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ENERGY EFFICIENCY

IN ELECTRICAL MOTOR SYSTEMS

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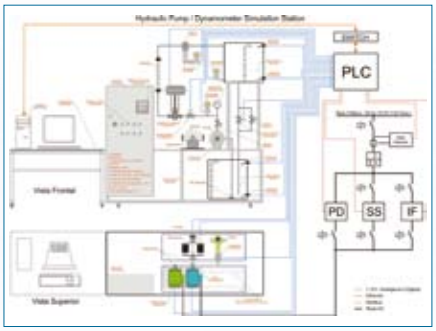
ENERGY

ELECTRICAL MOTOR SYSTEMS

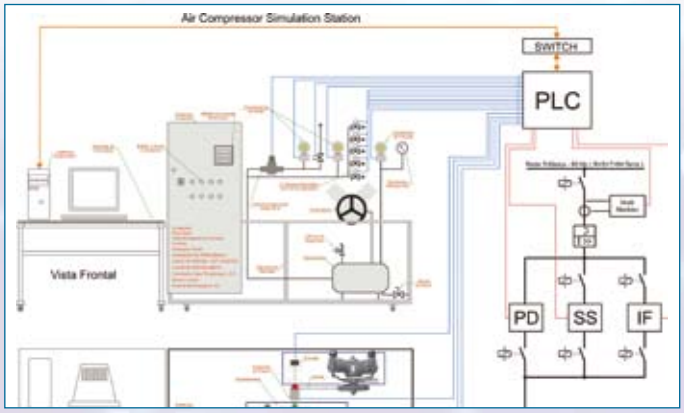
They represent 50% of the consumption of the industrial sector and a great potential for reducing losses.
They are composed of:

- Electrical motors
- Electrical-electronic driving
- Motor-load coupling
- Mechanical loads (pumps, compressors, conveyors, fans, etc.)
- Industrial instrumentation
- Facilities

OBJECTIVES OF THE LABORATORY



- To prepare the professionals with knowledge and attitude for rational use of energy
- To evaluate the aspects related to the energy efficiency in industrial consumers
- To study the rationalization of the production and of the consumption of electrical power
- To get knowledge to reduce the electrical power wastes
- To get knowledge to reduce costs and investments in this field
- To experiment equipment, instruments and technologies that are currently used in the industrial plants
- To evaluate the possibility of efficiency savings associated to electrical motor systems



EFFICIENCY
IN ELECTRICAL MOTOR SYSTEMS

STRUCTURE OF THE LABORATORY

This laboratory has been developed to simulate a large number of operative conditions of the following most common equipment currently used by the industry:

- **Hydraulic pumps**
- **Air compressors**
- **Fans**
- **Air conditioners**
- **Belt conveyors**

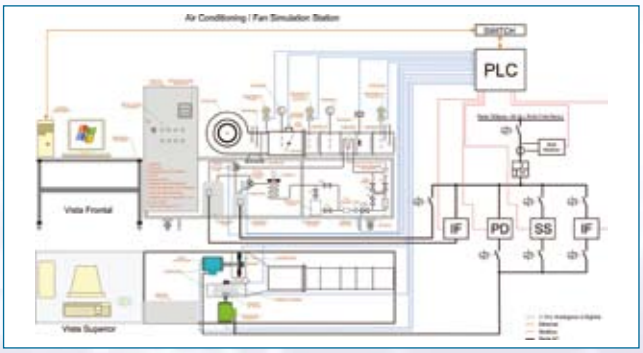
In addition to the above industrial loads, the laboratory has a Dynamometer for dynamic analysis of the motors.

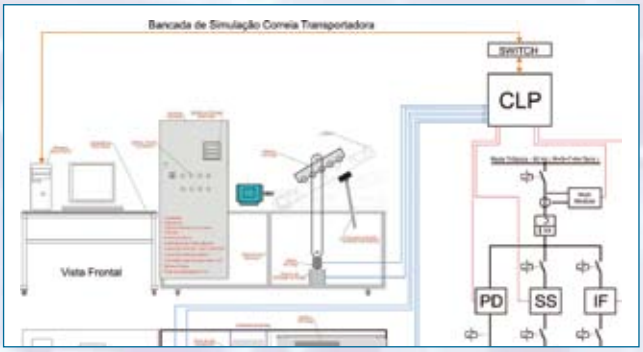
The above equipment have been arranged to form four Working Stations that allow the actual demonstration of the electro-mechanical operations and their implications in the consumption of electrical power.

