EDUCATION OF ROBOTICS AND POWER ELECTRONICS AT SZÉCHENYI ISTVÁN UNIVERSITY OF APPLIED SCIENCES

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Abstract: *The education of Robotics and Power Electronics has an increasing role at Széchenyi István College. Our intention is to give students a wide range in design, realisation and measuring activity using micro-teams. Students work in groups of 3 or 5 persons. Project based learning plays also an important role in our new curriculum.*

Keywords: education, robotics, power electronics, resonant converter, DC motor drive, project based learning

Robotics are taught for the students of Mechanical Engineering and Electrical Engineering Faculties at our College. Students of Mechanical Engineering Course have got the opportunity to choose the subject Industrial Robots for 8 years. The one semester long subject basically focuses on the application and usage of robots. Students have to prepare control programmes for a FANUC M0 robot and can practice working with it. (Robot was built with original Japanese control system and with Bulgarian manipulators.)

Students of Electrical Engineering Course have the possibility to choose the subject Robotics lasting 2 semesters for 4 years. Second semester of the subject mainly deals with robot control systems. Within the education of Robotics students have to solve problems in transformation of co-ordinates. Another task deals with precision motion in connection with trajectory planning, especially with different solution of the peg-hole problem [2].

In the second semester of Robotics students have to simulate simplified robot controls taking into consideration the physical effect of configuration changes during robot operation as well as the influences of loop gain changes of different controllers using VISSIM [1] simulation and software programme (Fig. 1).

Students are building the DC motor driving system with variable electromechanical time constant which becomes a programmable adaptive system according to Fig. 2, on base [9].

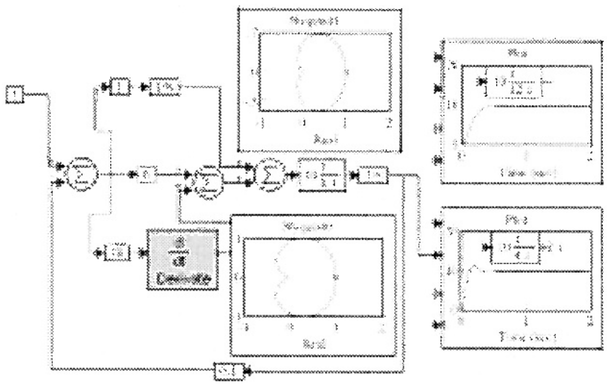

Fig. 1: Transition and Nyquist curves of a PID position control system (effects of T changes, damped case with constant gain value below)

A robot control software (ABB-S4C under Windows operation system) bought 3 years ago helps the education of Robotics. This software programme with restricted applicability makes available for the students to study real robot software problems. This year we could make a considerable improvement acquiring an ABB IRB 140 industrial robot together with its software package and 6 working terminals for the education of Mechanical and Electrical Engineers at a reduced price. From the next academic year this robot makes available for the students working in small groups to prepare control programmes and to make special measurements and evaluation in connection with control and driving systems as well as to study the different solution in mechatronics furthermore the special sensors and actuators.

At present we are working with different interface equipment which connect the robot with NC and material handling machines used in store houses as well as with the improvement of grippers having different sensors. Such equipment are also used in the education of Mechatronics.

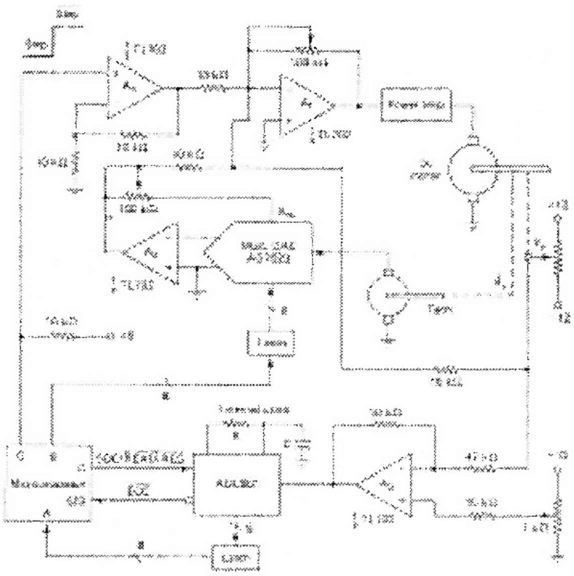

Fig. 2: Adaptive position control system. The microprocessor maintains the system critically damped in the presence of load and other parameter fluctuations.

The robot has AC motor driving which also serves measuring possibilities for Power Electronics education.

