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E-Learning Practical Teaching of Uncontrolled Rectifiers

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Abstract – The paper describes blended learning approach to teaching uncontrolled rectifiers. It is based on "Learning by Doing" paradigm supported by several learning tools: electronic course materials, interactive simulation, laboratory plants and real experiments accessed by Web Publishing Tools under LabVIEW. Studying and experimenting access is opened for 24 hours a day, 7 days a week under the Moodle booking system.

Keywords: Internet-based remote experimentation, autonomous learning environment, computer aided instruction, courseware, uncontrolled rectifiers.

I. INTRODUCTION

Efficient learning in engineering assumes a mixture between theory and practical work. The drawback of a pure theoretical approach in a curriculum is that less attention is paid to the phenomena looming around laboratory experiments and real components. The results of this, corroborated with the rapid development of computer simulations, was that hands-on laboratory experience was vanishing and that computer simulations gained more and more attention. However, it is of crucial importance for the student to gain practical experience. Physical experiments help the students in practical testing and allow them to see the influence of second and higher order effects or parasitics, that are often difficult to simulate as in reality. Hence it is of great importance to give the student a real world experience. Although classical hands-on laboratories are very useful, they may have limitations regarding space, time and staff costs. These problems can be significantly alleviated by using remote experiments and remote laboratories when the students operate with real systems, although they are not present in the laboratory. The proliferation of web based distance education courses in recent years involves new challenges for teaching of disciplines involving a high level of practical work. For engineering related distance education the use of a web-based delivery mechanism is the only realistic method of providing hands-on experience, allowing remotely located students to complete laboratory assignments, unconstrained by time or geographical considerations, while developing skills in the use of real systems. In this way access to the experiments is available 24 hours a day, giving the users the possibility to access the laboratory when they most need it, sitting comfortable in a remote location. They can change parameters, perform experiments, observe results in graphical or numeric view and download them. In addition, a booking system allow the remote users to plan their time and experiments.

II. LEONARDO DA VINCI PROJECT AND ITS PHILOSOPHY

The Leonardo da Vinci project with the acronym EDIPE (E-learning Distance Interactive Practical Education) is approved to create a full set of distance experiments called PEMCWebLab in an integrated learning platform, providing the user with a practical experience in Power Electronics and Electrical Drives education. They are real experiments conducted in the laboratory but remotely accessed, controlled and monitored by web-based tools. The participants are twelve universities with the span across the EU. The expected results are:

- Elaboration of clear learning objectives for distance experimental education,
- Guidelines for project oriented measurements,
- Synthesis oriented experimental work,
- Technology and technical documentation for distance practical education and measurements via Internet,
- Different experiments, each with its own specificity.

The expected outputs from the project are:

- Teaching material: guidelines, manuals, documentation in English and other languages,
- Distance and virtual laboratories approaches via web,
- Measurement results and reports obtained via Internet.

Each experiment has its own server because it is located at a different location. Remote users first log

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onto a main booking server, located at the University of Maribor, after which they will be directed to the specific server for actually performing the experiment into a separate individual page. The booking system is based on the Moodle course management system (www.moodle.org). Moodle is a widely adopted software package for producing Internet-based courses and websites. In addition to the original booking system, some modifications have been made [1], enabling easy booking creation for those remote experiments that were developed under the LabVIEW Web Publishing Tools. The layout of Moodle pages for all experiments are uniform. The users are divided in two groups: authorized users and guests. Only authorized users can control the experiment. The guests can only observe measured values and waveforms but they have no control of any part of the system.

The learning issues addressed in the PEMCWebLab integrated learning platform are:

- Learning objectives
- Education
- Animation and Simulation
- Experiment

The order of these issues is important. For safety reasons no student will be allowed to perform any experiment until he or she has proofed adequate knowledge of the requested experiment. First the Learning objectives are defined, while a theoretical background of each individual experiment is given in part Education. Interactive animation and/or Simulation are the steps preceding the real Experiment.

After completion of the real experiment the students are given a questionnaire and have to submit their report for the final evaluation. All learning procedures are recorded for future reference and analysis.

The structure of the distance laboratory is shown in Fig. 1 in the situation when the chosen module is "Single Phase and Three Phase Rectifier Circuits".

