International Journal on Emerging Technologies **7**(2): 15-22(2016)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Study of Tension and Bending in Coilers of Mobarakeh Steel Company Hot Strip Mill and Preparing a Computer Model to Calculate the Required Current in Coilers

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(Received 16 May, 2016 Accepted 19 July, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: This study has been carried out to overcome the problems in the coilers section of hot strip mill of Mobarakeh Steel Company, including the work piece loosening and telescopic form which resulted in production of undesirable products. The paper reports the study of the electrical and mechanical parts of the coilers section in which the coiler motors and the other parts have been simulated along with the existing controls; a suitable model for analyzing the operation of the coiler motors has been attained. The simulation results are in good conformity with the observed outputs of the coilers section.

Keywords: Hot rolling mill, Coiler, Telescopic Phenomena, Slab loosening

I. INTRODUCTION

The purpose of this paper is to propose a model to analyze the performance of coiler motor. The first section explains coiler system functionality and control circuits and the second section presents the simulation of coiler system accompanied with its controllers.

II. FINAL ROLLING SECTION

After exiting the preliminary (roughing) rolling section, bar acquire suitable temperature, thickness, and width in order to enter final rolling section and its thickness get reduced until reaching desired thickness. Bar width variation in final rolling section is limited and bar width can be assumed constant.

If the output slabs of final rolling shelve, the temperatures of which are about 850°C, get coiled without getting cooled, firstly they will adhere and weld together and secondly desired mechanical properties of slab will not be met. To solve these problems, before getting into coilers, they pass through walls including slow flow of water, for about 100m, which lower the temperatures of slabs to about 600°C while entering the coilers.

III. COILER SECTION

Exiting the cooling section and reaching desired temperature, the slab is ready to be coiled. Hot rolling factories include three coilers which are mounted after each other. Slabs get coiled at temperature about 600°C. Finishing coiling process, coil gets on the output conveyor and gets secured (fastened), by strapping machine, and transferred to complementary hot rolling factory or a cold rolling one.

IV. FUNCTIONAL ANALYSIS AND SIMULATION OF COILER SYSTEM

Block diagram of feeding circuit of coiler motor is shown in Fig. 1, [1]. Each coiler moves by two independent excited DC motors which are connected in a parallel way. Motors features are shown in table 1. The armature of both motors is fed by a three phase dual converter which regulates armature voltage and control motor speed in torque constant mode.

Field coil of motors are also fed by a three phase full wave rectifier which regulate field current and control exciting flux which results in controlling motor speed in constant power or field weakening mode.

Considering motor control block diagram, it can be concluded that blocks C and D are responsible for supplying reference armature current and, in other words, regulating armature voltage for controlling torque (velocity). Moreover, block B is responsible for supplying reference field current to regulate exciting flux.

Table 1: Motors' properties (two motors are coupled in parallel).

Rated Power		590 KW
SPEED	BASE AT RATED VOLTAGE	225 RPM
	BY FIELD	945 RPM
ARM. VOLT	RATED	700 V
ARM. CURRENT	RATED	925 A
ARM. CIRCUIT	TOTAL HOT RESISTANCE	56.2 mOHM
	SATURATED INDUCTANCE	1.1 mH
	NOT SATURATED INDUCTANCE	1.3 mH
SHUNT FIELD	HOT RESISTANCE	6.95 OHM
HOT SATURATED INDUCTANCE		16.5 H
	CURRENT BASE SPEED-FULL LOAD	36 A
	CURRENT MAX SPEED -FULL LOAD	6.7 A
MOTOR INERTIA		2650 Kgm^2
GEAR RATIO: MOTOR RPM TO LOAD RPM		1.793
	MAX LOAD	21000 Kgm^2
	MANDREL	2000 Kgm^2
	BRAKE	35 Kgm^2

Table 2: Tacho-generator properties.

GEAR RATIO: TACH. GEN. RPM TO MOTOR RPM	1
TACH. GAIN V/RPM	0.1

Table 3: Power excitation circuit.

