Assignment Report

Free Acceleration Characteristics of Induction Machines

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1 Simulation conditions

Figure 1 shows the Simulink model of free acceleration of an induction model. To achieve full voltage starting condition, the rated voltage of the motor is applied directly as the input of machine, and the initial slip rate of the motor is set to 1, i.e. the initial speed is 0. In this model, the input torque T_m of this model is simply an inertia link with the same moment of inertia as the rotor, without any external torque, i.e. no load torque, friction or windage loss. Plus, the parameters are shown as Figure 2. The number of pole pairs is 2, and the working frequency is 60Hz.

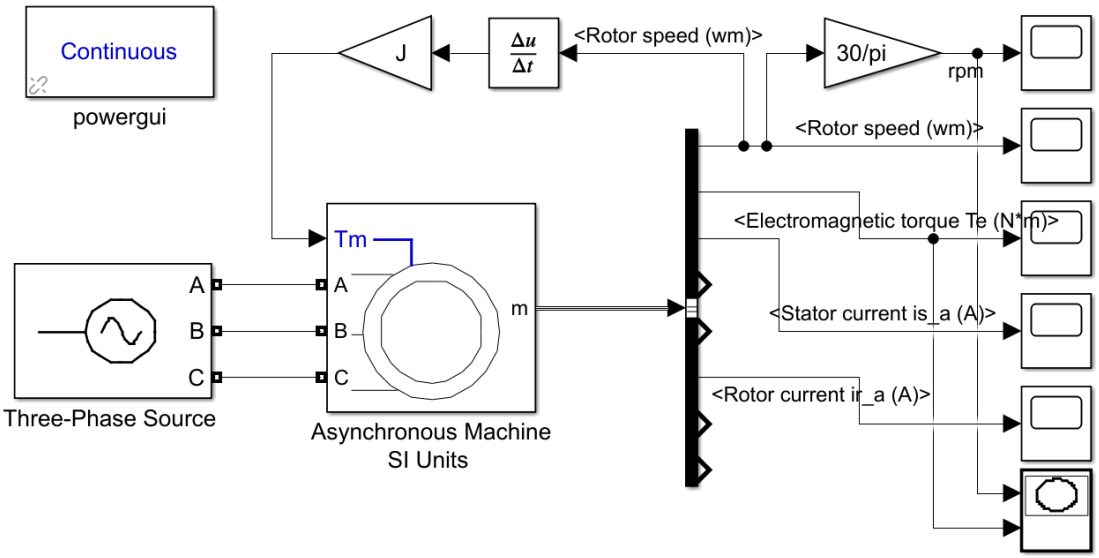

Figure 1: Simulation scheme on Simulink

Machine Rating										
hp	Volts	rpm	T_B (N · m)	$I_{B(abc)}$ (amps)	r_s (ohms)	X_{ls} (ohms)	X_M (ohms)	X'_{lr} (ohms)	r'_r (ohms)	J (kg · m^2)
3	220	1710	11.9	5.8	0.435	0.754	26.13	0.754	0.816	0.089
50	460	1705	198	46.8	0.087	0.302	13.08	0.302	0.228	1.662
500	2300	1773	1.98×10^3	93.6	0.262	1.206	54.02	1.206	0.187	11.06
2250	2300	1786	8.9×10^3	421.2	0.029	0.226	13.04	0.226	0.022	63.87

Figure 2: Parameters used in simulation

2 Simulation results and analysis

Simulation results are shown in the following series of graphs. Firstly the torque versus speed characteristics of the 4 machines are demonstrated. And for the sake of simplicity, only the transient curves of the 3-hp motor and the 2250-hp motor are shown.

