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LABORATORY USE OF AN INDUSTRIAL DRIVE CONTROL SYSTEM

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Abstract. Speed control system with slip-ring AC motor (ASTAT®) is a system for tasks in the field of industrial cranes. Some modifications have been made on this system in order to perform DC motor speed control in the laboratory environment. Main purpose is to present laboratory system for DC motor control to students. This system can be used to compare the different power converters used for DC motor drives supply. There is a possibility to control more than one DC motor drives which are supplied by thyristor or IGBT converters. This laboratory model enables our students to become familiar with real problems in industrial drive control systems.

Keywords: Education, DC machines, Control

1. INTRODUCTION

ASTAT is the standard industrial system that contains the following components: main control unit, process input-output unit, converter interface and AC/AC converter (Fig. 1.), [3].

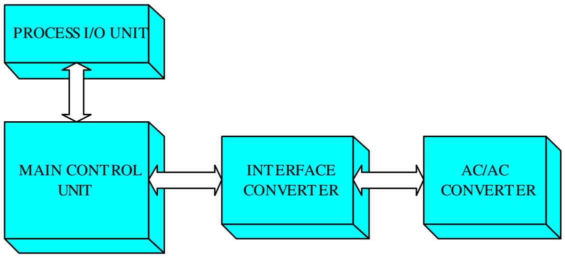


Fig.1. Simplified block structure of ASTAT industrial drive controller

For the application of such industrial system in the laboratory environment for the DC motor control some changes have to be made in the converter interface and in the application program for AC/DC converter control. Laboratory model that controls speed of dc motor has been made. Controlling and monitoring, watching of typical values, parameters changing and regulation structures has been accomplished by means of the PC. Laboratory model of this industrial system contains all components for dc drive control: hardware and software of ASTAT, different types of AC/DC converters, measuring devices, DC motor and load. It is possible to present and observe different operating stages of DC drive on the lectures and laboratory work (starting, breaking, reversing, load influence and instability of DC drives). Students can observe on PC typical values of DC motor: armature voltage, armature current and motor speed.

2. STRUCTURE OF THE LABORATORY MODEL

Fig.2. presents structure of the laboratory model. The model has two feedbacks, current feedback and speed feedback. The incremental encoder which is connected to the port of the I/O board provides the speed information. The control unit and the input/output unit are connected by optical link. The input/output board has several digital inputs and outputs, and several analog inputs and outputs. The program containing control structure is stored in the flash memory that is a part of the control unit. The application program for this laboratory model is made in the standard industrial developing software tool called PCASE. That is the standard programming tool for ASTAT system.

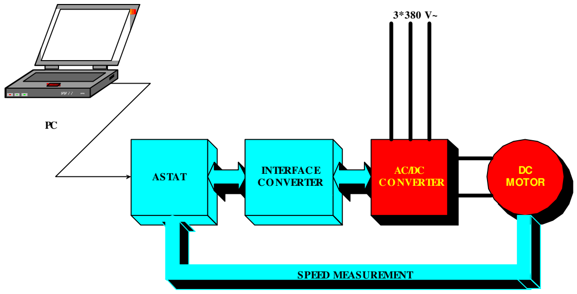


Fig.2. Structure of the laboratory model

The control structure of this laboratory model (Fig. 3.) consists of the following parts:

- Speed reference generating
- Current control circuit
- Speed control circuit

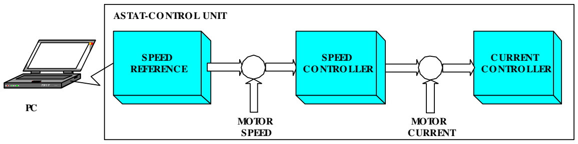
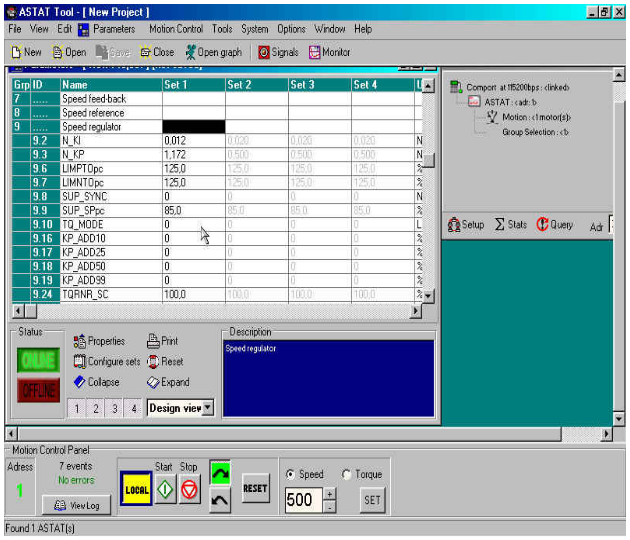