III. TEACHER ORIENTED AND STUDENT ORIENTED EDUCATION

Many teachers continue to think their main duty is to transfer their knowledge to the students by giving lectures or by organizing laboratory experiments. In this view, the accent is on *teaching*, rather on *learning* [2] Presently, the new philosophy assumes that knowledge is not transferred, but that the learner himself constructs knowledge on the basis of prior knowledge and additionally acquired information. "Learning by doing" or "Learning by experimenting" approaches are accompanied by an output oriented curricula as part of the shift emphasis from teaching to learning. This view is referred to as *constructivism* While in the *teaching-oriented* approach the student is rather passive, in the vision of *learning-oriented* approach the student plays an active role, constructing knowledge on the basis of prior knowledge and additionally acquired information, with teaching as a facilitating precondition.

In this spirit the PEMCWebLab experiments are oriented not only to analysis but also to synthesis. They include design aspects and the measurements are thought as a project with clear targets.

The learning process in power electronics includes all important steps: general theory, key design factors (device stresses, ripple estimation, power quality aspects, etc.), simulation and real experiment measurements.

In this paper the module "Single Phase and Three Phase Rectifier Circuits" will be discussed in detail.

IV MODULE AND EXPERIMENT DESCRIPTION

The course module "Single Phase and Three Phase Rectifier Circuits" with the hardware architecture presented in Fig. 2, is dedicated to bachelor students and anyone interested in understanding uncontrolled rectifier operation with emphasis on a comparison between theory and practice. The aim of the course is

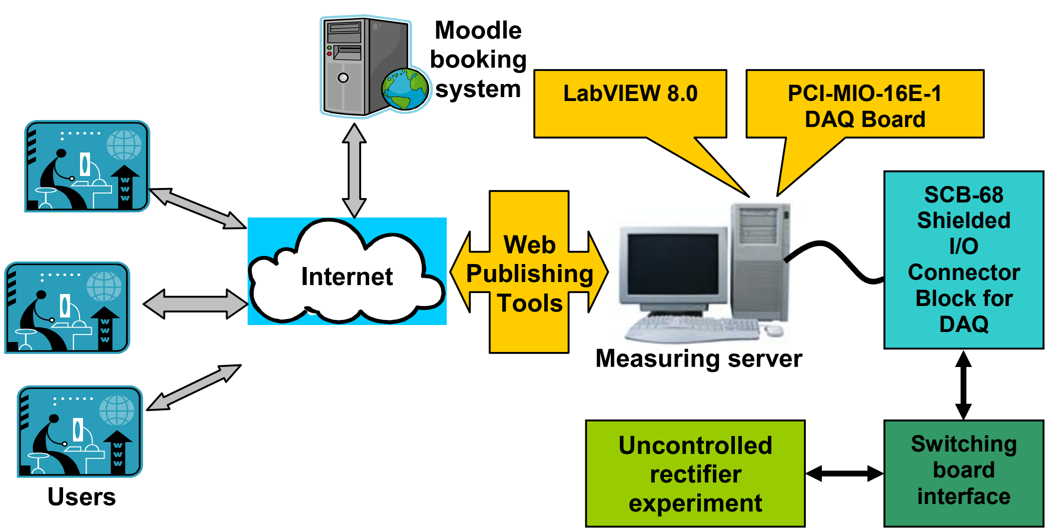

Fig. 1. Structure of the distance laboratory for E-learning practical teaching of uncontrolled rectifiers.