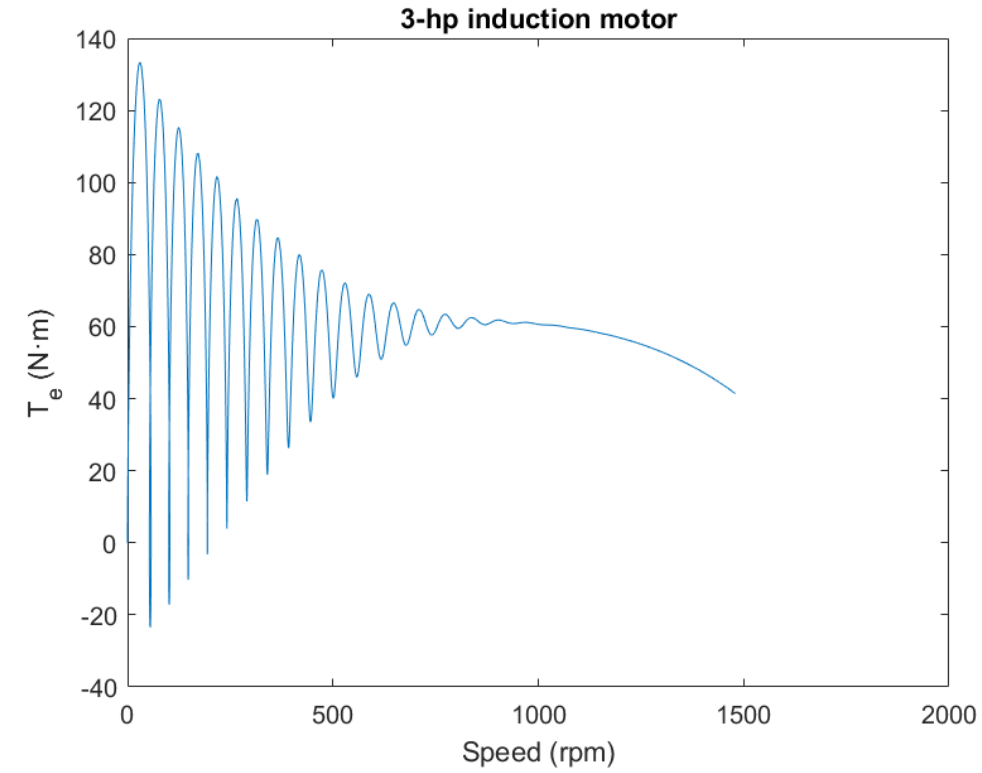

Figure 3: Torque-speed characteristics during free acceleration: 3-hp induction motor

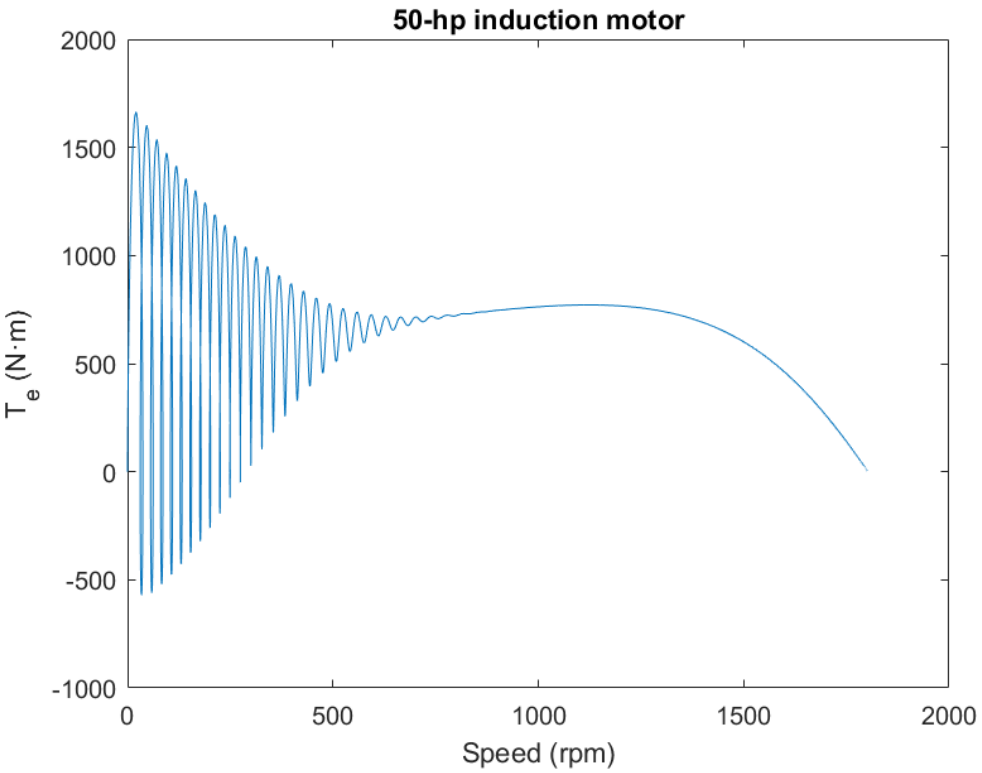

Figure 4: Torque-speed characteristics during free acceleration: 50-hp induction motor

