

Experiment-1

Introduction to the DSP-based Electric-Drives System

IT IS PREFERRED that students ANSWER THE QUESTION/S BEFORE DOING THE LAB BECAUSE THAT provides THE BACKGROUND information needed for THIS LAB. (10% of the grade of the lab)

Q1: What are the main components of the Electric Drive System? What are the components which represent those components in our Drive lab station? Explain.

Q2: What is the power electronic converter which is used to control the DC motor? What are the three types (Topologies) in terms of the relationship between the input voltage and the output voltage? Explain and give the equation of each.

Q3: An important phenomenon occurs in DC Machine is called “Armature reaction “

a- Search the text and the web and learn more about it and then explain it (you can use the Text book).

b- Is the “Armature reaction “an advantage or a disadvantage? Explain in detail why you answered?

1.1 Introduction

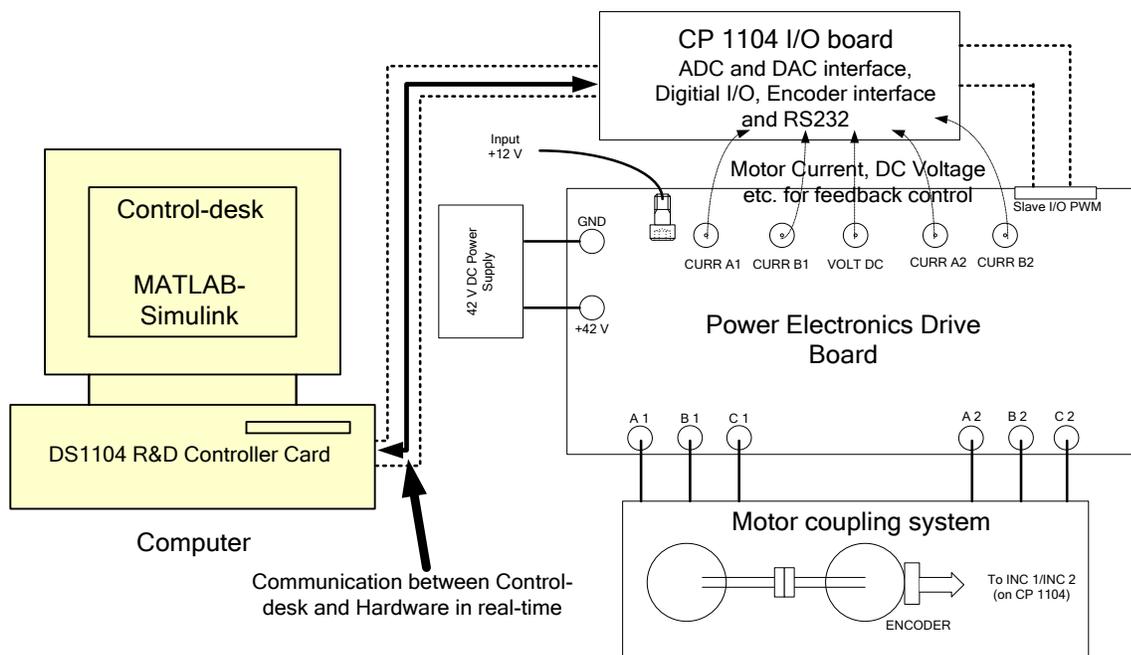
There are four major components of the DSP-based electric-drives system, which will be used to perform all the experiments in this course. They are as follows: 1) Motor coupling system, 2) Power Electronics Drives Board, 3) DSP based DS1104 R&D controller card and CP 1104 I/O board and 4) MATLAB Simulink and Control-desk. In this experiment, you will be briefly introduced to the role of above mentioned four components in the DSP-based electric-drives system. An example of speed-control of a DC-motor will be demonstrated. The Simulink file and Control-desk layout will be supplied to perform this experiment. The communication between the four components will be explained while controlling the speed of the motor. Section 1.2 details the DSP-based electric-drives system vis-à-vis the role of the four components listed above. In Section 1.3 a step-by-step procedure to run the DC motor speed-control will be performed.

1.2 DSP-based electric-drives system

Fig. 1.1 shows the block diagram of the DSP-based electric-drives system.

- *Motor coupling system:* This system contains the motor that needs to be characterized or controlled. The system has a mechanical coupling arrangement to couple two electric

machines. The motor under test (MUT) whose speed/torque needs to be controlled, could be either a DC motor or a Three-phase induction motor or a Three-phase Permanent-Magnet AC (PMAC) motor. The system also has an encoder mounted on the machine which is used to measure the speed of the MUT. This can be used for close loop feedback speed-control of the motor. The motor demands a controlled pulse-width-modulated (PWM) voltage to run at controlled speed or torque. The PWM voltage is generated by Power Electronics Drives Board (briefed next); the voltage source thus generated is connected to the motor coupling system as shown in Fig 1.2.



