Simulation of Electric Vehicles Movement

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Abstract: - In the paper it is presented the mathematical model of the useful movement of the electric vehicles. On the mathematical model basis it is built the structural diagram associated of the useful movement. The obtained structural scheme can be easily implemented in SIMULINK. An immediately example of the utilization of the useful movement model it constitutes it the drawing of the movement diagrams, which it illustrates the dynamics aspect of the useful movement. Like application, by means of the SIMULINK model they are traced, on the basis of the traction and braking characteristics and of the imposed conditions of the route, the movement diagram of the high-speed train.

Key-Words: - modeling, simulation, electric vehicle, high-speed train, useful movement

1 Introduction

In any electric vehicle, the developed electromagnetic torque of the traction electric motors has been transmitted of the motor wheels. These, through turning, establish the translation movement of the vehicle on the rail.

Because the rotation movement of the motor wheels it is "attached", through transmission, of the traction motor rotor movement, it results that the motor wheels movement equation can be deduced from the motor equation with which these are coupled. Thus, the motor torque transmitted of the motor wheels it is $M_R=i \cdot \eta_t \cdot M_2$, where M_2 is the developed useful torque of the traction motor. At the running radius $r=D_r/2$, the motor torque M_R it corresponds it the motor force F_o[N] at wheels [1]

$$Fo = \frac{M_R}{D_r/2} = \frac{2}{D_r} \cdot i \cdot \eta_t \cdot M_2 \qquad (1)$$

In the slip absence, the peripheral speed v of the motor wheels (which they are turned with the angular speed Ω_0)

$$v = \Omega_0 \cdot \frac{D_r}{2} \qquad (2)$$

it is the same with the translation movement speed (on the rail) of the vehicle. As $\Omega_0=\Omega_m/i$, where Ω_m it is the angular speed of the traction motor rotor, it results that

$$v = \frac{D_r \cdot \Omega_m}{2 \cdot i} \qquad (3)$$

The relations (1) and (3) are fundamentals in the traction calculations. They permit the establishment of the vehicle characteristics depending on the useful torques quantity M_2 and on the angular speed of the shafts of the all its traction motor (in the equality case of the diameters of the all motor wheels).

In the running, both under its traction motors action and under the rail resistance influence, it achieves the useful translation movement of the all vehicle in the long rail.

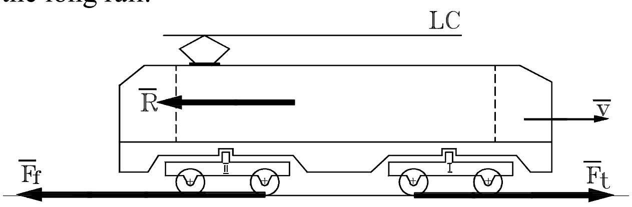

Fig.1 External forces which they establish the movement

Moreover, the useful movement of the train it is established only of the external forces action. These can be (fig.1):

- motor active forces (of traction), with the resultant $\overline{F_t}$ (of controllable magnitude, which they operate on the sense and direction of the useful movement);
- braking active forces, with the resultant $\overline{F_f}$ (of controllable magnitude, which they operate on the

useful movement direction, but on the contrary sense of the speed vector $\bar{v}$) and

- train resistance forces with resultant $\bar{R}$.

The active forces $\overline{F_t}$ (of traction) and $\overline{F_f}$ (of braking) they operate not simultaneously in none running regime (presence of one it is equivalent to the exclusion of other), while the train resistance $\bar{R}$ it is presented all the time, even in the active forces absence (in the coasting regime without current).

2 Modelling of Useful Movement

The train resistance forces, between with the traction characteristics of the high-speed train, they permit the useful movement study of the vehicle. In these conditions the useful movement equations is [1], [2]

$$m^* \cdot \frac{dv}{dt} = F - R; \quad m^* = m \cdot \xi \tag{4}$$

where F it is F_t in traction regime or $-F_f$ in braking regime, and ξ is the coefficient of increase the mass of the train that take account to the presence and weight of the turning parts from the train structure (ξ=1.06…1.2).

Thus, through the coefficient of increase the mass agency it can make abstraction of the turning parts presence, replacing the real mass "m" of the train with a "fictitious mass" $m^*=m\cdot\xi$ found in translation movement with the speed "v", the same of the considered train. From the physical viewpoint, this is equivalently with fictitious replace of the mechanical system of rigid solid parts through a material point with inertial mass $m^*=m\cdot\xi$.

