

A General Motor Modelling Method for Transit System Simulation Studies

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ABSTRACT This paper describes a general motor modelling method for transit system simulation studies. The method is based on a tabulated data approach. It has been applied to an existing multi-train simulation package for both DC and AC motor drives (including linear motor drives).

1. INTRODUCTION

Computer simulation studies have gained wide applications during both design and operations of transit systems in the last two decades [1,2]. With all simulation programs, traction motor modelling plays a very important role in representing the dynamic interaction between train motions and power supplies.

Past work in this field has mainly involved DC traction motors, which are usually modelled on the basis of a three-region control strategy describing control schemes ranging from rheostat-controlled motors to GTO controlled motors [3]. Recent years have seen more sophisticated control schemes being introduced and the increasing use of AC motors, that cannot be described by the traditional three-region control strategy. Furthermore, linear induction motors are also used in some transit systems.

Usually existing simulators have built-in motor model algorithms, which assume that the traction motor is controlled by one of a number of specific control schemes. If the actual control scheme for a given system that needs to be simulated is different from all the schemes that are contained in the simulator, the simulator

itself has to be modified.

There are two obvious drawbacks with this approach. Firstly, an expert programmer is needed to take on such a complicated task. Secondly, it is both inflexible and time consuming.

This paper describes a general motor modelling method as an alternative. This method has been applied to an existing multi-train simulation package for both DC and AC motor drives (including linear motor drives).

2. MOTOR MODELLING METHOD

Most transit systems use DC traction power supply systems. Therefore, DC power supply is assumed in this paper.

A basic observation shows that the interaction between motor dynamics and energy requirement can be completely described by four sets of motor characteristics. These are:

- tractive efforts vz. train speed in motoring mode;
- power demands vz. train speed in motoring mode;
- braking efforts vz. train speed in regeneratively braking mode;
- power feedbacks vz. train speed in regeneratively braking mode.

These characteristics are usually given under a specific DC operating voltage (e.g. rated system voltage). For voltage sensitive simulation, these characteristics are given under a number of DC voltages within the DC operating voltage range. Power demands or feedbacks under a given DC voltage can be represented in the form of DC currents drawn from or fed back to the DC traction power network.

(Note that if the traction power supply system is AC, two extra sets of characteristics are needed. These are power factors vz. train speed in motoring mode and in regeneratively braking mode respectively.)

The following equation is used to describe the interaction between train motion and power demand in motoring mode:

$$F(\omega, V) \cdot \omega + P_{\text{aux}} = V \cdot I(\omega, V) \quad (1)$$

where P_{aux} is the auxiliary power demanded by the train; ω is the train speed; V is the DC voltage on the train; $F(\omega, V)$ is the tractive effort of the train; $I(\omega, V)$ is the DC current supplied to the train. Both $F(\omega, V)$ and $I(\omega, V)$ are functions of train speed and DC supply voltage. Since the DC voltage seen by the train is affected by

other trains in the system, it is obtained in an iterative process.

For a regeneratively braking train, the equation is changed to

$$F(\omega, V) \cdot \omega = V \cdot I(\omega, V) + P_{\text{aux}} \quad (2)$$

The modelling method is based on a tabulated data approach. The motor characteristics are discretised in given speed intervals (typically at 1 km/h) and tabulated as look-up tables. These tables are then accessed by the multi-train simulator and stored in designated arrays. For a train moving at a specific speed and under a specific DC voltage (parameters which are derived from simulation), the actual electric model can be established by using these data by way of linear interpolation.

In order to have a meaningful interpolation, motor characteristics under at least two different DC voltages must be given to cover the whole DC operating voltage range: the maximum voltage at which full regenerative braking is available and the minimum voltage at which full motoring is available. As for train speed interval, 1 km/h speed interval gives reasonably accurate results for power flow study purposes.

Motor characteristics are best prepared from manufacturer supplied curves. In the case where such curves are not readily available, individual motor modelling programs that are detached from the main simulator can be used as pre-processing program modules to derive the characteristics in the required form.

Figures 1, 2 and 3 show some sample motor characteristics for three different types of motors. Although these motors behave very differently (as illustrated by the shapes of the curves), they are modelled in the multi-train simulator on the same basis.

Figure 4 shows a typical graphical plot for train performances using the AC motor characteristics given in figure 2.