Figure

1.1: DSP-based electric-drives laboratory system

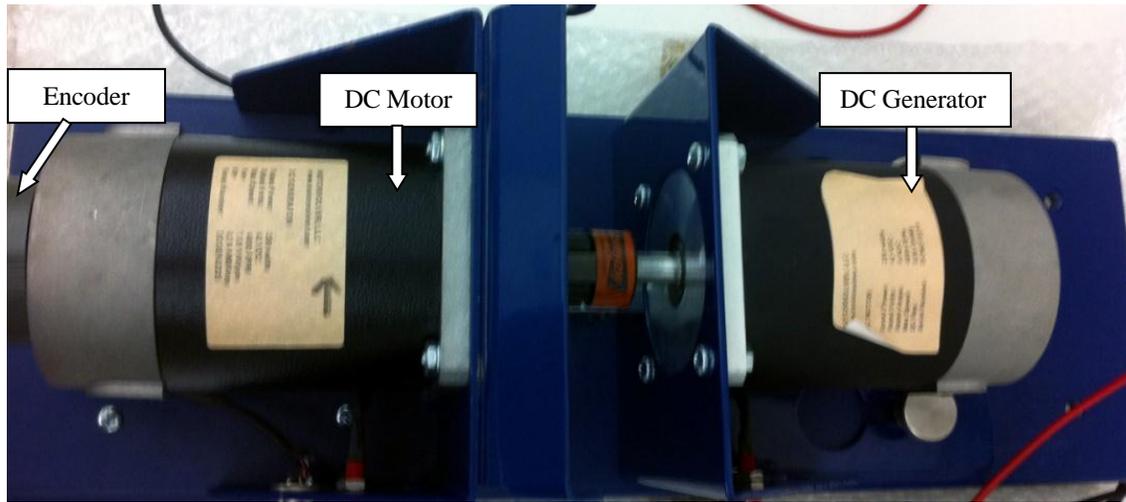


Figure 1.2: Motor Coupling System showing DC Motor, DC Generator and Encoder

- *Power Electronics Drives Board:* This board has the capability to generate two independent PWM voltage sources (A1B1C1 and A2B2C2) from a constant DC voltage source (see Fig 1 in Appendix). Hence two machines can be controlled independently for independent control of variables, at the same time. This board also provides the motor phase currents, dc-bus voltage etc. to control the motor for a desired speed or torque. To generate the controlled PWM voltage source, this board requires various digital control signals. These control signals dictate the magnitude and phase of the PWM voltage source. They are generated by the DS1104 R&D Controller board inside the computer.
- *DS1104 R&D controller Board and CP 1104 I/O board:* In each discrete-time-step, the DS1104 controller board takes some action to generate the digital control signals. The type of action is governed by what we have programmed in this board with the help of MATLAB-Simulink real-time interface. This board monitors the input (i.e. motor current, speed, voltage etc) with the help of CP1104 I/O board in each discrete-time step. Based on the inputs and the variables that need to be controlled (i.e. motor speed or torque); it takes the programmed action to generate the controlled digital signals. The CP1104 I/O board is an input-output interface board between the Power Electronics Drives Board and DS1104 controller board. It takes the motor current, dc-voltage etc. from the Power Electronics Drives Board and also, speed signal (from encoder) from motor coupling system, to the DS1104 controller board. In turn, the

controlled digital signals supplied by DS1104 controller board are taken to the Power Electronics Drives Board by CP1104.

- *MATLAB Simulink and Control-desk (Programming DS1104 and control in real-time):* Simulink is a software program with which one can do model-based design such as designing a control system for a DC motor speed-control. The I/O ports of CP 1104 are accessible from inside the Simulink library browser. Creating a program in Simulink and the procedure to use the I/O port of CP 1104 will be detailed in future experiments. At this stage, let us assume that we have created a **control-system** inside the Simulink that can control the speed of a DC motor. When you build the Simulink **control-system** (pressing CTRL+B) by using real-time option, it implements the whole system inside the DSP of DS1104 board, i.e. the **control-system** that was earlier in software (Simulink) gets converted into a real-time system on hardware (DS1104). Simulink generates a *.sdf file when you build (CTRL+B) the **control-system**. This file gives access to the variables of **control-system** (like reference speed, gain, tuning the controller etc) to a separate software called Control-desk. In this software a control panel (see Fig 1.3) can be created that can change the variables of **control-system** in real time to communicate with DS1104 and hence change the reference quantities such as the speed or torque of the motor.

