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By:

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Title:

Sensorless Automatic Control of Variable Speed Drive by Industrial Programmable Controller

Defended before a jury composed of:

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Dedication

To our dear parents,

For their unconditional love, sacrifices, and unwavering support throughout our academic journey. Without them, none of this would have been possible.

To our brothers and sisters,

For their constant encouragement and caring presence through both challenges and successes.

To our teachers,

For their dedication, discipline, and passion for knowledge, which have shaped our understanding and inspired our growth.

To our faithful friends,

For their moral support, sincere friendship, and the memories we shared during these university years.

To all those who, in one way or another, contributed to the completion of this work.

KHALIL DOUIOU & BENDENNI FAYCEL

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We are profoundly grateful to our families for their unconditional love, patience, and sacrifices. Their support has been our foundation and strength.

Finally, we thank our friends and classmates for their constant support, collaboration, and the memorable moments we shared during this academic journey.

KHALIL DOUIOU & BENDENNI FAYCEL…

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General introduction

GENERAL INTRODUCTION

Due to rapid technological advancements, industrial processing systems in what is called the Fourth Industrial Revolution are changing the way companies operate. Computerized control of production has become central in improving precision, quality, and performance in industrial manufacturing and processing.

Industrial automation primarily refers to the use of control systems such as computers, programmable logic controllers (PLCs), and robotics to manage industrial processes and machinery. These systems reduce the need for human intervention, especially in hazardous or repetitive tasks.

In this work, we attempt to develop an automated system for a fabric inspection machine using a Siemens S7-1200 PLC. A PC with TIA Portal software is used for system configuration, programming, and control.

Our thesis is structured as follows:

- **Chapter 1**: Description of the Control System to Be Implemented.
- **Chapter 2**: Overview of Profinet communication network and its benefits in industrial automation.
- **Chapter 3**: Practical implementation using TIA Portal,including HMI interface development and programming logic.

CHAPTER 1: Description of the Control System to Be Implemented

1. Description of the Control System

The control system to be implemented consists of designing a sensorless automatic control of a three-phase asynchronous motor used in a variable-speed electric drive. This control is carried out using a Siemens S7-1200 Programmable Logic Controller (PLC), which acts as the central logic processing unit. The speed variation and motor control are handled by a SINAMICS G120 Variable Frequency Drive (VFD), which modulates the frequency and voltage supplied to the motor. The entire system is monitored and controlled through a Human-Machine Interface (HMI), providing real-time feedback and interaction for the operator.

The communication between the PLC, VFD, and HMI is based on the PROFINET industrial Ethernet protocol. Speed control is achieved without using a physical speed sensor thanks to the sensorless vector control algorithm integrated into the SINAMICS G120, reducing hardware costs while improving system reliability.

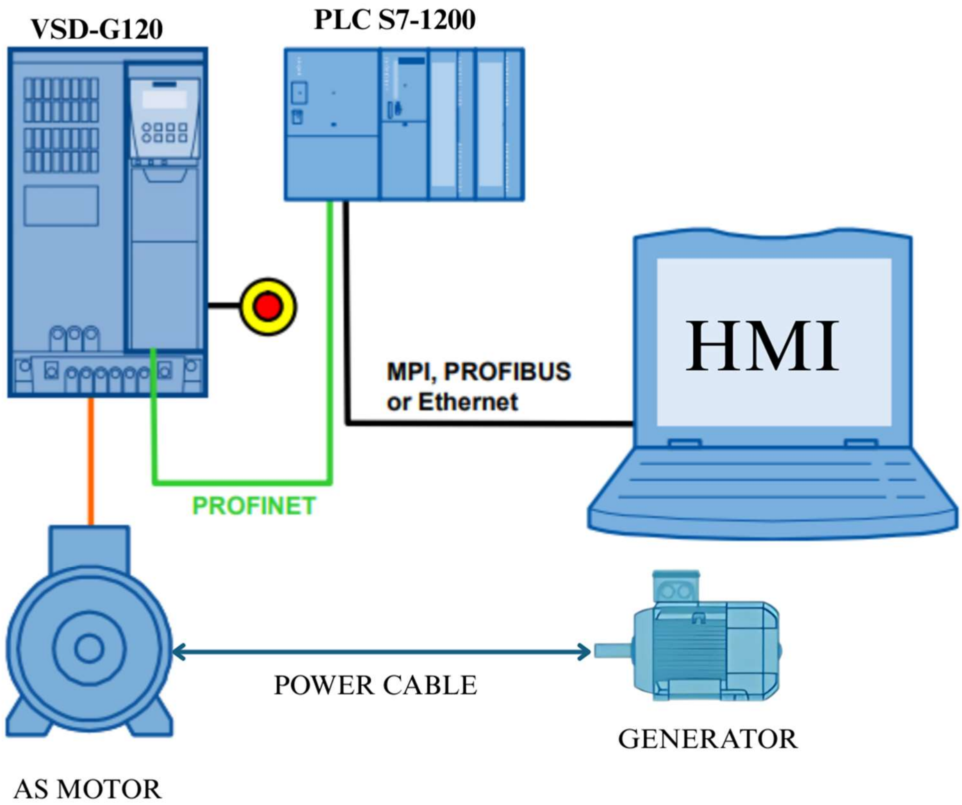


Figure 1 AUTOMATION SYSTEM OVERVIEW

Figure 2 REAL ASSEMBLY OF COMPONENT

2. Introduction to the Human-Machine Interface (HMI)

The Human-Machine Interface (HMI) is a crucial component in industrial automation that allows operators to interact intuitively with the automated system. It enables real-time monitoring of process variables, adjustment of control parameters, and display of alarms or system statuses. Integrated within the TIA Portal environment, the Siemens HMI panel, such as the KTP700, allows for the creation of customized screens including buttons, gauges, and trend graphs.

The HMI communicates with the PLC over PROFINET, exchanging data through mapped memory bits (%M), words (%MW), or control flags. It plays a central role in supervising motor speed, direction selection, speed mode (low/medium/high), and fault acknowledgment.

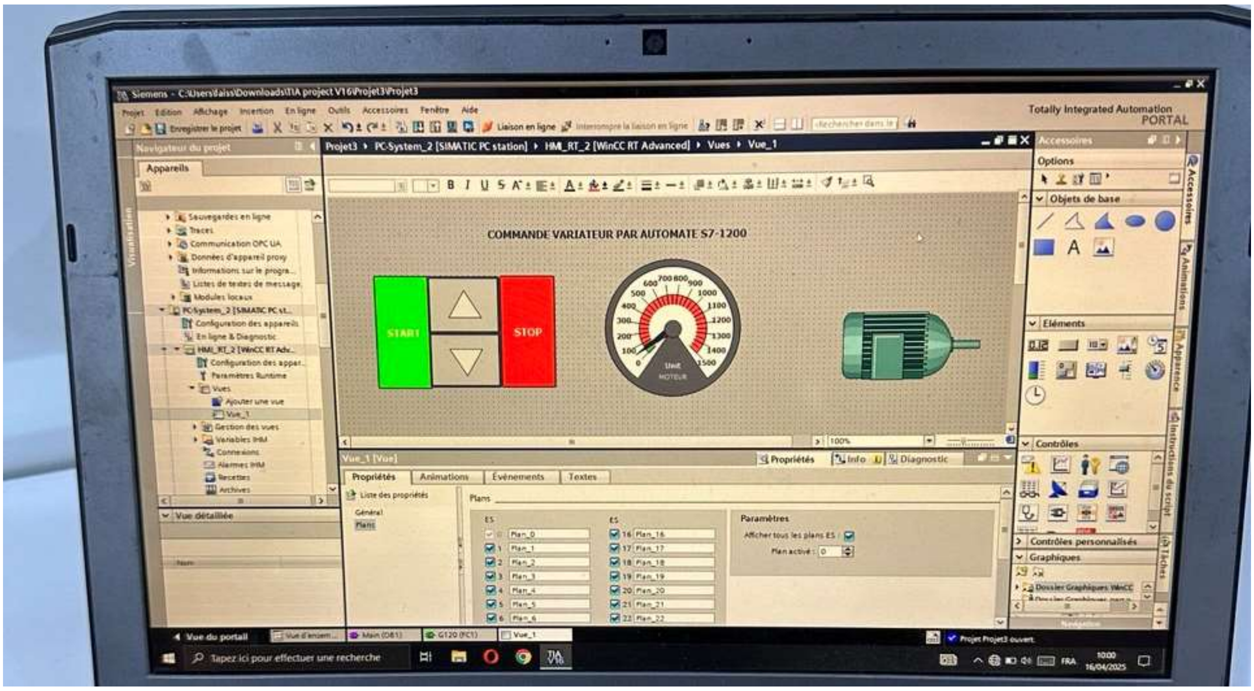


Figure 3Example of an HMI screen designed in TIA Portal

3. Introduction to the Siemens S7-1200 PLC

The Siemens S7-1200 Programmable Logic Controller (PLC) is designed for modular automation applications, offering flexibility, integrated communication (PROFINET), and advanced functions such as PID control, timers, and counters. It is programmed through the TIA Portal using IEC 61131-3 compliant languages such as Ladder Diagram (LAD), Function Block Diagram (FBD), or Structured Control Language (SCL).

In this project, the CPU 1212C AC/DC/RLY is used. It features built-in digital inputs/outputs, relay outputs, and can be expanded with analog modules such as the SB1222 AO. The PLC sends control words to the drive and receives status feedback, facilitating real-time closed-loop control.[4]

1. Role of PLCs in Modern Control Systems

PLCs are deterministic digital controllers specifically designed to manage automation processes. Compared to traditional hardwired control systems, PLCs offer:

- Modular design for expandability

- Real-time operation with predictable cycle times
- Rugged construction suitable for industrial environments
- Ease of programming with languages standardized by IEC 61131-3

Siemens' SIMATIC S7-1200 series provides a compact yet powerful solution for automation, with built-in PROFINET communication and analog/digital I/O.

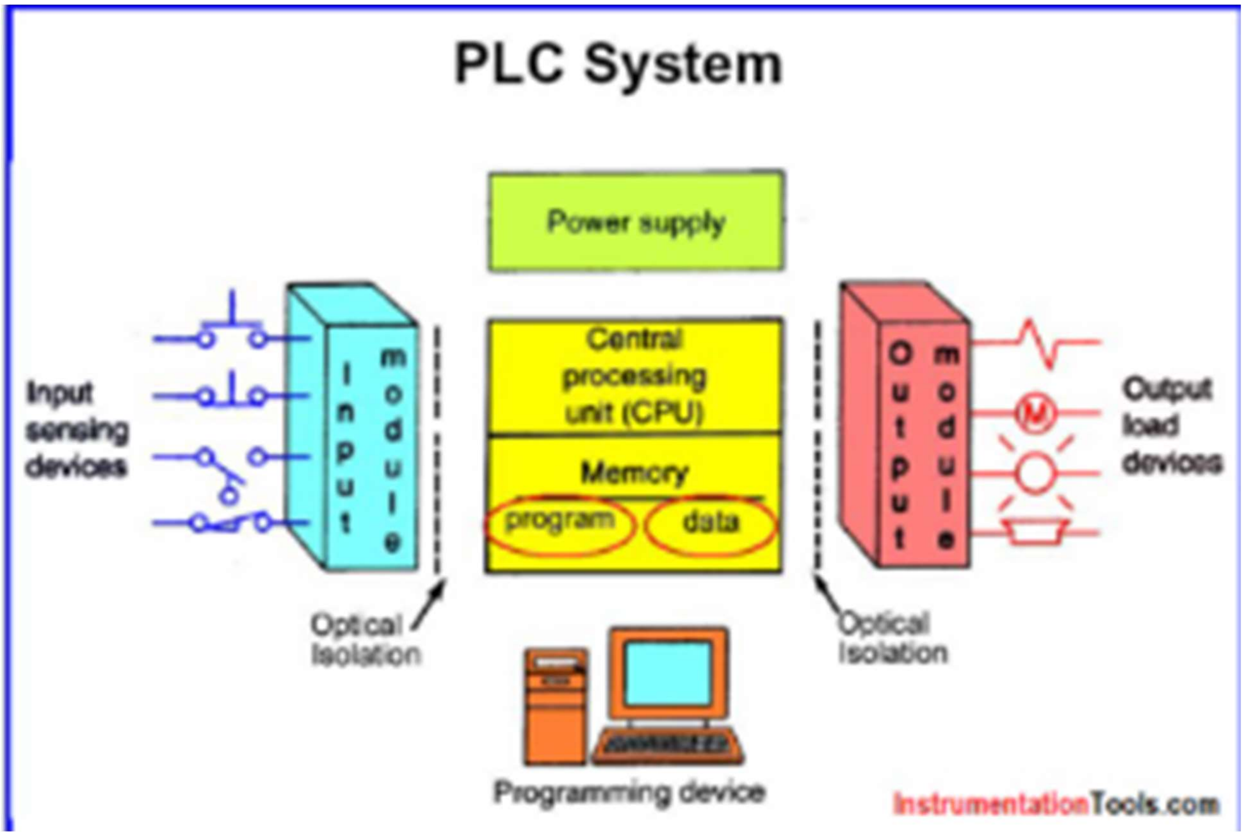


Figure 4: Architecture of the S7-1200 PLC with analog extension module[4]

[Diagram 1.2: Basic PLC System Architecture]

Include CPU, power supply, I/O modules, HMI, and communication ports.