Fig. 3. Control structure of the laboratory model

3. TUNING OF THE SYSTEM FOR CONTROLLING DC MOTOR

Based on the drive parameters, students calculate parameters of the control structure. The system has two closed loop, one to control the current and the other one to control the speed of the DC motor. Students need to tune these two closed loops. Calculated parameters can be inputted in the ASTAT tool window. ASTAT tool is an industrial software tool for controlling and monitoring (Fig. 4.). All the parameters witch define these system can be entered by these tool. On this way they can easily be changed and again downloaded in ASTAT. This tool has an option of downloading and uploading several set of the parameters to the system. On that way students can watch how the different parameters effect on the system behavior. Also it is possible to save and look all wanted responses and tuned the parameters of the control structure based on these saved responses. On this way students can come in contact with real industrial system and get experience of tuning control structures.



Grp	ID	Name	Set 1	Set 2	Set 3	Set 4	U
7	.....	Speed feed-back					
8	.....	Speed reference					
9	.....	Speed regulator					
	9.2	N_KI	0,012	0,020	0,020	0,020	N
	9.3	N_KP	1,172	0,500	0,500	0,500	N
	9.6	LIMPTOpc	125,0	125,0	125,0	125,0	%
	9.7	LIMNTOpc	125,0	125,0	125,0	125,0	%
	9.8	SUP_SYNC	0	0	0	0	N
	9.9	SUP_SPpc	85,0	85,0	85,0	85,0	%
	9.10	TQ_MODE	0	0	0	0	L
	9.16	KP_ADD10	0	0	0	0	%
	9.17	KP_ADD25	0	0	0	0	%
	9.18	KP_ADD50	0	0	0	0	%
	9.19	KP_ADD99	0	0	0	0	%
	9.24	TQRNR_SC	100,0	100,0	100,0	100,0	%

Description: Speed regulator

Adress: 1

7 events

No errors

View Log

● Speed ○ Torque

500

Found 1 ASTAT(s)

Fig. 4. ASTAT tool

4. EXPERIMENTAL RESULTS

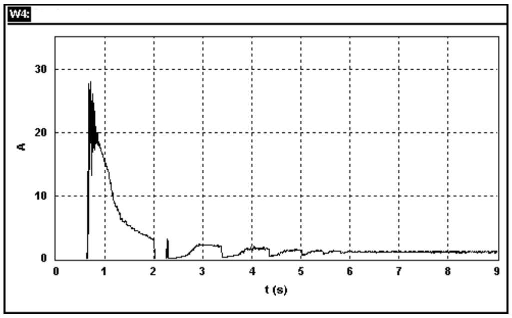
The laboratory model with thyristor converter

In these measurements the four-quadrant thyristor converter is used for DC motor supply. The measurements were made on the DC motor (SIEMENS U_N=420VDC, n_N =1480 1/min, I_N=40.6A, P_N=13.5 kW). The parameters of the current and speed controller for different responses are presented in the table 1.

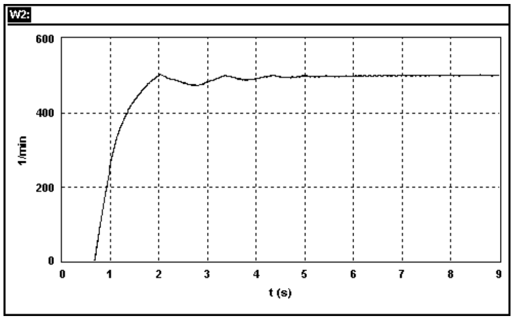
Tab. 1. Controller parameters

Current controller PARAMETERS	speed controller PARAMETERS	Related response
Kp=3,125 T=0,027s	Kp= 0,879 T= 0,819 s	Stable response
	Kp= 1,953 T= 0,0819 s	Unstable response
	Kp=0,1953 T= 8,192 s	Aperiodic response
	Kp= 0,879 T= 0,819 s	Reversing

The measured waveforms of the current and speed of the DC motor are presented on the following figures. The responses of the DC motor with optimal tuned parameters are presented on the fig. 5. The responses of the unstable system are presented on the fig. 6. Aperiodic response of the system is presented on the fig. 7. The behavior of the system for reversing DC motor with the optimal tuned parameters is presented on the fig. 8. From these measurements it can be observed how those parameters effect on the system behaviour.