1.3 Demonstration of Speed Control of a DC motor

The system for the speed-control of a DC motor is shown in Fig 1.3. Note that the currA1 (i.e. phase-current of DC motor) and encoder signal (speed of DC motor) is fed back to the DS1104 board via CP 1104. The requirement of feeding back phase-current and speed of the motor will be studied in experiment-4. For now, assume that these two quantities are required to control the speed of DC motor. Perform the following steps to run the experiment. The communication between the four components (explained in section 1.2) is detailed in each step, wherever necessary.

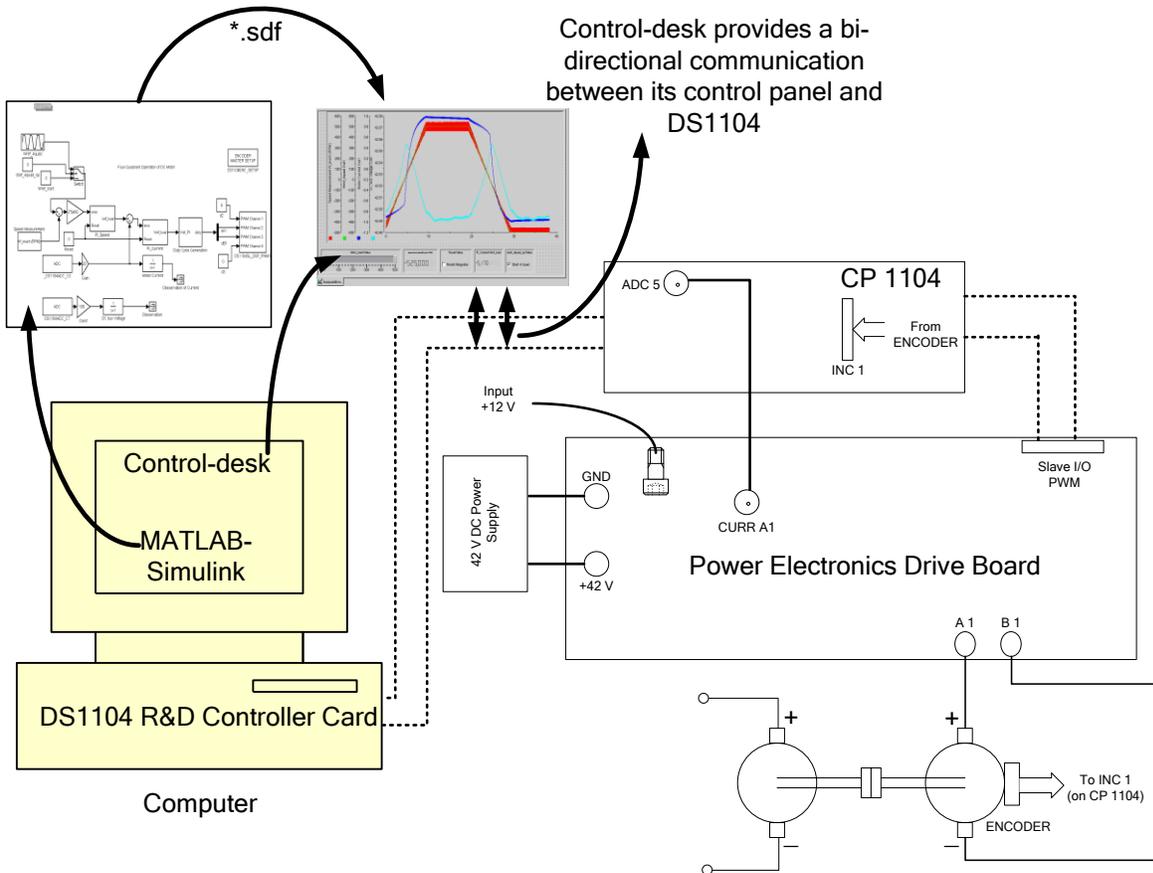


Figure 1.3: Demonstration of DC motor speed-control

- Connect the circuit as shown in Fig 1.3. You are given with files **Exp1.mdl** (Simulink control-system file) and **Exp1.lay** (control panel in Control-desk). Create a new folder on desktop as **Exp1** and bring these two files into that folder. Open MATLAB Simulink and set the folder **Exp1** as the path of the current working directory. Verify in the command window for the correct path (Fig 1.4). Open the Simulink file **Exp1.mdl** as shown in Fig 1.4.
- Note : (When the MATLAB[®] is opened, We chose RTI 1104 → OK)