Reference: SIEMENS MANUAL, Automate programmable S7-1200[1]

3.1. Presentation of the S7 1200 range

The S7-1200 controller offers the flexibility and power needed to control a wide range of devices to meet your automation needs. Its compact design, flexible configuration, and extensive instruction set make it an ideal solution for controlling a variety of applications. The CPU combines a microprocessor, integrated power supply, input and output circuits, integrated PROFINET, high-speed motion control I/Os, and built-in analog inputs in a compact housing to create a powerful controller. Once your program is loaded, the CPU contains the logic required to control and manage the devices in your application. The CPU monitors inputs and updates outputs according to the logic of your user program, which may include Boolean instructions, counting instructions, timing instructions, complex mathematical operations, as well as commands for communication with other intelligent devices. The CPU provides a PROFINET port for communication over a PROFINET network. Additional modules are available for communication via PROFIBUS, GPRS, RS485, or RS232 networks.[1]

Figure 5l'automate S7-1200

- **Possibilités d'extension de la CPU La gamme S7-1200 offre divers modules et cartes enfichables pour accroître les capacities de la CPU avec des E/S supplémentaires ou d'autres protocoles de communication.**

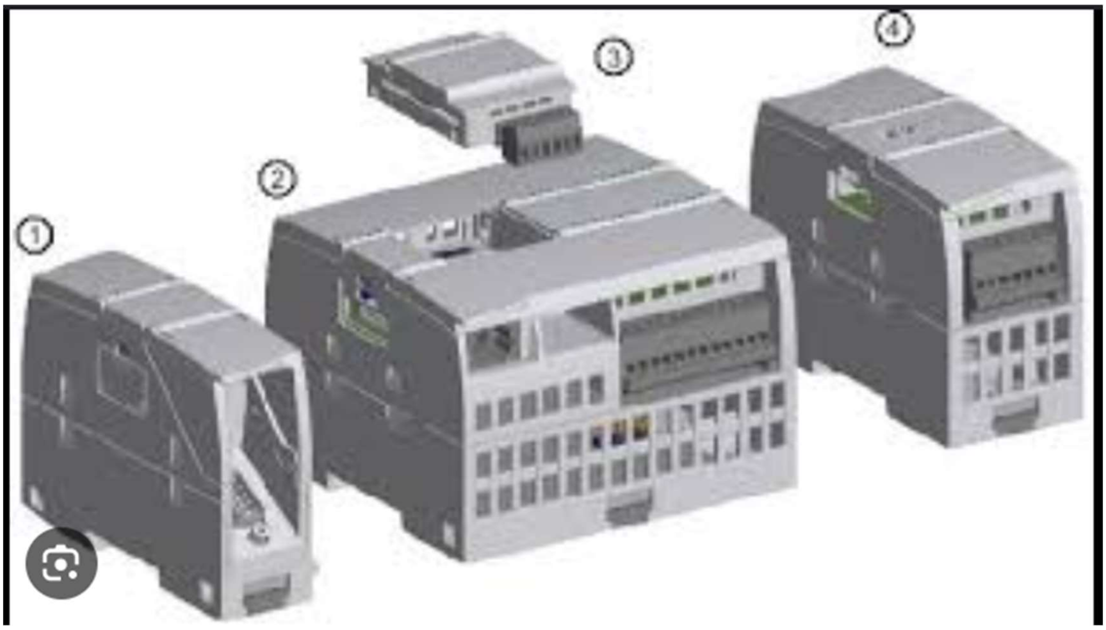


Figure 6Modules d'extension pour l'automate S7-1200

A programmable logic controller (PLC) is an industrial computer designed for automation tasks, especially in environments requiring high reliability, real-time control, and robustness. PLCs are used to monitor inputs, make decisions based on their programmed logic, and control outputs to automate processes.

- **Key Characteristics of PLCs:**
    - Modular architecture for easy expansion
    - Real-time cyclic execution
    - Ladder, function block, and structured text programming (IEC 61131-3 compliant)
    - High resistance to industrial disturbances

PLCs are structured with a central processing unit (CPU), memory for program and data, input/output modules, and communication interfaces. They are widely used in manufacturing, robotics, and infrastructure systems.


3.2. General Architecture of the Siemens S7-1200 PLC s 3d Reconstruction from images

The SIMATIC S7-1200 by Siemens is a compact, modular PLC suitable for basic to moderately complex automation tasks. It includes:

- CPUs (1211C to 1217C)
- Signal Boards (SBs), Signal Modules (SMs), Communication Modules (CMs)
- Integrated PROFINET communication

The CPU integrates a microcontroller, RAM, memory for code/data, and digital/analog I/O. The S7-1200 supports expansion with hot-swappable modules and structured programming using OBs (Organization Blocks), FCs (Functions), FBs (Function Blocks), and DBs (Data Blocks) (1)

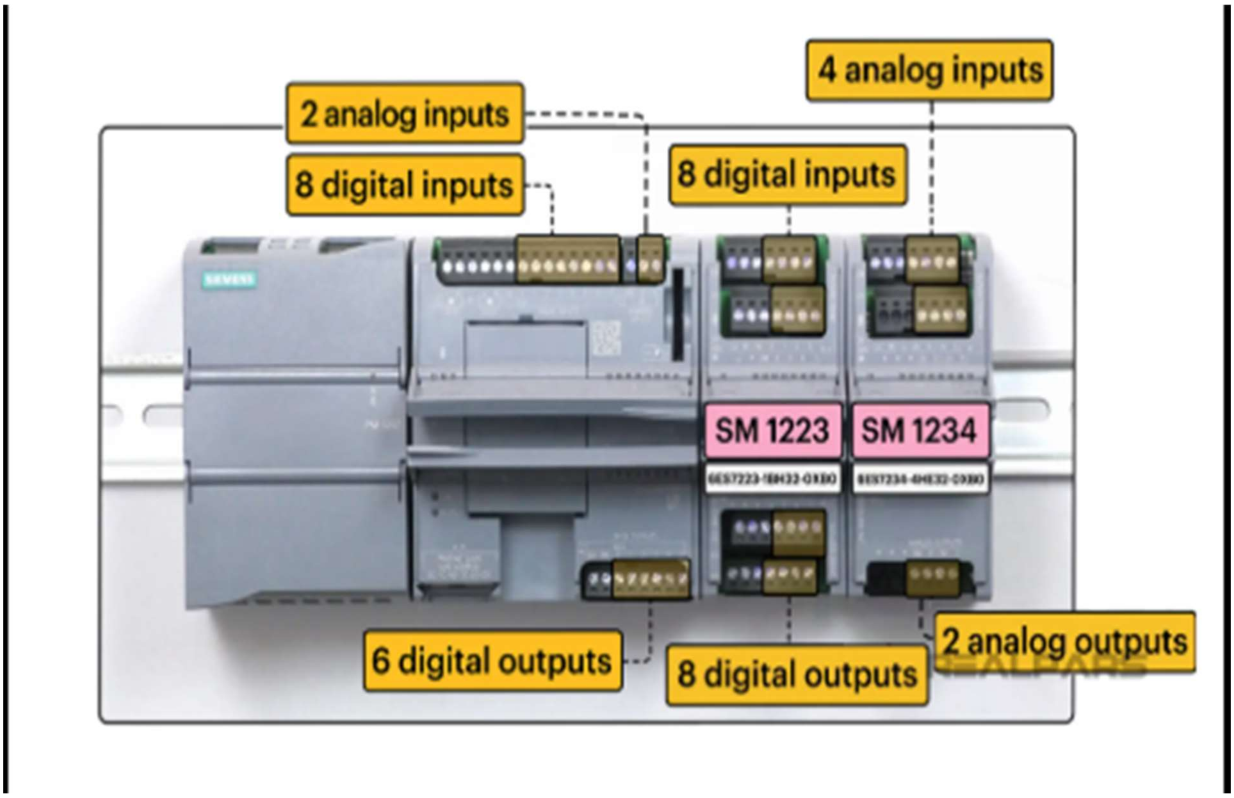


Figure 7Modular Structure of the S7-1200 PLC System]

3.3. Analog Acquisition and Actuation

Analog inputs (e.g., IW64) read physical signals (e.g., pressure or temperature) and scale them using FC105 (SCALE_X). Analog outputs (e.g., QW64) send processed signals using FC106 (UNSCALE_X) (2) 🖼 [Diagram 1.3: Comparison of Sensor-Based vs. Sensorless Drive Systems]

Show both systems and highlight the role of estimation in sensorless control.

Reference: Bose, B. K. (2002). Modern Power Electronics and AC Drives

Figure 8 ETHERNET INPUT

- Une lumière **JAUNE** indique le mode **STOP**.
- Une lumière **VERTE** indique le mode **RUN**.
- Une lumière **CLIGNOTANTE** indique le mode **STARTUP**.

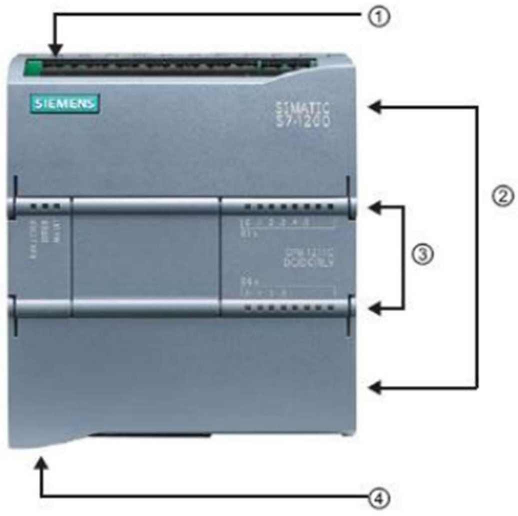


Figure 9 Digital Input OF PLC

1- 24V Power Supply

2- Removable terminals for user wiring (behind plastic covers)

3- LEDs for integrated I/O and CPU operation mode

4- TCP/IP Connection (under the CPU)

Figure 10 InPET and outPET of REAL PLC S7-1200

Figure 11 REAL PLS S7-1200

3.4. Introduction to the SINAMICS G120 Variable Frequency Drive

Figure 12 Simplified Diagram of VSD

The SINAMICS G120 is a modular Variable Frequency Drive (VFD) from Siemens, designed for precise control of three-phase asynchronous motors. It consists of a Control Unit (CU240E-2 PN) and a Power Module (PM240-2). The G120 supports sensorless vector control, secure integration over PROFINET, and is fully configurable within the TIA Portal Startdrive environment.

The drive receives run/stop commands, direction control, and speed setpoints through PZD telegrams (e.g., Standard Telegram 1, with 2 control words). It also returns its operating status and actual speed to the PLC. The G120 is configured according to the motor's nameplate data for accurate and safe operation..

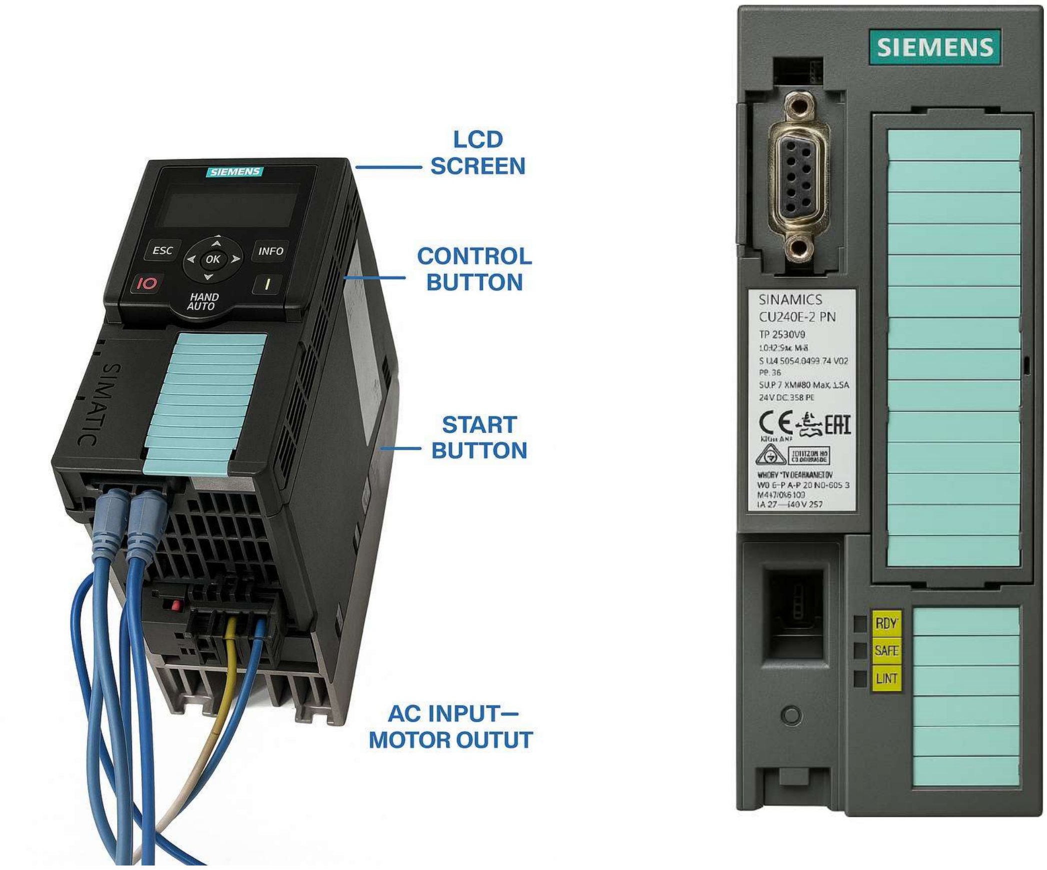


Figure 13 Wiring diagram of the SINAMICS G120 VFD with PLC and asynchronous motor

3.5. Industrial Automation and the Fourth Industrial Revolution

Technological developments in recent decades have led to the emergence of the Fourth Industrial Revolution, or Industry 4.0. This paradigm shift has revolutionized how industries operate by integrating cyber-physical systems, Internet of Things (IoT), and real-time data-driven decision-making into industrial environments. At the core of this transformation is industrial automation, which enables the control of processes with minimal human intervention through the use of Programmable Logic Controllers (PLCs), Human-Machine Interfaces (HMIs), sensors, and communication protocols like PROFINET or MODBUS.

