6TH INTERNATIONAL CONFERENCE ON ELECTROMECHANICAL AND POWER SYSTEMS
October 4-6, 2007 - Chişinău, Rep.Moldova

CONSTRUCTIVE AND EXPERIMENTAL ASPECTS REGARDING THE ELECTRIC POWER COLLECTING FOR VERY HIGH SPEED TRACTION

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Abstract **– The paper presents some aspects regarding the contact line and pantograph problems and problems regarding the catenary-pantograph interecation. There is presented a contructive solution for the active control of the pressure force of the crosshead slipper over the contact line.**

Keywords: *contact line, pantograph, electric power collecting, pantograph control solution.*

1. INTRODUCTION

The electric power's transfer to the moving units is realized through an electric contact gliding between the contact line and a collecting device.

The problem of the electric power collecting from the contact line is considerably increasing at the same time as the travel rate of the moving units (items) is increasing. Now, in the very high speed electric traction, it's circulating with 300 km/h speed with the visible increasing tendency of this value. Between the most important inconvenient in the electric power collecting we can enumerate:

- Electric arc generation, by the pantograph detachment from the contact wire;
- tHe generation of detaching in the electrical and electronic apparatus of the engine (locomotive);
- The untimely attrition and ageing of the contact wire because of the electric arc and the molten metal deposit along the conducting wire;
- The appearance of wrecks (damages) and accidental attrition at the pantograph's crosshead slippers;
- The formation of characteristic diggings on the contact wire's surface, respectively on the attrition bars of the pantograph;
- Radio disturbances.

2. THE PROBLEMS OF THE ELECTRIC POWER COLLECTING

We can underline that the contact line used in low speed electric traction and the contact line used on the secondary lines don't present important problems concerning the electric power collecting in the most favorable conditions. In exchange, the contact line used on the high speed and very high speed base lines (main highways) presents two kinds of problems: electric problems and mechanical problems.

2.1.1. Electrical problems

The electric problems especially refer to the maximum allowed voltage drops and the allowable electric power intensity values. The maintenance of the voltage drops between some prescribed limits firstly contributes to an efficient run of the traction engines and the power electronics that are equipped with the moving units. Besides this the streams limitation at certain values prevents the inadmissible heating of the electrically conducting. The problems related to the electromagnetic influence over the aerial electrical lines isolated to earth, the electromagnetic influence over the circuits that presents a binding point in the earth, the galvanic influence over the circuits with at least two binding points in the land are also electrical problems.

2.1.1. Mechanical problems

The mechanical problems make allowance for the suspension way of the contact wire, for its geometry and the measures that must be taken in order to avoid the detachment of the crosshead slipper's collector from the contact line, phenomena that are great amplified by the speed and traction effort increasing of the electric locomotive.

Along the contact line the variation of rigidity of the system where the contact wire is fit up, the differences in level and the mass concentrations determine a variation of the developed effort by the pantograph's spring and the position on vertical of its crosshead slipper, variation that may be estimated with a sine curve. The composing of the two oscillatory motions

may lead to resonance phenomena that determine that pantograph's crosshead slipper couldn't follow the contact wire determining in this way the detachment of the two elements that are in electric gliding contact. As a consequence, for an optimal electric power collecting at all the requested speeds and powers, the main problem is a mechanical one.
Adding to the above mentioned aspects the problems determined by the black-out (the break of the load current) of the traction engines and the appearance of some dangerous voltage in the electronic circuit of stress that the most of the modern locomotives are fit out with we'll immediately conclude the necessity to eliminate the phenomena of pantograph's detachment from the contact line.

2.1.3. Pantograph problems

The main characteristic of a pantograph is to assure a good current collecting, without interruptions of the current regardless of the height of the pantograph. For this, it is necessary for the pantograph to have a contact plan irrespective of the movement of the mechanical articulated system, a small inertia, a good lateral and transversal stability, to obtain in static and dynamic regime a contact pressure irrespective of the string height, and have a low sensibility at the aerodynamics effects. More of this, the pantograph needs to have a crosshead slipper with am adequate shape and way of suspension for the contact characteristics. Its shape, size and fixation depend on the characteristics of the electric current, on the geometrical characteristics of the contact line. Thus, in alternative current is used a slipper with two wearing stripes because of the low current, but in direct current there are used usually two slipper with two wearing strips. Having into attention the above aspects, it is important to know some characteristics:

- Pantograph have to assure the contact between the contact line and the strip at every speed and in the same line the wear of these two elements must to be as low as possible;
- The contact quality depends on the construction characteristics of the pantograph;
- The reduce mass it's not dependent of the absolute speed, but on the ratio between the speed of the movements parts;
- The pantograph is better if the up characteristics is closer on the down characteristics;
- The pantograph needs to have a small inertia, to follow the deformation of the catenary;
- As the very big speed, the pantograph trajectory is no longer a sinusoidal one, which increase the probability of the detachments from the catenary;
- To have a firm contact it needs a constant pressure force independent on the height of the strip;
- To maintain a constant pressure force, it is necessary a torque developed by the mechanical string of the pantograph which changes depending on the strip height, or on the open angle;
- The estimation of the equivalent mass of the pantograph imposes a good estimation of the dynamic behavior.