3. CONCLUSION

Motor characteristics for both DC and AC motors are generalised and the motor characteristics preparation work is detached from the main simulator, making simulation work much easier and more flexible.

4. ACKNOWLEDGEMENT

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this work, but would like to stress that the views expressed in this paper are entirely their own.

5. REFERENCES

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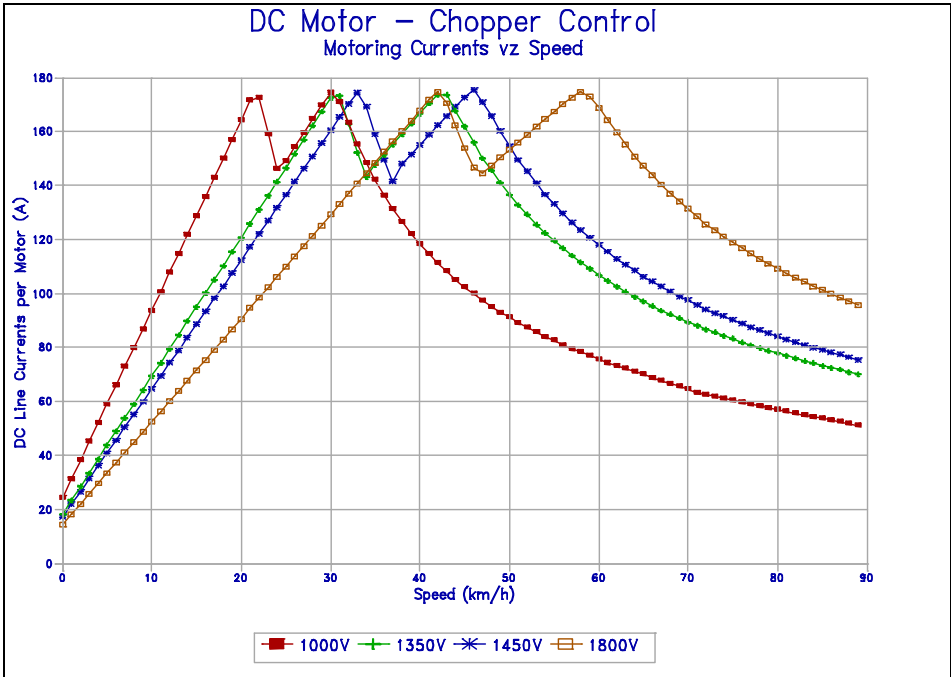
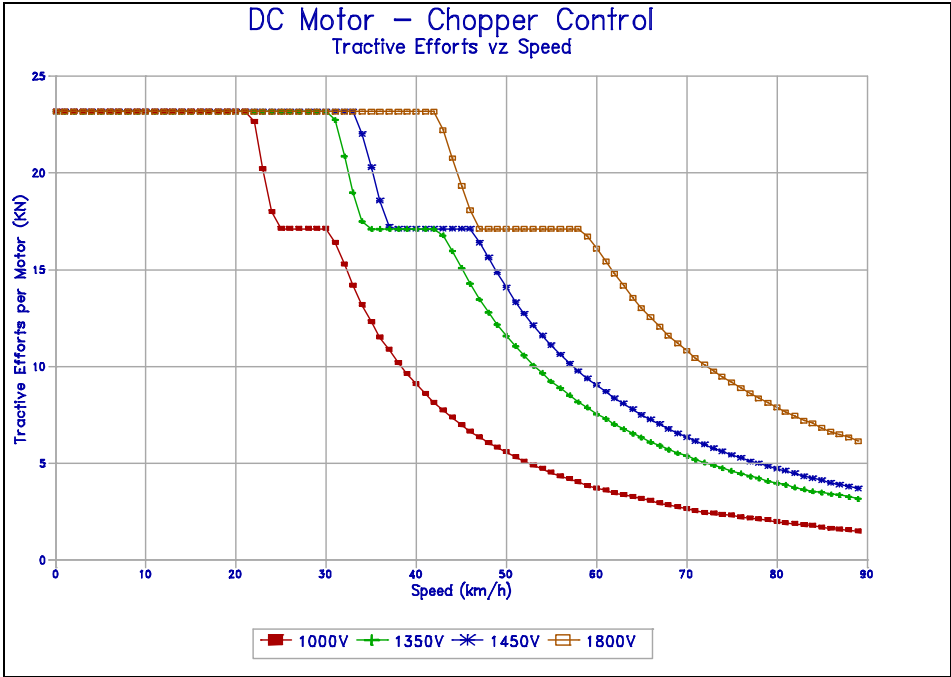


