Preview of PsimBook Exercises

PsimBook Exercises are a set of exercises that cover various subjects of power electronics and motor drives. Each exercise includes specific objectives, industrial background, required knowledge and resources, problems and questions, schematic circuits that are required to solve the problems and answer questions, and the answer kit.

A key advantage of the PsimBook exercises is that the schematic circuits in the exercise document are live and fully interactive, and can be simulated by the PSIM simulation engine. Users will be able to study the operation of a circuit, understand the industrial context, change circuit parameters and run the simulation, all in one integral environment.

The PsimBook Exercises are ideal for teaching, training, and education.

This set of exercises contains 13 exercises, and the titles are listed below.

- Exercise 1: Speed Control of a DC Motor
- Exercise 2: Series Excited DC Motor
- Exercise 3: Passive Harmonic Filter for Supply Network
- Exercise 4: Unified Power Flow Controller (UPFC): Rectifier with Sinusoidal Input Current
- Exercise 5: Separately Excited DC Motor
- Exercise 6: Characteristics of Asynchronous Machines
- Exercise 7: Distribution Transformer
- Exercise 8: Single Phase AC Choppers
- Exercise 9: Industrial Applications of Three-Phase Inverters
- Exercise 10: Phase-Controlled Rectifiers
- Exercise 11: Self-Controlled Synchronous Motor Drive
- Exercise 12: Scalar Control of Asynchronous Machines
- Exercise 13: Vector Control of Asynchronous Machines

The exercises are on average over 10 pages long. To give an idea of the exercise contents, snapshots of the first couple of pages of each exercise are provided below.

The complete Exercise 9, *Industrial Applications of Three Phase Inverters*, can be opened and viewed by the demo version of the PsimBook Viewer. To load this exercise, launch PsimBook.exe in the PSIM demo version folder. Go to "**File** -> **Open Book**", and load the file "09-Three_Phase_Inverters_demo.PsimBook" in the "PsimBook Exercise" sub-folder.

Screenshots of the 13 PsimBook Exercises are given below:

- **Exercise 1: Speed Control of a DC Motor**
  - Snapshot of Page 2:

CONTENTS

- Practical applications of current, torque, and speed control
- PID analog controllers
- Direct current (dc) permanent magnet machines

SPECIFIC OBJECTIVES

- To understand the process of deriving the model of a system
- To measure the stability and accuracy of a control loop
- To implement a tuning strategy for a closed loop system (PID)
- To check the system operation against the technical specifications

PREREQUISITES

- Understanding of the basic operation of a chopper circuit
- Ability to identify dc machine parameters (and the physical variables) to create the dynamic model
- Knowledge of the transient analysis of the first order system
- Ability to identify the operating modes of a servo system (open loop and closed loop)
- Ability to measure the performance of a linear servo system (i.e., stability, accuracy, and response time)
- Understanding of the LAPLACE transform

RESOURCES

Course documents:

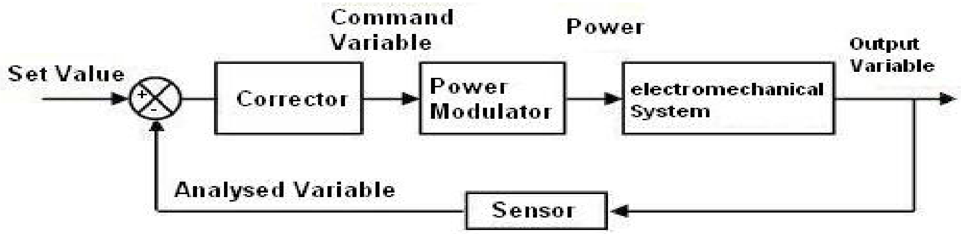
- Modeling of a dc chopper : mod_DC_Chopper
- Modeling of a dc motor : mod_DC_Motor
- PI analog controllers and first order systems : PI_order1
- How to use the AC Sweep in PSIM: ACSweep_Tutorial

- **Exercise 1: Speed Control of a DC Motor**
    - o Snapshot of Page 3:

INDUSTRIAL CONTEXT

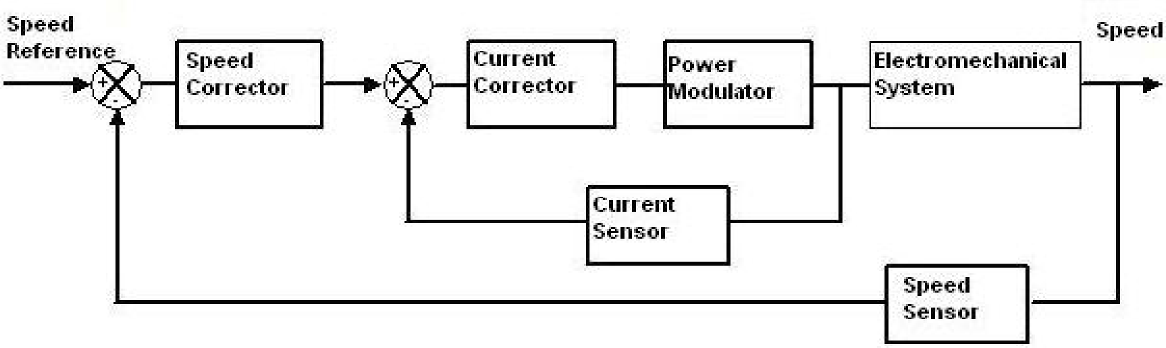
In the context of an industrial application, we want to implement a system to **control the speed** of a 50-Watt dc permanent magnet motor. This motor drives a conveyor belt that dispatches mechanical parts.
The system is controlled by an analog controller operating in the first quadrant. It is supplied through a power converter such as a dc chopper. The reference for the steady state error will be set to 0 and the response time will be set to less than 100 ms.