POWER RATING	8.7	KW
RATED FIELD VOLTS	240	V
HOT RESISTANCE	6.6	OHM
HOT SAT. INDUCTANCE	16.5	H
CURRENT (base speed-full load)	36	A
CURRENT MAX SPEED-full load	6.7	A

Two computational units are used in controlling system to calculate reference armature current and eventually the least amount of these two reference currents is considered as current control input to control motor speed, [1]. These two units are as illustrated below.

(i) First block (C) which is a general control block in speed controlling of DC motor is called DC motor speed regulator in which reference speed in compared to real one and enters a PI controller and consequently reference current for current regulator block will be supplied. Slab linear speed is equal to that of reference and angular speed of motor is feed backed by a tako generator and compared to reference speed at speed control block entrance which results in, considering considering $V=\int \omega\, dr$ equality calculating coil diameter in diameter calculator block.

(ii) Second block (D): inputs of this block are coil diameter, reference speed, slab width (l), slab linear speed variation with respect to time (dV/dt), and coil diameter variation with respect to time (dD/dt). Required inertia for a constant linear speed is calculated in inertia compensation calculator block and considering this inertia, proper reference current will be obtained in another block.

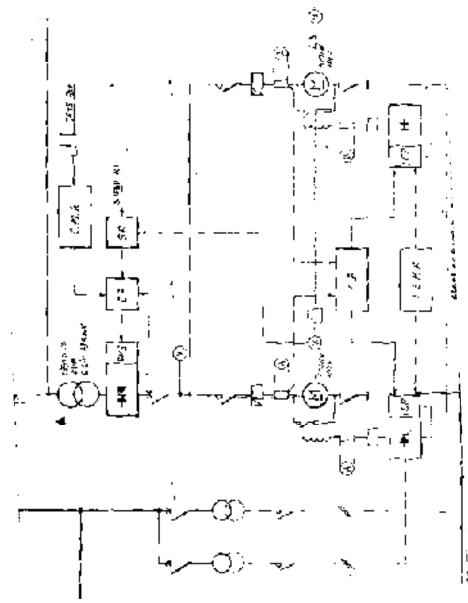

Fig. 1. Block diagram of feeding circuit of coiler motor.

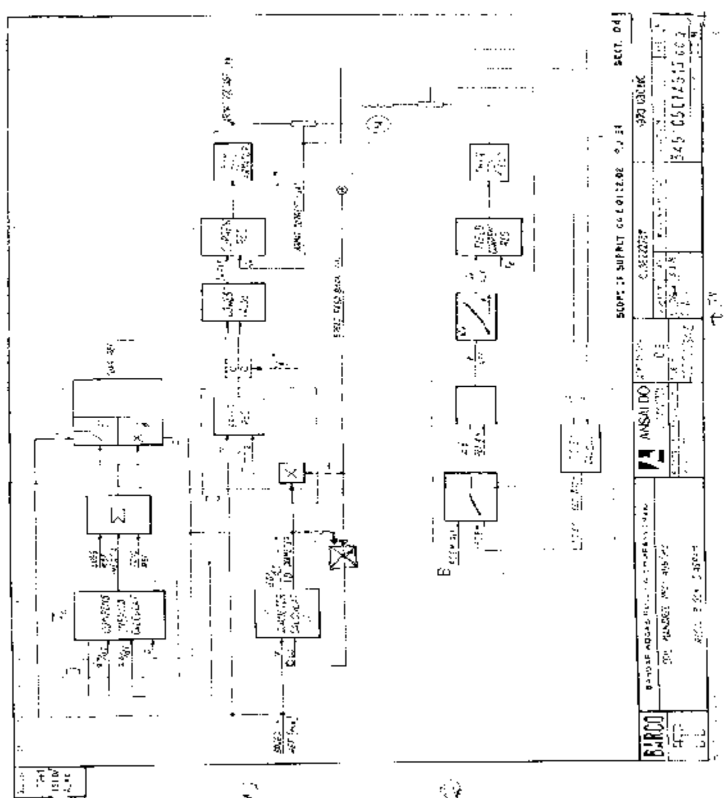

Fig. 2. Mandrel control circuit block diagram.