Our students also have good opportunities to study up-to-date robot applications in industrial circumstances of the region. Some interesting fields thereof are the following:

- Some possible solution of the peg-hole problem for different cases and dimensions using quite complicated grippers as well as programming technique,
- Centralised and decentralised structures in PLC networks, different hierarchic control systems involving 10 robots and another 30 working terminals. Robots and PLCs of this system should communicate with each other.
- Special sensor, actor and measurement applications and methods.

There is an another subject (Engineering Project) within the Electrical Engineering Course which also deals with robots and their usage. In the frame of this subject students work in teams of 4 or 5 persons, such teams have to solve an engineering problem in the field of Robotics, Power Electronics and Control Systems using PLCs. Time available for them is 3 months. Students should find relevant books, papers, catalogues in connection with their engineering problems and should make measurements in the laboratory and prepare also control software programmes. In form of short presentations the groups can show their final results and experiences.

The education of Power Electronics began appr. 30 years ago at the College. Students not taking part in Electrical Engineering Course have a module dealing with basic electrical engineering knowledge which is completed by engineering subjects like Electronics. Within this module students become acquainted with the traditional and new sections of power electronics and the various application possibilities.

Results of the researches of the resonant converters at our Department can be well embedded in the education. For example we have determined the transfer function of the symmetrical resonant buck converter (SBC) (Fig. 3).

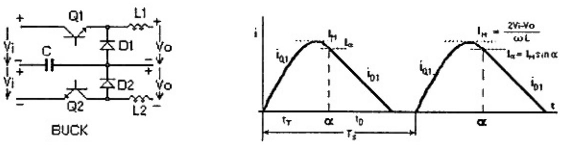

Fig.3 Symmetrical buck converter and the injected current waveform

In this SBC during the switching period (in discontinuous conduction mode) the injected current waveform is in Fig.3 and its average current is as follows [5]

$$i_i = 2Cf_s \frac{V_i^2}{V_0}$$

Injected-absorbed current analysis method [K4] will be used for the synthesis of the mathematical model. The injected absorbed method is based on the supposition, that only small changes are around the operational point of the variables. The average current can be determined using partial differentiation and upon this the transfer function and the functional model can be obtained. [3] (Fig. 4),

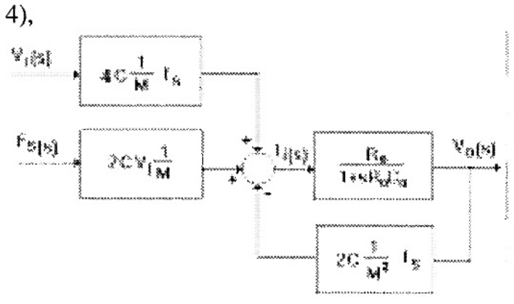

Fig.4. The functional model of the s. buck converter

Where $M=V_0/V_i$, $F_s(s)$-the switching frequency, $I_i(s)$- the injected current

Let us implement this type of converters for a DC motor control. The arrangement for this control is as follows (Fig. 5)

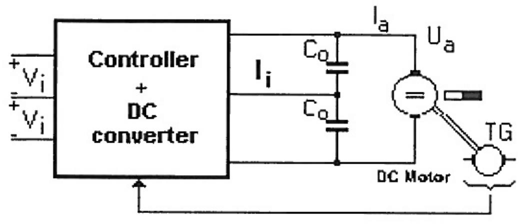

Fig.5 DC machine motion with SBC

Simplified approach to a DC motor modelling is used in the following (Fig. 6), [4]

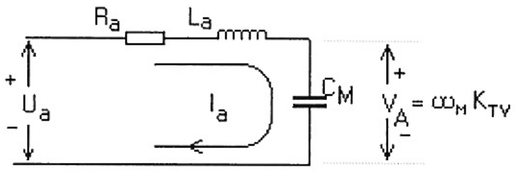

Fig. 6 Series DC motor model

where

ω_M angular velocity of the motor [rad/sec]
K_{TV} torque constant [Nm/A] or [V sec/rad]
V_A internal voltage of the DC motor
M_M torque of the motor, the current is I_A
J all of the moment inertia (rotor+load)

Where

$$C_M = \frac{J}{K_{TV}^2} \text{ [farad]}$$

$$K_{TV} = \frac{V_A}{\omega_M} = \frac{M_M}{I_A}$$

$$Q = \frac{\omega_n L_a}{R_a}$$

$$L_a C_M = \frac{1}{\omega_n^2}$$

The equation for the angular velocity

$$Y_1(s) = \frac{\omega_M(j\omega)}{U_a(j\omega)} = \frac{1}{K_{TV}} \frac{1}{\left(\frac{j\omega}{\omega_n}\right)^2 + \frac{j\omega}{Q\omega_n} + 1}$$