3.6. Motivation for Sensorless Variable Speed Drive Control

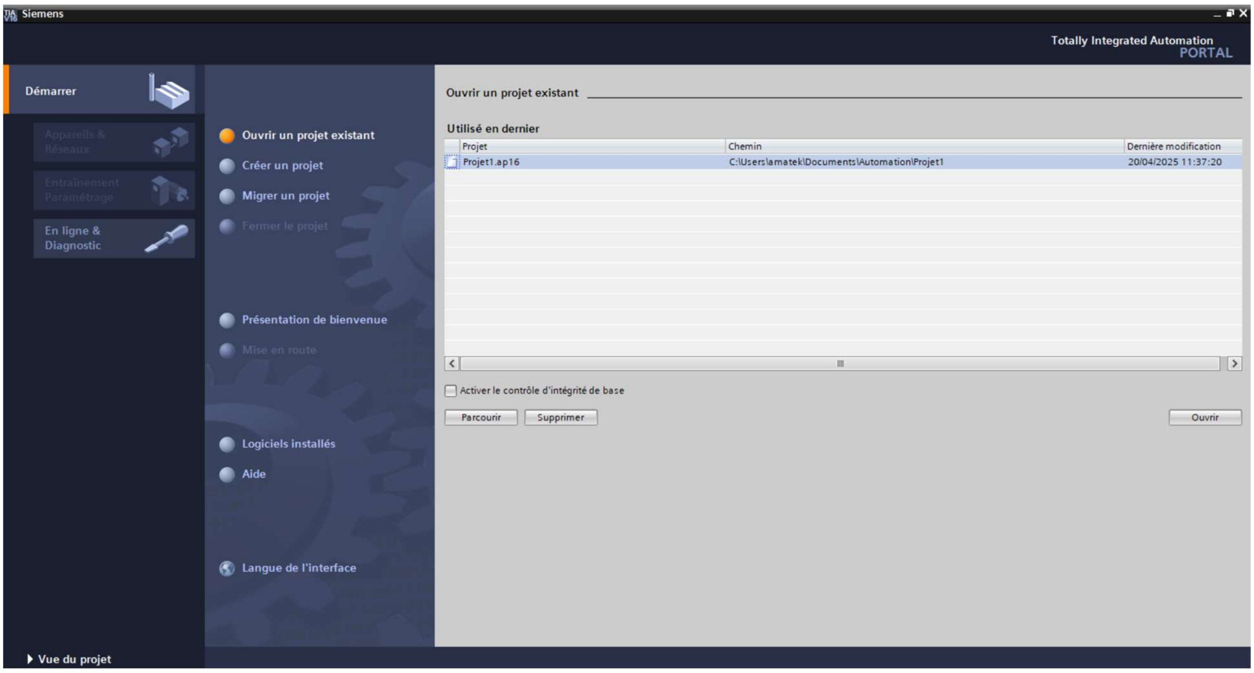
Sensorless control of electric drives eliminates mechanical speed or position sensors, thus:

- Reducing system cost
- Enhancing reliability in harsh environments

- Simplifying maintenance

Variable Speed Drives (VSDs) are essential in applications requiring adaptable motor speed. Sensorless vector control techniques infer motor speed from voltage and current feedback using estimators or observers implemented in the PLC or inverter firmware.

4. Generalities on TIA Portal



Totally Integrated Automation Portal (TIA Portal) is Siemens' unified engineering platform for configuring, programming, simulating, and diagnosing Siemens PLCs and HMIs.[2]

Core Components:

- **STEP 7 Basic/Professional** for PLC programming
- **WinCC Basic/Comfort** for HMI configuration
- **PLCSIM** for offline simulation

TIA Portal supports symbolic programming, modular coding, and online diagnostics. Projects are built using graphical editors and are structured using:

- OBs: For cyclic execution, startup routines, interrupts
- FCs/FBs: For modular program logic
- DBs: For variable storage

Key Features:

- Integrated hardware/software configuration
- Drag-and-drop linking of PLC and HMI components
- Access to Siemens libraries for control functions and analog processing
- Project consistency checks and versioning tools

4.1. Application Example: Hydraulic Press Control

In a referenced lab task, the S7-1200 is used to control a hydraulic press in manual and automatic modes. It involves:

- Position sensing (I0.0, I0.1)
- Actuator output (Q0.0)
- Pressure monitoring via analog module IW64
- Visualization through HMI panels (KTP400)

Program blocks include:

- SR flip-flops, TON timers for control timing
- FC blocks for manual/automatic modes
- OB1 for execution coordination

This practical implementation illustrates the core capabilities of the S7-1200 and TIA Portal when used together in sensorless automation systems 【125†TP_de_prise_en_main_du_S7_1200.pdf】.

5. CONCLUSION

The S7-1200, coupled with TIA Portal, forms a powerful and flexible automation system. It offers compactness and expandability through modular hardware, and supports accurate analog signal processing—key requirements for implementing sensorless variable speed control in electric drives. TIA Portal enhances this potential by enabling structured, modular, and symbolic programming, along with simulation and diagnostics capabilities. These features collectively align with the main objectives of this thesis: achieving precision control, system adaptability, and reduced sensor dependency in automation environments. S7-1200, coupled with TIA Portal, forms a powerful and flexible automation system. Its modular structure, advanced analog processing capabilities, and unified software environment make it ideal for developing reliable control architectures in sensorless drive systems and industrial applications

CHAPTER 2:
The asynchronous electric motor drive and variable speed drive

1. Introduction

In the industry, asynchronous motors are the most commonly used. Their main advantage is the fact that they do not contain sliding electrical contact; which ensures a robust structure and easy to manufactured.

Their stator is directly connected to the grid industrial, constant voltage and frequency, which runs at a slightly different speed than the synchronous speed.

They are used to implement almost all constant speed and also allows the realization of variable speed drives. The position that the synchronous motoroccupies in this field is constantly expanding.

This chapter is devoted to the development of a general presentation of the engine asynchronous starting by initially describing its components, its principle of operation, its characteristics and applications and finally the advantages and disadvantages. Thus the theoretical modelling of the squirrel cage asynchronous machine.

2. General about asynchronous machines

Electric motors are generally classified according to the type of electrical network in which the motor is connected: direct current (DC) motors and current motors Alternative (AC).

These motors with AC power supply are subdivided into two synchronous and asynchronous. The fundamental difference between an induction machine and a synchronous machine is in the rotor speed of the induction machine under load does not coincide (is asynchronous) with the speed of the magnetic field, generated by the supply voltage.

Induction motors are divided into two main categories; single-phase and three-phase, the first type of induction motors is not written in our work. Motors three-phase induction are classified according to the type of rotor: cage rotor and coiled rotor. The main classification is illustrated in Figure (7)

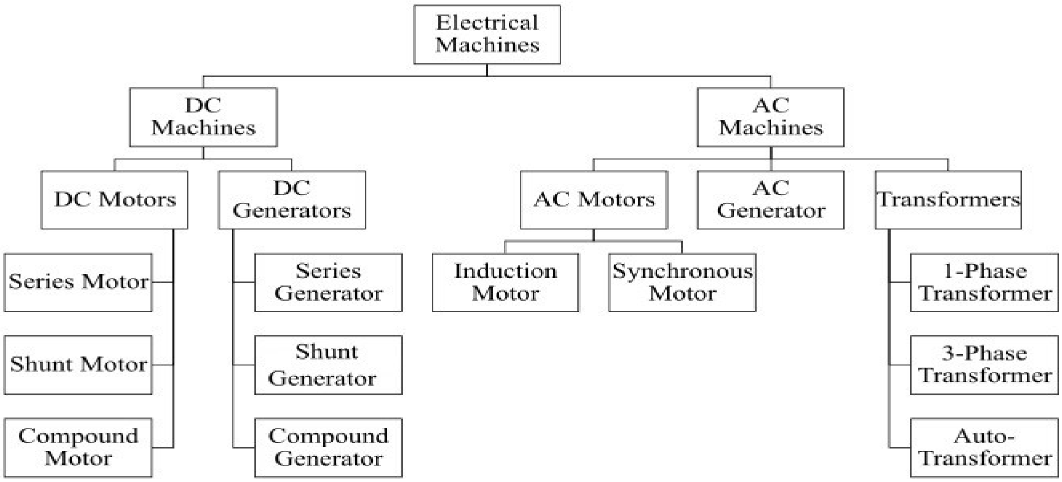


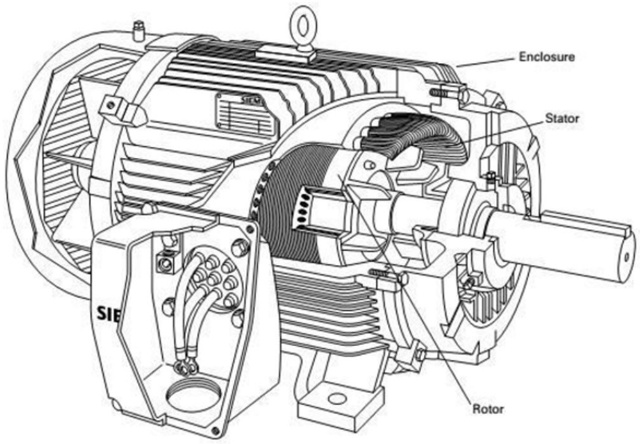
Figure 14 Classification of alternative electrical machines

2.1. Construction of the asynchronous machine

The asynchronous machine is composed of a fixed part called stator and a rotor Figure (8). Unlike synchronous and current-driven machines, continuous, only the stator windings are coupled to a supply network whose voltages (amplitude and frequency) define the magnetic state of the gap. Windings of the rotor are connected to themselves.

The asynchronous motor does not have any excitation windings or magnets permanent. In terms of the rotoric flux required for the formation of torque electromagnetic, it is produced from induction. Figure (8) represents the machine asynchronous. From the mechanical point of view, the asynchronous machine is subdivided into three parts distinct:

• Stator: stationary part is the part where the power supply is connected
• The rotor: rotating part, it allows to put in rotation the magnetic load
• The bearings: supporting elements, these last ones constitute the mechanical part the rotation of the motor shaft.
• The gap: This part is amagnetic (vacuum between rotor and stator). [7]



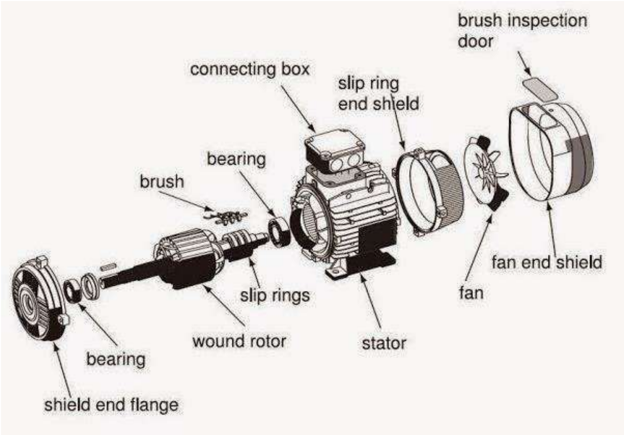
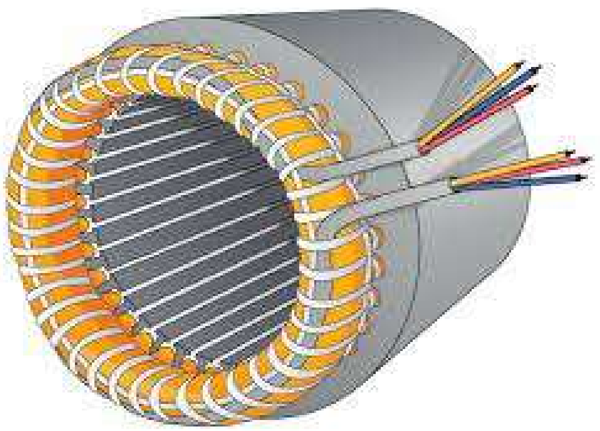


Figure 15 Asynchronous machine construction

2.3.1. The stator

It is the fixed part of the engine or a cast iron or light alloy carcass contains a thin plate crown (about 0.5 mm thick) made of silicon steel. The plates are isolated from each other by oxidation or by an insulating varnish. The «laminating» of the circuit magnetic reduces losses by hysteresis and eddy currents. The plates are equipped with of notches in which the stator coils for producing the Rotating field (three windings in the case of three-phase motor).