ARCHITECTURE OF THE SYSTEM



For this type of servo mechanical system, the current (and therefore the torque) should be controlled in order to avoid lurching and vibrations that can be destructive for the motor.
We will use a classical two-loop structure with one inner loop and one outer loop.

The flowchart of the control loops is shown below:



APPROACH

After the system is modeled, the simulation tool can be used to analyze the behaviour, to adjust the controllers and to carry out non-destructive tests on the motor:

- Search for variables associated with the operating point.
- Modelling of the motor and the load
- Modelling of the dc chopper
- Identification of the response signal and adjustment of the controller
- Identification of the response in terms of speed and adjustment of the controller
- Setting limitations on voltage and current, defining the field of application
- Analysis of the results and tests on the real structure.

- **Exercise 2: Series Excited DC Motor**
  - Snapshot of Page 2:

CONTENTS

- Series excited dc machines in traction applications

SPECIFIC OBJECTIVES

- To model a linear mechanical load in the steady state
- To measure the motor variables (power, torque, emf) in the steady state
- To justify the design based on technical specifications.

REQUIRED KNOWLEDGE

- Basic knowledge of mechanical motion (linear speed, rotational speed, reducing gear…).
- Knowledge of the characteristics of a series excited dc machine.
- Knowledge of the equivalent circuit and the electromagnetic equations of the motor
- Knowledge of the safety measures that must be taken when using such a machine.

RESOURCES

Course materials:

- Document ident_DC_Machine.PDF for the electromechanical equations of the machine.

- **Exercise 2: Series Excited DC Motor**
    - o Snapshot of Page 3:

LOCOMOTIVE BB 15 000

This subject is from the 2002 competitive examinations in Electrical Engineering

INDUSTRIAL CONTEXT

The basis for our study is the BB 15000 locomotive currently in service on the SNCF network in the East of France. It is a single-voltage locomotive that operates exclusively under single-phase 25-kV, 50-Hz overhead contact line.

BB 15000 locomotives are used to haul rapid passenger trains (at a speed of up to 180 km/h) or ordinary freight trains.

The locomotive that is the object of our study has two bogies with 2 motorized axles. Each bogie is equipped with a series excited dc motor that drives the two motorized axles of the bogie through a reduction gear.

The two traction motors, TAB 674, are fed independently. In normal operating conditions they produce the same power and run at the same speed. To feed the motors, the 25-kV voltage is lowered by a transformer and then rectified by ac converters that feed the motors.

Our goal is to determine the steady state performance (dynamic performance will not be studied in this workshop) and to justify the choice of the motor based the technical specifications of the SNCF.

TECHNICAL SPECIFICATIONS OF THE LOCOMOTIVE

The locomotive must be able to haul a freight train made up of **14 G10-type freight cars** at a speed of **110 km/h** up an incline of **0.88%**. We have :

M_L : mass of the locomotive **M_L = 89 tons**

M_w : mass of a freight car **M_w = 64 tons**

CONTEXT OF THE STUDY

The machine is considered as perfectly compensated. We shall consider that the flux in the machine only depends on the excitation current.

It is assumed that the magnetic circuit is not saturated (which is rather restrictive for this type of machine), and that the magnetic hysteresis is not considered.

Friction and losses by ventilation will be modeled.

- **Exercise 3: Passive Harmonic Filter for Supply Network**
  - Snapshot of Page 2:

CONTENTS

- Voltage and current harmonics in a power network
- Passive filters
- Compensation for reactive power

SPECIFIC OBJECTIVES

- To identify the consequences of connecting a nonlinear load to a network
- To measure the harmonic components
- To analyze different passive filter solutions for a specific application
- To validate the design based on specifications

REQUIRED KNOWLEDGE

- Knowledge of electrical quantities (voltages and current) and the operation of three phase controlled rectification.
- Knowledge of the Fourier series analysis.
- Understanding of harmonic distortion (voltage and current).
- Concept of active, reactive, and distorting power and characteristics of a network.
- Understanding of the BODE plot (cut-off frequency, bandwidth).

RESOURCES

Course materials :

- Document on ect160.pdf.

- **Exercise 3: Passive Harmonic Filter for Supply Network**
    - Snapshot of Page 3:

INDUSTRIAL CONTEXT

The growing use of power electronics system in the industry has lead to more and more problems of harmonics and consumption of reactive power by electrical networks.

Current and voltage harmonics are created by nonlinear loads connected to the distribution network. The most common nonlinear loads are adjustable-speed motor drives, computers and other electronic devices, electronic lighting, welding equipment, and uninterruptible power supply (UPS).