Block B is responsible for controlling motor speed in constant power or field weakening mode. This block gets a sample from armature voltage and current and considering DC motor model and e_A=V_A-$R_A I_A$ equality, e_A or FCEM (which is back emf) will be calculated in FCEM calculator block.

Since proper function of coiler is done by constant linear speed of slab, motor torque is nearly constant and subsequently motor current is constant.

Considering $e_A = V_A - R_A I_A$ equality, as VA increases, e_A increases too. In block shown in Fig. 2 the magnitude of reference e_A is compared to that of a real motor and until FCEM REF>FCEM the output is zero and there is no change in exciting (drive) current. When VA reaches its upper limit, FCEM REF-FCEM<0, and the output block of Fig. 2 is applied to the next block as $\Delta\varphi$ signal. In this block, reference flux is calculated by comparing $\Delta\varphi$ to maximum motor flux (load). This reference flux (flow), considering magnetic field graph, generates proper exciting current for motor function. Considering this current and field current regulator block, which is consist of a PI controller, the proper firing angle is obtained and its signal is sent to thyristor converter field block. Field feed in generated regarding full wave converter relation, $V_a = \frac{3\sqrt{3}V_m}{\pi} cos\,\alpha_a$.

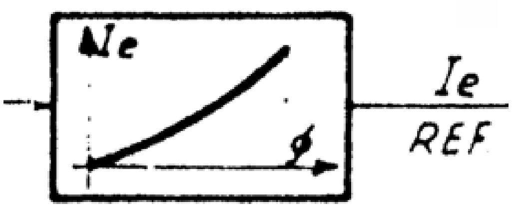

Fig. 3. Exciting coil saturation graph.

V. DATA ANALYSIS OF INFORMATION REGISTRATION SYSTEM, IBA ANALYZER

The first step in simulating a system is precise detection of system behavior. In this section, considering the information registered by Iba Analyzer, information of each coil has been studied and analyzed separately. In the following section different parts of registered information in this system will be explained. Moreover, since in this system of information, fields current of coilers driver motor and armature voltage are not registered, utilizing a four channel data logger, this information has also been registered for a number of coils. Considering this information, functional features of motors could be obtained, studied, and analyzed.

Since the information obtained from data logger and Iba Analyzer were not synchronized, in order to increase accuracy in obtaining features, tension reference signal, which has been registered in two systems, has been implemented and by comparing signal execution time in two systems, the information got synchronized. Moreover, in order to become certain of correctness of sent information, tension reference in data logger has been sent to PLC from input port while the information registered in Iba Analyzer are obtained from the command post section and consequently the comparison between these two pieces of information, considering correctness of data posted to PLC, has been done.

VI. IBA ANALYZER INFORMATION REGISTRATION SYSTEM

In this system the information is saved separately for each slab and wrapping (winding) time interval of each slab is saved as a signal named slab number by which the information concerning each slab can be extracted. Generally, for each slab 31 groups of information signals are registered in which the information regarding coilers, wrappers, PLCs, command signals, and etc. are registered continuously. In addition, other information concerning slabs such as slab width, slab thickness, and other basic parameters of each slab are also available.