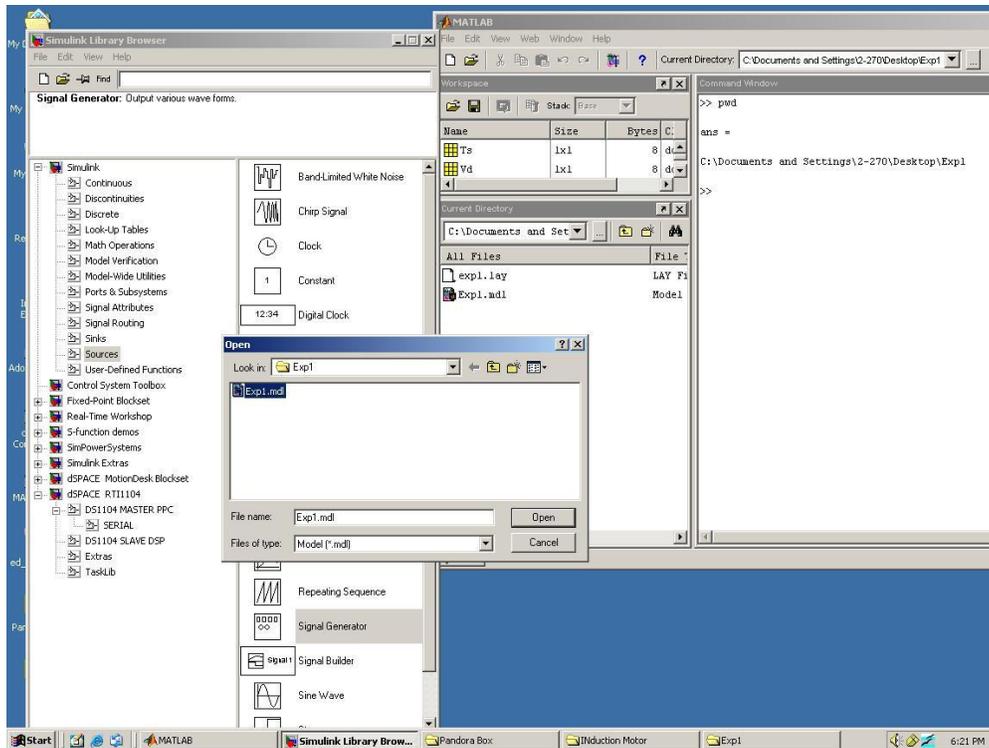


Figure 1.4: Opening the Simulink file Exp1.mdl, changing the path of current working directory

- The Simulink file **Exp1.mdl** will look as shown in Fig 1.5. Open the simulation parameters (**Or could be Configuration parameters based on the MATLAB version**) from the tools menu and set the parameters as shown in Fig 1.5. The fixed step size is the same as the discrete-step, which will be used by the DSP DS1104. This means that in every “discrete-step” the whole program (i.e. **control-system** in this case) will be executed, I/O data will be exchanged and the decision making will be done inside DS1104.
- Type $V_d=42$ and $T_s=1e-4$ in the Matlab prompt. Press CTRL+B to build the **control-system** in real-time now. Refer to Fig 1.6, note the sequence: 1) Compilation of C-code that is generated by Simulink, which will be used to implement **control-system** in hardware DS1104, 2) Generation of Exp1.sdf file, which will be used later on by Control-desk, to access the variables of **control-system**.

