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Modelling and Simulation of Electromechanical Systems Working with Nonlinear Frictional Loads and Controlled by Subordinated Control System of Coordinates

[1] R.Udayakumar, [2]G.Saritha and [3]T.Saravanan

[1]School of Computing Sciences, Bharath University, India
[2]Dept of EEE,Sathyabama University, Chennai, India
[3]Dept of ETC,Bharath University, Chennai-47, India

Abstract: This work is devoted to the modeling and simulation of subordinated automatic control system (SACS) controlled non linear one-mass electromechanical system (OEMS). The non linearity was considered in the load (viscous friction VF) which contains in its characteristic rising and fallen parts. The fallen part of the characteristic is known as negative viscous friction (NVF). Also another non linearity characterize the subordinated control system (SCS) is considered and mainly is a limitation in the current controller. The block diagram of the system for simulation was prepared. The equation describes the friction curve in compliance with the technical working regime of the system was done. Determination the parameters of the considered system to characterize the desired dynamical properties were introduced. The qualities of obtained dynamical processes are compared with analogue standard symmetrical optimum response (SSO) and finally a series of recommendations and conclusions about this were made.

Key words: One-mass electromechanical system・Negative viscous friction・Frictional loads・Fallen and risen parts・Dynamical process・Subordinated control system.

INTRODUCTION

The name electromechanical system is usually used to denote electrical drive system which consists of separately exited dc motors together with their mechanical loads and mechanism. Those systems when working with loads having nonlinear mechanical characteristic contains rising and fallen parts, will phase stability problems in some modes of operation when the working point moves along the fallen part. The instable regimes can be recorded in the dynamic and transient processes. Such electromechanical systems are working with outer loop speed control system containing inner loops to control the current (torque). To overcome the stability problems usually the speed and current regulators of PI type are used and their parameters are regulated with conjunction to the system parameters. The work presented in [1, 2, 3] dealt with determining the stability regions in the system parameters coordinates of linearized electromechanical systems with subordinated control loops and the load of type linear negative viscous friction. The results gave recommendations about the best control constructions for choosing the speed and current regulators parameters which lead to the best desired dynamical indexes. In work presented in [4], the synthesis of the PI regulators for linearized system (speed and current) was carried out with the help of root Loci method and the obtained results prove the theoretical analysis in [1, 2, 3]. The effect of non linearity may lead to stability problems which can not be recognized in simulating the linearized system. So this work is mainly devoted to modulate the non linear friction loads characteristic for different mechanisms given in the literatures and to simulate the OEMS in different working regimes whether are normal or non normal regimes.

The Proper Block Diagram of Oems for Simulation: The well known block diagram used to represent the OEMS given in [2, 3, 4] can be chosen as abase diagram

Corresponding Author: R. Udayakumar, School of Computing Sciences, Bharath University, India.

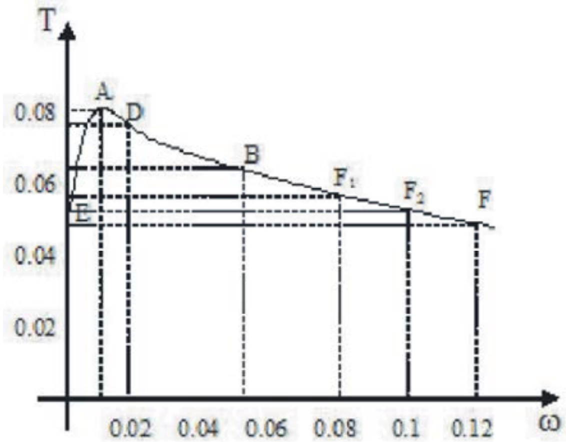

Fig. 1: Garsy- Chtribka curve in T_{load}^*, ω plane

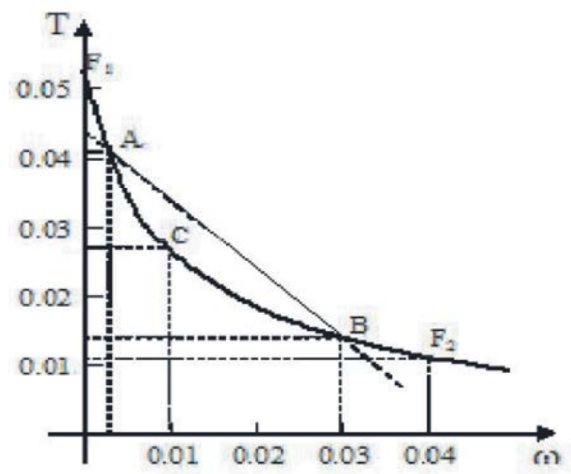

Fig. 2: Calculated load characteristic

for the simulation. But to achieve more general results and to carry easy simulation with the introduced parameters, the following extras are introduced: The block with parameter K_{emf} (were $K_{emf} = 1$ or $K_{emf} = 0$) is introduced to allow simulate the given system with two structures. The proper frictional load is given by $T_{load}^* = f(\omega)$. The OEMS basic block diagram used for simulation with generalized parameters is given in [1, 2].

