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Summary of PhD Thesis

Contributions to the Study of the Stability of Sensorless Vector-controlled Systems with Induction Motor

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CONTENTS

INTRODUCTION ........................................................................................................... 4

CHAPTER I. NON-LINEAR SYSTEMS STABILITY

1.1. The concept of stability of the continuous systems ............................................. 7
  1.1.1. Internal stability of the continuous systems ............................................. 7
  1.1.2. External stability of the continuous systems ............................................. 17
1.2. The concept of stability of the discrete systems .............................................. 20
  1.2.1. Internal stability of the discrete systems .............................................. 21
  1.2.2. Analysis techniques of the external stability ............................................ 24

CHAPTER II. THE STABILITY STUDY OF THE CONTROL SYSTEM OF THE
INDUCTION MOTOR WHICH INCLUDES IN THE LOOP A
ROTORIC FLUX’S CALCULATION BLOCK BASED ON THE
DIRECT MEASUREMENT OF THE FLUX IN THE GAP

2.1. The mathematic modelling of the speed control system ................................... 27
2.2. The controllers’ tuning within the speed control system .................................. 35
  2.2.1. The controllers’ tuning using the poles-zeroes method and the symmetry and
          the module criteria ........................................................................................... 37
2.3. The study of the stability of the control system— the continuous case .......... 39
2.4. The study of the stability of the control system— the discrete case .............. 46
2.5. Conclusions ........................................................................................................ 57

CHAPTER III THE STABILITY STUDY OF THE CONTROL SYSTEM OF THE
INDUCTION MOTOR’S SPEED WHICH INCLUDES IN THE LOOP
AN EXTENDED LUENBERGER OBSERVER

3.1. The mathematic modelling of the speed control system ................................ 58
3.2. The controllers’ tuning within the speed control system ................................. 68
3.3. The study of the stability of the control system— the continuous case .......... 78
3.4. The study of the stability of the control system— the discrete case .............. 83
3.5. Conclusions ........................................................................................................ 95

CHAPTER IV. THE STABILITY STUDY OF THE CONTROL SYSTEM OF THE
INDUCTION MOTOR’S SPEED WHICH INCLUDES IN THE LOOP
A MRAS TYPE ESTIMATOR

4.1. The mathematic modelling of the speed control system ................................ 97
4.2. The controllers’ tuning within the speed control system ................................. 104
4.3. The study of the stability of the control system— the continuous case .......... 106
4.4. The study of the stability of the control system— the discrete case .............. 113
4.5. Conclusions ........................................................................................................ 119

CHAPTER V. THE STABILITY STUDY OF THE CONTROL SYSTEM OF THE
INDUCTION MOTOR’S SPEED WHICH INCLUDES IN THE LOOP
AN EXTENDED GOPINATH OBSERVER

5.1. The mathematic modelling of the speed control system ................................ 121
5.2 The controllers’ tuning within the speed control system .................................. 127
5.3. The study of the stability of the control system— the continuous case ........... 130
5.4. The study of the stability of the control system— the discrete case .............. 132
5.5. Conclusions ........................................................................................................ 136
CHAPTER VI. THE ANALYSIS OF THE DYNAMIC PERFORMANCES OF THE SENSORLESS CONTROL SYSTEMS

6.1. Load and idling functioning at medium speed without measurement noise ............... 139
6.2. Load and idling functioning at low speed without measurement noise .................. 150
6.3. Load and idling functioning at medium speed in the variation conditions of the rotoric resistance and the omission of the measurement noise ........................................ 158
6.4. Load and idling functioning at low speed in the variation conditions of the rotoric resistance and the omission of the measurement noise ........................................ 169
6.5. Comparative analysis of the sensorless control systems ........................................ 177
6.6. Conclusions ................................................................................................................... 184

CHAPTER VII. RESEARCH CONCEARNING THE DESIGN OF A NEW CONTROL SYSTEM OF THE DIESEL FUEL FEED ON THE TRANSPORT TRUNK PIPE-LINE USING THE INDUCTION MOTOR'S SENSORLESS SPEED CONTROL SYSTEM, WHICH CONTAINS IN THE LOOP AN EXTENDED GOPINATH OBSERVER