Each winding is consists of several coils. The coupling mode of these coils defines the number pairs of motor poles, thus the rotational speed. [9]



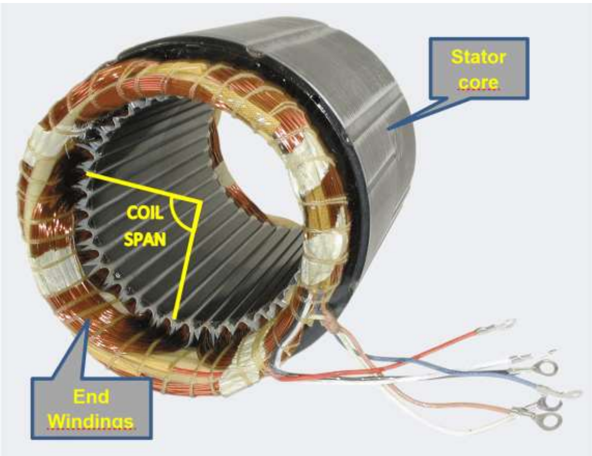


Figure 16 Diagram shows the stator winding

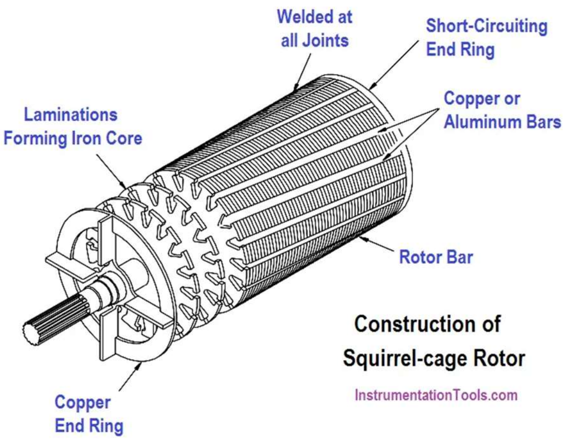
The rotor:

This is the moving part of the motor which consists of a stack of thin insulated sheets each other and forming a cylinder nailed to the motor shaft.

There are two types of rotor in the asynchronous machine:

2.3.2. The rotor:

All the conductors of the rotor are connected to each other by two rings. These permanently short-circuited conductors (Figure2). The limitations of the motor Asynchronous squirrel cage is located at start-up or torque and/or current are not not reasonable. [8] This type of engine is used for small powers or for high powers not having No need to start at full load. [8]



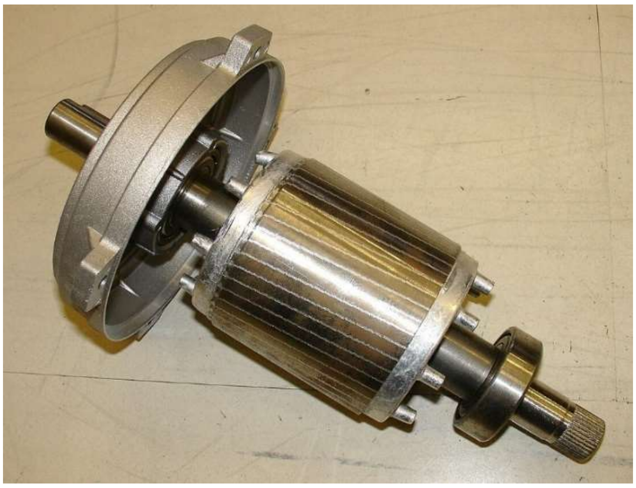


Figure 17 Cage rotor

1.3.1. The gap:

This non-magnetic part (it is a vacuum between the stator and the rotor) is the thickest low (in the millimetre range), this reduced thickness makes the air gap size sensitive to variations due to statorial notches. This creates so-called notch harmonics, for reduce, the notches are closed by magnetic shims that hold the winding. [6]

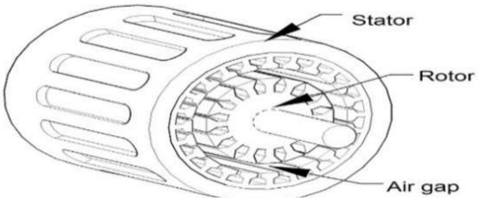


Figure 18 Cross-Sectional View of an Induction Motor's Stator and Rotor Assembly

1.3.1. The mechanical components:

The carcass serves as a support, it acts as an envelope and provides protection against the external environment.

The shaft is a transmission organ. It includes a central part that serves support to the rotor body and is supported by one or more bearings. These support the rotor and ensure free rotation.

The second bearing is free to ensure thermal expansion of the shaft. [6] Electrical isolation of one of the bearings ensures the elimination of currents in the shaft due to the dissymmetry of the magnetic circuit's resistances. They are usually with bearings.
For small and medium power machines. In Most of the time we find also a cooling fan.

Figure 19 Diagram of the components of an asynchronous machine

1.2. Principle of operation of an asynchronous machine

The operating principle of the asynchronous machine is based entirely on the law induction; the asynchronous machine is considered a field transformer rotating magnet whose stator is comparable to the primary winding and rotor has the secondary winding in short circuit.

This operation is based on the principle of the electromagnetic interaction of the rotating field, created by the three-phase currents supplied to the stator winding by the lattice, and currents induced in the rotor winding when its conductors are cut off by the rotating field. [9]

When the rotor is rotating at a speed Ns different from synchronism, the application of the FARADAY's law to one of the rotorian ruts shows that it becomes the seat of a electromotive force; which being short-circuited on the windings; which gives rise to a current whose intensity is limited by the impedance of the latter. [9]

The interaction between this current and the glide field gives rise to forces acting on the strands of the rotor whose moment with respect to the axis of rotation will constitute the machine torque when the field is sinusoidal rotation speed is:

$$n_1 = \frac{f}{p}$$

f: the feed frequency.
P: number of pole pairs.

The electromagnetic interaction of both parts of the machine is only possible when the speed of the rotating field (n1) differs from that of the rotor (n), that is when n ≠ n1, because otherwise (n= n1), the field would be immobile relative to the rotor and no current would be induced in the rotor winding. [9]

The report:

$$g = \frac{n_1 - n}{n_1}$$ Asynchronous machine slide. [9]

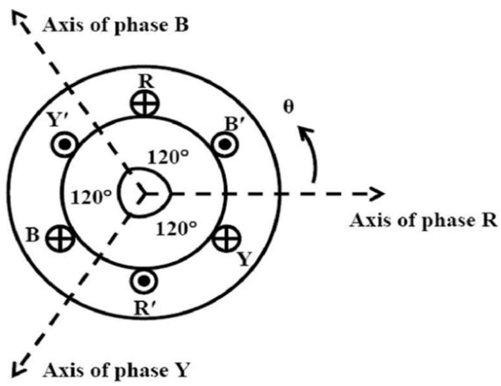


Figure 20 Schematic diagram of the operating principle of an asynchronous motor

1.3. Rating plate:

The rating plate is usually positioned on top of the electric motor. It is a metal plate containing a table that includes the characteristics motor techniques.

Figure 21 Three-phase asynchronous motor rating plate

1.4. The choice of an asynchronous motor

1.3.1. The mechanical components:

The choice of a MAS and its startup mode depends on:

• The installed power of the supply network.

• The motor supply voltage must be compatible with that of the network.

• The start-up voltage drop should be <= +- 5% of the mains voltage.

• The MAS must be selected to operate at rated power (both
power factor are the best).

• The torque of the engine must be higher at all times than the resistance torque of the machine has trained Torque resistance, power and network are the main factors for choosing a
three-phase asynchronous motor and its starting mode. [8]

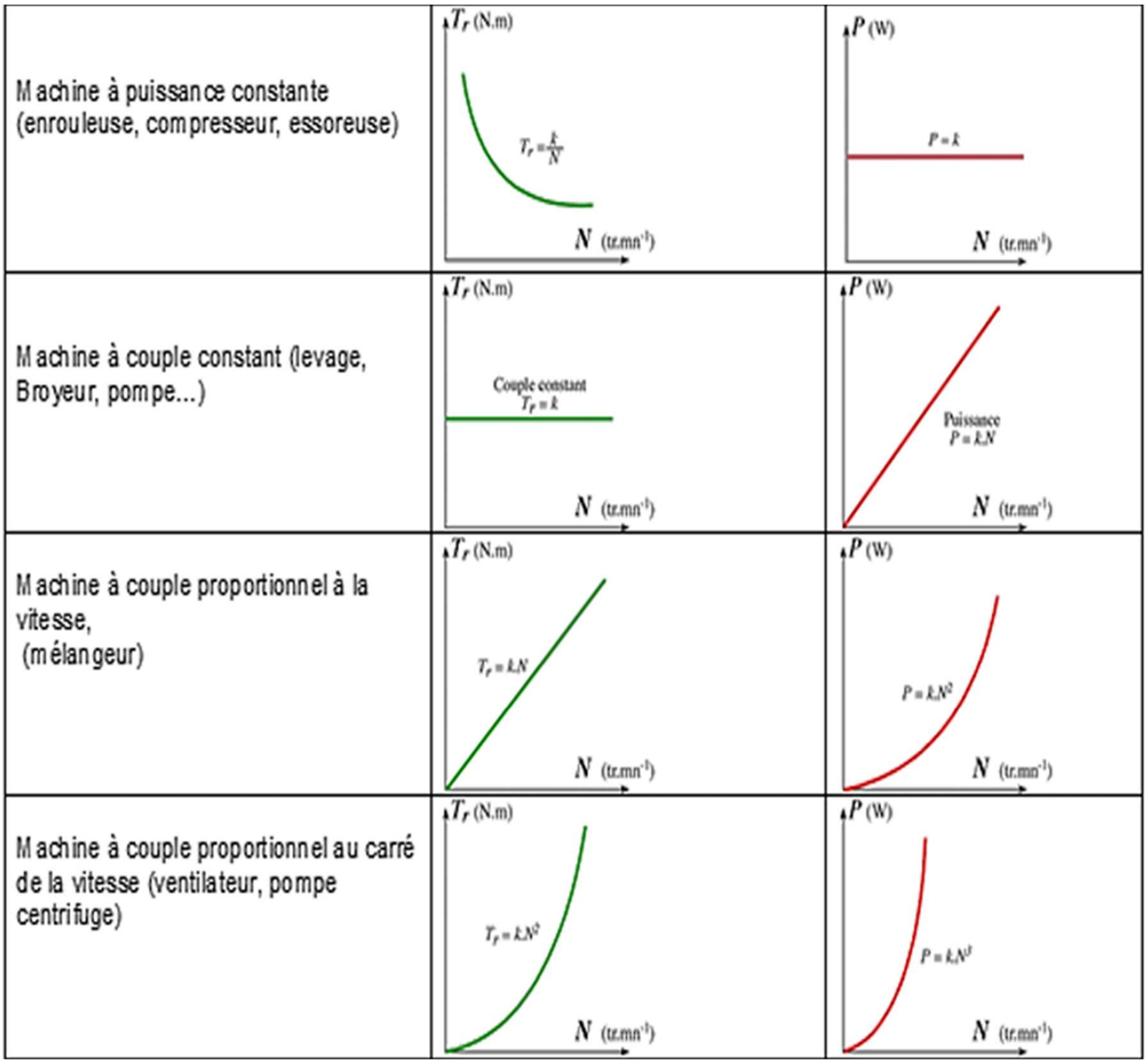


Figure 22 The various couples resistant[8]

3. Asynchronous generator:

An asynchronous generator, also known as an induction generator, is a type of AC electrical generator that operates based on the principles of electromagnetic induction, much like an induction motor. Unlike synchronous generators, asynchronous generators do not require an external DC power supply for excitation, making them simpler and more rugged in construction. They are widely used in wind turbines, small hydro power systems, and other decentralized renewable energy systems. The construction of this Generator is similar to an

Figure 23 generator

induction motor. But the machine works as a generator or motor mainly depends on the condition of whether the slip is positive (or) negative. These generators are provided always with squirrel cage rotors. The induction generator includes different parts like a rotor, stator, shaft, end plate, bearing, and electrical terminals. The construction of the induction generator is shown below [5]

3.1. Working Principle:

The asynchronous generator works on the principle of **Faraday's Law of Electromagnetic Induction**, which states that a voltage is induced in a conductor when it experiences a change in magnetic flux.

In an asynchronous generator:

- The rotor is mechanically driven at a speed **higher than the synchronous speed**.
- This speed difference (called **slip**) causes the rotor to "cut" the stator's rotating magnetic field, inducing a current.
- When the generator is connected to a grid or an external source of reactive power (capacitors or grid itself), it can generate electrical power.

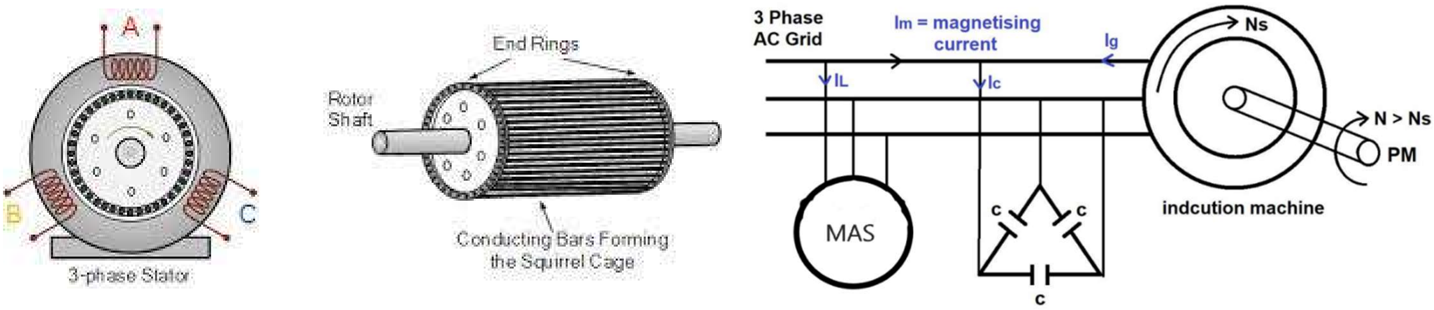
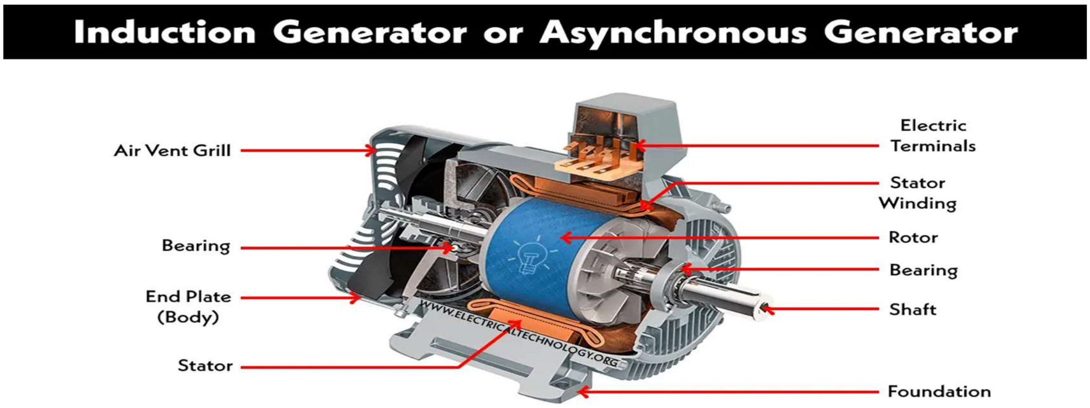


Figure 24 Components of a Three-Phase Induction generator (Stator and Squirrel Cage Rotor)

3.2. Main Components

1. **Stator** – Houses three-phase windings where the voltage is induced.
2. **Rotor** – Usually a squirrel cage type; rotated mechanically.
3. **Bearings & Housing** – Provide support and reduce friction.
4. **Cooling System** – Dissipates heat generated during operation.



