



Fig. 4: Speed tracking response for reference under different values of K1, K2 and K3

5.3 Discussion of the Results

The figure 1 shows the results of the simulation of the speed control by backstepping, in figure 1(a) the curves show that during the no-load start-up, the quantities stabilise after a response time of 0.02 sec, the rotation speed is the reference speed without any overshoot. Also in The figure 1(b) shows the results of the simulation with a change of set point and a speed reversal, we notice that this control presents very satisfactory results with good tracking dynamics and a relatively acceptable rejection of the disturbance. On the other hand, we notice that the speed is established at its nominal value with good dynamics and without static error, at the moment when the load torque is applied, the speed is reduced but it is re-established again without static error.

The figure 2 shows the behaviour of load torque and electromagnetic torque. The latter oscillates during power-up reaching a maximum value and disappears once the steady state is reached. When the load is applied, the electromagnetic torque increases so as to instantly compensate the load torque with some additional ripples in the electromagnetic torque.

The figure 3 shows the characteristics of the stator currents i_d and i_q at start-up the machine draws a large current afterwards we notice a decrease as the machine has the normal operating regime. The stator current components i_d and i_q show the decoupling introduced by the PMSM Backstepping control ($i_d = 0$). The electromagnetic torque follows well the current i_q as shown in figure 2(b) and figure 3(b) with a peak related to the start-up, which is reached in the steady state, which shows the objective of the Backstepping control the

stabilization of PMSM operation with presence of disturbances.

In order to test the robustness against parametric variations, the simulation results of the dynamic behaviour are presented as shown in Figure 4 for different values of K1, K2 and K3. The table 2 below gives the minimum, maximum and optimum values of K1, K2 and K3, it can be seen that the variation of these parameters influence the dynamics of the velocity ordered by Backstepping. This is mainly due to the recursive nature of the latter, which makes it possible to this is mainly due to the recursive nature of the latter, which allows the global system to be considered in cascaded subsystems, to guarantee the stabilisation of the measurements.

Table 2. The minimum, maximum and optimum values of K1, K2 and K3 .

minimum value	optimum value	maximum value
K1=300	K1=1000	K1=2000
K2=300	K2=1000	K2=2000
K3=20	K3=100	K3=300

6 Conclusions

The permanent magnet synchronous motor PMSM is an electric actuator of great industrial interest, due to its compactness, low inertia, efficiency, robustness and high power density, but its non-linear structure makes its control more complex, which led us to use the non-linear control model that can provide good performance. Thus, the work presented in this paper is essentially a contribution to the backstepping control. The results of the simulation show that the backstepping controller was successfully designed a good response of the PMSM, in pursuit the response time is low and a high control performance regarding the rapidity, the stability and robustness in relation to applied loads and parametric variations vis-à-vis. this way, she presents very satisfactory results with a good tracking dynamics as well as a good rejection of the disturbance. On the other hand, we notice a very good dynamics when applying the load torque.

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