The effects of harmonics include:

- Overheating due to additional losses.
- Interference with communication networks.
- Premature wear and tear of installations.
- Risk of resonance excitation.

In general, the harmonics taken into account in an electrical network **are lower than 2500 Hz**, which are considered as **low frequency harmonics**.

Resource document ect160.pdf

A three phase electric load that is not balanced and is fed by a balanced three phase network leads to imbalances in voltage due to the unbalanced currents in the impedances of the network. This is frequent in single phase low-voltage loads. This can also be caused by high-voltage loads, such as welding machines, arc furnaces, and railway traction.

The effects of imbalance can lead to:

- Malfunctions and even the destruction of single phase equipment.
- The presence of uncharacteristic harmonics (orders that are multiples of 3).
- The creation of a reversed rotating field (which causes braking torque).
- Drops in the voltage.
- Large current in the neutral conductor.

The objective of this practical workshop is to analyze and to implement filters for converters or unbalanced loads.

This workshop focuses on traditional filter solutions (passive filters and special transformers). A second workshop (Practical Workshop n°5) will deal with active filters.

- **Exercise 4: Unified Power Flow Controller (UPFC): Rectifier with Sinusoidal Input Current**
    - Snapshot of Page 2:

CONTENTS

- PWM rectifier with sinusoidal input current
- Compensation of reactive power
- Active filters

SPECIFIC OBJECTIVES

- To analyze the characteristics and the control strategies of a rectifier with sinusoidal input current
- To demonstrate the bi-directional flow of the current of the system
- To implement a control loop
- To analyze the harmonics of the system and propose a solution

REQUIRED KNOWLEDGE

- Understanding of the operation of voltage rectifiers/inverters
- Understanding of the transfer direction of power
- Be familiar with the PI controller, and the design of a control loop
- Knowledge of typical harmonic amplitudes of a full-wave rectifier (3 phases)
- Calculation of power due to voltage and current harmonics
- Calculation of the THD

RESOURCES

Course materials :

- PI_order1.pdf
- pwm.pdf

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Exercise 4: Unified Power Flow Controller (UPFC): Rectifier with Sinusoidal Input Current

- Snapshot of Page 3:

INDUSTRIAL CONTEXT

The growing use power electronics systems in the industry has caused more and more problems of disturbances in electrical networks (high levels of harmonics, imbalance of currents, consumption of reactive power).
Solutions based on passive filters already exist (see PsimBook Exercise "Passive Harmonic Filter for Supply Networks"). However, solutions based on active compensators (also referred to as Unified Power Factor Controller (UPFC)), provide better performance.

An active compensator can be of two types: parallel and series. The parallel active compensator can be used to compensate for harmonics, unbalanced currents, and reactive power. The series compensator, on the other hand, can compensate for both harmonics and unbalanced voltages and drops in voltage.

In this exercise, we will focus on the study of the implementation of a parallel active filter at the medium power, using a PWM voltage source inverter.

As a PWM-controlled voltage source inverter can transfer power in both directions (see PsimBook Exercise "Industrial Applications of Three-Phase Inverters"), it behaves as a power amplifier which means we can control, almost at will, the ac currents and voltages.
We can illustrate the principle of this converter by the diagram below:

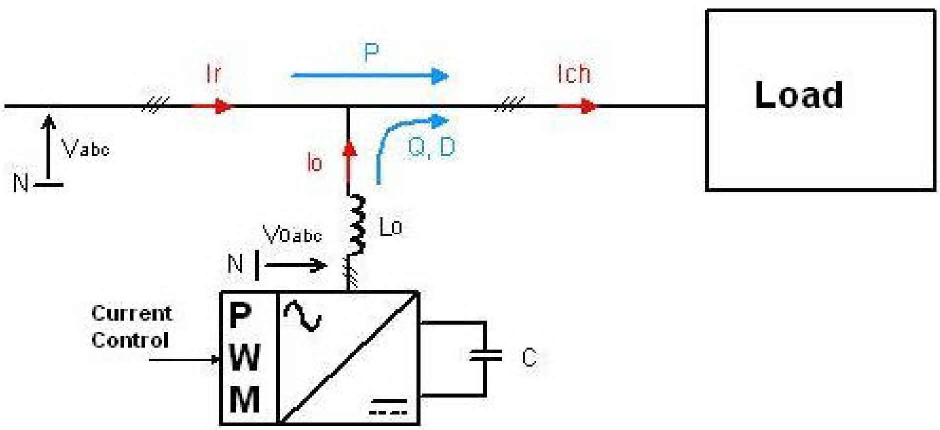


Figure 1

The active compensator must supply the active power and compensate for the current distortion. The network provides only the active power. The control circuit, by acting on the PWM control, must set the instantaneous value of the inverter output current so that the current supplied by the network is sinusoidal and in phase with the corresponding phase voltage (V_{abc}).

Depending on how the current reference is set, the system can operate in the follow modes:

- PWM rectifier: sinusoidal current reference in phase with V_{abc}
- Reactive power compensator: sinusoidal current reference in quadrature with V_{abc}.
- Active filter: current reference corresponding to the current harmonics that are to be eliminated.

