Study and Sliding Mode Control of the Permanent Magnet Synchronous Machine

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Abstract*—The PMSG permanent magnet synchronous machine is increasingly used in the industrial field thanks to its superior performance compared to other types of machines. this paper deals with the PMSG control. The modeling of the machine, the inverter and the PWM pulse width modulation control will be studied. In a first part we treat the vector command using PI regulator. In this part is interested in the design of a new nonlinear speed control. The proposed control is designed using a Backstepping control technique supplemented by the introduction of integral actions to improve its robustness. Using Lyapunov's stability theory, we show that trajectory tracking dynamics are asymptotically stable. Finally, a conclusion summarizes the main results obtained.

***Keywords*—control, modelling, vector, slaiding, PMSG**

I. Introduction

In the field of variable speed, the synchronous machine with permanent magnets currently ensures a very large and ever increasing share of the market thanks to its simplicity, its robustness and its low manufacturing cost. Despite all these advantages, its control remains one of the most complex compared to that of the DC machine, because its mathematical model is non-linear and strongly coupled, which is the opposite of its structural simplicity. However, over the past thirty years, rather laborious controls have been developed to enable decoupled control of the permanent magnet synchronous machine by the use of appropriate markers. They are called vector controls, which provide dynamic performance equivalent to that obtained by the DC machine.

In this work we have discussed the PMSG modeling and the simulation results in both cases (engine, generator). the vector control allows to have a dynamic close to that of the DC machine, in other words, an asymptotically linear and decoupled dynamic. However, this control structure requires that the parameters of the machine are precise. This requires a good identification of parameters. Consequently, the use of robust control algorithms, to maintain an acceptable level of decoupling and performance, is necessary.

And here we have adopted the technique of sliding mode variable structure control (CSV), Application of sliding mode control to the permanent magnet synchronous machine, three-surface adjustment strategy, Advantages and disadvantages of sliding mode control and after the simulation result and finally the comparison between vector control and sliding mode control [1, 2].

II. Vector Control of the PMSG

A. Principle of Vector Control

First, the purpose of the control is necessary. It depends on the two variables : (torque, speed or position control). The main objective of the vector control of the PMSG is to control the torque optimally according to a selected criterion. Given the importance of thermal stress in electrical machines, the criterion chosen often corresponds to the minimisation of Joule losses at given torque. But this criterion calls for the solution of an optimization problem that requires simultaneous control of I_d ; I_q . To simplify control, the current is often set so that the torque is proportional to I_q within a given speed range.

In smooth-rotor machines, where torque depends only on the quadrature component of the current, the optimum value of the current *Id* is obvious. The vector control technique is used to establish a linear model and to transform the magnet synchronous machine into a structure equivalent to the torque-separated excitation DC machine, to allow a decoupling of the torque and flow [7], [8].

B. Summary of Regulators

The purpose of regulation or control is to ensure the best robustness with regard to external disturbances and parameter variations. For MSAP, the oriented field method decouples the interactions between the two axes. Thus the expression of the torque shows that its variation can be obtained by cancelling the current in the axis d and by varying the component in quadrature. This decoupling allowed us to study separately a current and speed control loop. The role of a regulator is to maintain an output quantity equal to its imposed reference quantity despite the presence of internal or external disturbances. Among the performance criteria of the regulators, there are essentially: [9]

- Static and dynamic accuracy,
- Rapid response time,
- Process limitation (maximum permissible current).