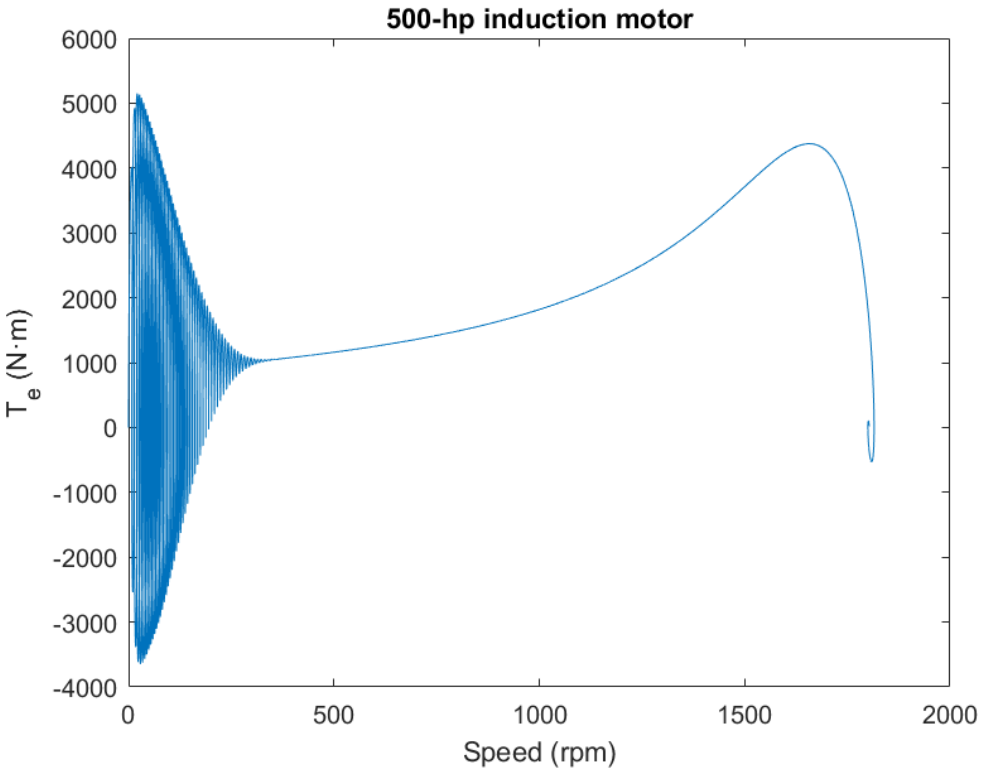

Figure 5: Torque-speed characteristics during free acceleration: 500-hp induction motor