3.3. Types of Asynchronous Generators

3.3.1. Grid-Connected Induction Generator

- Requires connection to a power grid to supply the necessary **reactive power**.
- Common in **wind turbines** connected to utility networks.

3.2.2. Self-Excited Induction Generator (SEIG)

- Uses **capacitors** to provide the reactive power.
- Operates in **isolated or off-grid systems**, like micro-hydro or remote wind systems.
- Requires residual magnetism in the rotor to initiate voltage build-up.[5]

3.4. Characteristics :

- **Speed**: Operates above synchronous speed.
- **Reactive Power Requirement:** Needs external reactive power source.
- **Slip:** Positive slip is required for generator action.
- **Frequency Stability**: Frequency depends on the grid or load conditions, not constant in isolated mode.
- **Efficiency**: Generally lower than synchronous generators but acceptable in many applications.
- **Ruggedness**: Simple construction, minimal maintenance.

2.1. 4 Industrial variable speed drive:

2.2. 4.1 Introduction:

A number of applications require an adjustment of torque and speed.

the acceleration or other quantities for a satisfactory conduct of the process:

- Gradual start of the process, controlled acceleration and deceleration.
- Precise control of torque, speed in static and/or dynamic conditions.
- On-demand workflow adjustment/control.

The investment for an electronic variable speed solution will only be made if brings gains by:

- Quality of finished products (sheet metal for the food industry, paper...)
- Production savings (variable flow pumping/propulsion...)
- Flexibility of operation (adaptation of production flows to demand...)
- Reduced maintenance (direct drive replacing components mechanics...)

To choose a variable speed drive system it is absolutely necessary to know the constraints imposed by the load on the network/converter/machine assembly.

- Characteristic torque speed of the driven machine
- Inertia of the driven machine
- Expected static and dynamic performance
- Regime and service in all operating cases

Speed means all the electrical and mechanical quantities characterizing the operation of a machine at a given time Service is defined as the different regimes to which the machine is subject with their their respective durations and their order of succession. The choice of a converter/machine assembly for a specific application results from the most perfect match between specifications, technical solutions available to at a given moment, the human resources and the financial profitability of the investment.

2.3. 4.1. Principle of operation of speed variators

Variable speed drives are used to vary the speed of motors asynchronous with a constant speed design. The speed variation is obtained by varying the frequency of the motor supply voltage the power module constitutions

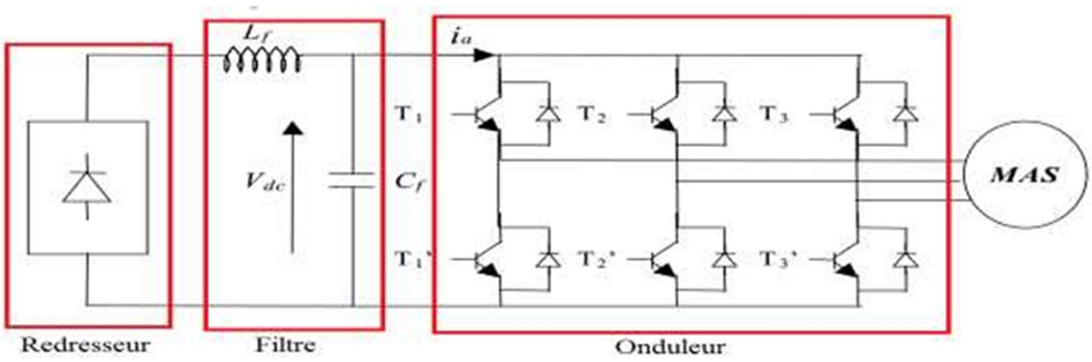


Figure 25ELECTRICAL DIAGRAM OF VSD

4.2 The SIEMENS SINAMICS G120 range:

In our work we will handle on a SIEMENS variable speed drive (SINAMICS G120), Each SINAMICS G120 inverter always consists of a Control Unit and a Power Module.

- The Control Unit controls and monitors the Power Module as well as the connected motor by offering several selectable control types. The dimmer is controlled by the Control Unit locally or centrally.
- Power Modules are available for motors in a range of power from 0.37 kW to 250 kW.

4.2.1 Identifying the converter :

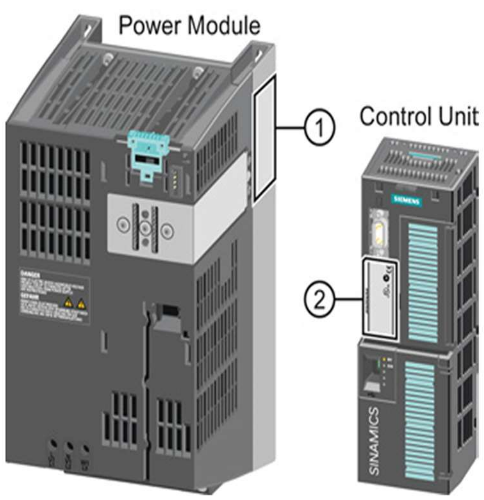


Figure 26 Siemens SINAMICS G120 Power Module and Control Unit

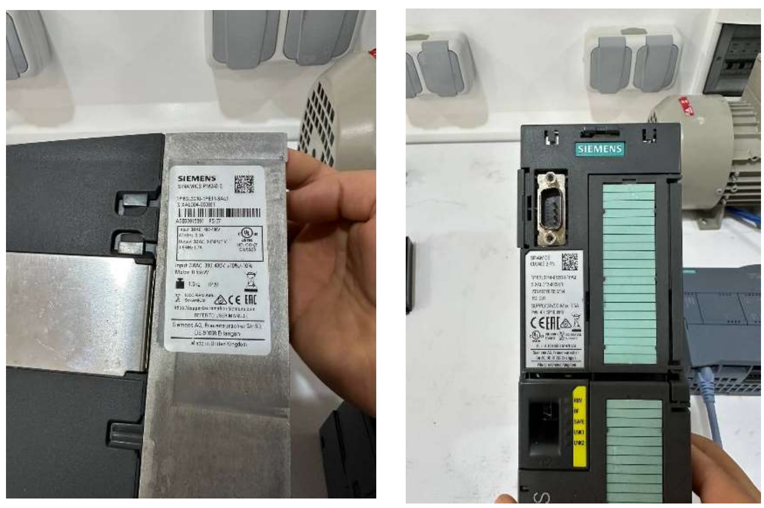


Figure 27 Siemens SINAMICS G120 Control Unit 240E-2PN with PROFIBUS DP Interface

4.2.2 Main components of the inverter

The following data is provided on the Power Module type plate (①):

- Designation: e.g. Power Module 240
- Technical data: Voltage and current
- Order number: e.g. 6SL3224-0BE13-7UA0
- Version: e.g. A02

The following data can be found on the Control Unit type plate (②):

- Designation: e.g. Control Unit CU240E-2 DP-F
- Order number: e.g. 6SL3244-0BB13-1PA0
- Version: e.g. A02 (hardware) [3]

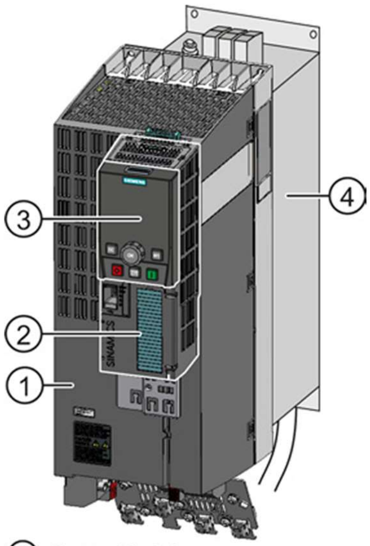
4.2.3 Power Modules frame sizes :

① + ② As a minimum, the inverter comprises a Power Module and an inserted Control Unit: Overall depth of the inverter = depth of the Power Module + 60 mm (Control Unit)

① + ② + ③ Inverter with inserted operator panel:

- Overall depth of the inverter = depth of the Power Module + 73 mm (Control Unit + Basic Operator Panel BOP-2)
- Overall depth of the inverter = depth of the Power Module + 82 mm (Control Unit + Intelligent Operator Panel IOP)

① + ② + ③ + ④ Power Module (degree of protection IP20) on a base component: The overall inverter depth increases by the depth of the base component.[3]



① Power Module
② Control Unit
③ Intelligent Operator Panel IOP
④ Base components: Filters, reactors or braking resistors

Siemens SINAMICS G120 Power Module and Basic Operator Panel (BOP-2)

4.2.4 Connecting the inverter :

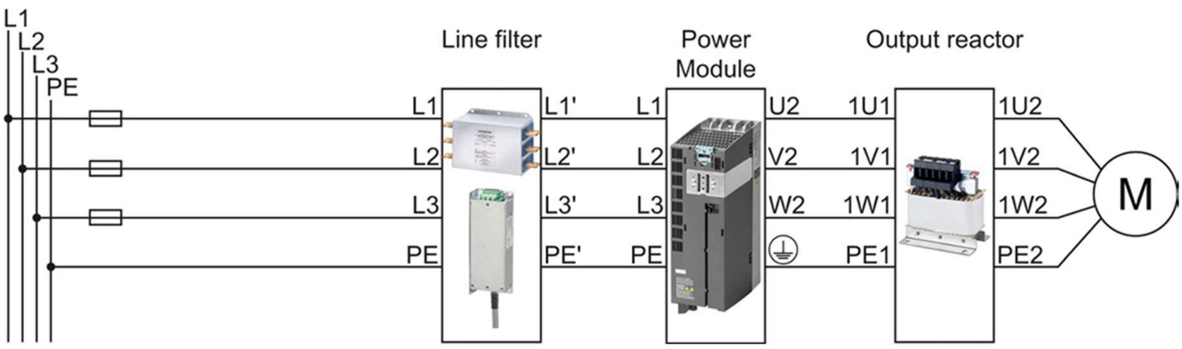
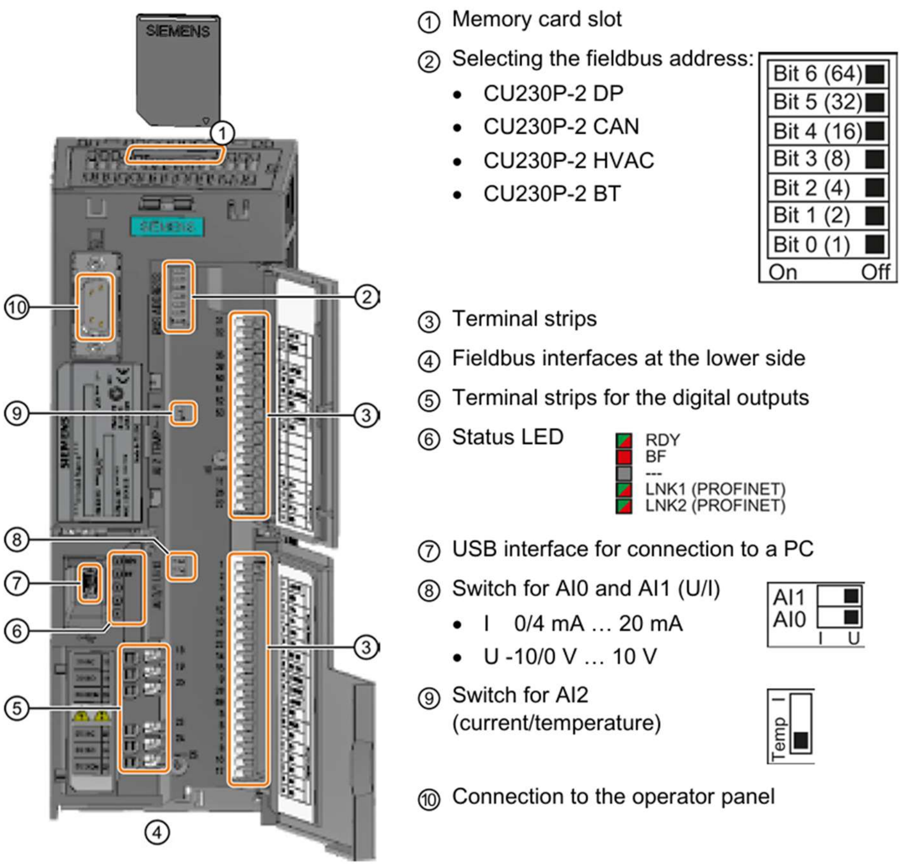


Figure 28 Connecting the PM230 IP20 and push-through Power Module[3]

4.3 Interfaces at the front of the Control Unit:

To access the interfaces at the front of the Control Unit, you must lift the Operator Panel (if one is being used) and open the front doors.