Exercise 5: Separately Excited DC Motor

- Snapshot of Page 2:

CONTENTS

- Separately excited dc machine
- Measurement of friction and the moment of inertia of a machine

SPECIFIC OBJECTIVES

- To identify the parameters of the machine through measurement
- To measure the power, torque, emf, and efficiency of the machine
- To determine the moment of inertia of the rotor.

REQUIRED KNOWLEDGE

- Knowledge of the characteristics of a separately excited dc motor
- Knowledge of the equivalent circuit and the equations of the motor
- Knowledge of the fundamental principle of dynamics applied to a solid in rotation.
- Knowledge of the safety measures that must be taken when using such a machine.

RESOURCES

Course materials :

- ident_DC_Motor.pdf
- Rectification.pdf

Exercise 5: Separately Excited DC Motor

- Snapshot of Page 3:

INDUSTRIAL CONTEXT

Speed control of separately excited dc motors is widely used in industrial applications. In order to model the speed regulation, one needs to know the parameters of the machine and define the settings associated with the nominal operating point (in the steady state).

In this exercise, the motor with the following nominal values will be used:

$U_m = 220\ V \quad I_a = 6.8\ A \quad N = 1500\ rpm$

APPROACH

The simulation tool will allow us to confirm the operating modes similar to these in a real situation.

CONTEXT OF THE STUDY

In this study, the motor is considered as perfectly compensated. We assume that the flux in the machine only depends on the field excitation current. Also, magnetic saturation and hysteresis are not considered.

The friction will be modeled using the mechanical load in PSIM.

Exercise 6: Characteristics Asynchronous Machines

- Snapshot of Page 2:

CONTENTS

- Electromechanical characteristics of the asynchronous machine (also referred as the induction machine) with constant frequency and voltage
- Equivalent circuit in the steady state
- Speed control through the rotor circuit
- Motor and generator operation

SPECIFIC OBJECTIVES

- To determine values associated with the equivalent circuit through measurement
- To use the equivalent circuit to modify the mechanical characteristic of the machine
- To demonstrate the two operating modes and their implications in terms of power transfer (stator and rotor)
- To identify the specific actions for setting the speed for a particular application
- To carry out the power calculation under the load condition

REQUIRED KNOWLEDGE

- Knowledge of the structure and the operating principle of asynchronous machines
- Be familiar with the characteristics of the machine
- Capability to calculate the slip
- Knowledge of the structure of the equivalent phase circuit in the steady state
- Ability to identify the direction of the power transfer

RESOURCES

Course materials:

- gewe_15.pdf
- Asynchronous_machine.pdf

Exercise 6: Characteristics Asynchronous Machines

- Snapshot of Page 3:

INDUSTRIAL CONTEXT

With over 2,300 units in operation throughout the world, the 1.5-MW GE 1.5 type wind turbine is the most commonly used in its power range.

This type of wind turbine is characterized by a doubly fed induction generator associated with an active and reactive power control system that avoids the use of capacitors. This system also controls the orientation of the blades according to the speed of the wind.

For a wind speed between 5 m/s and 12 m/s, the rotation frequency of the turbine is adjusted in such a way as to obtain the maximum power on the motor shaft. In addition, the orientation of the blades is used to limit the power of the turbine to its nominal value of 1.5 MW.

APPROACH

Our goal is to determine the characteristics and performances of the wind turbine in the steady state.

CONTEXT OF THE STUDY

Concerning the generator, iron losses, magnetic saturation phenomena and friction will be ignored. The value of the electromagnetic torque of the machine will be considered as equal to the shaft output torque.

The inertia of the turbine and the reduction gear will not be taken into account.

Exercise 7: Distribution Transformer

- Snapshot of Page 2:

CONTENTS

- Single phase transformer and the equivalent circuit
- Characteristics of a voltage distribution network

SPECIFIC OBJECTIVES

- To determine the parameters of the transformer equivalent circuit from measurements
- To calculate the voltage drop and the efficiency of a transformer under load condition, and verify the calculation with measurements
- To study the magnetic saturation phenomenon
- To analyze the influence of impedances in a distribution network

REQUIRED KNOWLEDGE

- Ability to obtain the equivalent circuit diagram of a single phase transformer from short-circuit and no-load tests
- Ability to validate the amplitude of a magnetic current from the hysteresis cycle of the magnetic material
- Ability to understand harmonic spectrum
- Knowledge of the expressions of active, reactive, and apparent powers
- Knowledge of different methods of measuring the efficiency of a transformer (direct method and separate losses method)
- Knowledge of the general architecture of a medium voltage distribution network

RESOURCES

Course materials:

- Course on electromagnetism

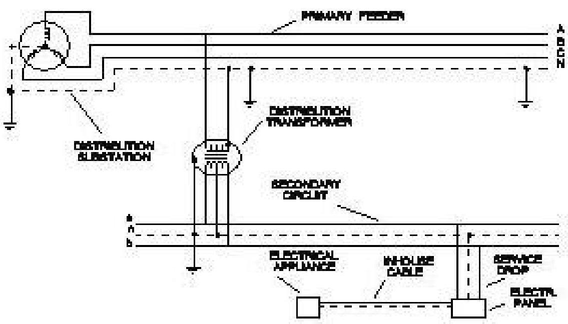
Exercise 7: Distribution Transformer

- Snapshot of Page 3:

50-KVA DISTRIBUTION TRANSFORMER

INDUSTRIAL CONTEXT

In Canada, due to the disparity of the network, a series of studies was carried out by the Hydro-Québec Research Institute before setting new standards, in order to determine the technical characteristics of the lines. These studies were able to determine impedance values that are common to 95 % of the network.
The simplified diagram below (the protections are not shown) outlines a residential distribution network from a medium voltage distribution substation to the delivery point of residential customers.



