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AN INNOVATIVE SYSTEM FOR 25 KV TRACTION POWER SUPPLY, THE 2X25 KV + +

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Abstract
This innovative system for rail traction power supply, christened "2x25 kV + +", is achieved by modifying the arrangement of the conductors on the catenary. This concept delivers a substantial decrease in impedance, opening up important avenues for optimisation in system design to improve power supply quality. It reduces the number of substations required for the operation of a railway line. This innovative idea can be implemented without any technological change of components in the catenary and / or sub-stations.

Summary

1. Introduction

Every major railway operation activity today calls for higher standards in order to improve service quality and optimize costs. As a result, the power levels of traction units have generally increased to meet new operational needs.

These developments in the railway system have led to an increase in the voltage level of lines supplying traction power in order to attain higher short-circuit power levels, reducing the rate of imbalance caused to the national electricity grid.

In general the density of transmission lines in the national grid is lower where the level of voltage is higher, from high voltage such as 63 kV or 90 kV up to very high voltage such as 225 kV or 400 kV. The connection points between the national grid and transmission lines feeding the traction sub-stations consequently tend to be further apart when the national grid voltage is higher.

To respond to this more difficult and increasingly more common situation, we have devised a simple and robust "2x25 kV++" system. We subsequently filed a patent application for this innovative system.

2. The principle of 2x25 kV

In the conventional 2x25 kV system, the power is supplied by one or more sub-stations, with a main transformer on its primary side connected to the national grid and on the secondary side delivering voltage of 50 000 V AC. One of the terminals of the secondary side is connected to the catenary, another is connected to the feeder called "negative feeder" and the mid-point on the secondary side is connected to the rail. This negative feeder is positioned on the "catenary" masts. The negative feeder is thus at a potential in phase opposition with that of the catenary.

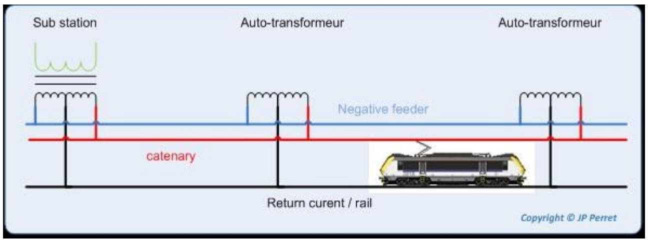

Fig. 1 - Schematic diagram of conventional 2x25 kV power supply

The conventional 2x25 kV system's main features are as follows:

- Sub-stations;
- Stations equipped with autotransformers;
- Compared to a conventional 1x25 kV catenary the addition of an additional conductor, the negative feeder, in opposite phase to the electric potential of the contact wire;
- The RC conductor called, in France, the CdPA (air protection conductor).

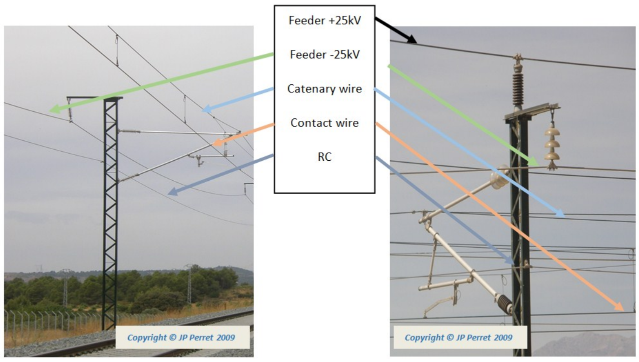

Fig. 2 - Conventional 2x25 kV system

Fig. 3 - Conventional 2x25 kV system with positive feeder

3. The limitations of the conventional 2x25 kV system with or without positive feeder

Despite the undeniable qualities of 2x25 kV, widely used in the railway world, we should remain aware of the limitations that it may display in view of future developments in the railway industry. The fact remains that its performance can be imperfect in terms of the quality of voltage delivered to the pantograph.

This limiting factor is inseparable from the 2x25 kV configuration. Indeed, this set-up generates significant inductive impedance on the traction circuit.

4. Complementary systems related to the conventional 2x25 kV system already deployed in Europe

Three complementary systems have been implemented to improve the conventional 2x25 kV system: capacitors in series on the negative feeder, the HVB (High Voltage Booster) and, in certain locations, an additional positive feeder near sub-stations to reduce thermal effects.

5. The 2x25 kV++ system

The 2x25 kV++ system is an innovation based on a proven feasible improvement of the conventional 2x25 kV system. It intrinsically allows for the reduction of the catenary system impedance through the intelligent repositioning of conductors.