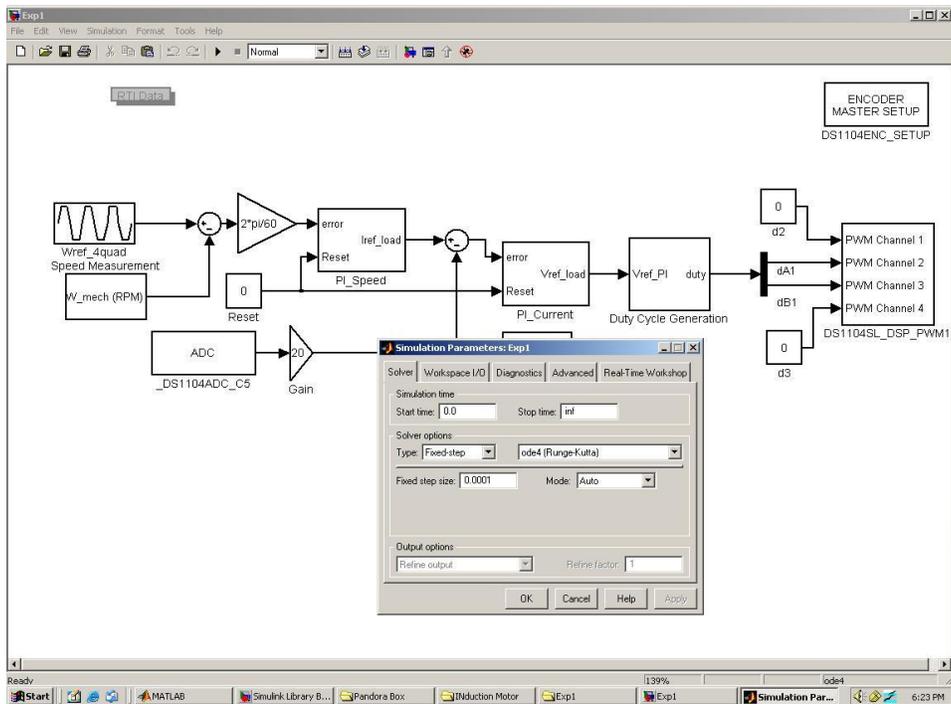


Figure 1.5: Simulink file Exp1.mdl, setting the simulation parameter

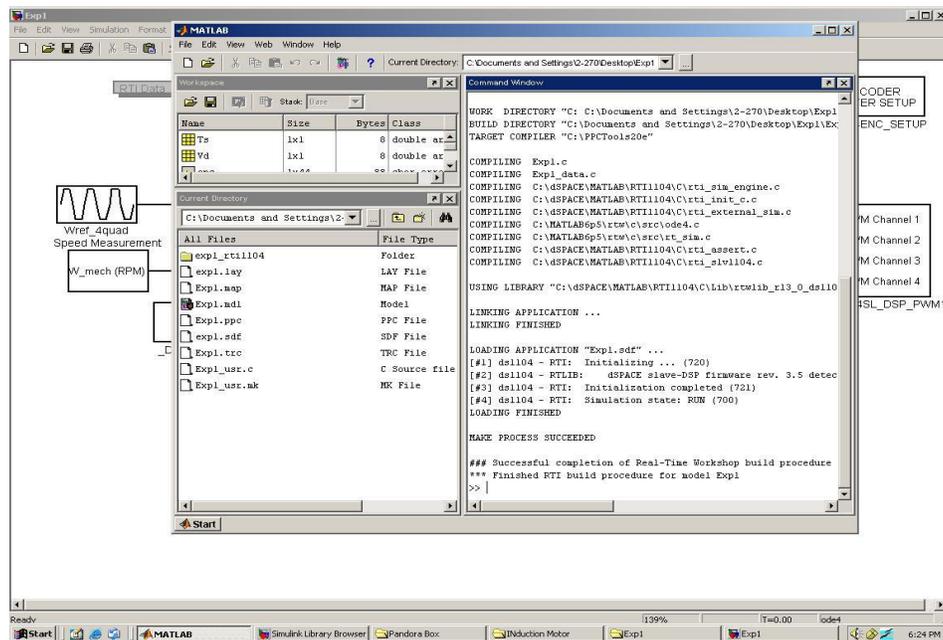


Figure 1.6: Building the Simulink program, real-time implementation

- Check the folder **Exp1**; this should contain the file **Exp1.sdf** in addition to the other system files. Leave them as such for the proper operation of Control-desk. Open Control-desk by

double clicking on the **dSPACE ControlDesk** icon. The icon should be located on the desktop of the computer; the opened control-desk is shown in Fig 1.7 (ignore the lower panel window shown in Fig. 1.7 at this moment, and also the pop-up window showing Exp1.lay). Click **File->Open Variable File**. A pop-up window will appear, locate the **Exp1.sdf** file in the directory **Exp1** and click **Open**. Now you should be able to see the lower panel window shown in Fig 1.7. Click **File->Open**, the pop-up window will appear again asking for layout file this time. Locate the file **Exp1.lay** as shown in Fig 1.7 and click **Open**. Click **yes** if a pop-up box opens asking for data-connection. The layout thus opened should look as shown in Fig. 1.8. At this stage the control panel of the control-desk is ready to communicate or transfer data with DS1104 via CP1104. Click **Start (PLAY)** and switch to the **Animation mode**. The motor will start running. It will rotate in the positive direction for some time and in the negative direction for some time, i.e. the direction of rotation alternates. Right click on the graph and select **edit capture** setting, and set the capture setting as shown in Fig 1.9.