A pantograph needs some characteristics, like:

- mechanical construction as light as possible;
- a small inertia of the articulated system;
- a good aerodynamic shape;
- a high lateral stability end a good damping of the vibrations due to the catenary and the locomotive without negative effects over the contact
- a constant pressure force independent on the strip high, a safe control mechanism end a low cost.

3. THE PROBLEMS OF THE PANTOGRAPG-CATENARY DYNAMIC SYSTEM

The big speeds of the train bring many problems for the pantograph construction. Because of that speeds, even a small vibration of the contact line on vertical needs relative high acceleration for the pantograph. More of that, the air pressure over the pantograph it is big enough and the aero dynamical properties has an important effect on the pressure of the strip. The dynamics depend on many parameters (the shape and the position of the pantograph, the locomotive shape etc). The quality of the contact is depending on the pantograph and catenary construction, which can't be treated separately.
The railway administrations are in a real competition for speed and comfort of the transport, the advanced areas being Europe and Japan. The USA is still connected to a large aerial transport system. In Europe there is more interest for the big speed trains, but here there are different railways systems and the changing from one to another impose problems for pantograph-catenary compatibility.
Generally, in Europe each railway administration had developed its own catenary system and its own pantograph. To solve the problem of different systems, there are two ways to action over the pantograph-catenary interaction:

- The design of the pantograph which can work on different catenaries (even in the same railway system)
- The new trains will have higher speeds which will bring more competitive on the transports.

From the point of view of the current collector, the optimal solution will depend by the new and superior characteristics of the catenary system. Anyway, to design and accomplish a new catenary it's very expensive. So, it is more efficient to develop the existing equipment (already used on the locomotives). From these, its results a real challenge to maintain the speed and travel performances when the trains are going from a conventional to a new system. Here is the important place pantograph-catenary system with the purpose to assure the energy flow from the contact line to the locomotive.

The critical criterion in the estimation of the contact quality (and the transmission of the electric energy) is the response in time of the contact force between the strip and the contact line. Usually, the contact force is obtained from a static force (given by the strings) and a dynamic force that depends on the speed and the oscillations of the pantograph-catenary system. The dynamic force gives important oscillations in the contact line and because of these the wear of the materials is more important.

The best way to collect the current is to have a contact force between the pantograph and the contact line. For this is necessary a constant level for the catenary and for the vehicle too, but these conditions can't be obtained. The oscillations must to be compensated by the pantograph movements (which is like an elastic element). The catenary is a second elastic element and it results a system of two elastic elements with a variation of the contact force between them – which is named dynamic pressure. If the pressure force is low, the strip detaches from the contact line and results electric arcs which can destroy the pantograph and the contact line and with negative effects over the traction equipment. There are some essential aspects and problems regarding the dynamic of the pantograph-catenary system:

- The vibrations of the track and of the vehicle generate vertical forces with effects on the pantograph up and down movements that modify the contact pressure. More of that, there are also the effects of the pantograph spring.
- The masses (considered being concentrated at the top of the pantograph) and the accelerating forces vary with the pantograph level.
- The contact pressure is higher with 20-60% for the descending movement than the elevation movement of the pantograph because of the friction forces and its maintenance, and the differences are more important with the arcs tension.
- The air drag of the pantograph can affect the contact pressure; it depends on the shape and structure of the locomotive roof and of course, of the pantograph shape.
- The lower the mass of the pantograph ratio to the mass of the contact line, the better is the dynamics of the pantograph-catenary system.
- The best values for the contact pressure must be estimated having into attention the current intensity, the materials of the strips, the catenary type.
- The contact force F must to be as high as possible in aspect to the mass of the collector. The ratio F/m is a coefficient of quality of the pantograph for its dynamic behavior. This force must to almost the same for the elevation movement and for the descending movement of the pantograph.
- The elasticity differences on the contact line must to be as low as possible. The elasticity must to decrease when the height of the pantograph increases. The limits of the values for a maximum speed can be estimated having into attention the worst temperatures conditions.
- The distance between the catenary and the train roof must to be as minimum as possible; thus, the pantograph mass will be lower and the strip will not be at a very high height, with dynamic and aerodynamic advantages.

The pantograph-catenary system is assimilated with a system of masses that are elastically connected; the contact force between the contact line and the strip of the pantograph influences the height of the contact point in relation with the kinetic energy of the two masses.

a) The pantograph-catenary system is considered to have a degree of liberty only on the vertical direction.
b) The dynamic forces due to the auxiliary movement of the vehicle are neglected.
c) The friction force between the contact line and the pantograph strip is neglected and also is neglected the influences of the air drag.
d) The elevation of the catenary with the pantograph movement is considered to be proportional with the contact force.
e) The elasticity of the contact line is considered to have a sinusoidal variation along a span.
f) The equivalent mass of the pantograph is considered to be constant and independent on the open angle of the pantograph.
g) The contact force due to the mechanical system of the pantograph (the springs) is considered to be constant.