Figure 1 A sample set of DC motor characteristics (motoring)

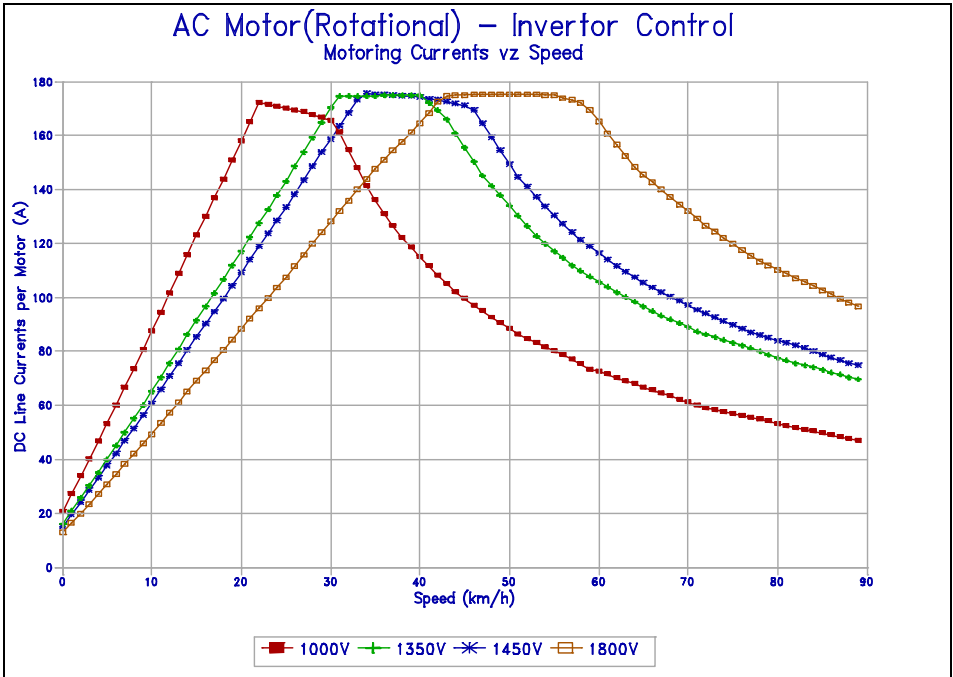
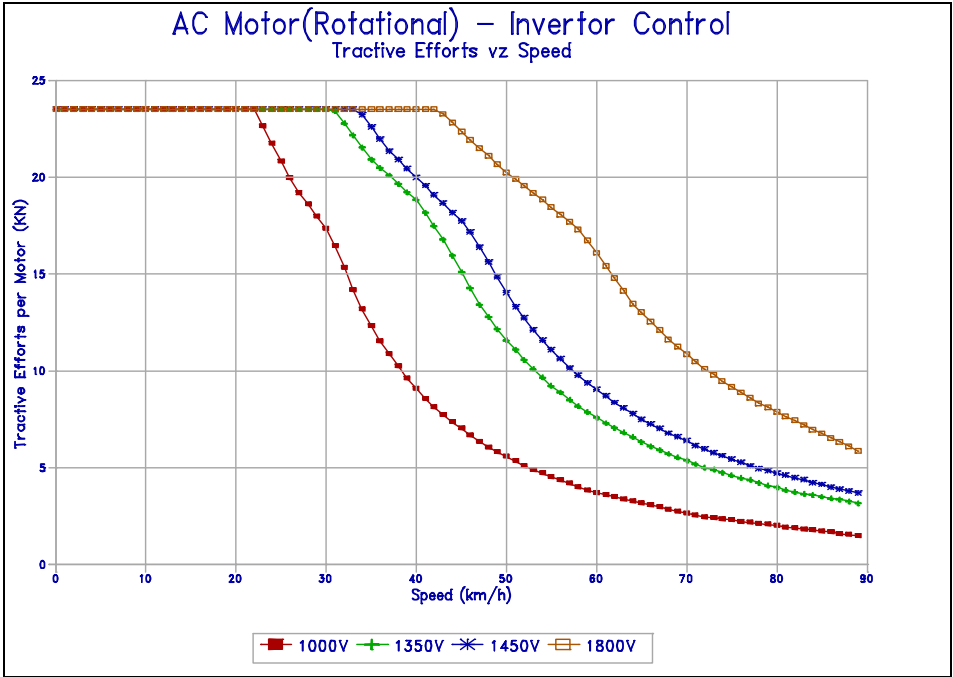