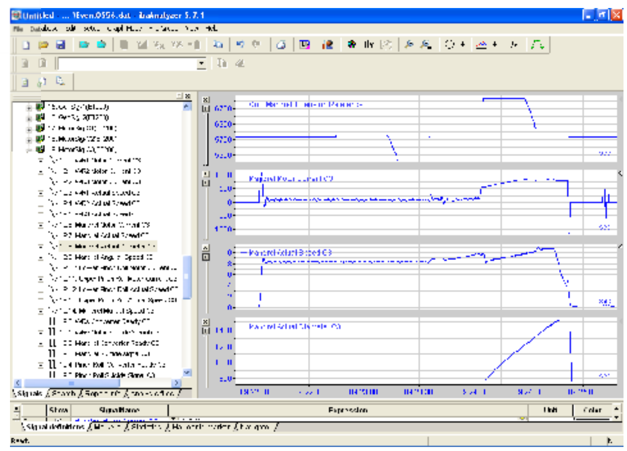

Fig. 4. Iba Analyzer software.

Information regarding mandrel motors is in Motor-sig group. In this section, the information about current, speed, and other parameters of wrappers, mandrels, and pinch rolls are registered.

VII. SIMULATION OF COILER MOTOR (MANDREL) AND RELATED CONTROLLERS

Considering analysis done on registered information in previous section and utilizing control system and mandrel motor information, the motor function has been analyzed. Fig. 7-10 show the system block diagrams. Based on information of tables 1-4, mandrel motor, current controller converter, and exciting field have been modeled and simulated and in the following, block functions and simulation results have been presented.

Grid Equivalent System block, in Fig. 7, is feeding model of the whole system which is simulated by balanced three phase voltage source and system equivalent impedance. Mandrel Motor & Drive System block includes model of converters, motor, and control system which is shown in Fig. 8.

Inputs of this block are:

(i) SP: which is reference current ($I_{A\ REF}$) in block diagram of Fig. 1. Considering presented explanations in previous sections, this current is evaluated by two methods. One of which is by speed control loop and the other is by calculating required tension for slab movement and eventually the minimum of these two current enters current controller as reference current. Since the block information and real setting used in cards were not available and considering influential effects of these setting and parameters on simulation results, these results are not reliable to be used for system error detection. So, the idea of using measurement results to simulate real system behavior had been studied. In this method, real system model is estimated using measurement data and intelligent techniques. In this paper the whole system has been modeled as one block and transfer function of this block has been obtained using Artificial Neural Networks (ANN), [2].

Neural network inputs are slab width (L), coil diameter (D), and coil diameter variation ($\dot{D}$). The information of one coil has been used to train neural network. The multi-layer perceptron network has been used and Levenberg-Marquardt and gradient descent with momentum weights and biases algorithms are used to train neural network and update weights respectively.

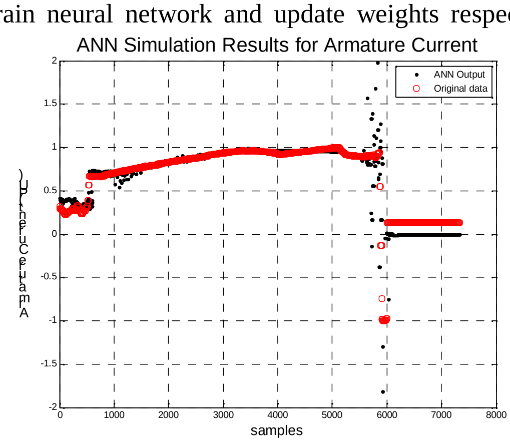

Fig. 5. Neural network output results for reference armature current evaluation.

However, here is a problem associated with neural network training system. Since slab width information, as input to neural network, is invariant, the neural network cannot be trained properly and goes wrong if the output width get changed. To solve this problem, considering limited diversity of slab width, the neural network is trained for each width using data related to that coil. Consequently, the final neural network is made up of a number of neural networks, each of which is responsible for a specific slab width and subsequent output.

As a result, reference armature current signal is obtained from neural network output. An output sample of neural network for evaluating reference armature current is shown in Fig. 5 and the GUI for the trained neural network is shown in Fig. 6.