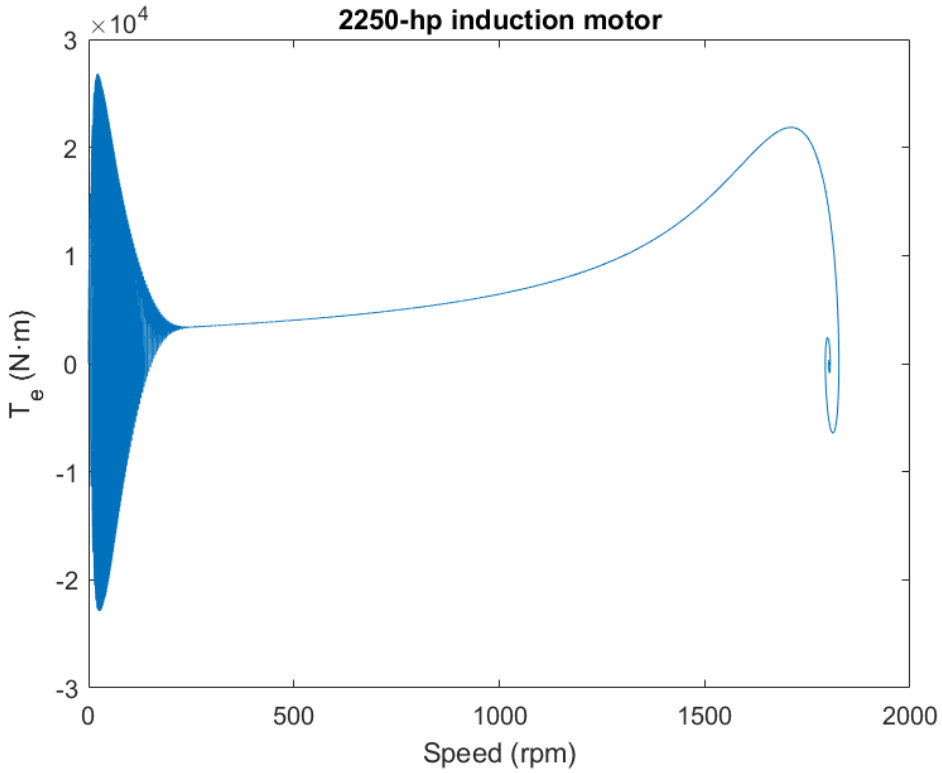

Figure 6: Torque-speed characteristics during free acceleration: 2250-hp induction motor