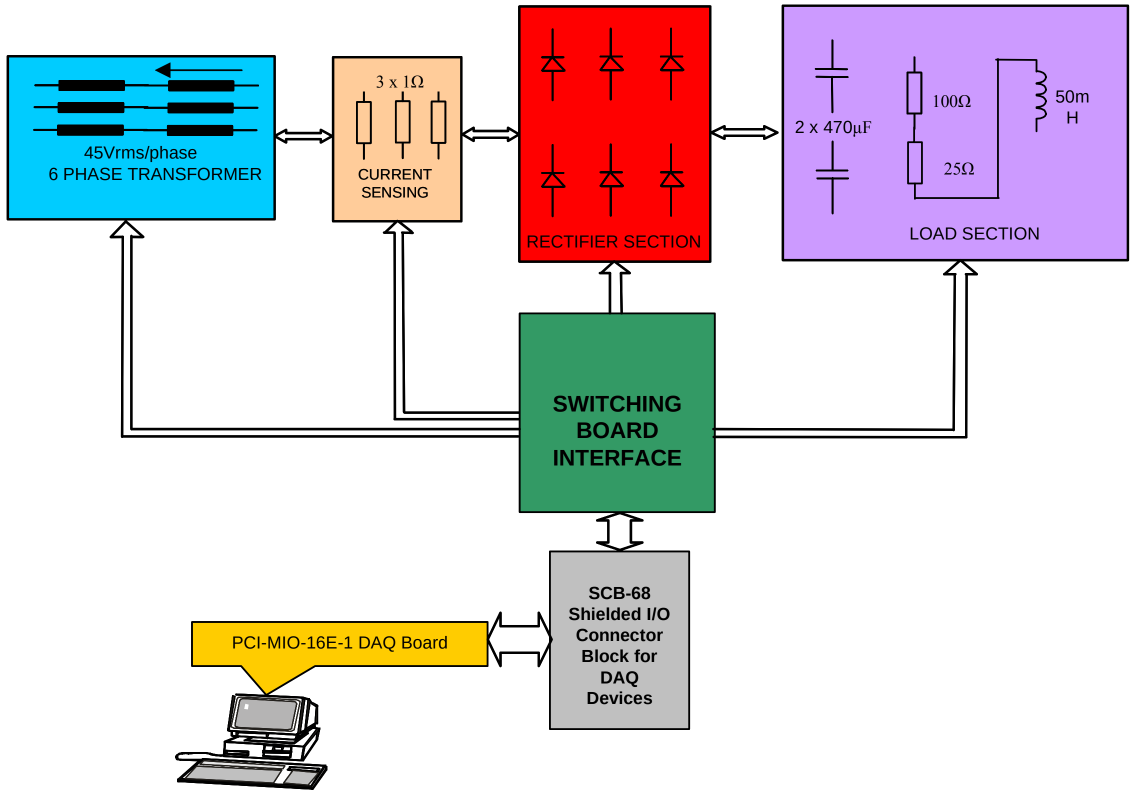

Fig. 2. Hardware architecture of the "Single Phase and Three Phase Rectifier Circuits" module.

to explain and practice the basic principles of rectifying and rectifier design. Simulations are performed before any experiment in order to understand the basic work principles of the rectifier under study. The component values are the same as will be used later for breadboard. Simulation is performed with the Caspoc package [3]. The user friendly interface allows one change the power circuit using drag and drop procedures. Another interesting feature of Caspoc is the animation capability which is extremely useful in switching circuits as it reveals the on and off devices at a certain time moment and the currents paths as well. Of course, the simulated waveforms are obtained without parasitic elements or measurement noise, which is quite an advantage as it offers the possibility to compare them to the real ones and notice the differencies. Simulation results of a single phase half wave rectifier with inductive load is depicted in Fig. 2.

The local server uses LabVIEW [4] for controlling the experiment. The Web Publishing Tools that come with LabVIEW are used both for interfacing and remote controlling the experiment. The proposed solution is based on ELWE teaching module hardware. The PCI-MIO-16E-1 DAQ card together with the SCB-68 shielded I/O connector block for DAQ devices are used for acquisition and measurements. The Switching Board Interface (SBI) is controlled from LabVIEW and is used for configuring the desired rectifier topology and the signals for data acquisition. Functionally, it consists of a 32 bit shift register followed by buffers that switch on and of a relay matrix.

Eight types of single phase and three phase uncontrolled rectifiers are investigated as presented in Table 1.

Table 1

Experiment	Title
1	Single-Phase Half Wave Rectifier with inductive and capacitive load
2	Single-Phase Half Wave Rectifier with inductive load and freewheel diode
3	Single-Phase Center-Tapped Full Wave Rectifier with inductive load
4	Single Phase Bridge with filter capacitor and with inductive load.
5	Voltage Doubler
6	Simple Three Phase Rectifier with inductive and capacitive load
7	Three Phase Bridge Rectifier with inductive and capacitive load
8	Simple Six Phase Rectifier with inductive and capacitive load

In fact, because the load can be inductive or capacitive in nature, the number of experiments is doubled, and therefore 16 distinct experiments can be studied.