4.3.1 Terminal strips of the CU :

The following applies to systems complying with UL: A maximum of 3 A 30 V DC or 2 A 250 V AC may be connected via terminals 18 / 20 (DO 0 NC) and 23 / 25 (DO 2 NC).

① The analog input is supplied from an external 10 V voltage.

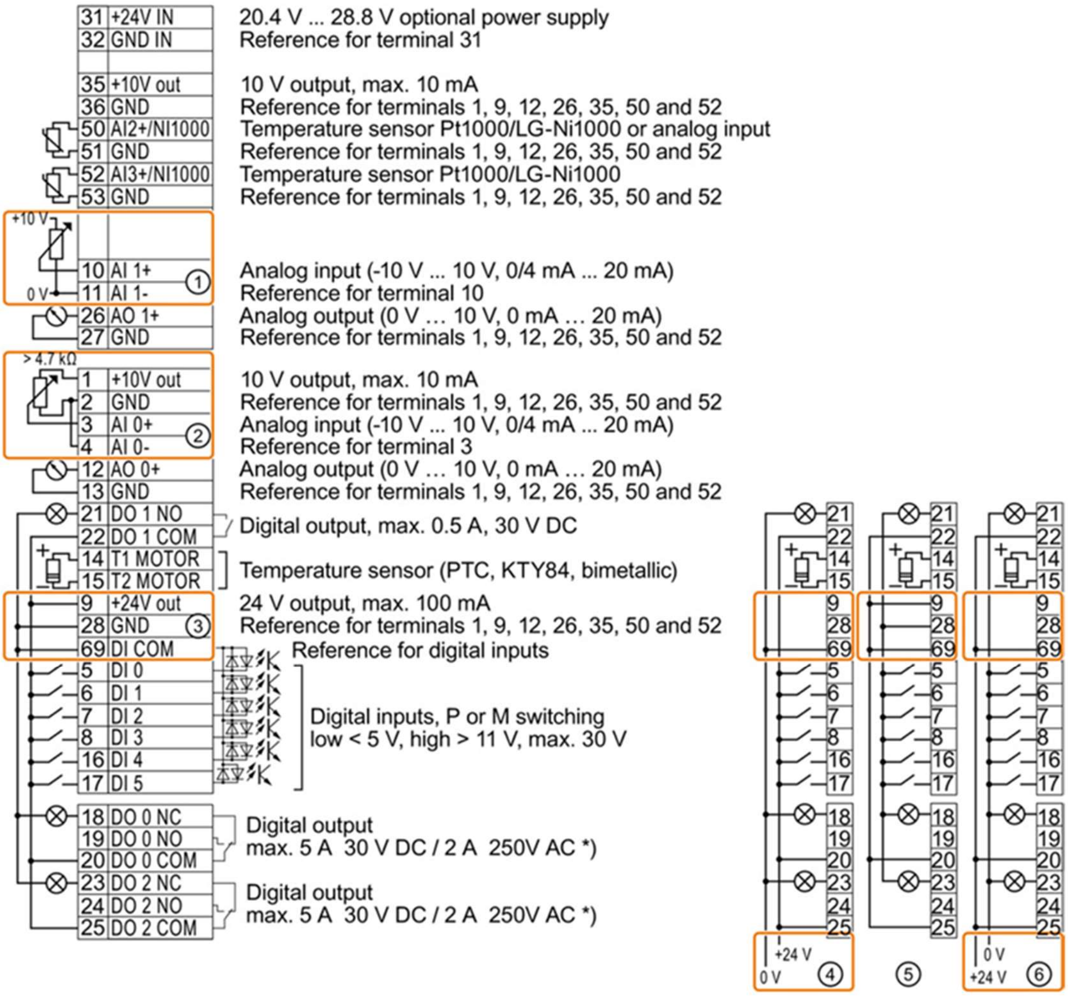
② The analog input is supplied from the internal 10 V voltage.

③ Wiring when using the internal power supplies. Connecting a contact switching to P.

④ Wiring when using external power supplies. Connecting a contact switching to P.

⑤ Wiring when using the internal power supplies. Connecting a contact switching to M.

⑥ Wiring when using external power supplies. Connecting a contact switching to M.[3]



4.4 Communication via PROFINET :

PROFINET (Process Field Network) is a communication standard based Industrial Ethernet offering a wide range of applications. The fieldbus uses TCP/IP and standards of information technology, allows real-time processing and integration field bus systems. PROFINET was developed by Siemens and the enterprises members of the PROFIBUS user organization (PNO) and is used in association with Siemens control systems. Thanks to IEC 61158 and IEC 61784, PROFINET has been standardized and covers, as a communication technology universal, all the requirements of automation technology.

The international compatibility of a PROFINET device is guaranteed by certification of the PNO user organization.

You can either communicate via Ethernet using the inverter, or integrate the inverter in a PROFINET network.[10]

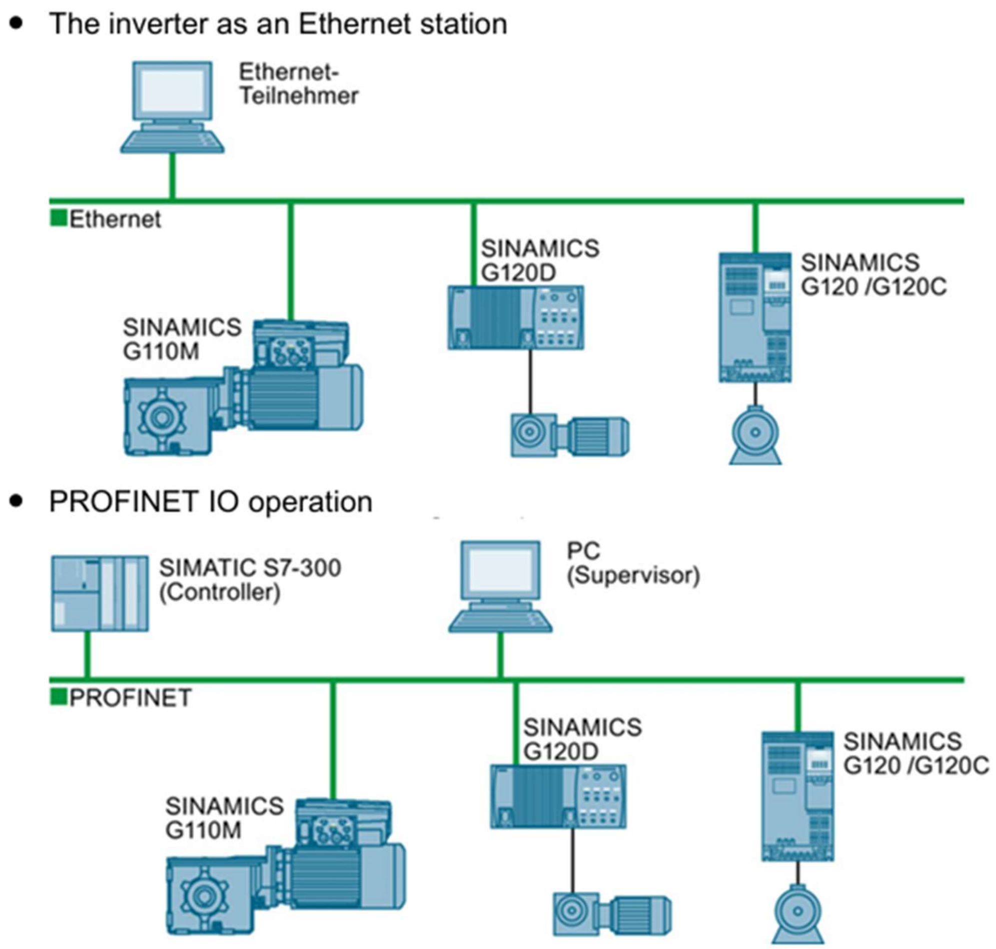
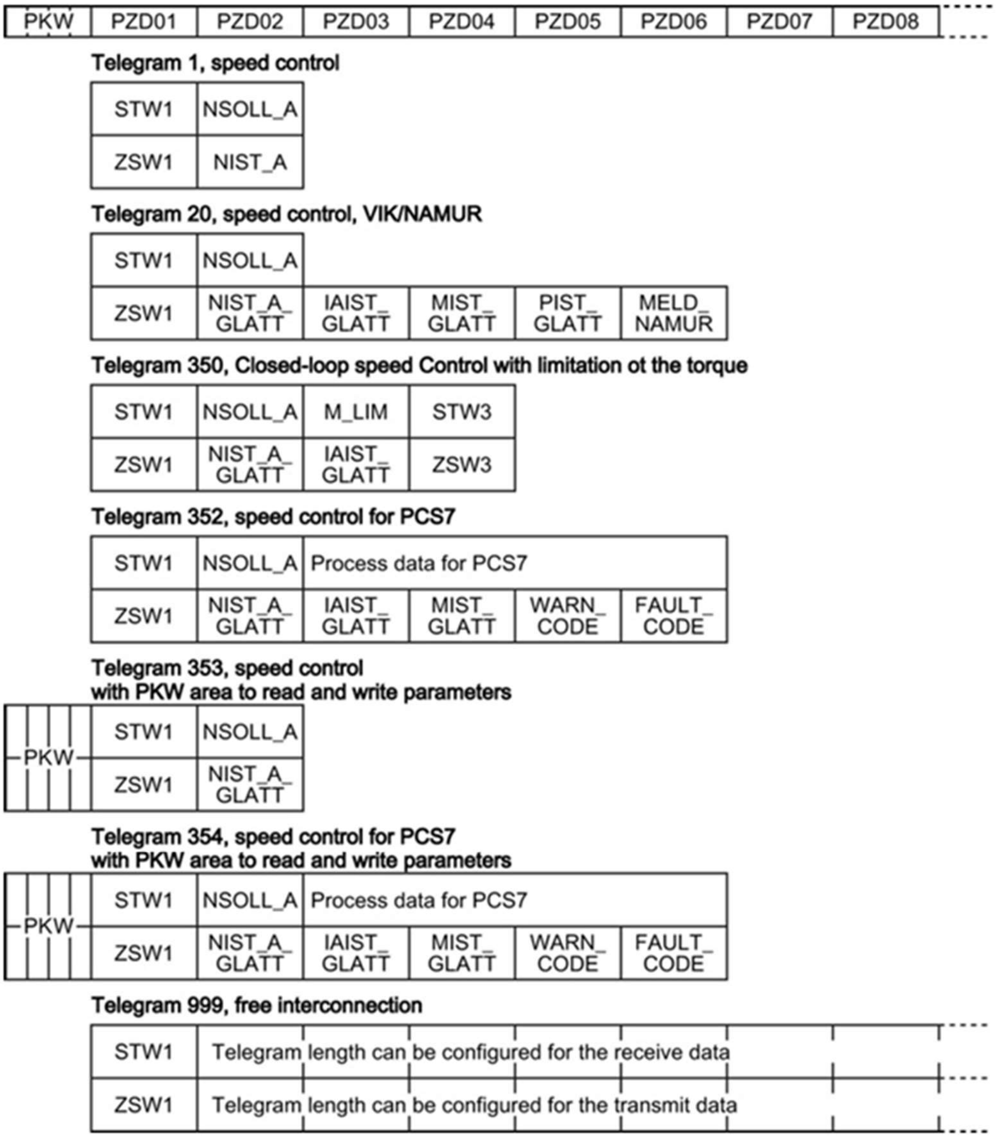


Figure 29 Network Integration of Siemens SINAMICS Inverters via Ethernet and PROFINET IO[3]

4.5 PROFIdrive profile for PROFINET:

4.5.1 Cyclic communication

The send and receive telegrams of the inverter for the cyclic communication are structured as follows:

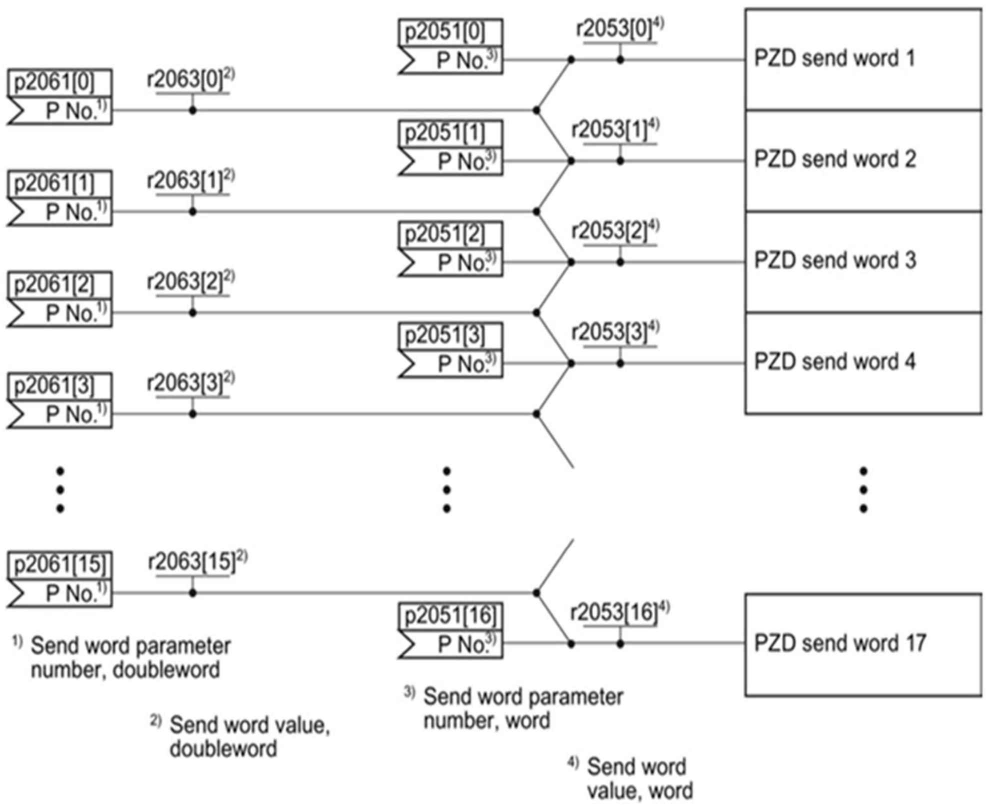


Telegrams for cyclic communication

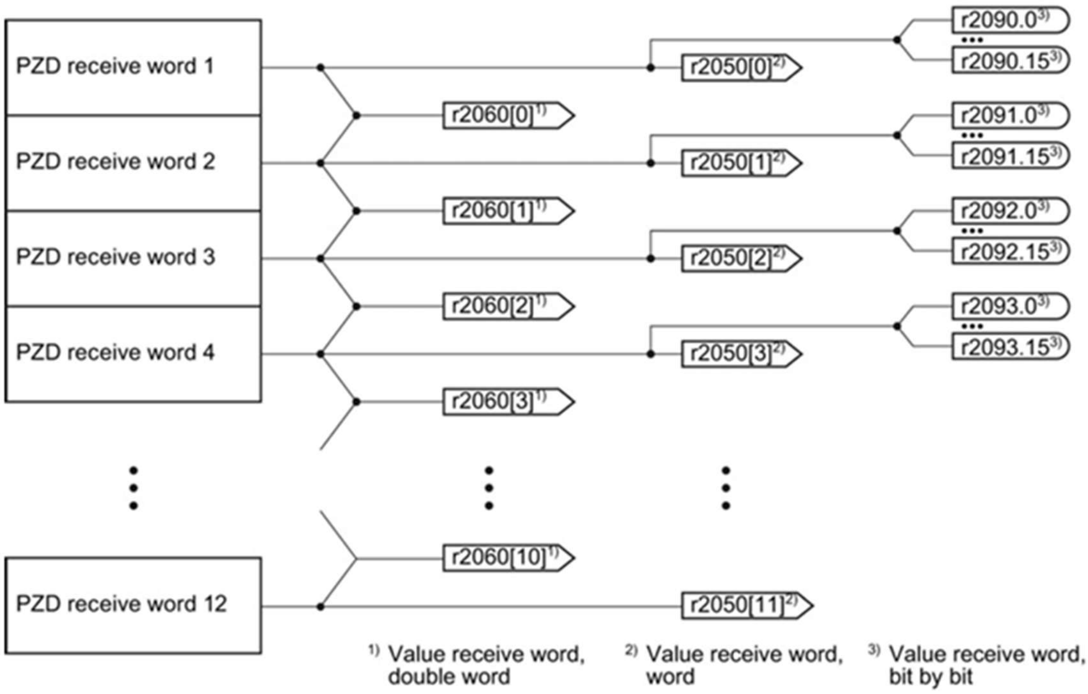
Table 5- 3 Explanation of the abbreviations

Abbreviation	Explanation	Abbreviation	Explanation
STW	Control word	MIST_GLATT	Actual smoothed torque
ZSW	Status word	PIST_GLATT	Actual smoothed active power
NSOLL_A	Speed setpoint	M_LIM	Torque limit value
NIST_A	Speed actual value	FAULT_CODE	Fault number
NIST_A_GLATT	Smoothed actual speed value	WARN_CODE	Alarm number
IAIST_GLATT	Smoothed current actual value	MELD_NAMUR	Control word according to the VIK-NAMUR definition

4.5.2 Interconnection of the process data :



Interconnection of the send words



Interconnection of the receive words

The telegrams use - with the exception of telegram 999 (free interconnection) - the word-by word transfer of send and receive data (r2050/p2051).[11]

4.6 Control and status word :

4.6.1 Control word 1 (STW1)

The PROFIdrive profile, used within PROFINET networks, standardizes communication between controllers (e.g., PLCs) and drives (e.g., motors, servos). Control Word 1 (CW1) and Status Word 1 (SW1) are critical 16-bit data structures for real-time command and status exchange. Below is a detailed explanation:

- Telegram 20 (VIK/NAMUR):
  - Bit 0 … 11 corresponds to PROFIdrive profile,
  - Bit 12… 15 manufacturer-specific
- Other telegrams:
  - Bit 0 … 10 corresponds to PROFIdrive profile,
  - Bit 11… 15 manufacturer-specific50/p2051).

Parameter	Description	
p0922	**PROFIdrive telegram selection**	
	999:	Free telegram (message frame) configuration
p2079	**PROFIdrive PZD telegram selection extended**	
	1: 20: 350: 352: 353: 354:	Standard telegram 1, PZD-2/2 Standard telegram 20, PZD-2/6 SIEMENS telegram 350, PZD-4/4 SIEMENS telegram 352, PZD-6/6 SIEMENS telegram 353, PZD-2/2, PKW-4/4 SIEMENS telegram 354, PZD-6/6, PKW-4/4
r2050[0…11]	**PROFIdrive PZD receive word** Connector output to interconnect the PZD (setpoints) in the word format received from the PROFIdrive controller.	
p2051[0…16]	**PROFIdrive PZD send word** Selection of the PZD (actual values) in the word format to be sent to the PROFIdrive controller.	

Table 1 PROFINET Telegram Configuration Parameters for PROFIdrive Communication

Bit	Significance: Telegram 20	Significance: All other telegrams	Explanation	Signal interconnection in the inverter
0	0 = OFF1		The motor brakes with the ramp-down time p1121 of the ramp-function generator. The inverter switches off the motor at standstill.	p0840[0] = r2090.0
	0 → 1 = ON		The inverter goes into the "ready" state. If, in addition bit 3 = 1, then the inverter switches on the motor.	
1	0 = OFF2		Switch off the motor immediately, the motor then coasts down to a standstill.	p0844[0] = r2090.1
	1 = No OFF2		The motor can be switched on (ON command).	
2	0 = Quick stop (OFF3)		Quick stop: The motor brakes with the OFF3 ramp-down time p1135 down to standstill.	p0848[0] = r2090.2
	1 = No quick stop (OFF3)		The motor can be switched on (ON command).	
3	0 = Inhibit operation		Immediately switch-off motor (cancel pulses).	p0852[0] = r2090.3
	1 = Enable operation		Switch-on motor (pulses can be enabled).	
4	0 = Disable RFG		The inverter immediately sets its ramp-function generator output to 0.	p1140[0] = r2090.4
	1 = Do not disable RFG		The ramp-function generator can be enabled.	
5	0 = Stop RFG		The output of the ramp-function generator stops at the actual value.	p1141[0] = r2090.5
	1 = Enable RFG		The output of the ramp-function generator follows the setpoint.	
6	0 = Inhibit setpoint		The inverter brakes the motor with the ramp-down time p1121 of the ramp-function generator.	p1142[0] = r2090.6
	1 = Enable setpoint		Motor accelerates with the ramp-up time p1120 to the setpoint.	
7	0 → 1 = Acknowledge faults		Acknowledge fault. If the ON command is still active, the inverter switches to"closing lockout" state.	p2103[0] = r2090.7
8, 9	Reserved			
10	0 = No control via PLC		Inverter ignores the process data from the fieldbus.	p0854[0] = r2090.10
	1 = Control via PLC		Control via fieldbus, inverter accepts the process data from the fieldbus.	
11	0 = Direction reversal		Invert setpoint in the inverter.	p1113[0] = r2090.11
12	Not used			
13	---[1)]	1 = MOP up	Increase the setpoint saved in the motorized potentiometer.	p1035[0] = r2090.13
14	---[1)]	1 = MOP down	Reduce the setpoint saved in the motorized potentiometer.	p1036[0] = r2090.14
15	CDS bit 0	Reserved	Changes over between settings for different operation interfaces (command data sets).	p0810 = r2090.15

Table 2 Significance of Control Bits for Inverter Operation and PROFIdrive TelegramsStatus word 1 (ZSW1)

The status word 1 is pre-assigned as follows.

- Bit 0 … 10 corresponds to PROFIdrive profile
- Bit 11… 15 manufacturer-specific

Bit	Significance: Telegram 20	Significance: All other telegrams	Comments	Signal interconnection in the inverter
0	1 = Ready to start		Power supply switched on; electronics initialized; pulses locked.	p2080[0] = r0899.0
1	1 = Ready		Motor is switched on (ON/OFF1 = 1), no fault is active. With the command "Enable operation" (STW1.3), the inverter switches on the motor.	p2080[1] = r0899.1
2	1 = Operation enabled		Motor follows setpoint. See control word 1, bit 3.	p2080[2] = r0899.2
3	1 = Fault active		The inverter has a fault. Acknowledge fault using STW1.7.	p2080[3] = r2139.3
4	1 = OFF2 inactive		Coast down to standstill is not active.	p2080[4] = r0899.4
5	1 = OFF3 inactive		Quick stop is not active.	p2080[5] = r0899.5
6	1 = Closing lockout active		It is only possible to switch on the motor after an OFF1 followed by ON.	p2080[6] = r0899.6
7	1 = Alarm active		Motor remains switched on; no acknowledgement is necessary.	p2080[7] = r2139.7
8	1 = Speed deviation within the tolerance range		Setpoint / actual value deviation within the tolerance range.	p2080[8] = r2197.7
9	1 = Master control requested		The automation system is requested to accept the inverter control.	p2080[9] = r0899.9
10	1 = Comparison speed reached or exceeded		Speed is greater than or equal to the corresponding maximum speed.	p2080[10] = r2199.1
11	1 = current or torque limit reached	1 = torque limit reached	Comparison value for current or torque has been reached or exceeded.	p2080[11] = r0056.13 / r1407.7
12	---1)	1 = Holding brake open	Signal to open and close a motor holding brake.	p2080[12] = r0899.12
13	0 = Alarm, motor overtemperature		--	p2080[13] = r2135.14
14	1 = Motor rotates clockwise		Internal inverter actual value > 0	p2080[14] = r2197.3
	0 = Motor rotates counterclockwise		Internal inverter actual value < 0	
15	1 = CDS display	0 = Alarm, inverter thermal overload		p2080[15] = r0836.0 / r2135.15

Table 3 Status Bit Definitions for Inverter Operation and Diagnostics

4.6.2 Data structure of the parameter channel:

A. Structure of the parameter channel :

The parameter channel consists of four words. 1. and 2nd word transfer the parameter number and index as well as the type of job (read or write) The 3rd and 4th word contains the parameter contents. The parameter contents can be 16-bit values (such as baud rate) or 32-bit values (e.g. CO parameters).

Bit 11 in the 1st word is reserved and is always assigned 0.

Parameter channel						
PKE (1st word)			IND (2nd word)		PWE (3rd and 4th words)	
15 ... 12	11	10 ... 0	15 ... 8	7 ... 0	15 ... 0	15 ... 0
AK	SPM	PNU	Subindex	Page index	PWE 1	PWE 2

Table 4 Structure of a PROFIdrive Parameter Channel Data Frame

B. Telegram examples Read request: Read out serial number of the Power Module (p7841[2]) To obtain the value of the indexed parameter p7841, you must fill the telegram of the parameter channel with the following data:

- PKE, bit 12 … 15 (AK): = 6 (request parameter value (field))
- PKE, bit 0 … 10 (PNU): = 1841 (Parameter number without offset) Parameter number = PNU + offset (page index) (7841 = 1841 + 6000)
- IND, bit 8 … 15 (subindex): = 2 (Index of the parameter)
- IND, bit 0 … 7 (page index): = 90 hex (offset 6000 ≙ 90 hex)
- Because you want to read the parameter value, words 3 and 4 in the parameter channel for requesting the parameter value are irrelevant. They should be assigned a value of 0, for example**.**

Parameter channel							
PKE, 1st word			IND, 2nd word		PWE1 - high, 3rd word	PWE2 - low, 4th word	
15 ... 12	11	10 ... 0	15 ... 8	7 ... 0	15 ... 0	15 ... 10	9 ... 0
AK		Parameter number	Subindex	Page index	Parameter value	Drive object	Index
0 1 1 0	0	1 1 1 0 0 1 1 0 0 0 1	0 0 0 0 0 0 1 0	1 0 0 1 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0 0 0 0 0	0 0 0 0 0 0 0 0 0 0

Table 5 PROFIdrive Parameter Channel Structure with Example Bit Values

5 Commissioning:

5.1 Commissioning guidelines:

This flowchart outlines the step-by-step commissioning procedure for a Siemens G120 inverter (VSD). It starts by defining application requirements and emphasizes resetting to factory settings as a baseline. Key steps include**:**