Load Characteristic Model and the Simulation Regimes: To work out the more suitable models of the frictional loads it is necessary to consider the working regimes of mechanisms with viscous friction, so for this purpose we use the viscous friction curve (with lubricating oil) presented by Garsy-Chtribka [5]. This curve is transformed to T_{load}^*, ω coordinates. This curve is shown in fig. 1.

On the curve ABC there are two working points A and B, so the dynamical process will be analyzed along the curve from A to B and back. For this the dynamical indexes will be compared with those when the straight line AB is replaced the curve ABC. The coordinates of the points A and B were determined by initiating straight line in the T_{load}^*, ω plane with slop b = -1, then integrate it with the curve and then graphically measure the parameters T_A^*, $£s_A^*$, T_B^*, $£s_B^*$ [13][14][15]. Then the coordinates of the points F_1, C, F_2 are given to a formulate the friction curve and finally making interpolation with polynomial of third or fourth order with the help of special package (Numeri) to receive the coefficients of the polynomial which represents the non linearity in the block diagram. The mechanical characteristic of the friction load with the calculated numerical values is presented in fig. 2.

The up normal working mode for some electrical drive system like steel rolling machines in the fallen part of the load characteristic is considered normal. For this type of machines the general curve characterize the load is containing both parts [7][8]. The movement of the working point along the fallen part of the characteristic is during sliding the metal off the roles.

The mathematical model for the one mass electromechanical system concerned is worked out in unit less parameters (T_{μ}, $\__{em}$, m). These parameters have values change in a wide range dependence on the machine characteristic of the electrical drive. For this reason, the parameter T_{μ} = 0.003 – 0.005 seconds, frequency of not damped r esonance of the motor $\__{em}$ for high power motors is 30 < $\__{em}$ < 150 and the oscillations index is 0.5 < m < 2. For the simulation to consider the resistance of the armature circuit of the control system, the next values are chosen: $\__{em}$ = 100 1/ s, m = 1, T_{μ} = 0.005 S and T_{μ}^* = 0.5.

The Practical Block Diagram with the Simulation Data: To gather the different parts of the whole block diagram to be simulated it is necessary to solve two main problems [9]. The fist one is to construct the model of the PI speed controller with current cut off section and the second one is to realize the non linear models of the load characteristic in polynomial form and linear-parts form. The modeling of subordinated automatic control system contains limitations has technical character problem. The solution presented in [6] more or less depends on writing the exact information of the blocks, even the effect of charging the stabilizing capacitance by the dc voltage is not

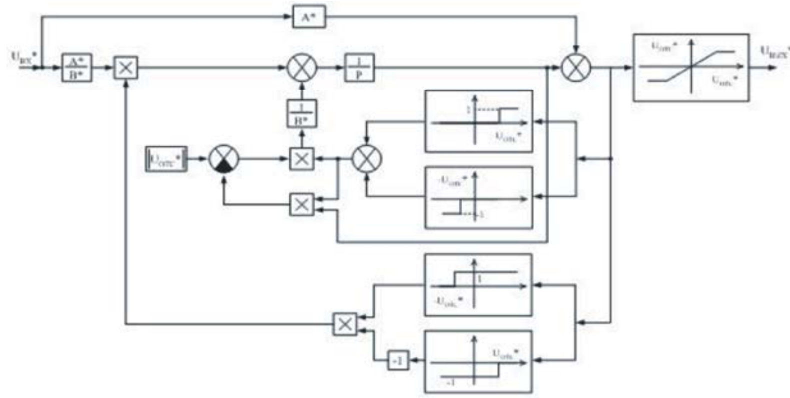

Fig. 3: PI speed controller with limitation characteristic.