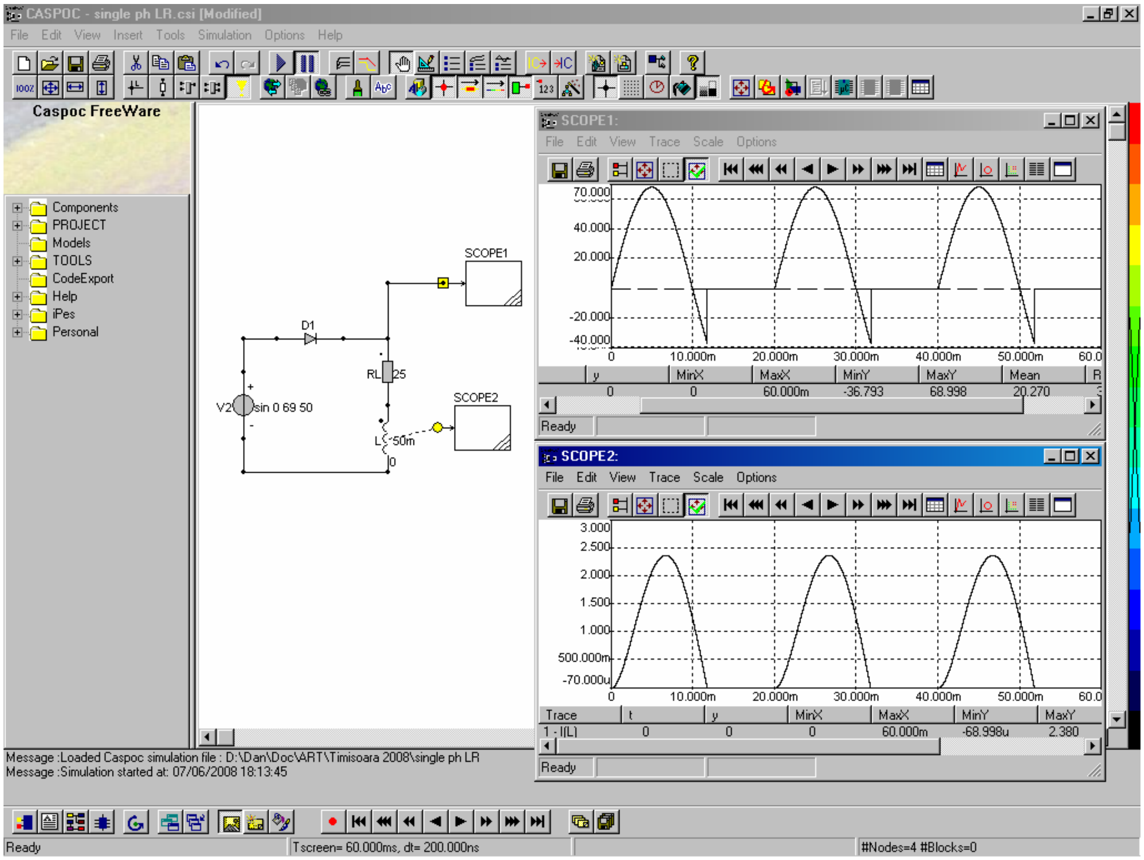

Fig. 2. Simulation schematic and waveforms of a single phase half wave rectifier with inductive load.

When the user performs an experiment he or she hets and handles two front panels: one for selecting the desired experiment, called Selection Front Panel (SFP) and the other for visualizing waveforms and measurements, called Measurement Front Panel (MFO). The flow chart of the main LabVIEW program is presented in Fig. 3. It can be seen that the program permanently monitors the user's window state. If by mistake the user closes the remote panel window without normally exiting the program, the experiment would remain permanently connected which can be unsafe for the power circuit. Therefore as soon as the user is disconnected without exiting the program, the experiment is automatically closed and a message is displayed. On the other side, as long as the power circuit configuration is established no control is available for the user. The same happens when an experiment is finished and another one is selected. In these situations first all the relays are set to off in order to be sure no remaining wrong connection could damage the circuit. The sequence the relays are switched is also important. The first set of relays that are switched on simultaneously are those for configuring the rectifier and the rectifier load This is done without any power supply applied and therefore the relays are switched at zero current. It is achieved writing a 32-bit word in the shift registers. Next, the rectifier supply voltage is applied. This is performed writing a second 32-bit word. In another separate word the power ground is connected to the analog ground of the acquisition board. The last relays switched on are those for providing the required signals to the acquisition board. The SFP is presented in Fig. 4.

