4* A To control the function point of an asynchronous motor, three different signals can be used: the stator voltage $\underline{u}_s$ in the referential rotating with magnetic axle and a frequency f_s of 3-phase system at stator. We can define a motor « frequency » f_m from its rotating speed ω_m and its number p of poles pairs (13.14). The translation speed V is proportional to ω_m by the factor k_v which includes wheel diameter and gear ratio (13.15). Rotor frequency is defined by motor frequency and stator frequency (13.16).

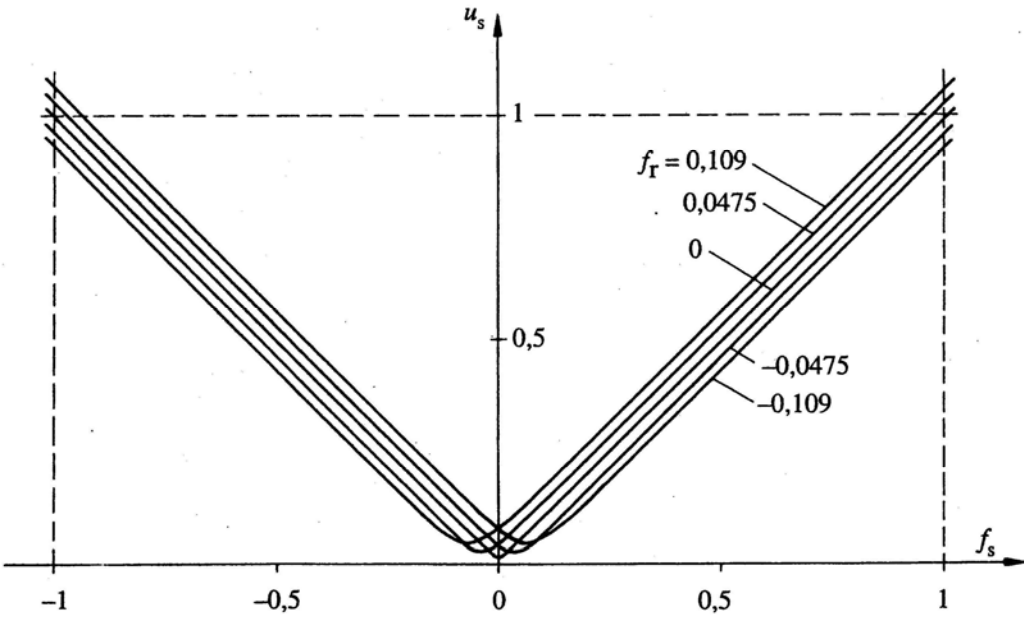
$$f_m = \frac{p}{2\pi}\omega_m \quad (13.14) \quad V = k_v \omega_m \qquad (13.15) \quad f_r = f_s - f_m \quad (13.16)$$

Near synchronism point, the force is approximately proportional to rotor frequency (fig. 5.8).

$$Z = k_z \, f_r \qquad (13.17)$$

Required precision and dynamics are not very high in this application case. So a simple control law can be chosen better as a vector control of the motor. The module of voltage vector is defined as proportional of the absolute value of the stator frequency.

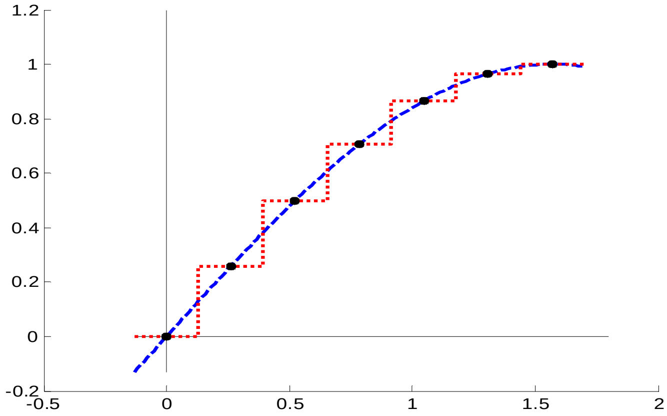
$$\left|\underline{u}_s\right| \cong k_u \left|f_s\right| \qquad (13.18)$$