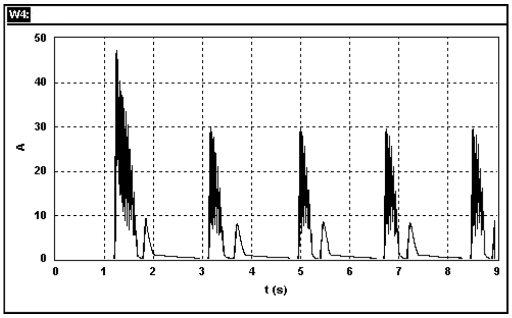


a) Motor current

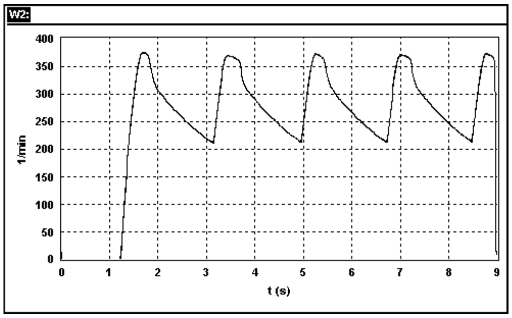


b) Motor speed

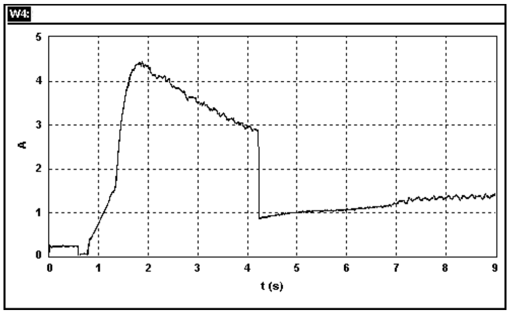
Fig. 5. Measurement results: Stable response



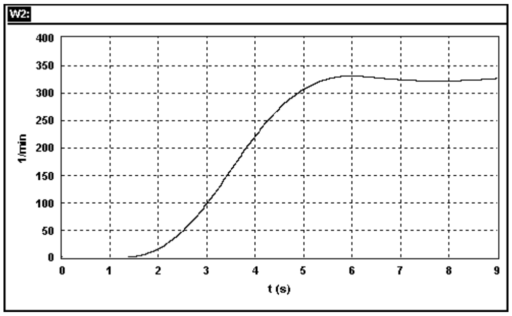
a) Motor current



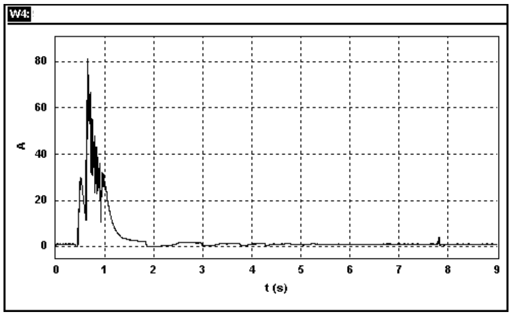
b) Motor speed
Fig. 6. Measurement results: Unstable response



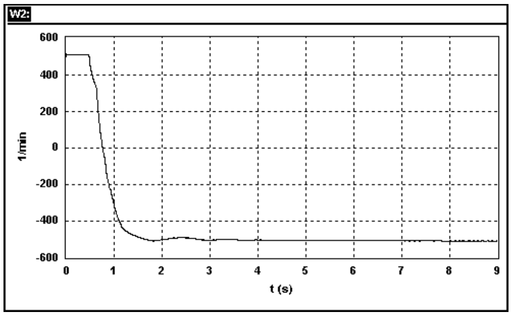
a) Motor current



b) Motor speed
Fig. 7. Measurement results: Aperiodic response



a) Motor current



b) Motor speed
Fig. 8. Measurement results: Reversing

Just like students can watch how the different parameters in the system can give different response, they can observe different working modes of the DC motor. On this way students can see the transient stage of the DC drive and may come to conclusions about behavior of the DC motors in non stationary working mode.

The laboratory model with IGBT converter

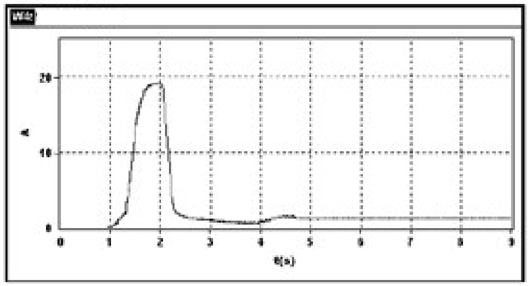
It is necessary to create the software model of the PWM modulator (in industrial development software PCASE) which is connected with the time processor unit of the micro controller MC68332. The PWM modulator is necessary for the control of IGBT 4-Quadrant converter, [2]. The output value of the current controller is a reference for the PWM block. Using this PWM block the switching frequency can be easily adjusted for the desired system operation. It is possible to combine different modulation types for the 4-quadrant operation of the converter. This PWM block enables the unipolar or bipolar modulation.