Each of the 16 experiments has its own DAQ assistant built according to the signals required by the corresponding rectifier. The signal list, the waveform graph and spectrum analyzer are also rectifier individualized. Any signal from the signal list can be displayed, inhibited and analyzed separately or together with any other signal. Simultaneous signal display is useful as the phase shift between the signals is always of interest in studying rectifiers. The user has the possibility to stop the acquisition at any time and to perform measurements on the displayed waveforms using cursors. Time, amplitude, phase, rms of harmonics, dc and rms values are available. The MFP is shown in Fig. 5 for the single phase half wave rectifier with inductive load and without freewheel diode. As it can be seen from Table 1, rectifiers are studied with emphasis on behavior depending on load nature, as they are nonlinear systems. Also for bridge structures with inductive loads in the so called continuous conduction mode, the fact that the rectifier can be decomposed in two independent rectifiers with the load connected between their outputs is underlined. Diode conduction angle and diode peak current value dependency on

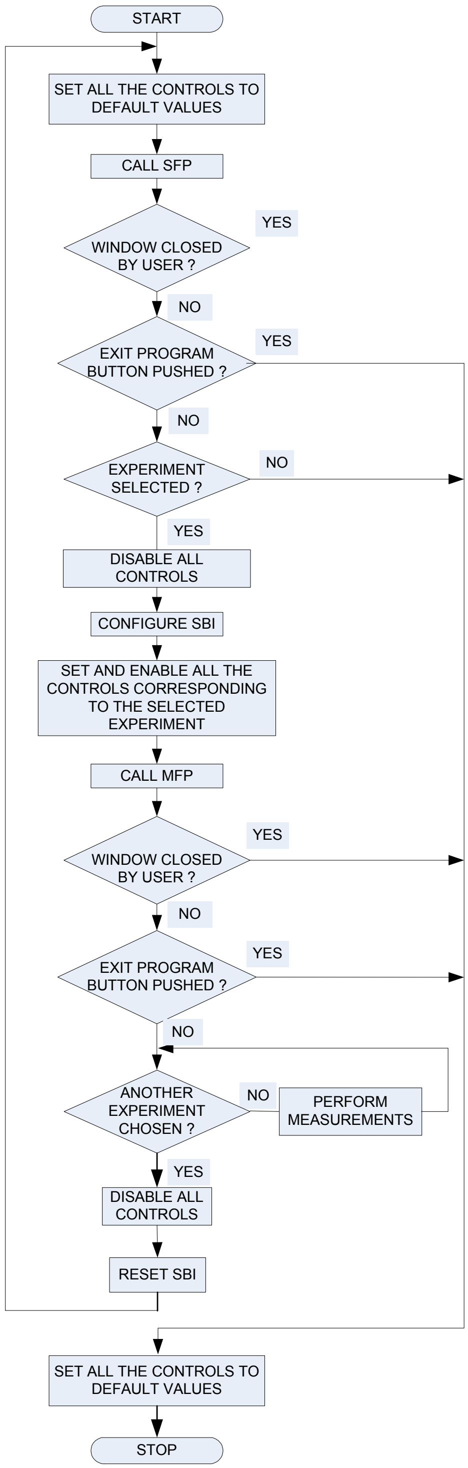

Fig. 3.Flow graph of the main LabVIEW program.

load nature is evidenced starting from resistive, then inductive and at last capacitive loads.

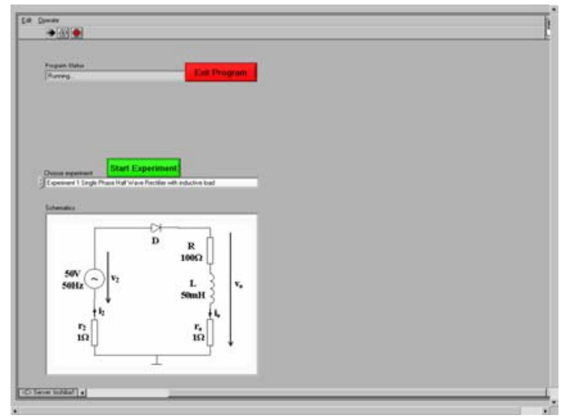

Fig. 4.Selection Front Panel window..