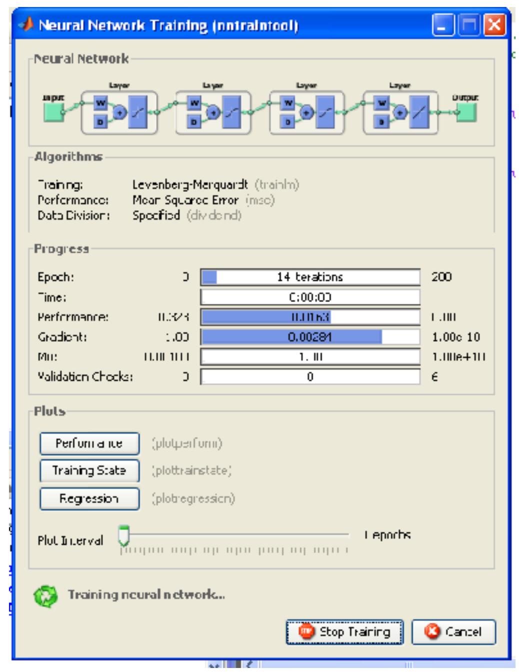

Fig. 6. Trained neural network.

(ii) Mech_T is motor load torque. Evaluated torque in previous section has been used for this input.

(iii) A, B, and C are three phase voltage inputs which are connected to field and motor converter.

Block outputs are motor parameters including thyristor firing angle, armature voltage and current, motor speed, and field current.

Fig. 8 shows detailed schematic of motor simulation circuit and speed control system. Motor control block, as shown in Fig. 9, is motor speed control block in constant torque mode which sets proper firing angle for three phase dual converter by receiving reference current signal and passing through a PI controller. Afterwards, using these firing angles, Firing Angle Control block supplies proper firing angle pulses for firing thyristors.

Figure 10 shows exciting control circuit. Based on this circuit, exciting current is compared to reference one and after passing a PI controller, proper firing angle is sent to firing pulse generator block. This block generates proper pulse for firing three phase thyristor rectifier and consequently maintains motor speed in field weakening or constant power mode.

Simulation results for a sample slab of code 432506 are shown in figures 11-13.

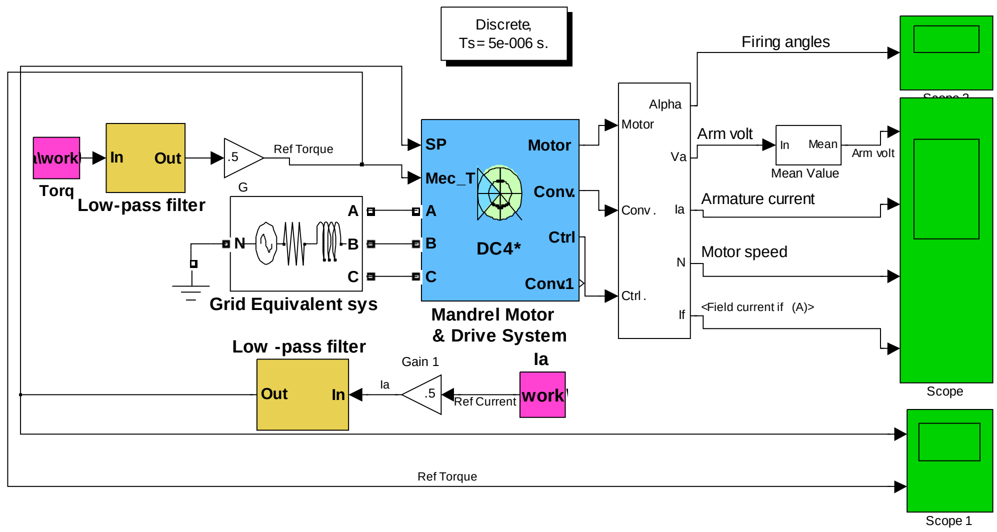

Fig. 7. Schematics of motor simulation circuit.