The measurements were made on the DC motor (SIEMENS U_N=420VDC, n_N =1480 1/min, I_N=40.6A, P_N=13.5 kW). The parameters of the current and speed controller for different responses are presented in the table 2.

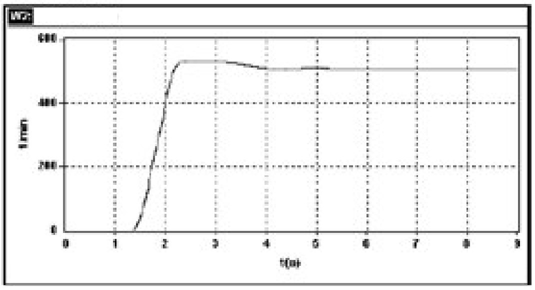
Tab. 2. Controller parameters

Current controller parameters	Speed controller parameters	Related response
Kp= 0,39 T= 0,056 s	Kp= 0,879 T= 0,546 s	Stable response
	Kp= 1,953 T= 0,546 s	Unstable response
	Kp=0,5 T=1,64 s	Aperiodic response

The responses of the DC motor with optimal tuned parameters are presented on the fig. 9. The responses of the unstable system are presented on the fig. 10. Aperiodic response of the system is presented on the fig. 11.

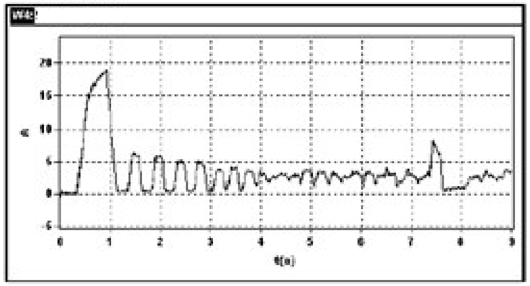


a) Motor current

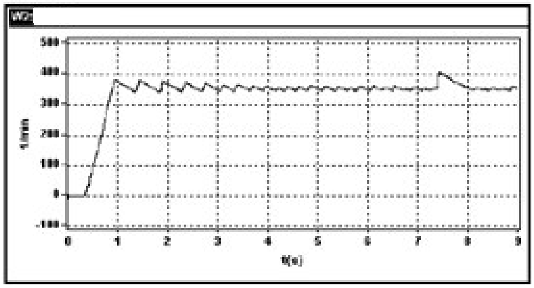


b) Motor speed

Fig. 9. Measurement results: Stable response

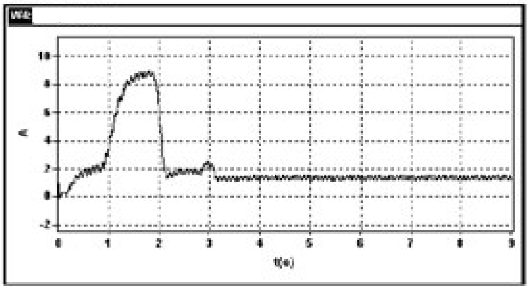


a) Motor current

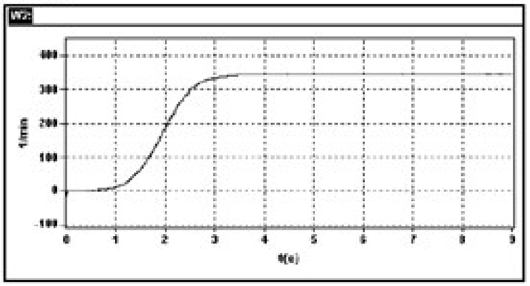


b) Motor speed

Fig. 10. Measurement results: Unstable response



a) Motor current



b) Motor speed

Fig. 11. Measurement results: Aperiodic response

5. CONCLUSIONS

On this laboratory model students can realize how things work in the real world. They have to calculate the parameters for the current and speed controller based on the defined criteria and given parameters of the drive. Calculated parameters can than be entered in the simulation model to verify the responses of the system. If the responses satisfy the given criteria the parameters can be downloaded to the micro controller using the industrial software tool. Now they are watching a behavior of the real system with the calculated parameters. On this way they learn on behavior of the real industrial system and can see how that something that they calculated on the paper works in the real world.

6. REFERENCES

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[4] ABB ASTAT Software Development Tools

[5] The Motorola MC68332 Assembly Language Programming Tools

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In 1966 at the Faculty of Electrical Engineering and Computing, Zagreb, Croatia he started as an assistant of Fundamentals of Electrical Engineering. He works today at the Department of Electric Machines, Drives and Automation and as a Professor he teaches undergraduate and graduate students.

Also, Mr. Erceg is a project leader of several industrial and government projects. He authored numerous technical papers and studies in Control Engineering field, and is a member of IEEE Industrial Electronics Society, IEEE Power Society, KoREMA Society and Croatian Electric Engineering Society.

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