The laboratory is composed of the following four benches:

- Hydraulic Pump / Dynamometer Working Station
- Air Compressor Working Station
- Air conditioner / Fan Working Station
- Belt Conveyor Working Station

In the above benches, each load is driven by two different motors, with three different control methods, to allow for large combinations of ways to control and operate similar industrial systems.





HYDRAULIC PUMP / DYNAMOMETER WORKING STATION

The load system of this bench is composed of a hydraulic pump of 1", with a flow capacity of 1 cubic meter per hour, driven by a 1.5 HP motor, that moves water from two 100 liter tanks, built with transparent acrylic.
Between the tanks there is a drainage tube installed with a retention valve and a manual valve connected in parallel with a solenoid valve, controlled by the PLC.
The bench also includes: a retention valve; a flow volume pneumatically controlled valve; a differential pressure transmitter with local pressure indication in Kgf/cm; a pressure differential transmitter for the flow indication in cubic meters/hour through an orifice holes plate; a 4" petrochemical type manometer with measuring in Kgf/cm and a rotameter for the analogue indication of the flow and in the upper tank a differential pressure transmitter for level measurement with local indication in liters.
Another load system is a dynamometer with 3 HP capacity, made of a braking system by Foucault disk, for the control of the torque to the axis of the motor up to 120% of its nominal torque.

DESCRIPTION OF THE WORKING STATIONS

GENERAL

Each Working Station is composed of:
- A workbench, complete with loads, motors and data acquisition systems.
  Approximate dimensions:
  2000 mm x 800 mm x 1700 mm (h).
- A control panel, with all the electric and electronic components arranged in an ergonometric way.
- An auxiliary table for PC, bench-top instruments and equipment like oscilloscope, multimeters, etc.

The workbench is built with structural reinforced aluminium profiles with wheels, adjusting height levels, ground locks and input sockets for equipment connection.

Each Working Station includes:
- Motors (conventional and high efficiency, 1.5 HP)
- Load Module
- Motors driver systems:
  Frequency Inverter
  Soft-Starter
  Contactor
- Driving system and protection elements such as:
  Circuit breakers
  Regulators
  Switches
  Keys
  Lights
- Measurement system for complete input power parameters
- Mechanical and electrical data acquisition instruments
- Programmable Logical Controller (PLC)
- SCADA Software for supervision system

The student has the possibility to easily select which motor (conventional or high efficiency) will be coupled to the load.

AIR COMPRESSOR WORKING STATION

The load system of this bench is composed of a two piston air compressor, with 1.5 HP motor capacity. The air compressed tank has a capacity of up to 40 liters, regulated by an electric valve that controls the air pressure of the tank through the supervision software.
Additionally, the tank has a safety valve specified in agreement with the conditions of the tank's capabilities.
The coupling of the motors with the compressor is made of pulleys and belts in "V" shape.
The air piping allows the simulation of the load losses through holes of different diameters (5 holes), selected by solenoid type valves and activated by the supervision software. The location of these holes allows the measurement of these losses.

The motor is driven by:
- Frequency inverter or
- Soft start key or
- Direct start by contactors intercalated and controlled by the user through the supervisory software.

The corresponding load for each Working Station allows a variation - controlled by the supervision software – from 0 to 120% of the nominal load of the motor.
Each motor (conventional and of high-efficiency) has a PT-100 temperature sensor in the carcass and in each stator coil that allows the monitoring of this parameter through the supervision software.
The torque and rotation transducers are installed in the load axes to avoid to be moved when changing motors.
All of the electrical connection for motors input power and sensors are made with fast connectors that allow for a rapid change of the motors and also protect against possible inversion of polarity.

MEASUREMENT SYSTEM

The measurement system of the input power is composed of a Multifunction Energy Meter that measures: phase-phase and phase-neutral voltage, current, active, reactive and apparent power, three-phase and single-phase power factor, frequency and active and reactive energy.