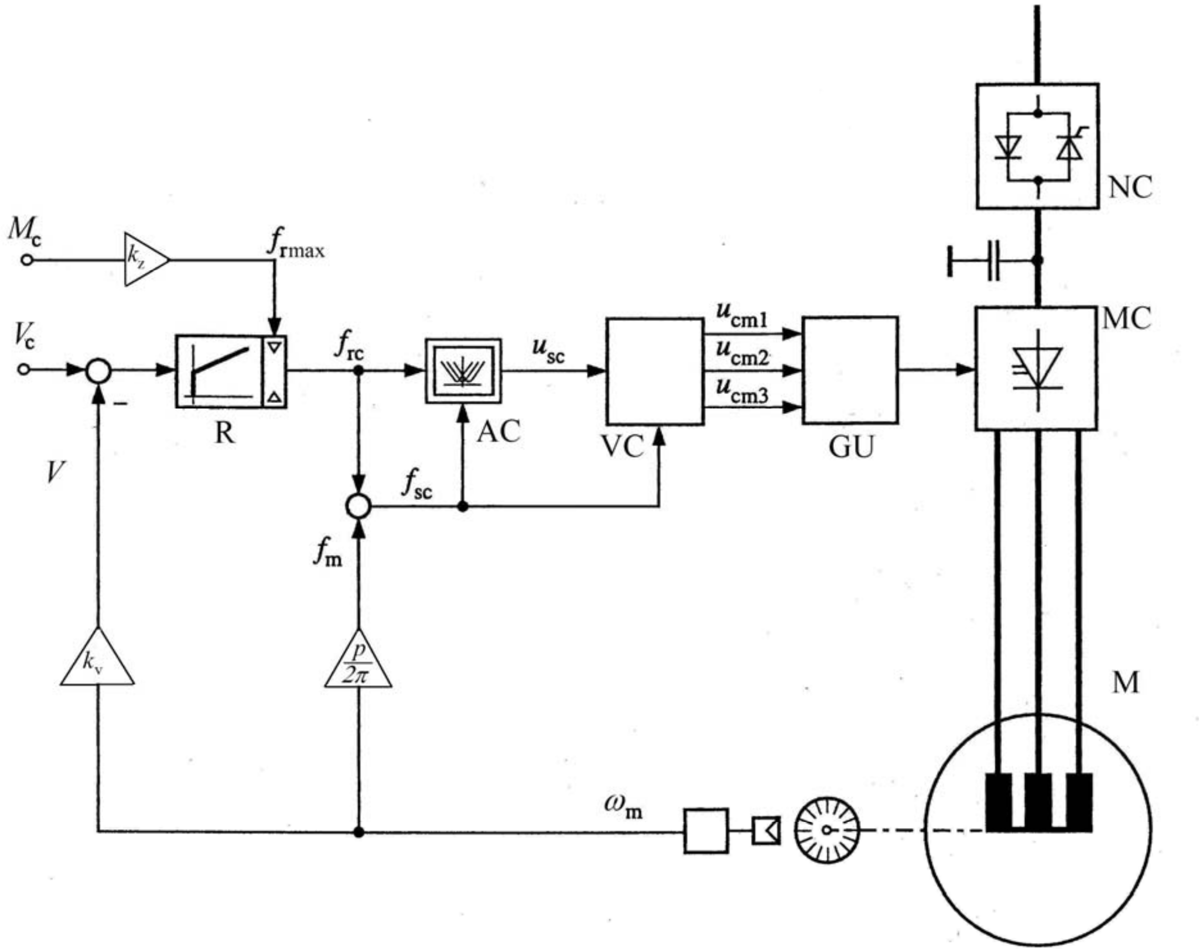


With such a control law, the control schema can now be designed from the previous equations. The main controller R (speed controller) defines the rotor frequency from the control difference. The AC-block (amplitude control) is computing the chosen control law. From the amplitude and the stator frequency, the VC-block (voltage controller) is building a model for the 3 sinus-voltages u_{cmi}. To have a simple gate unit, we can choose a chopper frequency of converter branches proportional to the fundamental frequency of the 3-phase sinus-system.

$$f_H = 24 f_s \qquad (13.19)$$

The gate unit (GU) is giving the signals to the transistor gates (or bases) from the model calculated on VC and the time intervals. The high of the steps define the duty cycle of the time interval (in this example: 6 steps pro period quarter).