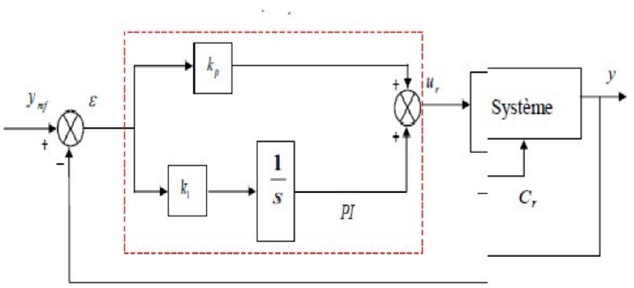

Fig. 1. Example of a Regulator model

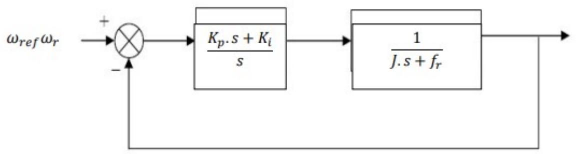

Fig. 2. Block diagram of speed control

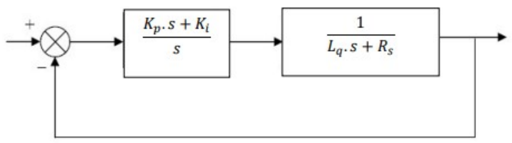

Fig. 3. Block diagram of the current regulation

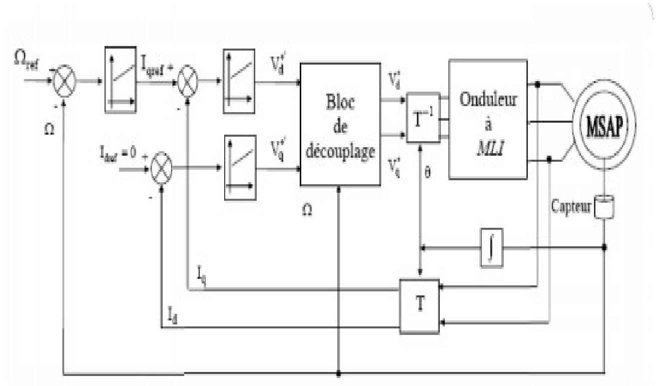

Fig. 4. Vector control of the machine PMSG

III. SLIDING MODE CONTROL

The sliding mode variable structure (CSM) control technique is well-known for its robustness towards internal uncertainties (variations in machine parameters), and external uncertainties (disturbances due to load), and to phenomena omitted in the modelling, while having a very good dynamic response [10, 11].

A variable structure system (SSV) is a system whose structure changes during operation. It is characterized by the choice of a function and a switching logic [12].

In systems with variable structures with sliding mode, the state trajectory is brought to a surface (hyperplane), then by means of the switching law, it is obliged to remain in the vicinity of this surface. In general, system dynamics can follow several surfaces.

The trajectory in the phase plane consists of three distinct parts [11, 15, 17]

The convergence mode (MC)

The sliding mode (MG):

The permanent mode (MRP

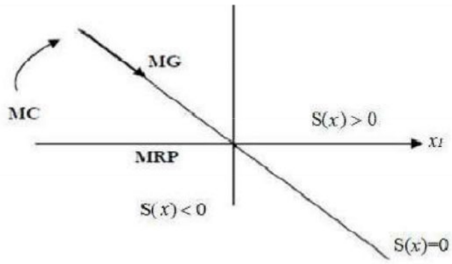

Fig. 5. Different modes for the trajectory in the phase plane

Adjusting the speed of the PMSG requires the control of the current absorbed by the machine. A classic solution is to use the principle of the cascading adjustment method (structure of three surfaces) the internal loop allows to control the currents, while the external loop allows to control the speed. shows the MSAP Cascade Mode Slip Speed Control structure powered by a voltage inverter [19, 20].