APPROACH

The objective of this practical exercise is to simulate the operation of part of this network using the results of the study. We will determine, through different experiments, the value of the short-circuit current at the supply terminal.

CONTEXT OF THE STUDY

The impedances linked to protection equipment will not be studied.
For the study of the transformer, hysteresis losses are not considered.

Exercise 8: Single Phase AC Choppers

- Snapshot of Page 2:

CONTENTS

- Single phase AC chopper
- Energy and power associated with an AC/AC power converter
- Harmonic analysis

SPECIFIC OBJECTIVES

- To analyze this type of converter.
- To calculate the active, reactive, apparent, and distorting power, and the power factor of the converter
- To compare different operation modes of a AC chopper on a resistive load.
- To analyze harmonic spectra under different operation modes (phase controlled or wave trains).

PREREQUISITES

- Knowledge of the main characteristics of a SCR and how it works with the ac load
- Knowledge of the expression and measurement of powers with the ac load
- Intepretation of the harmonic spectrum results

RESOURCES

Course materials:

- Course on decomposition in Fourier series.

Exercise 8: Single Phase AC Choppers

- Snapshot of Page 3:

5 kW Thermoplunger for liquid aluminum baths

INDUSTRIAL CONTEXT

This electric thermoplunger is specially designed for reheating baths of melted aluminium and is meant to be plunged directly into the melted metal.

It consists of:

- A ceramic sheath specially designed for working with liquid aluminium. It has the following features:
  - resistant to changes in temperature
  - strong
  - good level of thermo-conductivity
  - very low level of corrosion from aluminium and most of its alloys.
- A heavy load electric heating element made of wires in Nickel-Chrome alloys imbedded in a high performance insulating material that ensures both optimum insulation and heat transfer.

APPROACH

The objective is to analyze the control of the heating element and the exchange of power.
We will carry out a comparative study between the two types of commands: phase and wave trains.

CONTEXT OF THE STUDY

The on/off command, which is less efficient, will not be studied.
The control of the temperature will not be studied.

Exercise 9: Industrial Applications of Three-Phase Inverters

- Snapshot of Page 2:

CONTENTS

- Three-phase voltage source inverter
- Control of voltage source inverters (full-wave, sinusoidal PWM, PWM lookup tables)
- Three-phase asynchronous squirrel-cage induction machines

SPECIFIC OBJECTIVES

- To calculate the power of the inverter - induction motor drive system
- To implement different control strategies
- To evaluate harmonics with different control methods

PREREQUISITES

- Understanding of the voltage source inverter and its field of application.
- Identification of the parameters (and the physical variables) of an asynchronous machine in the steady state
- Understanding of voltage and current harmonics; decomposition in Fourier series; calculation of harmonic distortion
- Understanding of the principles of PWM (sinusoidal PWM and lookup table based PWM)

RESOURCES

Course materials: pwm.pdf

Exercise 9: Industrial Applications of Three-Phase Inverters

- Snapshot of Page 3:

The technical specifications are from the competitive Electrical Engineering examination in 2000.

INDUSTRIAL CONTEXT

A light rail train in made up of four bogies, three of which are motorized. One bogie motor has four wheels that are each powered by an asynchronous three-phase motor through a reduction gear. A light rail train is therefore powered by twelve asynchronous motors.

The asynchronous three-phase motor has 4 poles, and are cooled by a mixture of water (56%) and ethylene glycol (44%) under pressure at about 1.5 bars with a flow of 5 Litter/min.

The rotor is made up of a squirrel cage winding in die-cast aluminum.

- Nominal output power — P_{un} = 24.6 kW
- Nominal effective torque — T_n = 90 Nm
- Nominal line current — I_{sn} = 35.4 A
- Nominal voltage between phases — U_{sn} = 585 V
- Nominal statoric frequency — f_{sn} = 88 Hz
- Pairs of poles — p = 2
- Nominal rotation speed of the rotor — N_n = 2610 rpm
- Nominal power factor — $\cos \varphi_n$ = 0.7341
- Efficiency for the nominal point — η_n = 93.09%
- Moment of inertia of the rotor — J = 0.112 kg*m^2

Exercise 10: Phase-Controlled Rectifiers

- Snapshot of Page 2:

CONTENTS

- SCR circuit
- Re-generation of the rectifiers applied to the control of dc machines
- Anti-parallel connection, with or without circulation current

SPECIFIC OBJECTIVES

- To determine the voltages and currents of the SCR circuit (continuous and discontinuous current flow).
- To demonstrate the problem related to the commutation of the SCR (start-up)
- To implement a circuit which can operate in several quadrants (active load)
- To calculate power in the four quadrants.
- To study and compare two rectifier circuits: wired and antiparallel