The network converter NC is controlled by a controller – not represented on the figure – which holds a quite constant value at the voltage intermediate circuit.

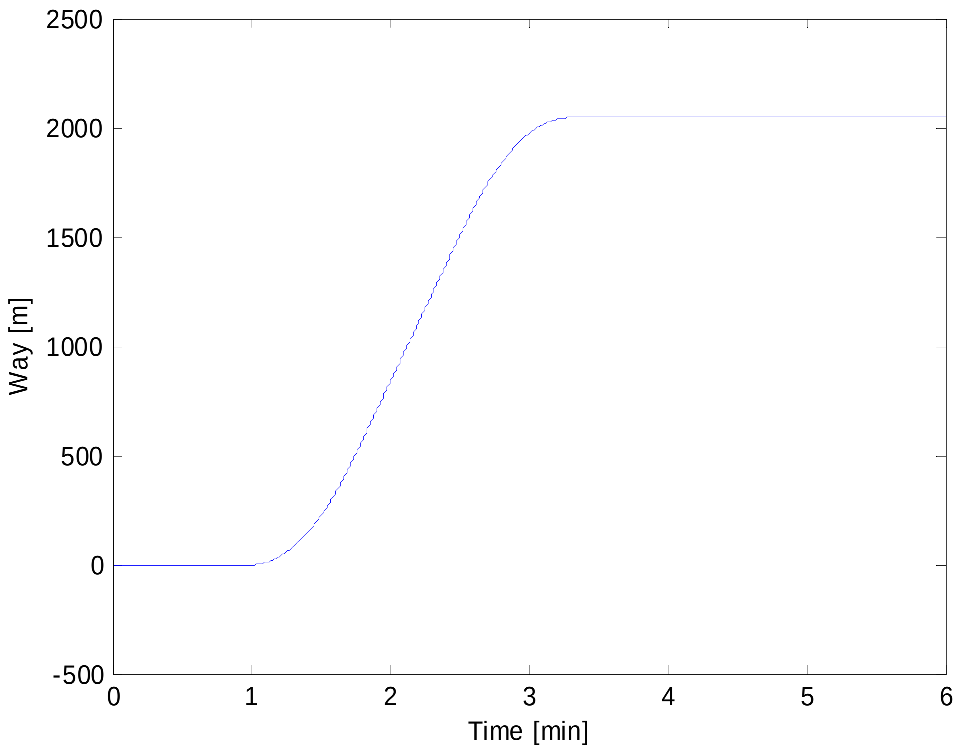
If the locomotive driver chose to control his train in force (or torque Mc), he is taking the role of a speed controller. He is acting directly on the frequency limiter.

In case of a synchronous machine, the blocs VC, GU and R are the same. In this case the force (or torque) is proportional to the angle between the magnetic axles of rotor and stator, which has to be measured. The part of schema between controller output and VC blocs input has to be adapted.

As controller, we can choose a PI (or a state-space controller). The main parameter for the controller conception is the train dynamics, in particular its weight, when the speed is stabilised. It is not good to dimension a very performing controller, because the train would always changes in “driving – braking” mode. A *dead band” has to be implemented. As consequence, a little difference between set point and real value of speed is accepted. In phase of acceleration, the system is not linear; the force limitation through the rotor frequency is active. Note that the system “train” is only linear for little speed changes.

In case of a wheel-slip, the characteristics of the system becomes very different; the inertial value is not defined by the full train weight, but only from the rotating parts (rotors, wheels, ...). The main time constant becomes 20 until 50 times lower than the studied commuter train. An anti-slip system has to be added, which acts on the force limiter.

E The counteracting forces are declivity force and frictional force. The traction force is the output of first order block mentioned in question. To know the acceleration, sum of forces has to be divided by corrected mass. The position is found by two integration of acceleration. See `Exercise13_4E.mdl`.



After one minute stop-time at Ringlikon, the end-station Uetliberg is reached after 3,5 minutes. On the time schedule, 6 minutes between stop in Ringlikon and Uetliberg are reserved: two minutes reserve remains.