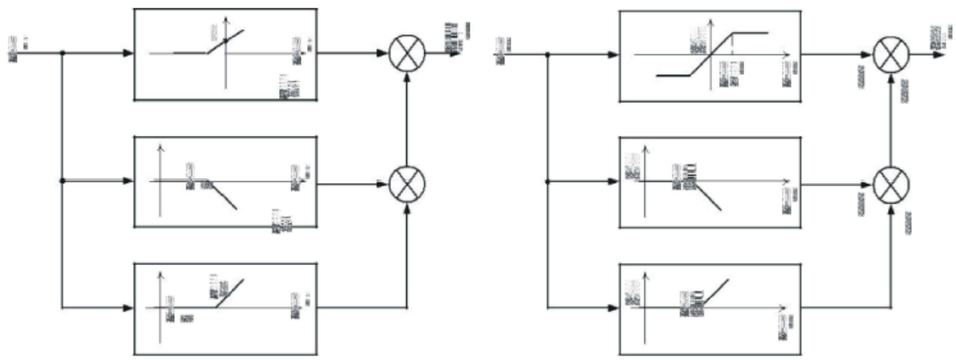

Fig. 4: The realization by linear-sections approximation.

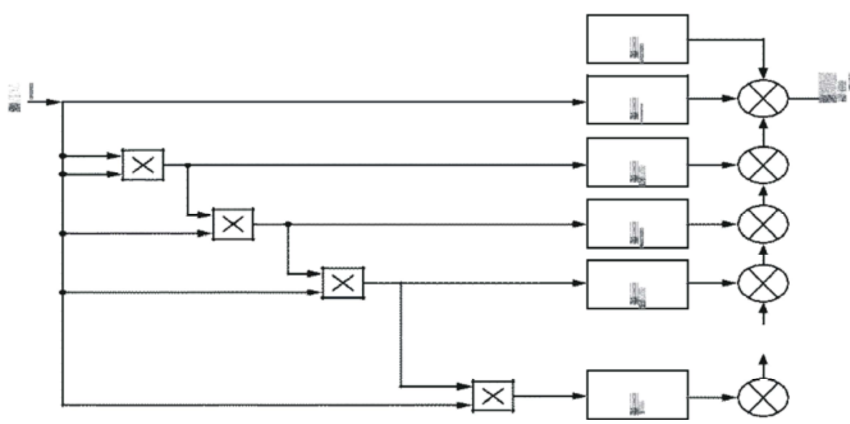

Fig. 5: The polynomial realization

considered. This effect may change the dynamical properties of the studied non linearity. The proposed model of the PI speed controller with limitation characteristic is shown in figure (3).

The different realizations of the non linear frictional loads are shown in figures (4 and 5). Figure (4) shows the realization by linear-sections approximation, while figure (5) shows the polynomial realization.

The Results of Simulation and its Snalysis: With the help of computer program prepared for simulation the systems in block diagram form and using the prepared different sub blocks, a wide computer experiment is done [10]. The revived results for non linear one mass electromechanical system with non linear friction load give special characteristics of the dynamical process. Figure (6) shows the dynamical process for construction the system in symmetrical optimum criteria and can be

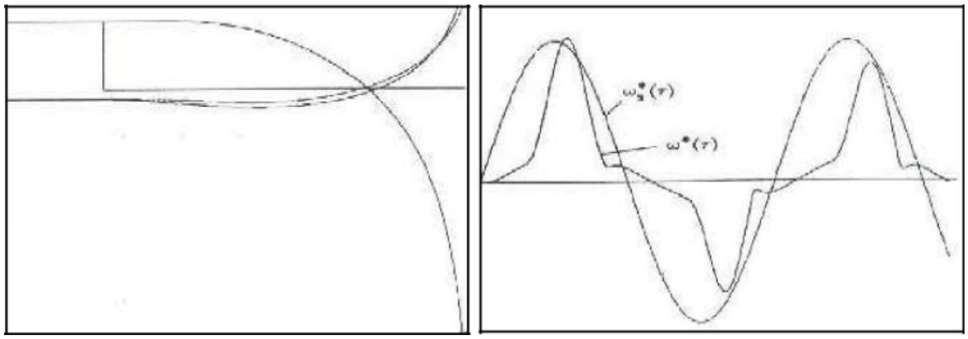

Fig. 6: The dynamical process for construction the system in symmetrical optimum criteria.