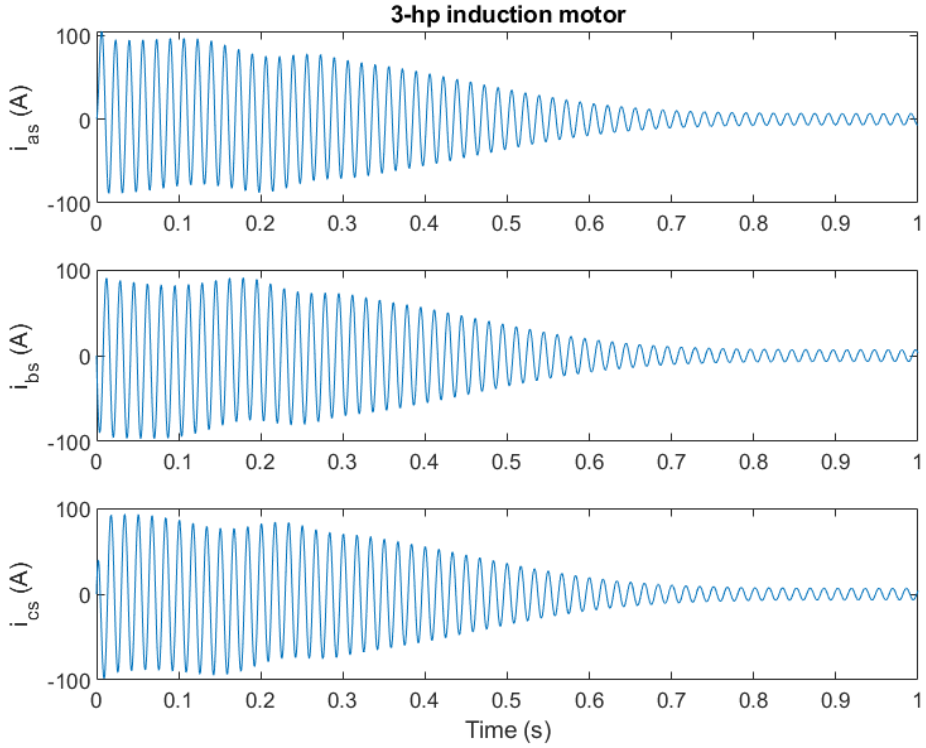

Figure 7: Stator currents during free acceleration of a 3-hp induction motor

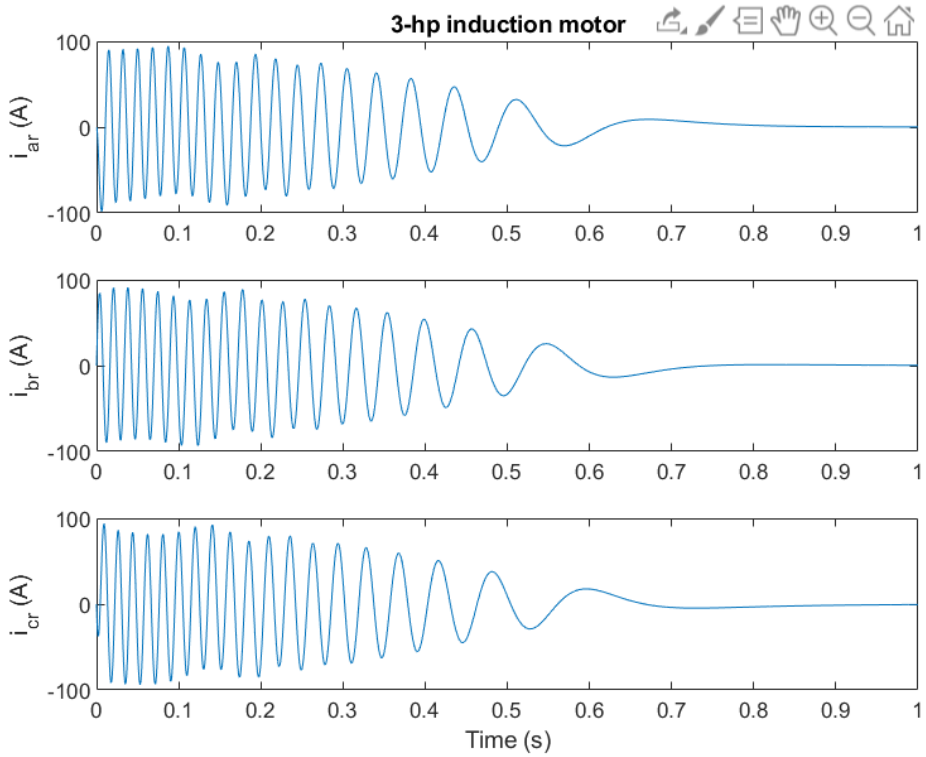

Figure 8: Rotor currents during free acceleration of a 3-hp induction motor

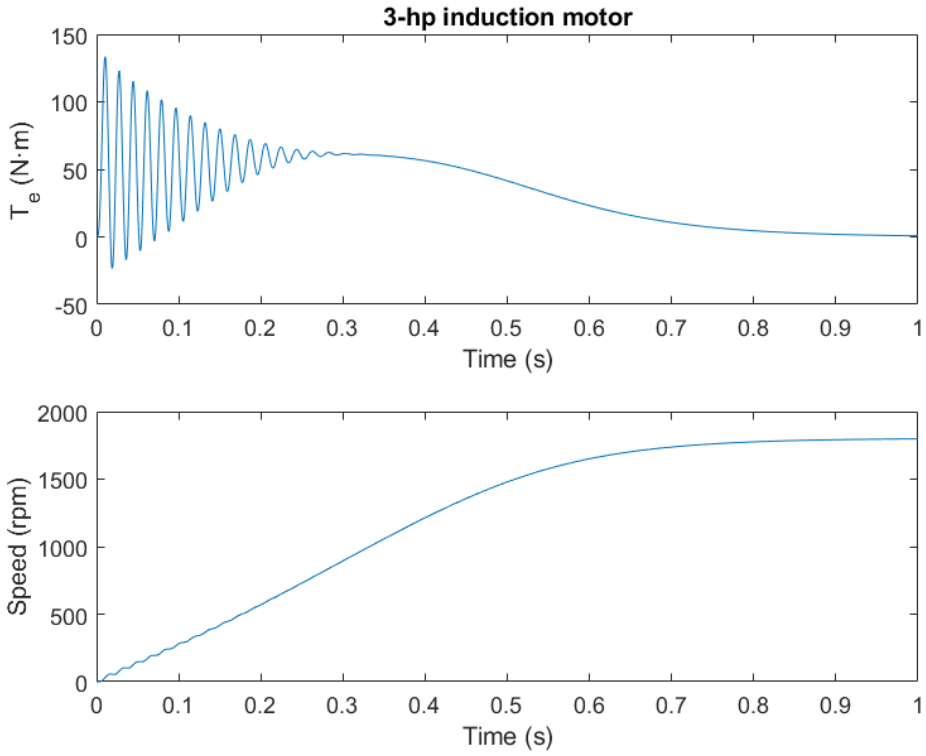

Figure 9: Rotor performance during free acceleration of a 3-hp induction motor

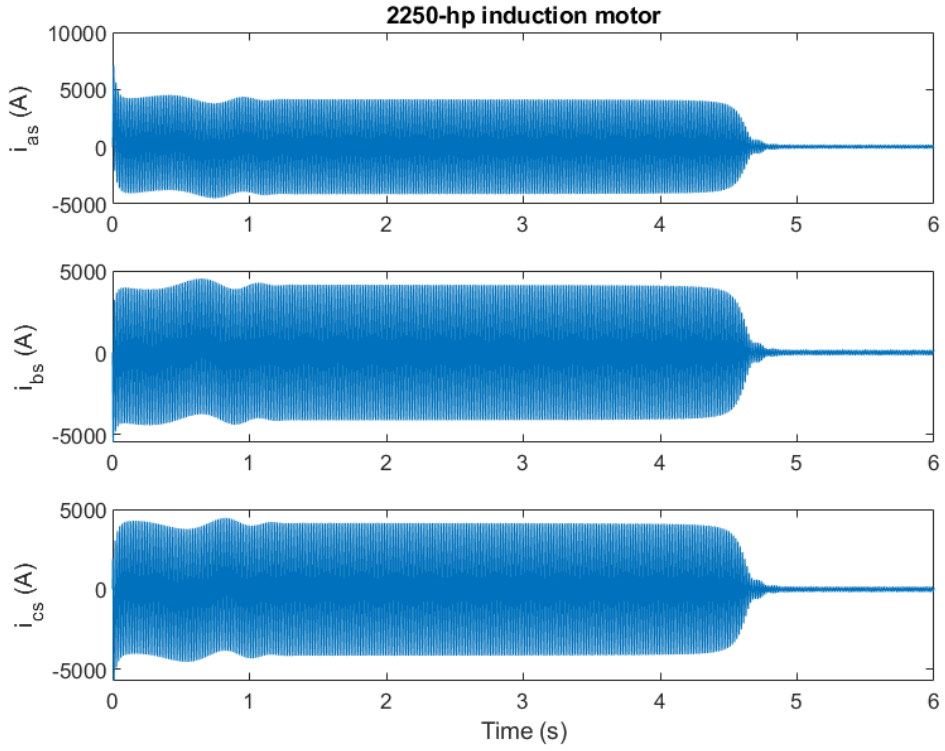

Figure 10: Stator currents during free acceleration of a 2250-hp induction motor

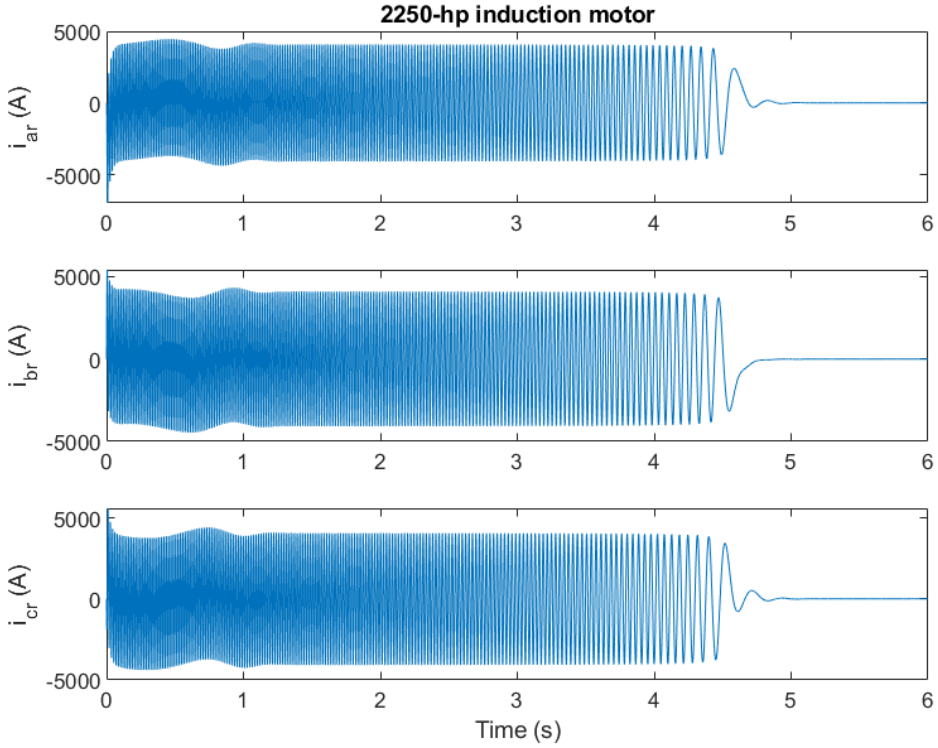

Figure 11: Rotor currents during free acceleration of a 2250-hp induction motor

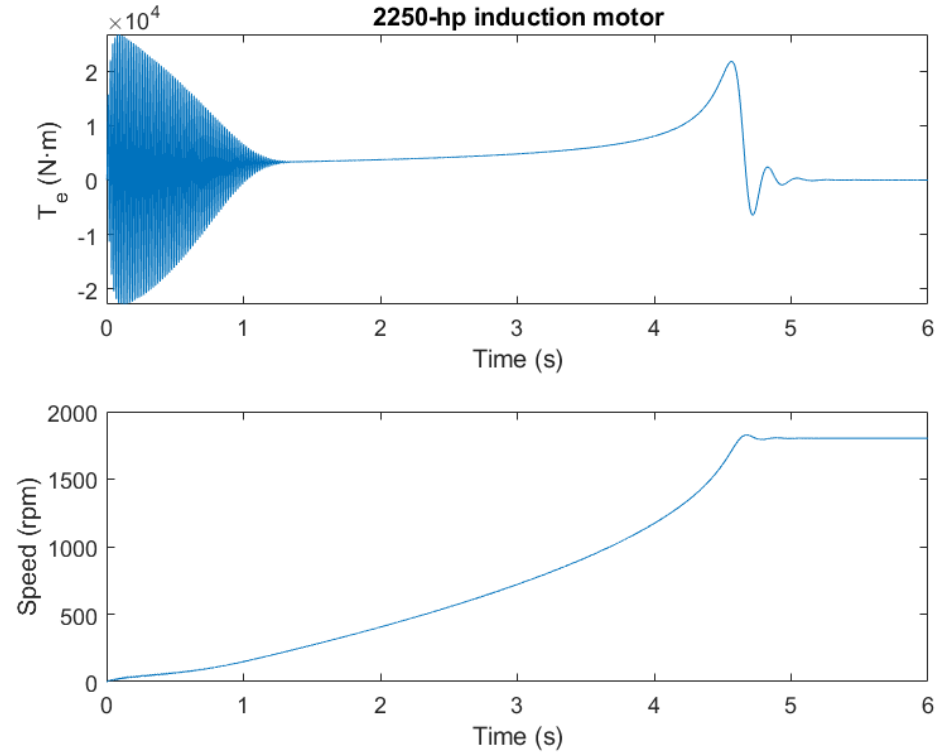

Figure 12: Rotor performance during free acceleration of a 2250-hp induction motor

As can be seen from the simulation results graphs above, the rotor current are particularly large at starting, exceeding the rated value by a factor of 10. This is because at startup the rotor speed is 0 and thus the stator field cuts the rotor windings at maximum