The 4 or 5 conductors feeding a conventional 2x25 kV catenary system are as follows:

- The catenary wire (or messenger wire) : on which droppers are connected to support the contact wire;
- The contact wire: positioned to meet the geometrical requirements. It is the only element considered as a wear part, through contact with the pantograph;
- The RC (CdPA, air protection conductor): connecting with the bonding metal masses;
- The negative feeder: its location is mainly determined by considerations of space and isolation distance.
- The positive feeder (when present): has always been positioned as close as possible to the catenary wire in order to facilitate connections with it.

The 2x25 kV++ stands out by systematically having 5 conductors (the contact wire, the catenary wire, the RC, the negative and positive feeders). The spatial arrangement of conductors is specific: the negative feeder is surrounded by the positive catenary wire (with the contact wire) and the positive feeder, as shown in Figure 4.

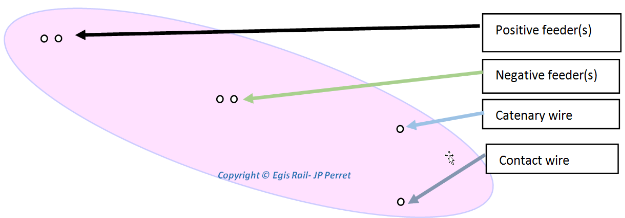

Fig. 4 - Principle of positioning of the four major conductors in 2x25 kV + +

The area inside the ellipse represents the arrangement of the various conductors.

Each feed line being made up of one or more feeders.

6. Simulation assumptions used for comparing 2x25 kV and 2x25 kV++ systems

The assumptions used for traction power computer simulations in each configuration is as follows:

- Catenary type is a catenary for 350 km/h on dual track;
- A substation with a 60 MVA transformer and 15 MVA auto-transformer stations every 15 km;
- One traction unit consuming 12 MW with a cos phi of 0.95.

6.1. Catenary configurations in conventional 2x25 kV system with or without positive feeder

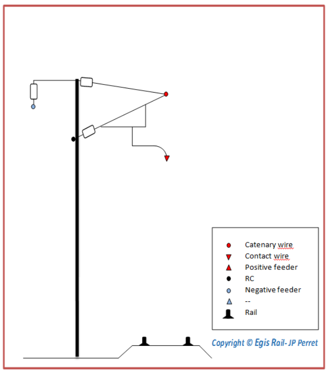

Fig. 5 - Conventional 2x25 kV system

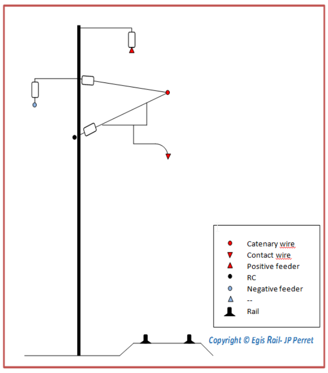

Fig. 6 - Conventional 2x25 kV system with positive feeder

6.2. Catenary configuration in 2x25 kV++ system

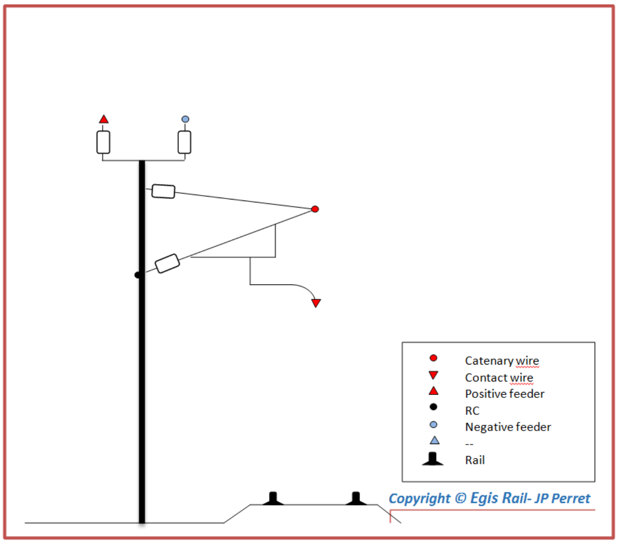

Fig. 7-Schematic diagram of the 2x25 kV++ system configuration

Figure 8 shows the voltage delivered to the pantograph as a function of the distance from the sub-station for the two known configurations and the innovative 2X25 kV++ configuration.