If the load of the SBC is the DC motor, we can obtain the following functional model (Fig.7)

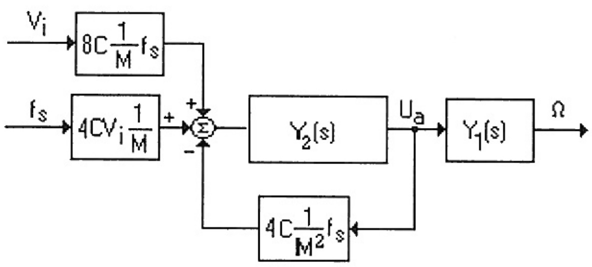

Fig.7 DC motor + power supply

where

$$Y_2(s) = \frac{1 + sR_a C_M + s^2 C_M L_a}{1 + s(2C_M + C_0) + s^2 R_a C_M C_0 + s^3 C_M C_0 L_a}$$

We can use a frequency controller, which consists of a P or PI controller (the output is for example +/- 1V), a DC clamper (to obtain only positive switching frequencies) as well as of a voltage/frequency transformer (Fig. 8)

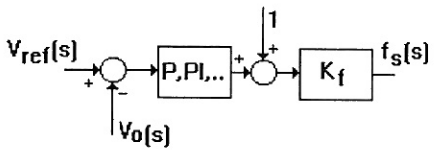

Fig. 8 Frequency controller

Using this we can determine the full functional control model for ω angular velocity (Fig 9)

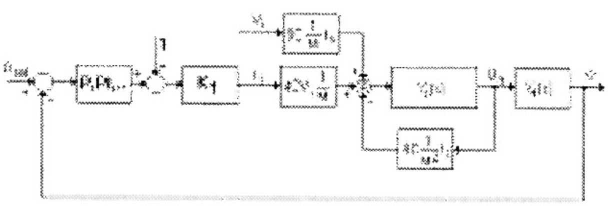

Fig. 9. Motion control model for DC motor with switch mode power supply using a frequency controller

This model (Fig. 9) can be easily applied using the simulation software programmes (MATLAB, VISSIM, etc.).

Students of Electrical Engineering Course have the choice in the 4th semester to continue their studies in automation or in telecommunication specialisation. Students taking part in automation specialised course have the opportunity to study Power Electronics in the 5th and 6th semesters.

Within the education of Power Electronics our intention is to give selected passages from the relevant literature [6,7,8] showing traditional and up-to-date solutions for problems.

Theoretical lectures are supplemented by

- laboratory work
- directed learning within micro-teams (Scientific Student Group, SSG)
- tutoring final diploma thesis.

Within the wide range of Power Electronics we emphasise the following fields:

- principal power electronic devices, their operation, characteristics (IGBT, MOSFET, Power Bipolar Transistor, GTO, Diode, etc.);
- driver circuits (factory manufactured and self-made direct drivers and potential-free drivers);
- active protective circuits (operation);
- some widely used control ICs (3842, 4700, 4800 series, etc.).

Practical education is also supplemented by literature research work. Students work in groups of 2 or 3 persons, such groups have the task to become acquainted with catalogues and papers about practical usage of control ICs in English and German languages and they should translate these materials into Hungarian as well as design and prepare printed circuit board to show other groups how these circuits operate.

Our intention is to widen students work in the field of simulation using SPICE software programmes.

Any type of switched-mode converters or the control circuit of a brushless DC motor were the most favourable tasks to design and build up within this activity.

Although we know that not all the graduated students will work in the field of power electronics we think project based learning contributes to give students a real view about differences between theory and practical usage.

The tasks given the groups incorporate among others different types of converters and their driver circuits. We find it important that the groups should make a complete documentation which shows all the stages of their work (selection of devices, planning, construction, test results, application).

In many industrial applications there is a requirement of potential-free driver circuits of the switching elements (MOSFET, IGBT, GTO, power transistors). We are of the opinion that the students should become acquainted with different types of driver and control circuits and/or methods and their most important characteristics (advantages, disadvantages, boundaries of usage). Selection of driver circuits is always a compromise. There should be considered for example the performance, complexity, cost, etc. of the elements.
The following part of the paper shows some selected circuits which were built and tested by the student groups.

SUMMARY

This paper shows using an example how we embed the motor control systems and power electronics for the education of robotics. Our conclusion is that the application of complex simulation software programmes are unavoidably in the education of the Electrical and Mechanical Engineering students.

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