7.1. The fluid flow’s control system on the trunk pipe-lines ........................................... 185
7.2. The mathematic model of the trunk pipe-line .......................................................... 186
7.3. The mathematic model of the centrifugal pump ...................................................... 189
7.4. The flow controller’s tuning ...................................................................................... 196
7.5. The flow controller’s simulation ............................................................................... 198
7.6. Conclusions ................................................................................................................... 207

FINAL CONCLUSIONS, CONTRIBUTIONS AND PROPOSALS ........................................ 208

BIBLIOGRAPHY .................................................................................................................... 217

ANNEX 1 ............................................................................................................................... 226
ANNEX 2 ............................................................................................................................... 227
ANNEX 3 ............................................................................................................................... 229
ANNEX 4 ................................................................................................................................... 234
The direct control systems by the rotoric flux, sensorless type, of the induction motors’s speed; assume the rotoric speed estimation as well as the module and the rotoric flux position estimation. In case the excitation frequency becomes zero the rotoric speed can not be estimated [75]. On the other hand, at very low running speeds the electrical parameters of the induction motor modify with the increase of the temperature. This, in case that the electrical parameters of the motor are not online identified, together with the fact that at excitation frequency close to zero, the rotoric speed is very hard to estimate, makes that the sensorless control systems to have very weak performances at very low speeds. The main problems appear due to the instability of the control systems at very low speeds, when the induction machine is either in motor running, or in generator running – recovering brake. Nowadays, there are only a few strategies of improving the performances of the sensorless control systems, at very low speeds. [64], [66], [67], [108], [122], [147], [148], [155]. For this particular reason, one of the thesis’ objectives, is that of identifying the most suitable strategies of improving the dynamic performances of the sensorless control systems Load and idling functioning at medium speed without measurement noise, at very low and medium speeds. One of the criteria on what this evaluation is realised is the control systems’ stability at very low and medium speeds. Considering that these control systems are described by a non-linear mathematic model, the stability study should be made based on the non-linear systems’ theory.

As we know, vectorial electric drive systems of the induction motors are non-linear systems, their stability analysis must be done with instruments specific to these systems’ types. For this reason, chapter one is based on the main stability study methods of the non-linear systems, highlighting the most used analysis criteria of the equilibrium points’s stability of these systems.

For a very correct comparative evaluation of the dynamic performances of the sensorless control systems, withion the chapter two is shown the speed control system with the direct measurement of the flux in the gap. The control system shown, is one with direct orientation by the rotoric flux which is based on the speed and the magnetising flux measurement of the induction motor with the short-circuitated rotor. Still in this chapter we present the analytic formula of the controllers’ tunning within the speed control block [123]. These controllers’ tunning is based on the poles-zeroes method and on the module and symetry criteria [8], [9], [11], [13], [16], [22]. These strategies of tunning the controllers within the induction motors’ speed control systems, are based on the research made in this area by Harnefors and R.D.Lorenz in tunning the current controllers [53], [68], as well as on the research made by Briz in tunning the flux controller [54]. In the end of this chapter we realise the study of the equilibrium points’ stability of the control system as well as the determination of the variation field of the identified rotoric resistance, for which the equilibrium points remain asymptoticly stable. This study, aims to highlight the instability of the equilibrium points of the control system, when the rotoric resistance is modified, due to the increase of the temperature. The study of the stability of the equilibrium points as well as the determination of the parametric field of stability, is made both in the continuous case as well as in the discrete case. The discrete case is obtained after the discretisation of the mathematical model of the control system through the Euler method [11], [13], [29], [30].