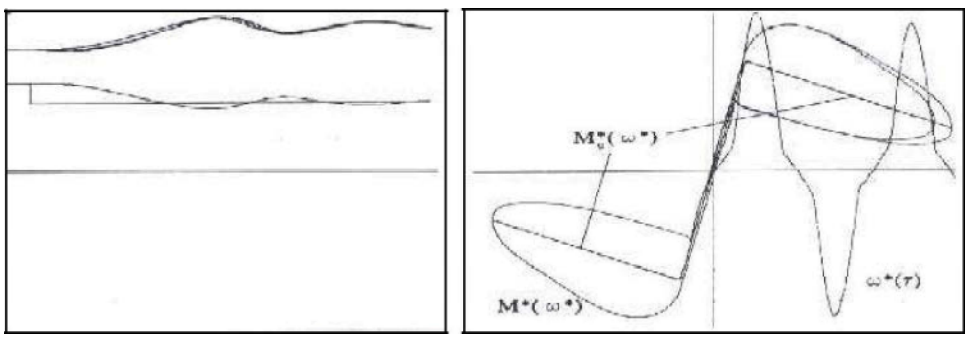

Fig. 7: The dynamical processes by Butterworth criteria

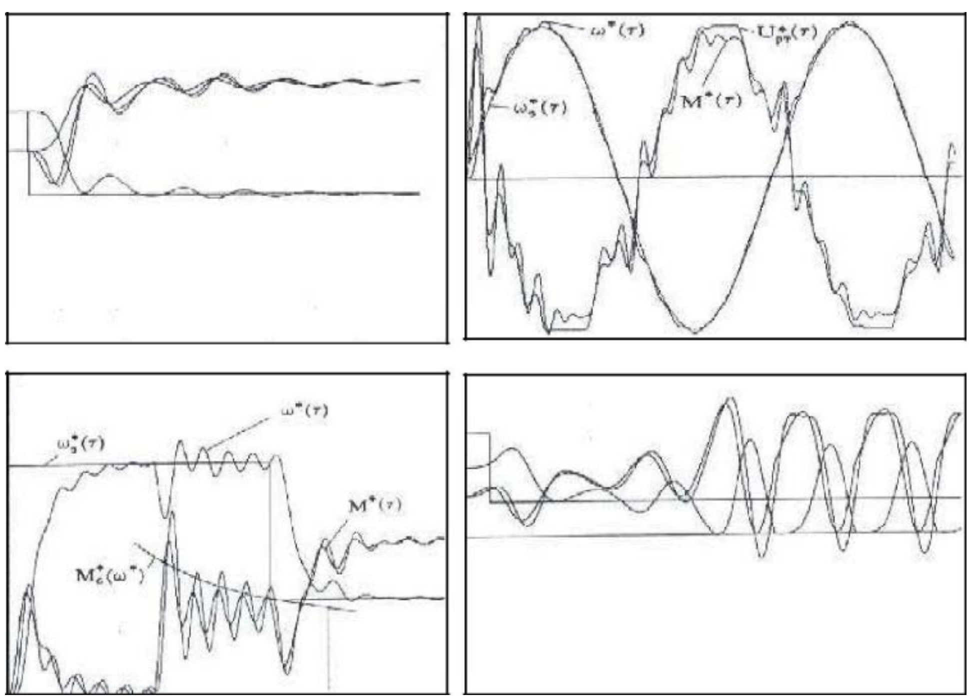

Fig. 8: The dynamical processes by Chepechev criteria

noted when decreasing the signal of the reference speed the situation is to move the dynamical process from stable state on the fallen part of the load characteristic to non stable one. This is happened because of movement of the working point on the fallen part in range of lower speed signal, where slop of the curve is increased and push towards the end of stability.

The construction of the simulated system by Butterworth criteria shown in figure (7), where can be said that reducing the speed signal results in reduction in the slop in the dynamical process which leads to higher over shoot and more oscillations in the new balanced point [11-12].

The simulation of the system constructed by Chepechev presented in figure (8) shows more stable dynamical process than the others, were the overshoot within standards and the high response is kept. The curves show that this construction is less sensitive to the variation of the slop of the friction curve.

CONCLUSIONS

- Modeling electrical drives systems work with frictional loads have both risen and fallen sections in the non linear characteristic depends on the technical working regimes on the location of the working point on the curve.
- The characteristic of the friction curve various from one mechanism to another.
- The modeling of the non linear load characteristic should be presented by sect ionized linearization or higher order polynomial depending on the technical working regime of the one mass electromechanical systems.
- The speed controller is modeled with current limitation has technical difficulties and the accuracy of the receiving results on direct connections with the exact writing of the different blocks data.
- The dynamical indexes and system stability depend on the type of criteria and the Chebechev criteria can be recommended.
- The results of the simulation shown by the different dynamical processes gave clear picture about the behavior of the studied system in both risen and fallen parts of friction characteristic and can prove the stability regimes.

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