COMMUNICATION

The communication of the Multifunction Energy Meter with the PLC is made through a serial interface with ModBus protocol and all the parameters (historical, time curve, etc.) are shown and monitored on a suitable window of the supervision software.
Also the selection of the motors drive system is made through the supervision software.
The PLC controls the driving systems, collects the pa-

AIR CONDITIONER / FAN WORKING STATION

One of the load systems of this bench is composed of a centrifugal fan and an axial fan, both with 1.5 HP motor capability.
These fans are coupled to the same air tube. Parallel operation of the fans is possible, once they are placed in a "Y" format in the left extremity of the air tube.
The conventional and high-efficiency motors can be alternated from the fans through direct joining of an elastic glove.
An electric damper is installed in the air tube, controlled by the PLC, allowing the control of the air flow through the supervision software.
One air flow and speed transducer is installed in the air tube, after the fans, to allow for the checking of these parameters.
A further load of this bench is composed of a complete air conditioning system.
With the purpose of allowing the study and the performance of different types of compressors for air conditioning, this system has a piston hermetic type compressor and another compressor of the same capacity, but "SCROLL" type. The latter compressor is driven by a frequency inverter controlled by the PLC of the Working Station to control the speed variation of the compressor and, consequently, its performance.
The air conditioning system is complete with all its components and the compressors are dimensioned for the 20.000 BTU's capacity.

rameters from the sensors, the transmitters and the data acquisition devices through digital input/outputs and ModBus port communication and communicates with the supervision software through Ethernet.

OTHER FEATURES

The main devices, Frequency Inverter, Soft-Starter Key, PLC and the Multifunction Energy Meter, are assembled in a didactic and ergonomic way; they are visible and easily accessible.
Shunt resistors are installed in the inputs and outputs of the driving systems, to allow for reading the voltage and current signals through an oscilloscope.
The supervision software has a main window for each Working Station, with the schematic drawing of the process and each element of the Working Station (Multifunction Energy Meter, driver, load, etc.) has a shortcut for their corresponding monitoring window. The main components shown in the software's window are "animated" when active. Each sensor, transducer, and transmitter has its own window with a graphical representation of the component, showing its numeric value and average measurement.
Each measuring element, driver and load system has its own window. These windows supply real-time data, provided by the electrical and mechanical sensors.
The PLC is programmed in SFC, LADDER, FBD, SL and IL language.
The instrumentation used in each Working Station as well as the driving system and motors are fully industrial; in other words, the equipment used (sensors, meters, driving systems, inspection tools, etc.) are designed for industrial use, commercially available and listed in the catalogues of their respective manufacturers.

BELT CONVEYOR WORKING STATION

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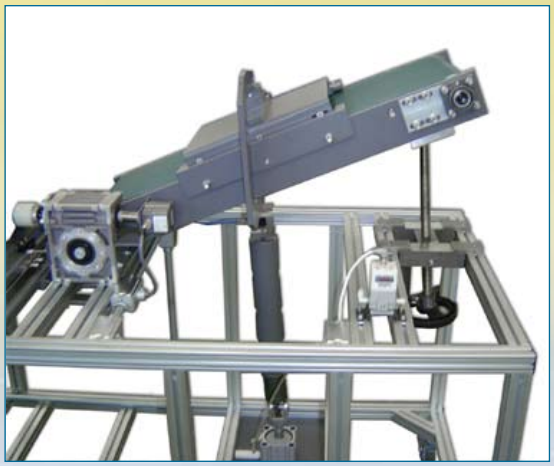

The load system of this bench is composed of a 1 meter long belt conveyor with inclination angle adjustment from 0 to 30 degrees.
The coupling of the motor and the conveyor is made by a speed reducer, to have a maximum conveyor speed of 0.1 m/s in full load conditions.
The mechanical system, with linear displacement controlled by a pneumatic actuator, simulates the load, exercising pressure on the belt, in agreement with the load conditions of the belt that are established by the supervision software.
The system is mainly completed with: a conveyor speed transducer, a load cell (for measurement of the pressure exercised on the conveyor, with indication of the measured values in the supervision software), a torque & rotation transducer with incorporated angle of rotation.

EXPERIMENTS

With each single Working Station it is possible to perform a large number of practical experiments. As an example, the following is a short list of performable exercises that apply to the Stations:

- Study of the energy efficiency of the motors for a 0 to 120% variation of the load
- Study of energy efficiency of the motors as a function of the use of the frequency inverter application, through the variation of the speed of the motor-load combination
- Generation of the characteristic curves of the main devices (electrical and mechanical parameters, pumps, fans, etc.)
- Generation of the characteristic curves of the motors (conventional and high efficiency)
- Comparison of the electrical and mechanical values from direct driving, soft start and frequency inverter as a function of the variation of the load
- Comparison of the consumption of energy for different configurations and types of devices
- Analysis of the energy efficiency considering different setups in the coupling between the motor and the load

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