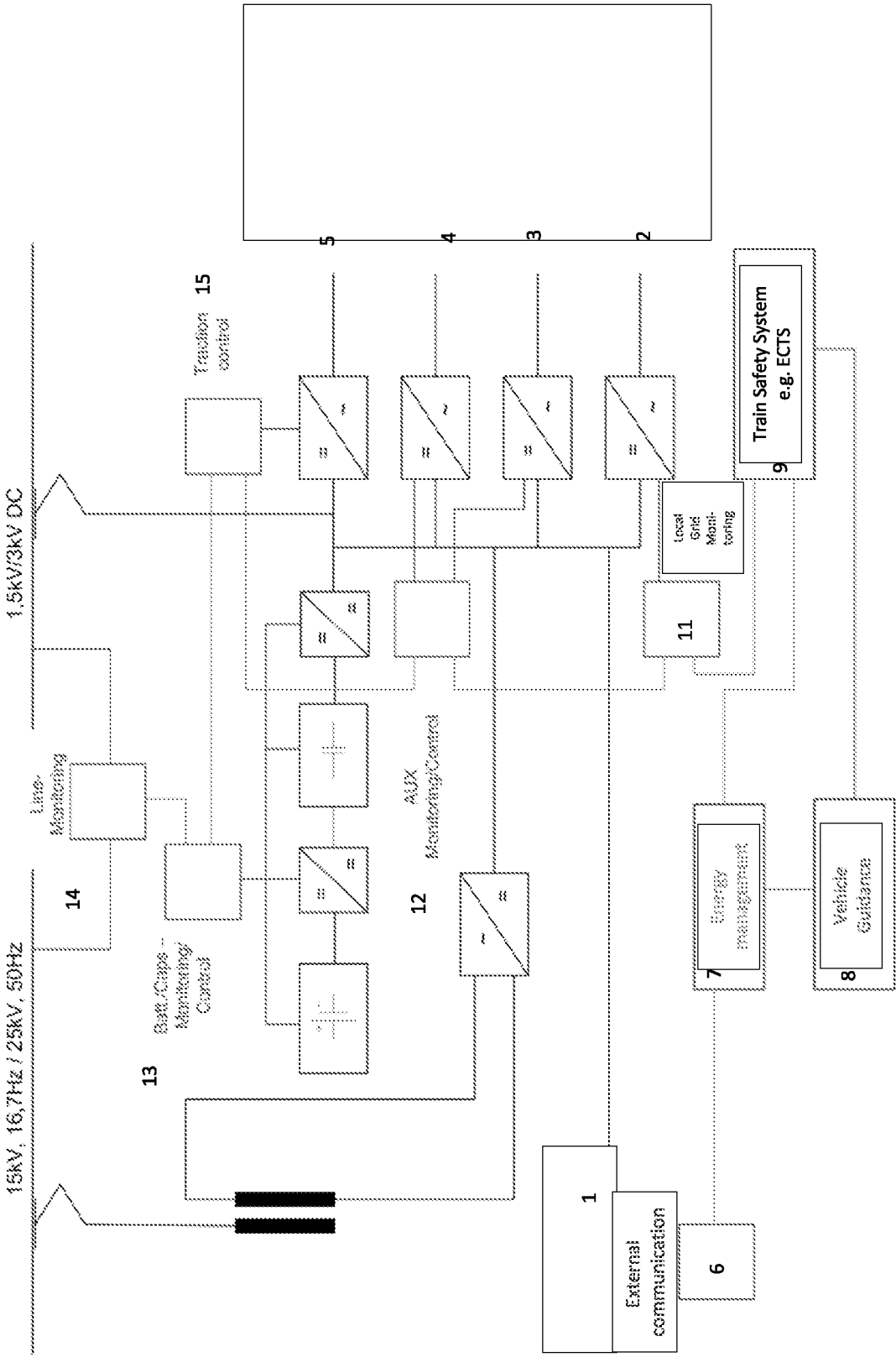


Fig.3

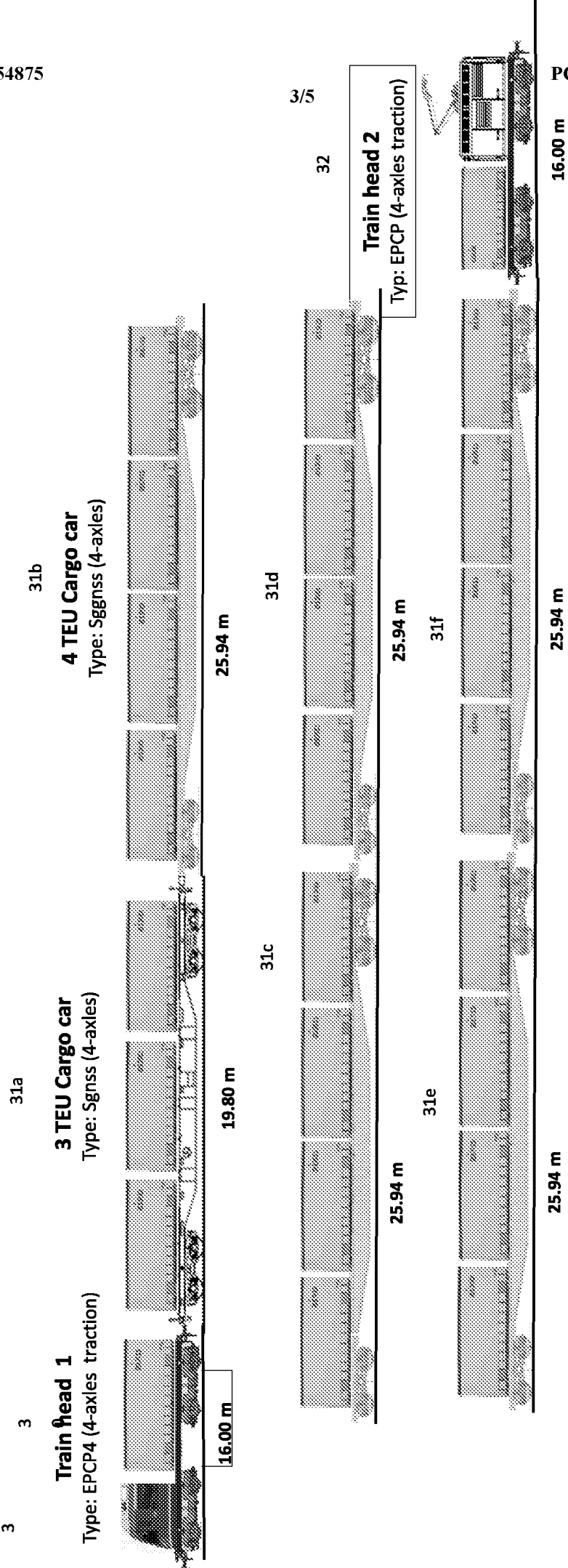


Fig.4

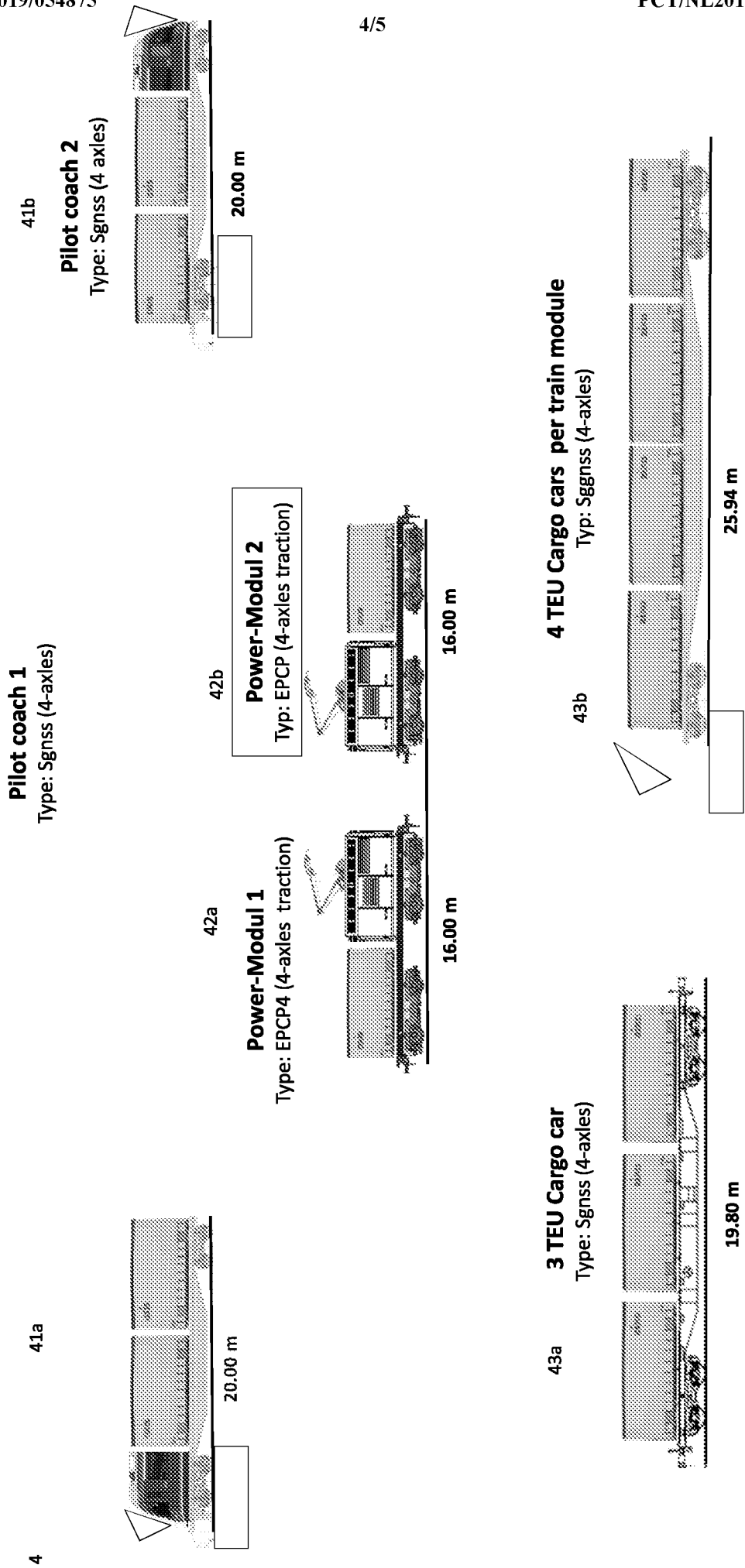
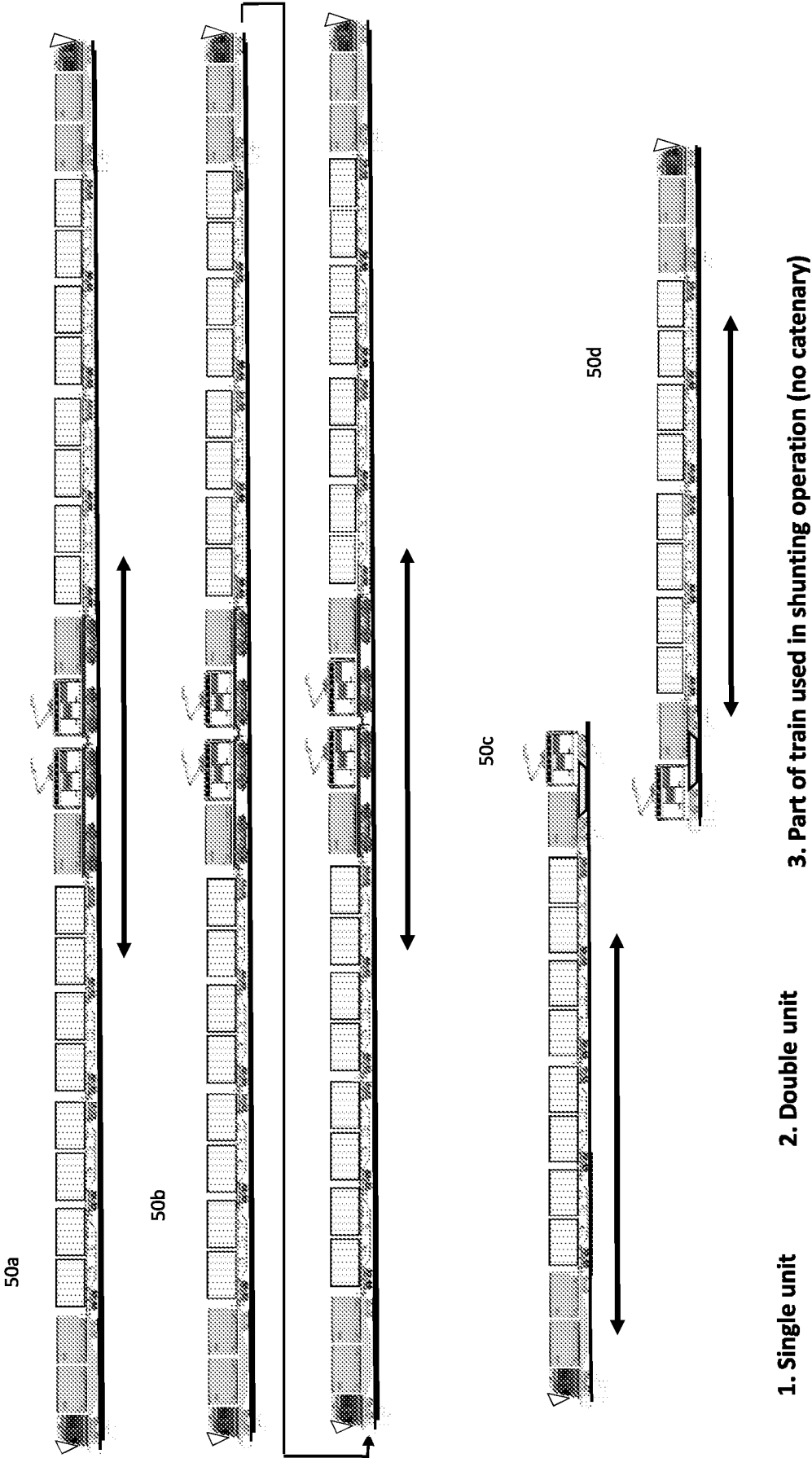


Fig.5



INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2018/050612

A. CLASSIFICATION OF SUBJECT MATTER

INV. B61C3/02 B60L9/00 B60L7/10 B60M7/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B61C B60L B60M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 871 744 A1 (ALSTOM SA [FR]) 23 December 2005 (2005-12-23) the whole document -----	1-38



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/NL2018/050612

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
FR 2871744	A1	23-12-2005	EP 1765631 A2	28-03-2007
			ES 2626608 T3	25-07-2017
			FR 2871744 A1	23-12-2005
			WO 2006008391 A2	26-01-2006