speed, i.e. synchronous speed. The rotor coil is exited with a large BMF to counteract the effect of the stator flux; at the same time, the current in the stator coil increases to counteract the induced current in the rotor coil.

It is also observed that the amplitude of the electromagnetic torque is also large at startup, which is caused by the fact that this torque is proportional to the motor current. The oscillations of this torque reflect the interaction of electric transients between the stator and rotor. However, the torque always oscillates around a certain positive value to achieve acceleration of the rotor.

In the process of rotor acceleration, the oscillations of the currents in stator and rotor and torque decay till they reach steady state. This is because as the rotor speed increases, the speed of stator magnetic field cutting rotor winding decreases, BMF, current and torque also decrease accordingly. Also, from the energy point of view, the input power is continuously supplied to this electromagnetical system in a fixed frequency and voltage, and part of the electromagnetic is continuously converted into mechanical energy, i.e. kinetic energy. This decrease of electromagnetic power is reflected in the decrease of the current amplitude.

Since friction and windage losses are neglected, the machines accelerate to synchronous speed and electromagnetic torques converge to 0. It is also observed that for 2250-hp machine there is a certain overshoot before the rotor speed reaches the steady state, which is reflected as a loop at the end of the torque-speed characteristics curve of the motor. This phenomenon is explained in the reference book: it is a typical feature of high-horsepower machines because of the high ratio of leakage reactance to resistance of the rotor.

Finally, for machines with higher hp, they have more violent oscillation during free acceleration, and also need more time to reach steady state. This is mainly due to a larger moment of inertia.