4. A SOLUTION FOR ACTIVE CONTROL OF THE PANTOGRAPHE

The solution is referring at the pantograph current collectors used on tramways and electric locomotives to collect the electric current from an elastically contact line placed along of a rail track.

The solution doesn't modify the basics of the pantograph-catenary system, the idea being applied only to the solution to control the pantograph. Using this solution, the pantograph detachments will be avoided and the electric traction equipments will be supplied in good conditions.

The figure 1 presents an asymmetrical pantograph drive by a linear induction motor.

In figure 2 is presented a static characteristic of the pantograph. It has an almost invariable zone of the pressure force and it can be defined an optimal working area (ZL) which is preferable to be the same on the pantograph movement under the contact line.

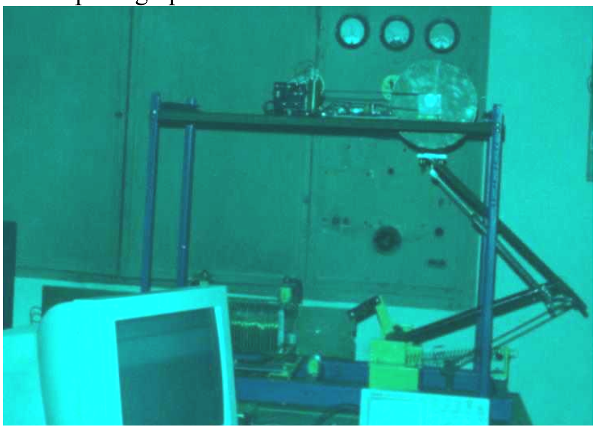

Figure 1: The solution for active control of the pantograph.

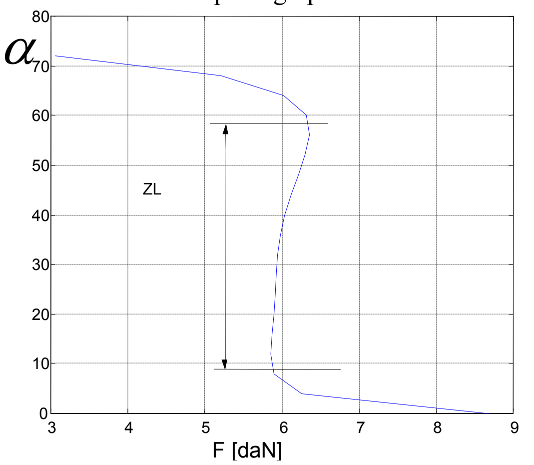

Figure 2: The static characteristic of the pantograph.

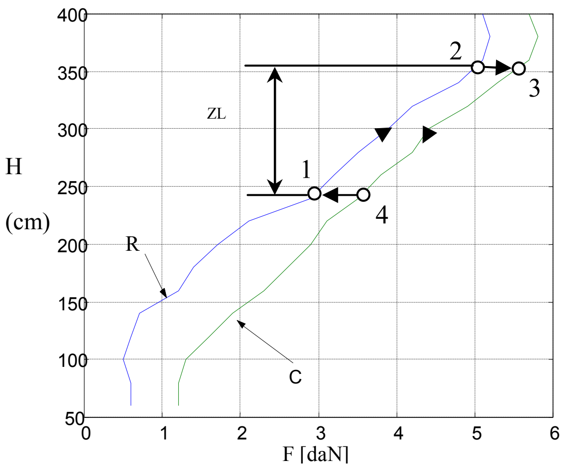

Figure 3: The compensation of the supplementary effort.

In these conditions, to eliminate the detachments of the pantograph from the contact line, at very high speeds, it is proposed to work after a hysteresis cycle (1-2-3-4, figure 3). The proposal shape of the characteristics depends on the catenary geometry, the friction forces in the articulations, the contact force, the speed of the train and the angle or the height of the pantograph.

The compensation of the supplementary effort and the transition from the elevation characteristics (R) on the descending characteristic (C) will be obtained with a controlled linear motor (figure 1).

In front of the pillar of the catenary the pantograph is on the elevation characteristic in point 1 and pushes with a force F_1 on the contact line. During the train movement, the pantograph moves on the elevation characteristic and in the middle of the span (between two pillars) it pushes with a force F_2 on the contact line (the point 2). After that, the pantograph is on the descending characteristic, on the point 3 and pushes with a force F_3 the contact line. Near to the next pillar, the pantograph is on the point 4 and pushes with a force F_4 the contact line. After the next pillar, the process is repeated and so on. The phenomenon is repeated for every span, all the way and depends on the train speed. The supplementary effort and the optimal current collecting will be assured by the controlled linear motor movement alone or in combination with the pantograph springs.

4. CONCLUSIONS

The solution doesn't modify the contact line geometry and the current transfer from the contact line to the traction equipments. The solution will:

- give a controlled pantograph-catenary system,
- develop new technologies for the active control of the pantograph,
- improve of the current collecting process for the high speed trains,
- reduce the wear of the pantograph and of the contact line,
- reduce the maintenance cost for the pantograph and catenary.

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