For the dynamic aspect approach of the useful movement it is necessary a mathematical model. In this purpose it is considered a electric vehicle of mass *m[t]* and coefficient of increase the mass ξ having the train resistance r[daN/t]. On the useful movement duration, the speed v(t) and the distance x(t) they are ruled at the equations

$$m \cdot \xi \cdot \frac{dv}{dt} = F - R\,; \quad \frac{dx}{dt} = v \tag{5}$$

If the movement has been made under the useful torques action M_2 (identical), developed of those "z" traction motors of the electric vehicle, then in accordance with the relations (1) and (3)

$$\Omega_m = \frac{2 \cdot i}{D_r} \cdot v\,; \quad F = z \cdot \frac{2}{D_r} \cdot i \cdot \eta_t \cdot M_2 \tag{6}$$

Moreover, if the mass m of the train it is expressed in [t], the total train resistance R[N] it is established with

$$R[\mathrm{N}] = r[\mathrm{daN/t}] \cdot m[\mathrm{t}] \cdot 10 \tag{7}$$

The equations ensemble (5), (6), (7) they form the mathematical model of the useful movement. Written togheter,in the shape of

$$\begin{aligned} & v = \frac{1}{m \cdot \xi}\int (F\text{-}R)dt\,; \quad \Omega_m = \frac{2 \cdot i}{D_r} \cdot v; \quad x = \int v \cdot dt\,; \\ & F = z \cdot \frac{2}{D_r} \cdot i \cdot \eta_t \cdot M_2\,; \quad R = (r_{ps}(v) \pm i_{de}(x) + r_c(x)) \cdot m \cdot 10 \end{aligned} \tag{8}$$

they permit the structural diagram construction of useful movement (fig.2).

For the mask block they have been considered like input quantity the M torque and like output quantity the Ω_m speed, time variable quantities on the useful movement duration.

By means of this scheme ("coupled" at the structural diagram of electromagnetic part of traction motor) can be simulated the useful movement of any electric vehicle as compared with the concrete modality by leadership (or by control) of this. Accordingly they are obtained the running diagrams v(t) and x(t), too. The modification of vehicle mass, of dependences i_{de}(x) or r_c(x), specific to certain vehicle or route, can be easily operated, obtaining an exact mathematical model, which it respects all the running conditions.

In the motor wheels diameters inequalities case, the scheme suffers a minor change, the total force F resulting like sum of partial forces developed by each motor partly.

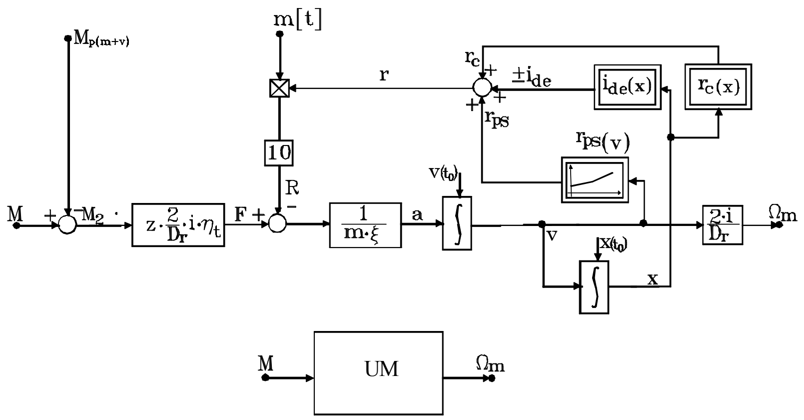

Fig.2 Structural diagram and mask block of useful movement

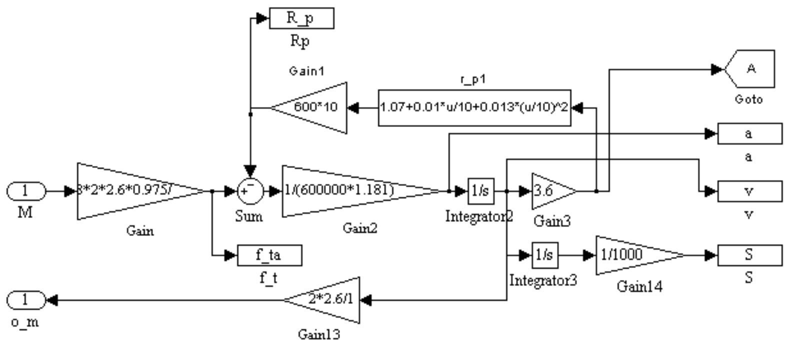

Fig.3 Content of SIMULINK mask block „UM"

3 Simulink Model of Useful Movement

The SIMULINK model corresponding to the useful movement of the electric vehicle can be easily implemented, having with a view the topological comparison with the associate structural diagram. In the traction electric motor consideration case, too, at the electromagnetic part model "MAT" it is coupled the block „UM" (fig.3 and fig.4). The useful movement block has been achieved on the corresponding structural diagram basis (fig. 3).

Fig.4 Model of traction induction motor at consideration useful movement of train

Within the framework of the useful movement (fig.3), the transmission has been supposed ideal. In simulations in which they have been desired to be taken account the other mechanical phenomenous (like example the stick-slip [3]), too, can be interspersed the afferent elastic mechanical transmission model [1].