Figure 2 A sample set of AC motor (rotational) characteristics (motoring)

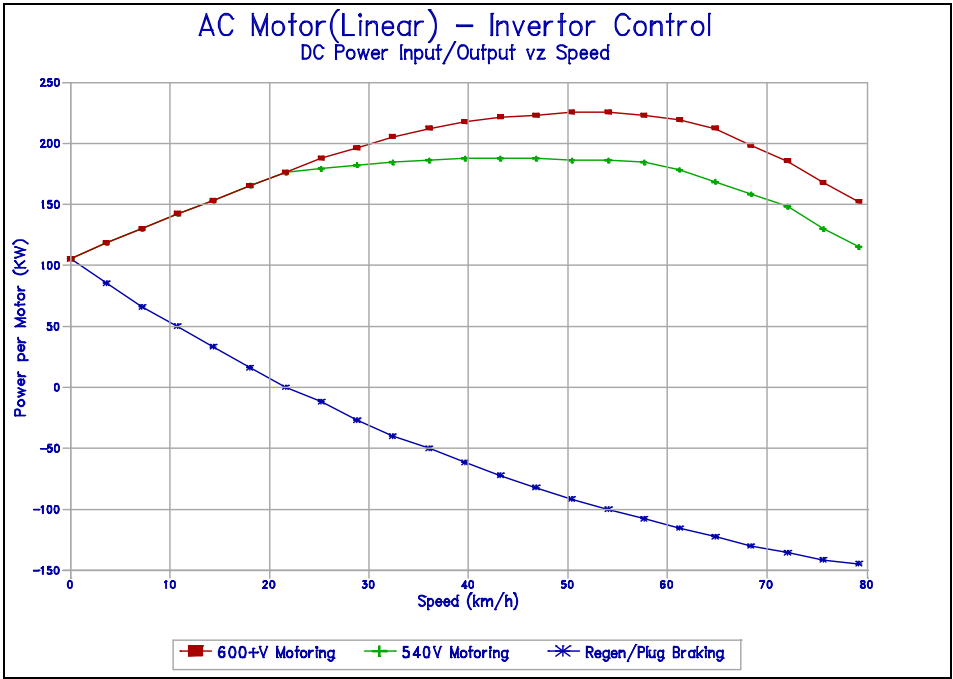
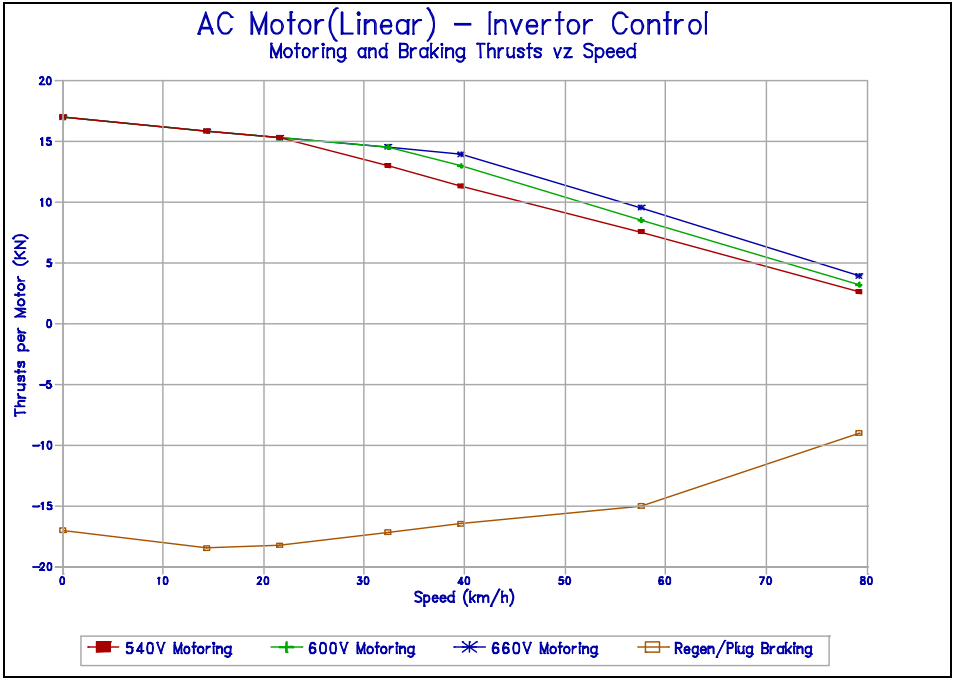