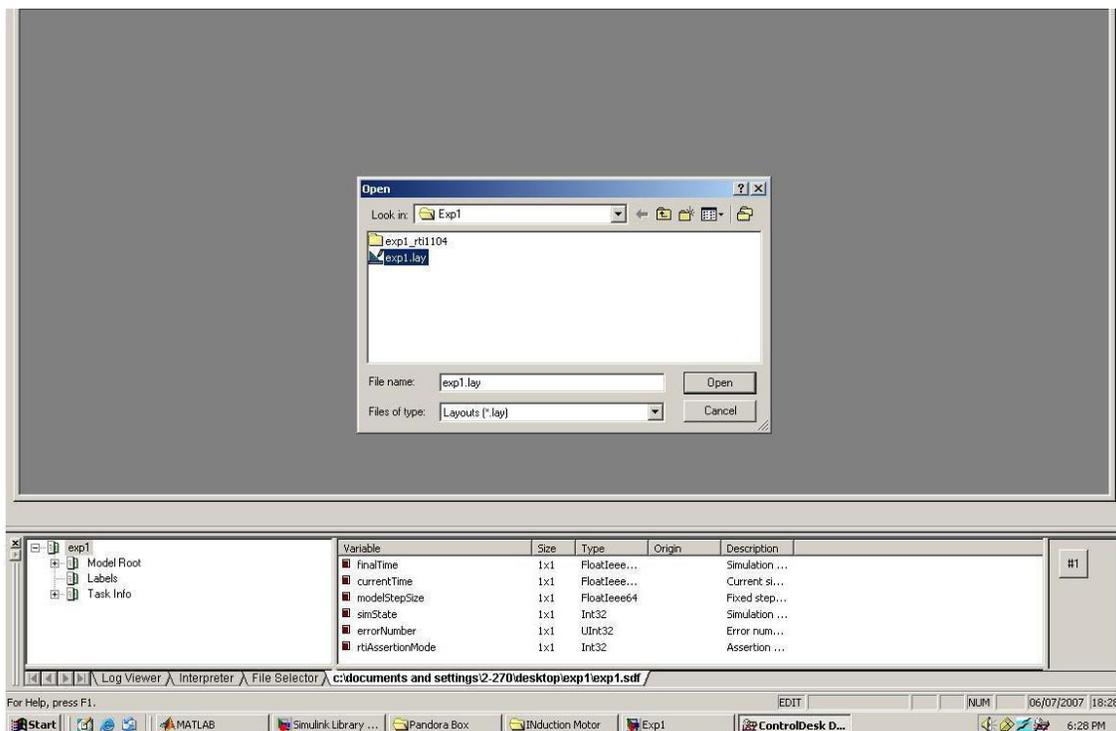


Figure 1.7: Control-desk panel, opening the layout

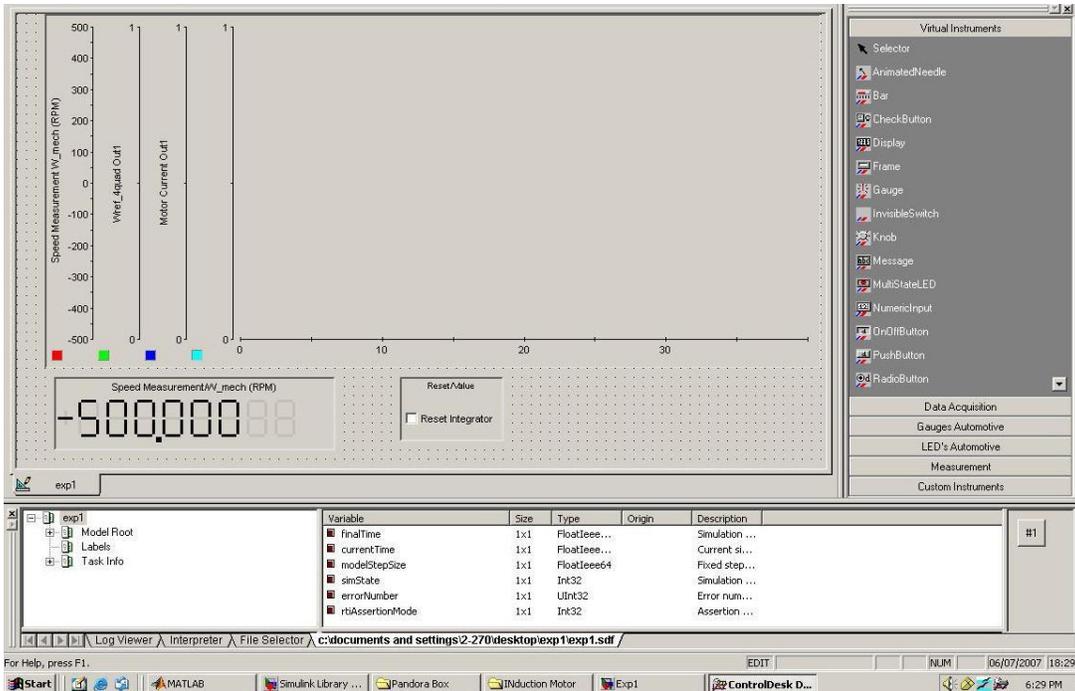


Figure 1.8: Control panel layout

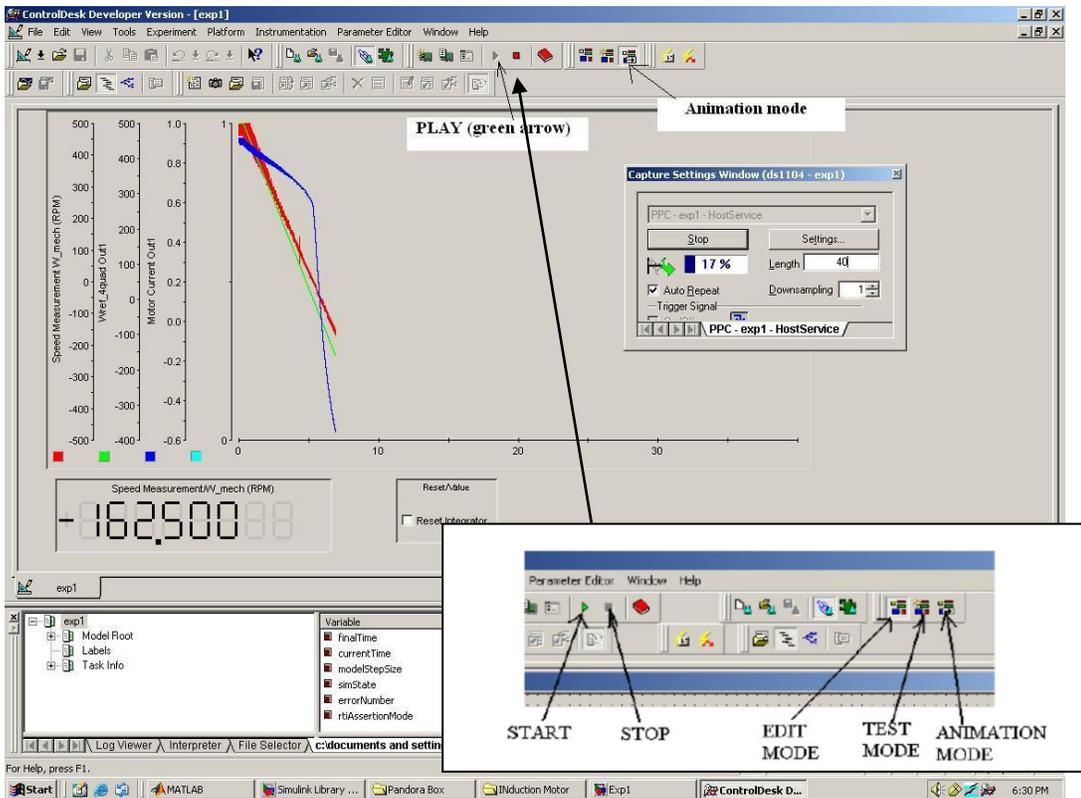


Figure 1.9: Various control buttons, starting and stopping the system

- You should be able to observe the speed of the motor on control panel (Fig. 1.9). The waveform for motor phase current, reference speed and actual speed is also shown. Press the button **Edit mode** and then press **STOP**. Take the waveform as shown in Fig 1.10. Study the explanations detailed next. The control-desk is able to access the following data with the help of **Exp1.sdf** file:
 - **Actual Speed of the motor** from **W_mech** subsystem which is inside the Simulink **control-system**. You can open the subsystem **W_mech**; you will observe how the input port INC1 (DS1104ENC_POS_C1) of **CP 1104** is utilized to read the actual speed of the motor. In the actual system, this port is connected (hardwired) to DS1104 though. But, this port is also a part of Simulink **control-system**; hence it will be listed as a variable inside the **Exp1.sdf**. Since the control-desk has access to the variables of **control-system** through **Exp1.sdf**, hence the control-desk can read the port INC1, modify the data and send it back to any of the output port of CP 1104, if necessary.
 - **Motor current, reference speed and actual speed** can be observed in the same manner, the communication among components is same as explained above.
 - Note that, in this demonstration, we are only observing the variables of **control-system** such as speed of the motor and current. It is also possible to change the variables of **control-system** in real-time from the control panel. In the future experiments, this will be done to give a reference speed command to run the motor at a desired speed. This reference speed command will be changed in real-time to change the speed of the motor.
- *Sequence of events, when **Start** button is pressed on the control panel:*
 - DS1104 will be commanded to generate the controlled digital signals as per the speed and phase-current of the motor in real-time. The information about the speed and current of the motor is available to DS1104 via CP 1104, which is connected to the Power-Electronics-Drives-Board (for current feedback) and the Motor coupling system (for speed feedback).