REQUIRED KNOWLEDGE

- Knowledge of the characteristics of a single phase rectifier
- Knowledge of the operating principle of a SCR
- Knowledge of the operation of a DC machine, in particular the relation between the average voltage of the power supply and the speed
- Identification of the power transfer between a source and an active load as well as the role of the fundamental current
- Knowledge of the calculation of power
- Knowledge of the basic architecture of speed control for a DC machine

RESOURCES

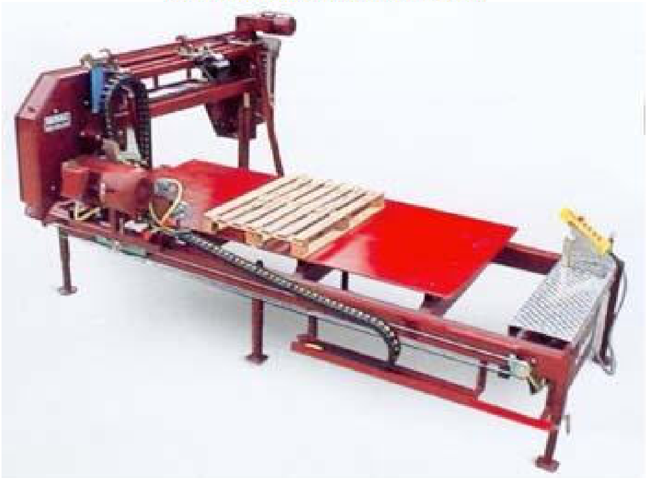
Course materials :

- Document Rectification.pdf.

Exercise 10: Phase-Controlled Rectifiers

- Snapshot of Page 3:

AUTOMATION OF A BAND SAW



INDUSTRIAL CONTEXT

The focus of this study is a band saw machine used to cut insulation materials for packaging. The saw has a vertical blade and a mobile machining head that are used to cut materials laid on a fixed table. The length of the cut, called gauge, is set with a rack and pinion system that was powered manually.
The blade (no teeth, double edge, called knife blade) cuts the material with the back-and-forth motion. A direct current machine is used to provide this motion. The motion speed should be adjustable. The cutting speed is constant.

APPROACH

Variables for the speed control of the motor will be identified, and two SCR bridge structures, that allow operation in the four quadrants, will be studied and compared.

FRAMEWORK OF THE STUDY

The designer has chosen a single phase controller supplied by a 230 V / 50 Hz ac main. The study of the control loops (speed and current) will not be developed in this exercise. Here are the nominal values of the dc machine:

- P_n = 1 kW
- U_n = 180 V
- I_n = 6.9 A
- T_u = 6.8 nm

Exercise 11: Self-Controlled Synchronous Motor Drive

- Snapshot of Page 2:

CONTENTS

- Self-controlled synchronous motor.
- Justification of the choice of motor.
- Speed control.

SPECIFIC OBJECTIVES

- To be able to determine the mechanical constraints linked with an industrial application (in dynamic state).
- To carry out a comparative study between two motorizations.
- To implement a control strategy in an open loop system (PID)
- To confirm operation in compliance with technical specifications.

REQUIRED KNOWLEDGE

- To know how to use the fundamental principles of dynamics.
- To know how to implement control strategies for a chopper and a voltage source inverter.
- To be capable of implementing speed control for a DC motor.
- To know the fundamental characteristics of a permanent magnet synchronous machine (operating mode, power supply, torque characteristics).
- To know the use of PID analog controllers.

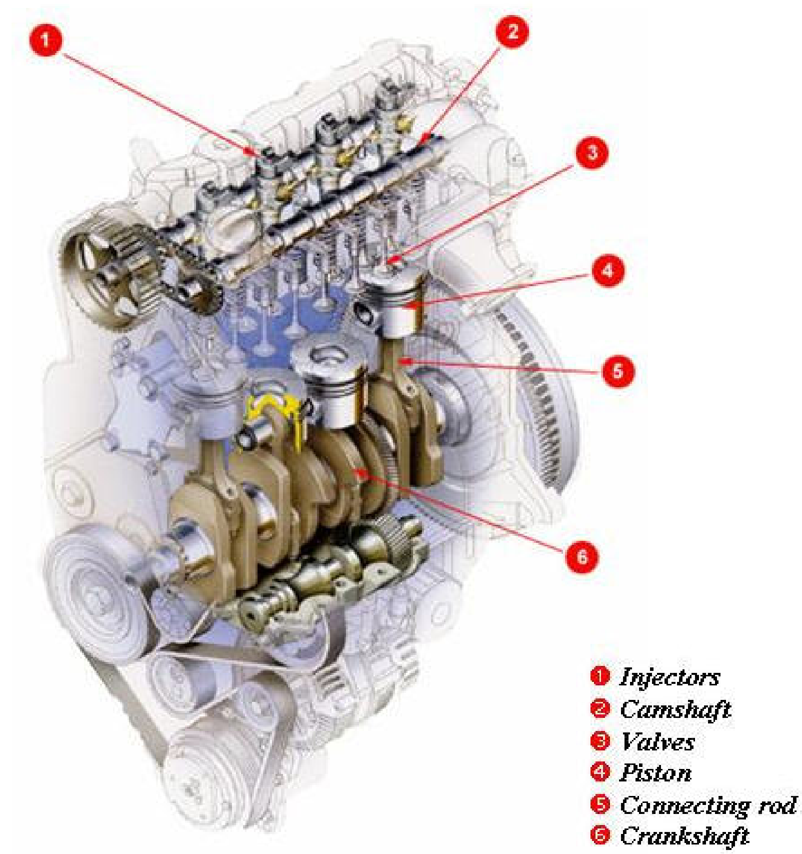
RESOURCES

Course materials :