Figure 3 A sample set of AC motor (linear) characteristics

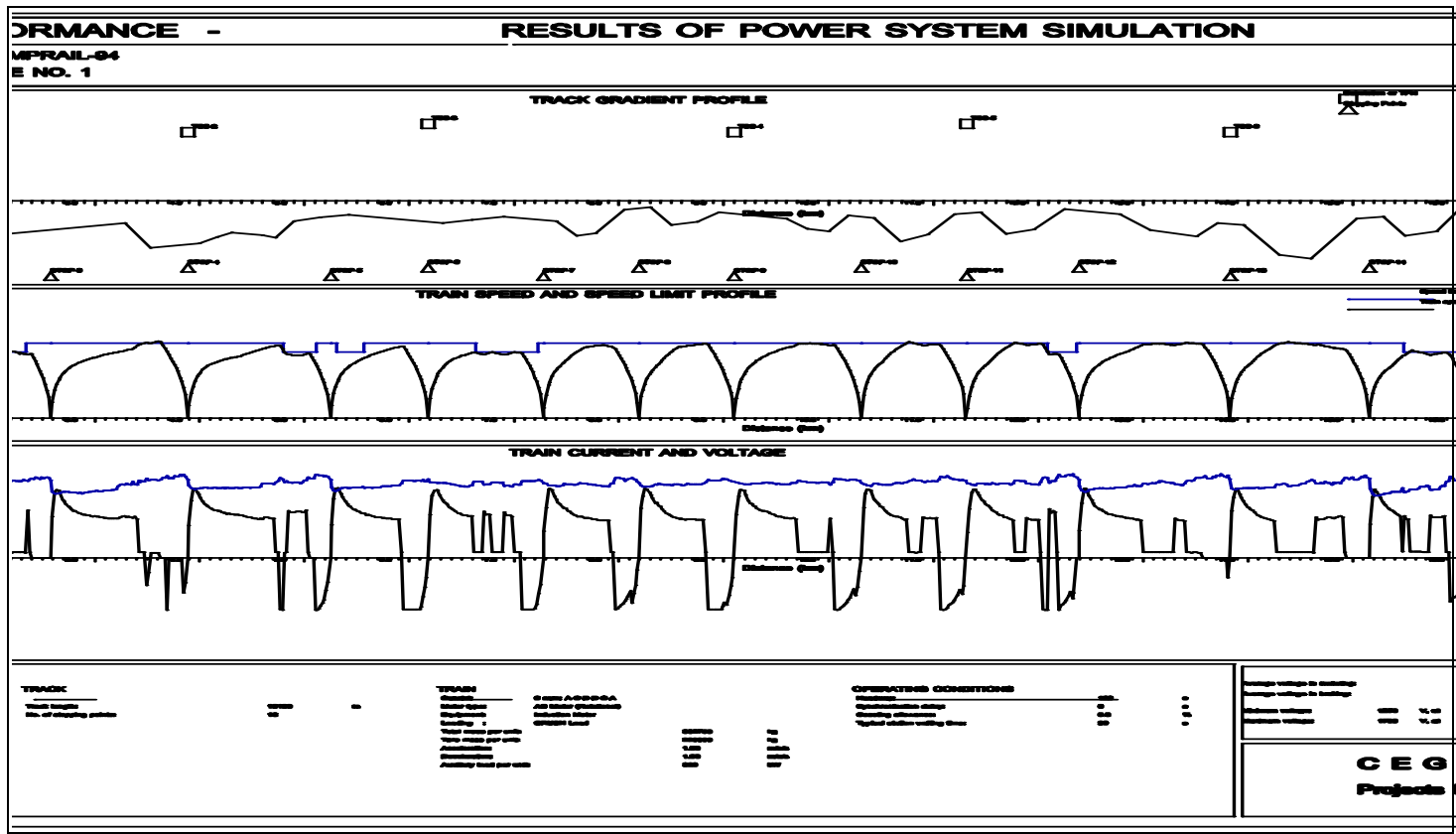


Figure 4 A typical graphical plot from simulation results