4 Simulations

An immediately example of the useful movement model it constitutes it the running diagrams drawing, which they illustrate the dynamic aspect of the dynamic aspect of the electric vehicle.

The running diagrams of the electric train they are drawn on the traction and braking characteristics basis and of the conditions imposed of route.

The traction and braking characteristics consort any presentation, however summarily would be, of a high-speed train. Like example, it has been considered the ETR 500 italian high speed train case, for which, except the traction and braking characteristics, they have more represented the train resistance, too, corresponding to the different specific features of the route (through the declivities consideration) (fig.5).

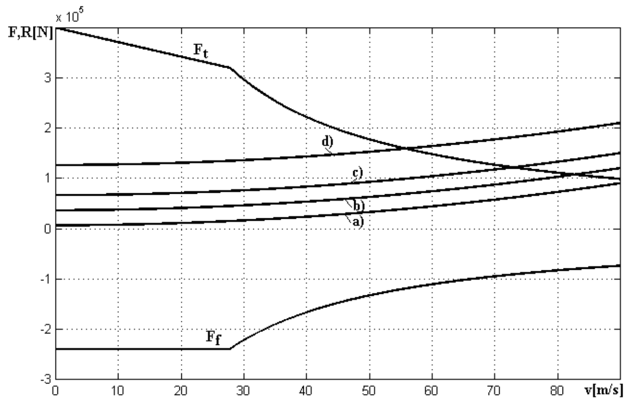

Fig.5 Traction and braking characteristics and 4 values of train resistance of ETR 500 italian high speed train resistance, m=600 t
i_{de}=0; b) i_{de}=5; c) i_{de}=10; d) i_{de}=20

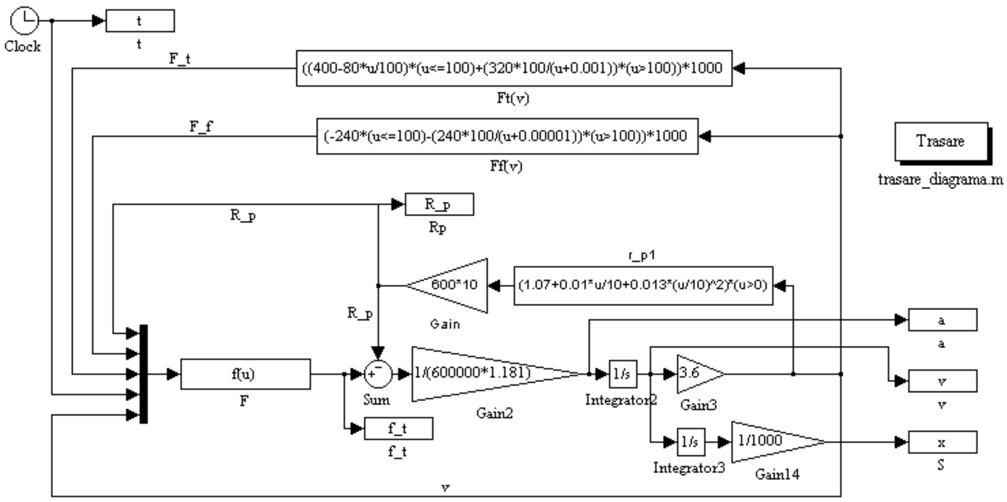

Fig.6 SIMULINK model used for running diagrams drawing

For the running diagrams drawing corresponding to a route of the ETR500 it is used a SIMULINK model based on the useful movement model (fig.6).
In the blocks „$F_t(v)$" and "$F_f(v)$" they are implemented the traction and braking characteristics (fig.5). The model is based on the useful movement model, at which the main input variable it is supplied of the block „F","which it models the useful movement phases:
- starting phase,
- running at constant speed phase,
- coasting phase and
- braking phase.

By means of this SIMULINK model (fig.6) they have been drawn the running diagrams corresponding to a test route of the high-speed train,