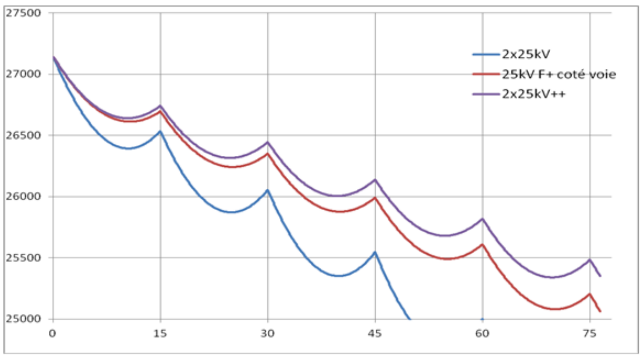

Fig. 8 - Pantograph voltage curve = f (distance) according to the three catenary configurations (see explanation in § 6.3.)

6.3. Analysis

The distance between two consecutive substations is a fundamental criterion for the optimisation of the design of the traction power supply system for similar levels and types of traffic on the railway line.

Where the initial spacing of substations is 90 km, and if the whole of the inter-distance is equipped with 2x25 kV++, then the expected gain when compared with 2x25 kV without positive feeder is four AT (autotransformer) distances (red and purple arrows in Figure 8). When compared to the conventional 2x25 kV with positive feeder trackside produces a gain of two AT distances (brown and red arrows. The position of the symbol in Figure 8 shows the level of unacceptability where the voltage is not Overall At Least Equivalent).

The above demonstrates that the potential gains of 2x25 kV++ compared to 2x25 kV are as follows :

- With the same train traffic, a larger distance between sub -stations, resulting in potential savings on the number of sub-stations and their connection to the national grid;
- With the same train traffic, better quality of line voltage;
- With the same distance between sub-stations, traffic growth is possible by merely adapting a catenary already configured as a conventional 2x25 kV system to a 2x25 kV++ configuration.
- The effect of the electromagnetic interaction between conductors is fully effective and provides the following benefits:
- Reduction of the overall linear impedance of the catenary system compared to the conventional 2x25 kV system;
- Reduction of voltage drops in the line when it is under traction load.

It is therefore apparent that 2x25 kV++ correctly positions the negative feeder providing better results compared to all others.

6.4. Other technical considerations

Although the process has been carried out without on-site experimentation, the feedback from 25 kV configurations in service allows for easy and effortless evaluation of compliance with other restrictions inherent in a 25 kV traction power system. The technical considerations discussed below for 2x25 kV++ have already been resolved or taken into account, in the case of conventional 2x25 kV with positive feeder :

- Mechanical feasibility;
- Electrical protection of catenary sectors;
- Protection from lightning strike- induced shocks;
- Resonance or ferroresonance;
- Phenomena of avalanche voltage drops;

- Adaptation of the system to Asian 2x25 kV sub-station systems;
- Circuit connections between the positive feeder and catenary wire.

It should also be noted that the levels of disruptive electromagnetic fields provided by 2x25 kV++ have sensibly the same level that 2x25 kV conventional system.

7. Financial and organisational impacts

By reducing the number of sub-stations and/or optimising connection costs by reducing distances for transmission lines to the national grid, the 2x25 kV++ delivers potentially interesting upsides, notably financial gains, even when including the negative impact on catenary cost. Today tenders are often split into two parts, with track and catenary on the one hand, and railway equipment (stations and sub-stations) on the other. Tenderers cannot produce all-encompassing offers, optimised with a 2x25 kV++ solution, where the additional investment on catenary is offset by savings elsewhere (traction power stations and substations, as well as the costs of connections to the grid).

It is therefore evident that the decision to use 2x25 kV++ is the responsibility of the project owner, well upstream of the tender procedure.

8. A way forward

2x25 kV++ is based on proven technologies from the conventional 2x25kV.

This is a solution compatible with the conventional 2x25 kV system and can be installed on appropriate power supply sections. The 2x25 kV++ is compatible with the devices mentioned such as serial capacitors and HVB. It also contributes new technical possibilities to the 2x25 kV environment.

This innovation allows network operators, starting from the design phase, to cater to future traffic increases by planning 2x25 kV++ installation in two steps. New rail corridors with continually rising traffic forecasts can be pre-fitted (essentially with masts and structures) to anticipate the future addition of a positive feeder when required.

The 2x25 kV++ scope covers the following two situations :

- The necessary adaptation of high-throughput conventional and high-speed lines, where distances between substations are great and low voltage is detected at the pantograph;
- The optimisation of the design of new railway lines: reducing the length of HV lines from the national grid to feed sub-stations, or even reduce the number of sub-stations yet still retaining the same efficiency levels and better power quality along the entire length of the line.

9. Poland and Croatia

For Poland and Croatia, introduction of or conversion to 2x25 kV would obviously be a major policy decision. If this idea is being seriously considered, it would be worthwhile to also consider 2x25 kV++. As an example, Egis Rail is presently a partner in a consortium designing the modernization and double tracking of the Dugo Selo – Novska railway corridor where such a conversion could be of considered.