Taking into acount the aim of this thesis, within chapter three we present the study of the stability of the equilibrium points of the sensorless speed control system, which contains in the loop an extended Luenberger observer. The Luenberger matrix’ coefficients are chosen based on the algorithm proposed by H. Kubota [83], [84], algorithm based on the proportionality between the eigenvalues of the matrix which defines the Luenberger observer and the eigenvalues of the matrix which defines the stator currents- rotor fluxes mathematic model of the induction motor. Likewise, within this chapter we propose a new strategy of choosing the proportionality coefficient between the eigenvalues of the motor and the eigenvalues of the Luenberger observer in order to stabilise the control system at very low speeds, when the induction machine is functioning in motor or generator- recovering brake running. The idea from
which we started in designing the proportionality coefficient is that within the Y. Tamura and H. Kubota’s work[148], where they propose a stabilisation solution of the extended Luenberger observer and implicit of the control system, based on an algorithm derived from the estimator’s stability study based on the Ruth Hurwitz criteria considering the controller within the speed adjusting mechanism, a PI- non- adaptive type. The novelty of the stabilisation’s strategy, presented in this thesis, of the control system at very low speeds, is based on the fact that the controller within the speed adjusting mechanism is a PI-adaptive type. The adjustment is made depending on the proportionality coefficient between the eigenvalues of the motor and the eigenvalues of the Luenberger observer. For this reason, the algorithm of choosing the proportionality coefficient between the eigenvalues of the Luenberger observer and the eigenvalues of the motor, is more complex than the one proposed by H. Kubota in his work [148]. The algorithm ensures, at least theoretically, the system’ stability at an imposed speed equal to zero. In the end of this chapter, we determine the variation field of the identified rotoric resistance for which the equilibrium points of the control system remain asymptotically stable. The study of the stability of the equilibrium points as well as the determination of the parametric stability field, is made both for the non-linear-discrete system, obtained through the Tustin method discretisation [11], [13], [29], [30].

Within chapter four we present the study of the stability of the equilibrium points of the sensorless control system which contains in the loop a MRAS observer (Model Reference Adaptive System). The MRAS observer studied in this chapter, is the one proposed by C. Schauder in his work [128]. Within this chapter we present in details the way of tuning the controllers within the control block and the adaptive mechanism, highlighting the importance of the time constant of the “low -pass” filter in the stability of the control system at low and medium speed. In the end of the chapter, we realise the study of the stability of the equilibrium points as well as the determination of the parametric stability field of the system, both for the non-linear-continuous system and for the non-linear-discrete system, obtained by discretisation through the Euler method.

Chapter five presents a new control system, sensorless type, of the speed of an induction motor with the short-circuitated rotor. The novelty of this control system is given by the extended Gopinath observer [61], [121], [126], [142], [143], [145]. The design of the extended Gopinath observer is made based on the Lyapunov terminology, it could be made based on the hiperstability theory of V.M. Popov [37] too, this synthesis being presented in details in the [61], [121], [142], [145] works. The idea that underlies the design of the new observer type was the generalisation of the classical Gopinath observer proposed by B. Gopinath [65] and T. Pană in the book [34]. In the end of the chapter we realise the study of the stability of the equilibrium points of the control system which contains in the loop an extended Gopinath observer. The analysis of the stability throughout the thesis is made based on the Lyapunov’s linearisation theorem [45], around the equilibrium points of the non-linear control system. Still here, the variation field of the identified rotoric resistance, for which the equilibrium points of the non-linear system remain asymptotically stable, are determined both for the non-linear-continuous system and for the non-linear-discrete system, obtained after the discretisation through the Euler method [11], [13], [29], [30].

In chapter six we test, by simulation, the dynamic performances of the direct vectorial control systems, presented in details within the previous chapters. All the tests are realised considering an ideal voltage inverter, and the controllers’ coefficients within the the control schemes are calculated based on the relations presented in details in the previous chapters. Within the analysis in time field we determine the overshoot and the transitory process’ period. In the end of this chapter, based on the simulated results and on the stability tests realised in the other chapters, we shall draw comparative conclusions concerning the dynamic performances of the three control systems, highlighting the most suitable sensorless control systems for applications that need low reference speed.
Chapter seven proposes an application of the sensorless control system of the induction motor, which contains in the loop an extended Gopinath observer, in the revolution’s control of a centrifugal pump within the diesel fuel feed control on a transport trunk pipe-line [145]. Likewise, we realise the modelling and the simulation of the flow control system, highlighting the way of tuning the flow controller as well as the dynamic performances of the flow control system.

The thesis is finalised with a general conclusions chapter in which there are highlighted the main personal contribution of the author as well as a series of research directions that can be approached in the future.

All these conclusions, at which we add the bibliography in the end of the thesis represent a real research basis in the future of the stability of the speed control systems of the induction motors.

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C. PhD THESIS


D. RESEARCH GRANTS


E. INTERNET RESOURCES

162. *** Catalogue pumps LQRY : www.ptcm.com
163. *** www.mathworks.com
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