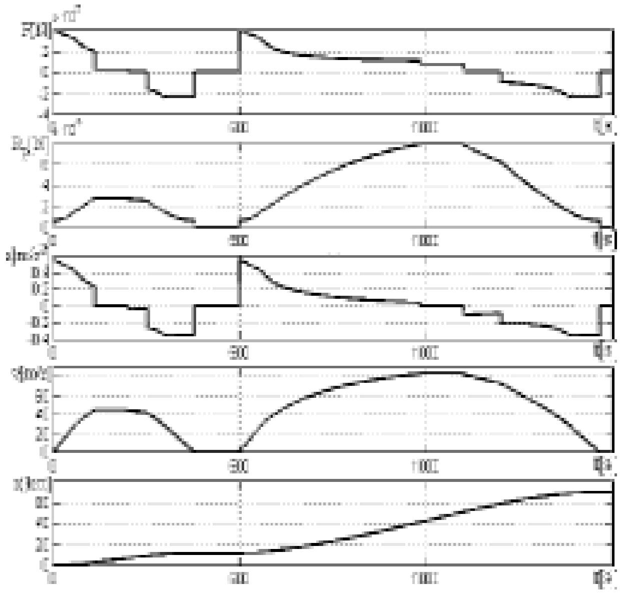

Fig.7 Running diagrams of high speed train

on its route has been reached the speed of 44,44 m/s (160 km/h) and respectively of 83,33 m/s (300 km/h). They have been drawn the variations of the force, of the train resistance, of the acceleration, of the speed and of the distance (fig.7).
The model, relatively easy of implemented and of used, it has a great importance in traction, can be useful in the establishment of a control methods, on a special route, based on the best utilization of the installed load. The respective methods are implemented then in the computer control system on the electric vehicles, contributing at the circulation safety increase, at the consumptions decrease and permitting even a possibly ATC (Automatic Train Control).
In the previous case has been taken account only the main train resistance corresponding to a route with conditions from case a, fig.5.
The next simulations referred to the same high-speed train, with the same performances (traction and braking characteristics), for which it is desired the speed variation obtainment on a distance of 100 km. They are considered another values of the train resistance established of the different declivities values existence, too (fig.5). The maximum reached speeds they correspond the conjunctions between the traction force and adequate train resistances, excepting the case a) (fig.5) where the maximum speed has been limited at 83,33 m/s (300 km/h).
For the respecting of 100 km distance must achieved an obtainment algorithm of the point from which the train start to brake. For this it is used a SIMULINK model(fig.8), what it permits the determination of the braking distance when it is known: the braking beginning speed, the braking force (variable depending on speed), the mass m of the train, the train resistance (variable depending on speed and

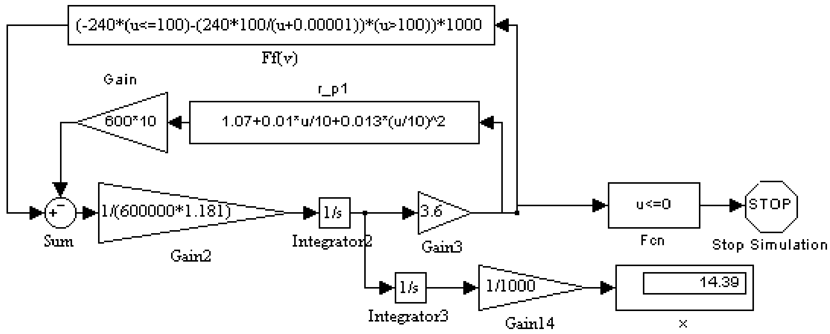

Fig.8 SIMULINK model used establishment of braking distance

distance). It is thus possibly the knowledge of the point from which it begins the braking and the stopping at fixed point.

For those, for cases (fig.5), by means those two SIMULINK models (fig.7 and fig.8), they have been simulated the speed diagrams (fig.9), all corresponding to a distance of 100km. They have been obtained the time of 1500 s (case a), of 1512 s (case b), of 1632 s (case c) and of 1982 (case d).

The model permits, through the specific features introduction of the routes from our country within the framework of the useful movement model, the testing and the comparison of the performances of different possible variants of the electric vehicles.

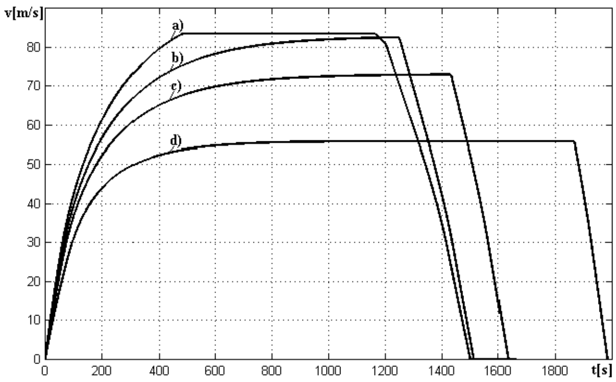

Fig.9 Speed diagram for different values of train resistance (m=600 t)
a) i_{de}=0; b) i_{de}=5; c) i_{de}=10; d) i_{de}=20

5 Conclusions

The mathematical model of the useful movement has a general nature can be easily adapted of the concrete conditions of the electric vehicle or the route. The structural diagram built on the mathematical models can be easy coupled at the structural diagram of the electromagnetic part of the traction motor, being thus possibly a formed construction associated of motor electric vehicle.

The topological similitude between the structural diagram and the SIMULINK model it permits an easy implementation in SIMULINK, both for the presented structural diagram and for the simulations of a concrete situations.

References

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