- The controlled digital signals will be received by CP 1104 from DS1104. Digital I/O of CP 1104 is connected to the Power-Electronics-Drives-Board; hence the board will start generating the PWM voltage source.
- The motor will receive the PWM voltage at its terminals and hence start rotating. It will speed up; the current in the winding will increase. Since the speed and the current of the motor thus increased are fed back to DS1104 in real-time, the DS1104 will take the next action as per **control-system**. DS1104 will change the pattern of digital signal to change the speed of the motor such that the motor will achieve the speed as commanded in the **control-system** (block **Wref_4quad**). Note that, the speed command in **control-system** is alternating; hence the motor alternates its direction of rotation. The instantaneous motor speed and current is shown in Fig 1.10.

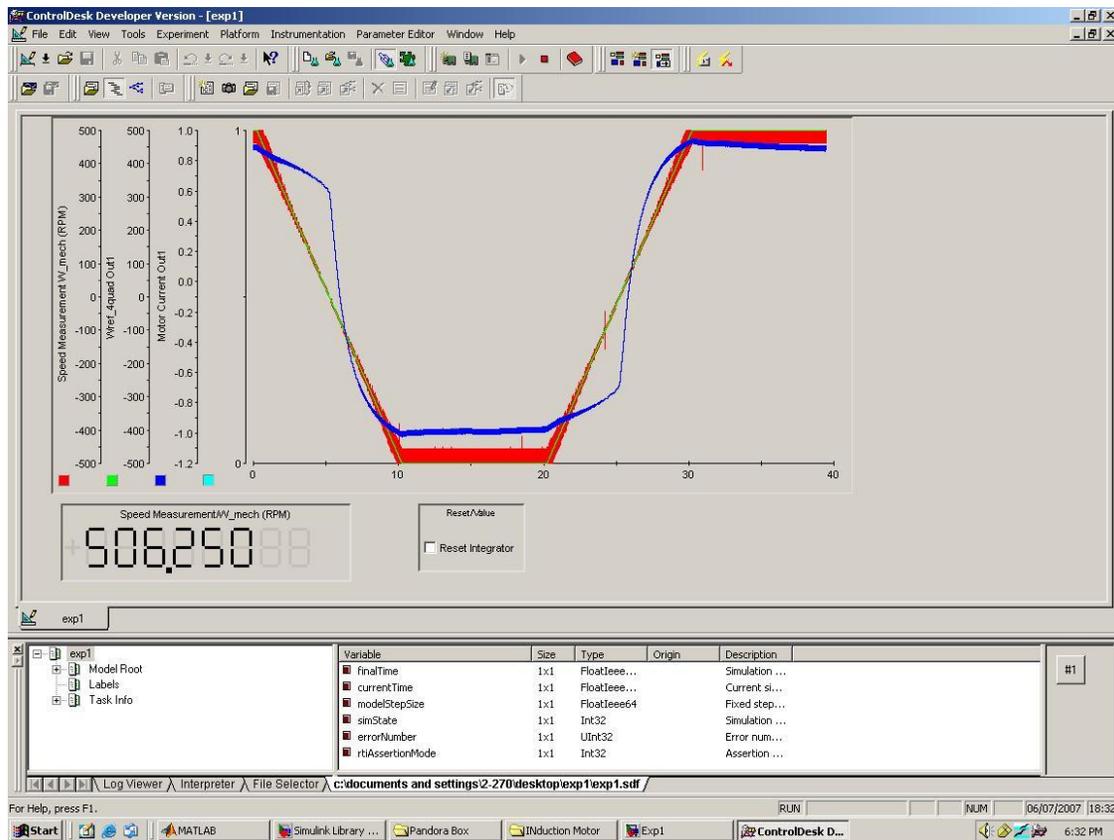


Figure 1.10: Motor actual speed (red), reference speed (green) and phase current (blue)

Lab Report and

- List the sequence of events i.e. the communication between the four major components when **STOP** button is pressed in the control panel.
- For this experiment draw a flowchart indicating step-by-step procedure to create a real-time model in Simulink, which is followed by controlling a DC motor from control-desk.
- Study thoroughly Appendix-A, pay special attention to the Power-Electronics-Drives-Board features. Make a note of voltage and current scaling in the Drives board.
- Draw a block diagram of Power-Electronics-Drives-Board indicating the inputs (like power supplies, digital input, resets etc) and outputs (like PWM voltage, motor current, dc-bus voltage etc).