V. CONCLUSIONS

The PEMCWebLab was conceived as a complete educational solution in the field of Power Electronics and Electrical Drives. Based on “Learning by doing” Philosophy it allows the students to perform experiments independently and safely, without any time limitation. due to a centralized booking system. The “Single Phase and Three Phase Rectifier Circuits” module described in the paper offers eight types of uncontrolled rectifiers to be studied. The simulation and animation before any experiment helps the student to understand the basic principles of operation. The real experiment allows the user both to visualize the main waveforms and to perform measurements on the acquired signals. Thus the user gets quickly familiar with the standard design steps carried out in power electronics.

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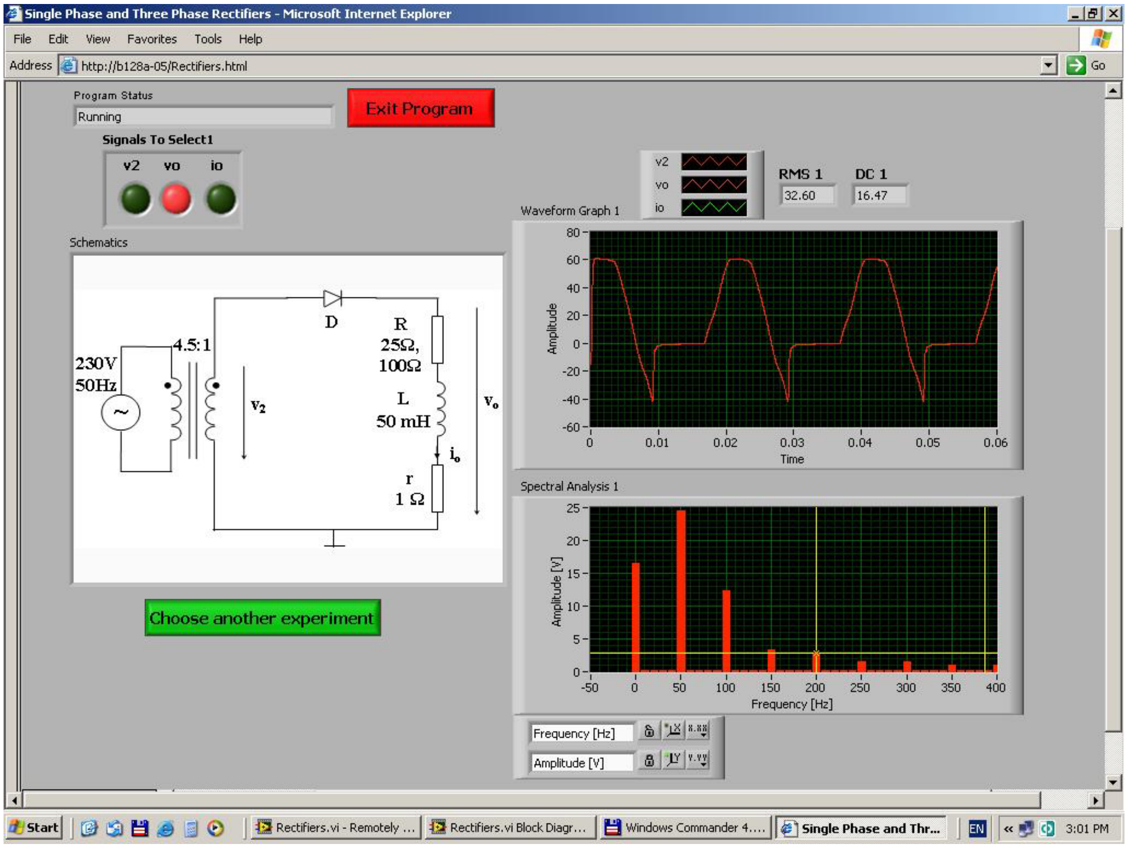

Fig. 4.Selection Front Panel window..

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