- nx630eaq.pdf
- PARVEX_MCC.pdf
- PARVEX_MS230.pdf
- ziegler_nichols.pdf

Exercise 11: Self-Controlled Synchronous Motor Drive

- Snapshots of Page 3:



The subject is from the CA/PLP2 competitive exams in Electrical Engineering 2000

Exercise 11: Self-Controlled Synchronous Motor Drive

- Snapshots of Page 3 (continued):

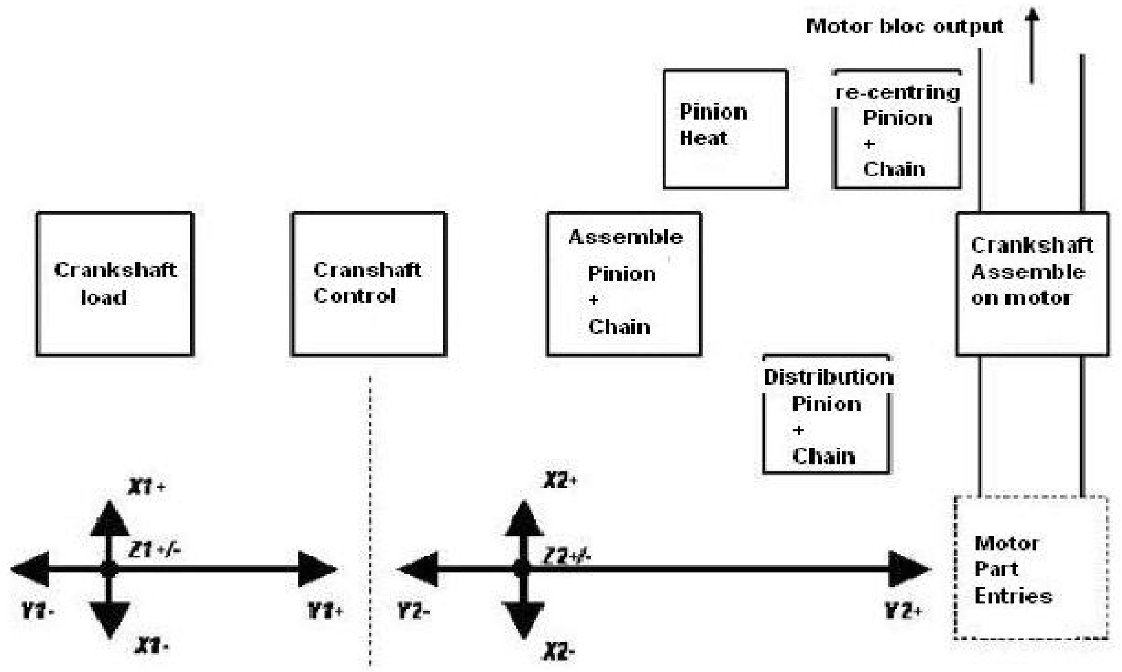
INDUSTRIAL CONTEXT

Our study is of a removal unit for crankshafts (N°6 in the photo) of a "DK" type motor. These motors are manufactured by the largest European car makers.
The motors that are being manufactured are transferred from one production unit to another with conveyors.

Two prehensile devices move the crankshafts between the different workstations of the production unit:

- Crankshaft loading station,
- Crankshaft control station (turbo or atmospheric),
- Chain sprocket fitting,
- Chain sprocket distribution,
- Chain sprocket re-centering,
- Sprocket heating,
- Installation of the crankshaft on the engine block.

The layout of the different workstations (seen from above), the prehensile devices and their scope of movement is given below:



Exercise 12: Scalar Control Asynchronous Machines

- Snapshot of Page 2:

CONTENTS

- Measurements of the characteristics of three-phase asynchronous machines
- Speed control of the asynchronous machine
- Implementation of the constant-flux control

SPECIFIC OBJECTIVES

- To identify the variables for speed control
- To perform power calculation
- To compare different control strategies
- To identify the limitations of the controller

REQUIRED KNOWLEDGE

- Ability to identify the parameters (and the physical variables) of an asynchronous machine in the steady state
- Ability to calculate power
- Knowledge of the equations and the equivalent of the machine in the steady state
- Knowledge of the operation of a PWM voltage source inverter
- Ability to implement a speed control loop

RESOURCES

Course materials :