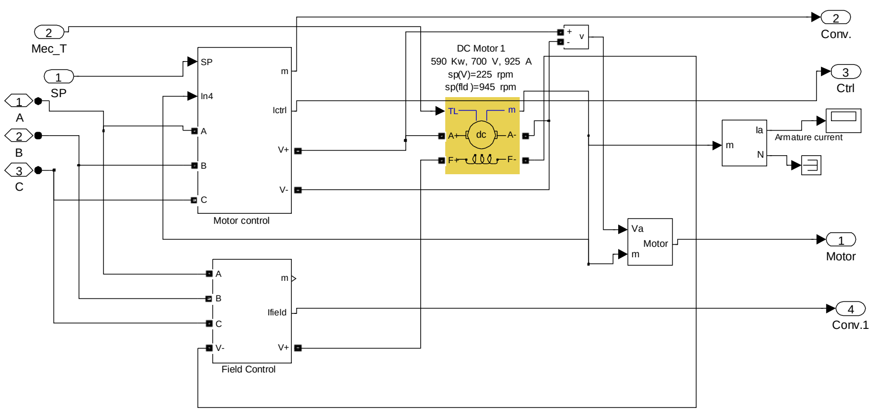

Fig. 8. Schematics of motor simulation circuit and speed control system.

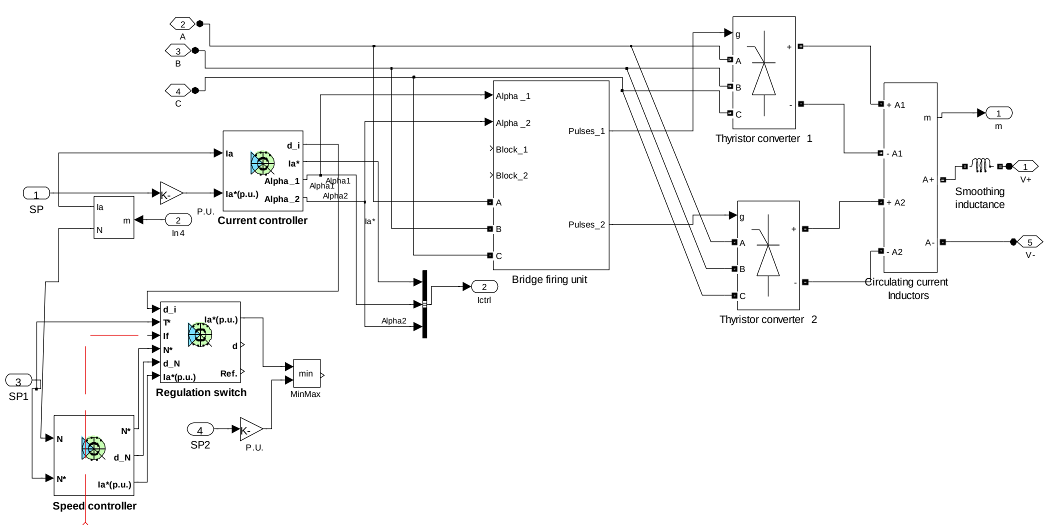

Fig. 9. Schematics of motor speed control system simulation at torque constant region.

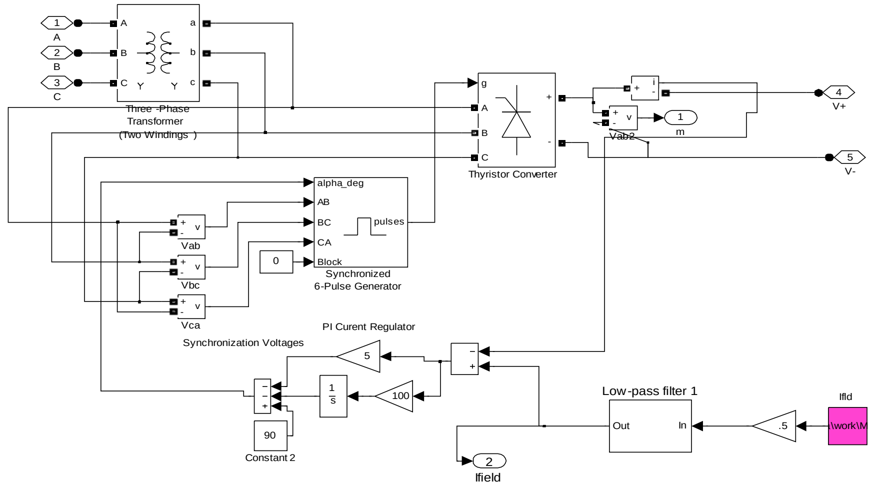

Fig. 10. Schematic of stimulation control system simulation.