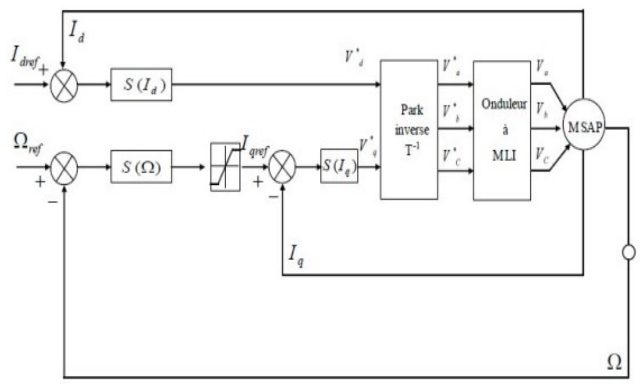

Fig. 6. Overall Sliding Mode Adjustment, Three-Surface Strategy

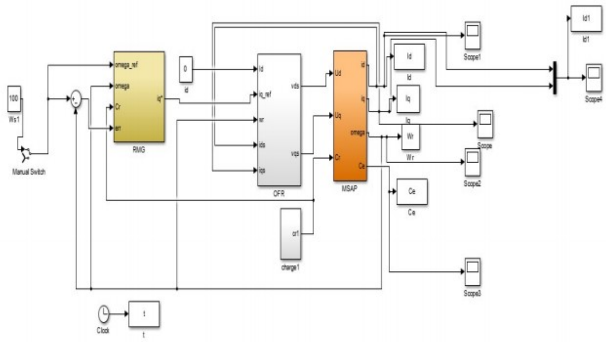

Fig. 7. Slide Mode Controlled MSAP Block Diagram

A. Results of simulation

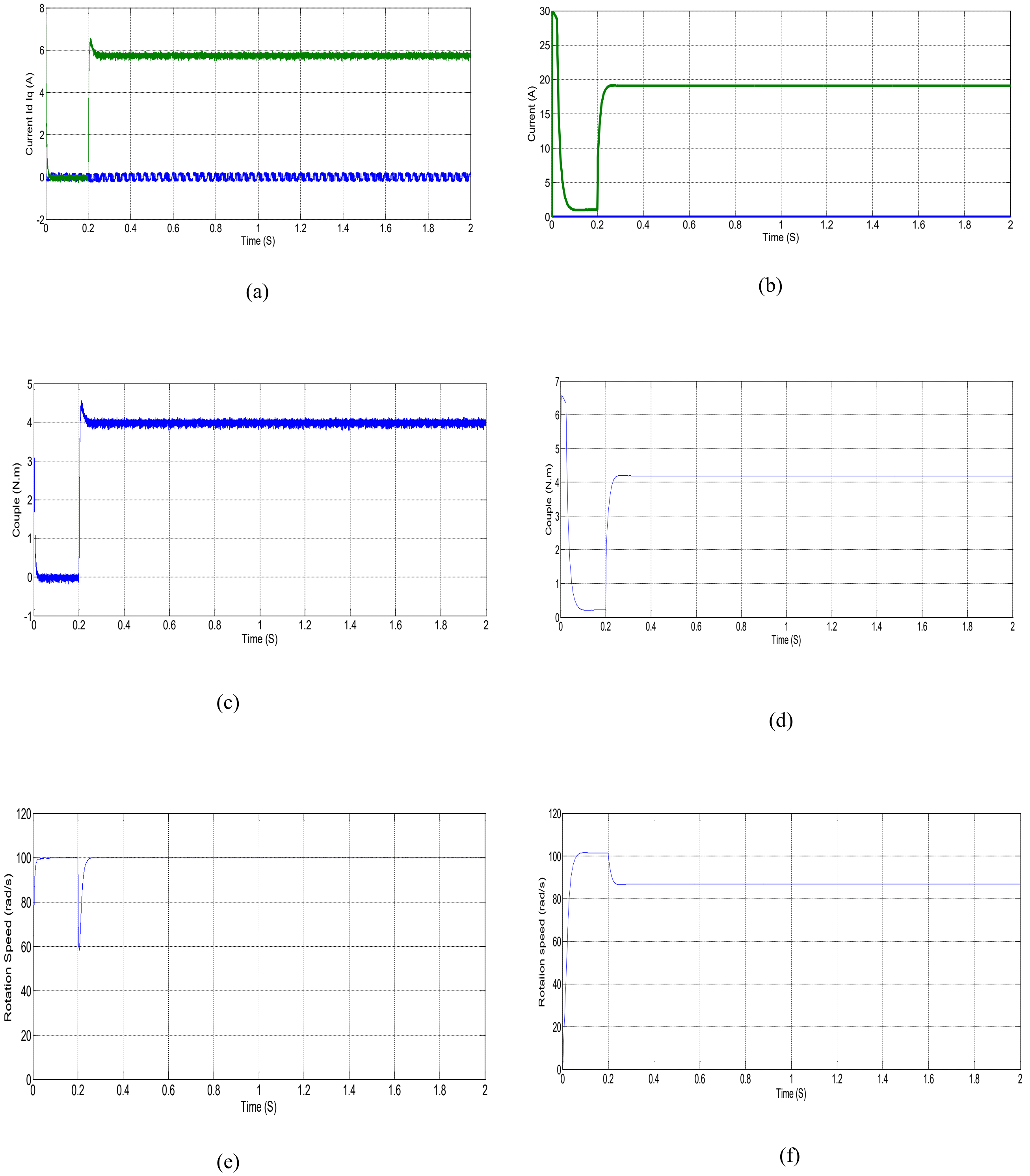

Fig. 8. Comparative simulation between vector control and control by sliding mode:

(a) Current Id Iq (A) with vector control (b) Current Id Iq (A) with sliding mode control;
(c) Couple (N.m) with vector control (d) Couple (N.m) with sliding mode control;
(e) Rotation speed (rad/s) with vector control (f) Rotation speed (rad/s)with sliding mode control;

B. Interpretation

The simulation results show in figure 8 that at the moment of application of the load the speed is subject to a subsequently rejected decrease in the case of the vector control, whereas in the sliding mode control the speed is not subject to any fall, It is also noted that the electromagnetic torque is strongly undulated in the case of the sliding mode control. So we can say that the command by sliding mode rejects the disturbance completely but has the disadvantage of creating the undulations at the level of the torque.

IV. CONCLUSION

In this work we studied Vector control of the PMSG associated with PI controllers. Training simulation results are generally acceptable. They show the performance of the vector command: the disturbance is rejected in a very short time, the response is fast and the overrun is negligible. However, the major drawback of this control technique can be seen in the parametric variations of the machine. robust control linked to systems with variable structures, the purpose of which is to overcome the disadvantages of conventional controls, since control with variable structures is by nature a non-linear control and their control law is modified discontinuously.

The advantage of this control technique is the simplicity of implementation and the robustness compared to the disturbances and uncertainties of the system. However the main disadvantage of the sliding mode setting is the existence of a discontinuous control law producing the Chattering effect. Finally, it can be concluded that the control by sliding mode shows good performance in speed monitoring and regulation (speed of response without exceeding, without static error and a rejection of instantaneous disturbance).

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