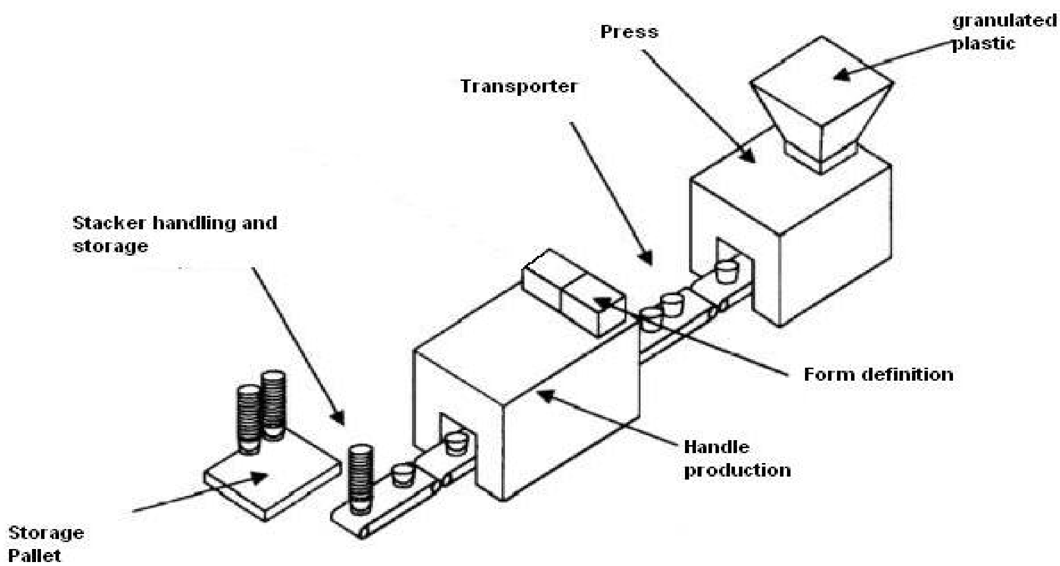
- pwm.pdf
- Asynchronous_machine.pdf

Exercise 12: Scalar Control Asynchronous Machines

- Snapshot of Page 3:

INDUSTRIAL CONTEXT

A factory that makes plastic buckets wants to expand its capability by making other products in different shapes and sizes. The production line for buckets is shown in the figure below:



Two hydraulic cylinders are used to form the handles. The oil pressure in the cylinders varies according to the output of the pump.
The pump is driven by a motor. We want to regulate the speed of the motor in order to control the output and thus the force of the shaping action and output speed of the cylinders.

THE NOMINAL VALUES OF THE MACHINE

A squirrel-cage asynchronous machine with 4 poles, 230/400 V, 3 kW, delta-connected, has the following nominal values:

• Nominal effective power:	$P_{un} = 3$ kW
• Nominal effective torque:	$T_n = 19$ Nm
• Nominal line current:	$I_{sn} = 12.5$ A
• Nominal stator frequency:	$f_{sn} = 50$ Hz
• Number of pairs of poles:	$p = 2$
• Nominal rotation speed of the rotor:	$N_n = 1\,440$ min^{-1}
• Nominal power factor:	$\cos\varphi j_n = 0.688$
• Efficiency of the motor:	ηn = 83.7 %
• Moment of inertia of the rotor:	$J = 0.112$ kgm^2
• Kinetic friction torque:	$C_{s0} = 1$ Nm
• Friction coefficient:	$\mu = 2$ mNm/rad/s

The kinetic friction torque can be expressed as: $C_{frot} = \mathrm{sgn}(\Omega).C_{s0} + \mu.\Omega$.

Exercise 13: Vector Control Asynchronous Machines

- Snapshot of Page 2:

CONTENTS

- Modeling of a three-phase asynchronous machine in PARK reference frame
- Implementation of the vector control with a voltage source inverter
- Comparison between between scalar and vector control

SPECIFIC OBJECTIVES

- To be familiar with the Park reference frame
- To study how the electromagnetic torque is controlled with different control strategies
- To identify the flux orientation in the control strategy
- To implement speed control

REQUIRED KNOWLEDGE

- Ability to identify the parameters (and physical variables) of an asynchronous machine in the steady and dynamic states
- Knowledge of Park and Clark reference frame transformation
- Understanding of the equivalent phase circuit of the machine in the steady state and other states in Park reference frame
- Understanding of how a PWM voltage inverter works
- Understanding of the principle and performance of a scalar control (constant flux)

RESOURCES

Course materials :

- Exercice 12
- Asynchronous_machine.pdf

Exercise 13: Vector Control Asynchronous Machines

- Snapshot of Page 3:

OBJECTIVE OF THE WORKSHOP

The objective is to continue the study of asynchronous machine contol by using a familiar application (see the Exercise on the scalar control), and to use the vector control. We will compare these two control methods in terms of the speed regulation.

THE NOMINAL PARAMETERS OF THE MACHINE

A squirrel-cage asynchronous machine with 4 poles, 230 / 400 V, 3 kW, delta-connected, has the following nominal parameters:

- Nominal effective torque: $T_n = 19Nm$
- Nominal line current: $I_{sn} = 12.5\ A$
- Nominal statoric frequency: $f_{sn} = 50\ Hz$
- Nominal rotation speed of the rotor: $N_n = 1440\ rpm$
- Moment of inertia of the rotor: $J = 0.112\ kgm^2$
- Kinetic friction torque: $C_{s0} = 1\ Nm$
- The load is related to friction of Cr = **kfrot.Ω** with **k = 0.12 N*m/(rad/sec)**