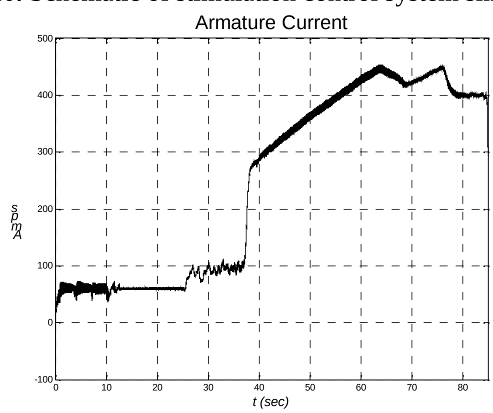

Fig. 11. Motor current vs. time.

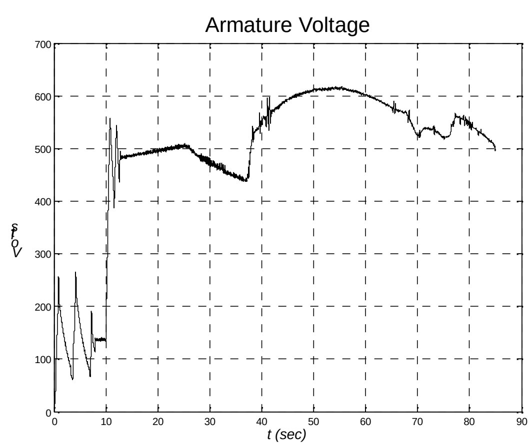

Fig. 12. Motor voltage vs. time.

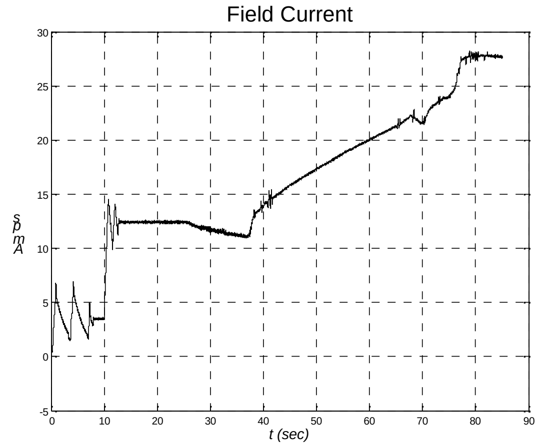

Fig. 13. Field stimulation current vs. time.

VIII. CONCLUSION

In electrical section of this paper, driver system behavior has been studied. Considering problems associated in defining system real parameters, using simulation to assess the whole system behavior has not been recommended. In fact, motor and converter, due to reliability of available parameters, have been simulated in an straightforward manner. However, motor reference current generator block diagram has been analyzed using advanced simulation techniques. By combining motor and converter model with reference current one, which have been modeled using neural network, it is possible to analyze the system for a variety of behaviors. To become certain of neural network functionality, measurement data of 20 coils has been used to train and test implemented neural network. It can be concluded that by having reference current (neural network model) and utilizing recommended model, motor and driver behavior can be simulated. System behavior can be studied by creating various artificial disturbances. Utilizing recommended model, the role of various factors affecting coiling process can be studied and analyzed. Considering that reference values are applied to driver system from computer system, any kind of disturbance affecting these reference values can be a factor of coiler system improper function. The idea of changing control system to separate tension process from coiling one is a way to response to such problems.

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