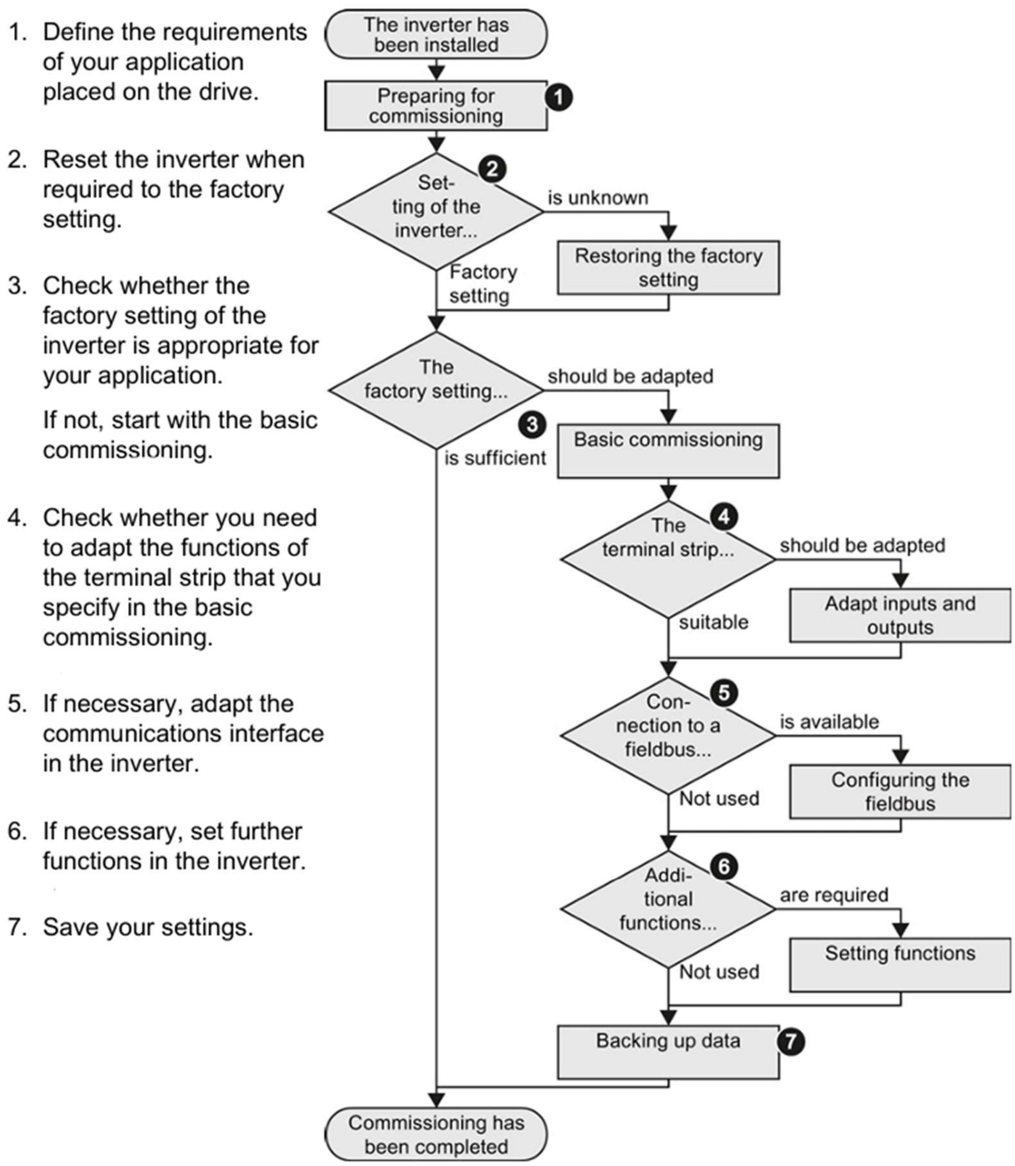


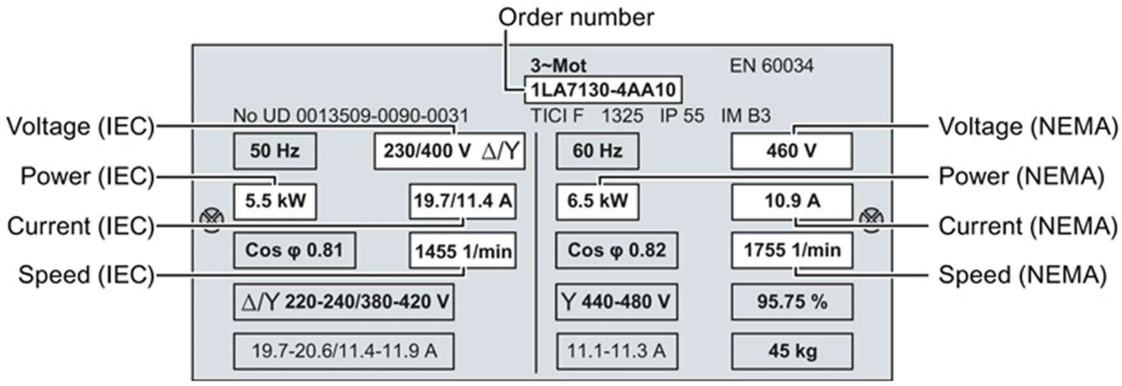
Figure 30 Flowchart for Inverter Commissioning and Configuration[12]

5.2 Preparing for commissioning:

5.2.1 Preparing for commissioning Motor

Which motor is connected to the inverter?

If you are using one of the STARTER commissioning tools or Startdrive and a SIEMENS motor, then you only need the order number of the motor. Otherwise, note down the data on the motor rating plate.



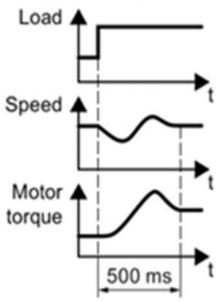
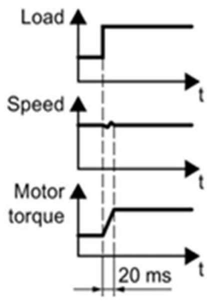
– In which region of the world will the motor be used?
  - Europe IEC: 50 Hz [kW] - North America NEMA: 60 Hz [hp] or 60 Hz [kW]
– How is the motor connected?
  - Pay attention to the connection of the motor (star connection [Y] or delta connection [Δ]). Note the appropriate motor data for connecting.
– What is the ambient temperature of the motor?
  - For commissioning, you will need the ambient temperature of the motor if it differs by more than 10 °C from the factory setting (20°C).[12]

5.3 Selecting the control mode :

Criteria for selecting either V/f control or vector control Multiple Control Modes:

– V/f Control (Voltage/Frequency): Simple, robust control suitable for most standard applications (pumps, fans, conveyors). Includes linear, quadratic, and programmable V/f characteristics.
– Sensorless Vector Control (SLVC): Provides higher dynamic performance and better torque control at low speeds without needing an encoder. Ideal for applications requiring better starting torque or speed stability.

Vector Control with Encoder (VC): Delivers the highest precision in speed and torque control across the entire speed range by using feedback from an encoder (resolver or sin/cos). Essential for demanding applications (hoists, extruders, centrifuges).
Positioning (Basic): Provides simple positioning functions without needing an external motion controller for certain applications.

	U/f control or FCC (flux current control)	Vector control without an encoder
Application examples	• Pumps, fans, and compressors with flow characteristic • Wet or dry blasting technology • Mills, mixers, kneaders, crushers, agitators • Horizontal conveyor technology (conveyor belts, roller conveyors, chain conveyors) • Basic spindles	• Pumps and compressors with displacement machines • Rotary furnaces • Extruder • Centrifuge
Motors that can be operated	The rated current of the motor must lie in the range of 13 % … 100 % of the rated current of the inverter.	
Properties of closed-loop motor control	• U/f and FCC are insensitive to inaccurate motor data settings, e.g. the motor temperature • U/f and FCC can be commissioned with just a few settings. • U/f and FCC respond to speed changes with a typical settling time of 100 ms … 200 ms • U/f and FCC respond to load surges with a typical settling time of 500 ms  • U/f and FCC are suitable for the following cases: – For motor power ratings < 45 kW – For accelerating times 0 → rated speed > 2 s – For applications with increasing load torque without load surges	• Vector control uses the Power Module, the motor and the mechanical system with a high degree of efficiency (95 % line voltage at the PM240 or PM240-2). • The vector control responds to speed changes with a typical settling time of < 100 ms. • The vector control responds to load surges with a typical settling time of 20 ms.  • We recommend vector control for motor power ratings > 45 kW • The vector control is required in the following cases: – For accelerating times 0 → rated speed < 2 s – For applications with fast and high load surges – For heavy duty starting using ≤ 90 % of the stall torque of the motor • Vector control typically achieves a torque accuracy of ± 5 % for 10 % … 100 % of the rated speed
Max. output frequency	240 Hz	200 Hz
Closed-loop torque control	Closed-loop torque control not possible	Closed-loop torque control without higher-level closed-loop speed control is possible

Starting/Stopping Control: Smooth ramp-up (acceleration) and ramp-down (deceleration) profiles to reduce mechanical stress and inrush current. Includes various ramp types (linear, S-curve).

6 Setting functions:

6.1 Overview of the inverter functions:

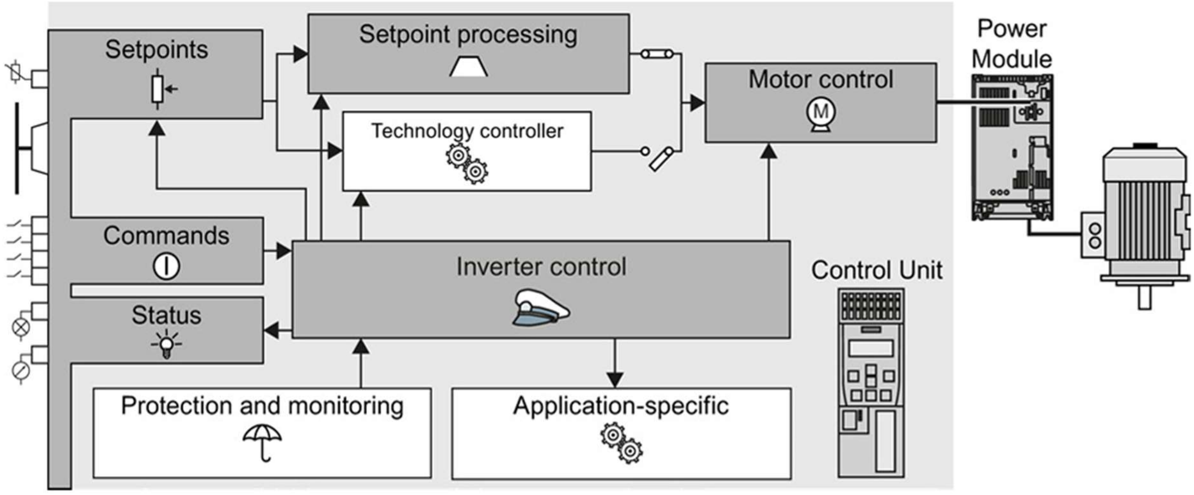


Figure 31 Overview of inverter functions[13]

6.1.1 Functions relevant to all applications:

The functions that you require in each application are shown in a dark color in the function overview above.

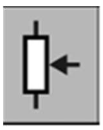
In the quick commissioning, the parameters of these functions are assigned an appropriate basic setting, so that in many cases the motor can be operated without having to assign any other parameters

Inverter control is responsible for all of the other inverter functions. Among other things, it defines how the inverter responds to commands from the higher-level control system.

The commands from the higher-level control are sent to the inverter via digital inputs or the fieldbus. The inverter returns its **status signals** to the outputs of the Control Unit or to the fieldbus.

Adapting the terminal strip

Configuring the fieldbus



You must define a setpoint, which defines the motor speed, for example.

Setpoint

The setpoint processing uses a ramp-function generator to prevent speed steps occurring and to limit the speed to a permissible maximum value.

Setpoint calculation

The motor closed-loop control ensures that the motor follows the speed setpoint. You can select either vector control or U/f control.

Motor control

6.1.2 Functions required in special applications only:

The functions whose parameters you only need to adapt when actually required are shown in white in the function overview above.

The protection functions prevent damage to the motor, inverter and driven load, e.g. using temperature monitoring or torque monitoring.

Protection and monitoring functions

unctions suitable for the application permit, for example, a higher-level closed-loop pressure or temperature control using the technology controller.

Further, the inverter provides solution options specifically for applications in the area of pumps, fans and climate control systems

Application-specific functions

7 Conclusion:

In this chapter, we have presented a comprehensive study of the asynchronous motor and its integration with a variable speed drive (VSD), laying the foundation for understanding modern motor control systems in industrial environments. We began with an overview of asynchronous motors, highlighting their robust construction, lack of sliding electrical contacts, and ease of manufacture. The chapter detailed their construction, including stator and rotor components, as well as the mechanical and electrical aspects that influence their performance.

We then explored the fundamental principle of operation based on electromagnetic induction, emphasizing the concept of slip and how torque is generated through rotor-stator interaction. Attention was given to the types of asynchronous motors—especially squirrel cage designs—and their advantages in various applications.

Subsequently, the chapter shifted focus toward variable speed drives, specifically the Siemens SINAMICS G120 series. The role of VSDs in adjusting motor speed and torque in accordance with process demands was illustrated, along with an explanation of the converter's architecture, including the Control Unit and Power Module. The operational principle of VSDs was clarified, where speed variation is achieved by modulating the frequency and voltage of the motor's supply.

We concluded by introducing the significance of PROFINET communication and PROFIdrive telegrams in enabling seamless real-time control and monitoring between PLCs and drives. The control word, status word, and parameter channel structures were presented as essential components of drive automation.

CHAPTER 3: CONTROL AND SUPERVISION

1. Introduction

The In this chapter, we present a comprehensive approach for the control and monitoring of a three-phase induction motor using Siemens automation technologies. The system comprises a SINAMICS G120 variable speed drive (VSD), an S7-1200 PLC, and a SIMATIC HMI screen. All components are connected and configured through PROFINET in the TIA Portal V16 environment. The aim is to achieve efficient, real-time motor control and diagnostics through a central control and visualization platform.

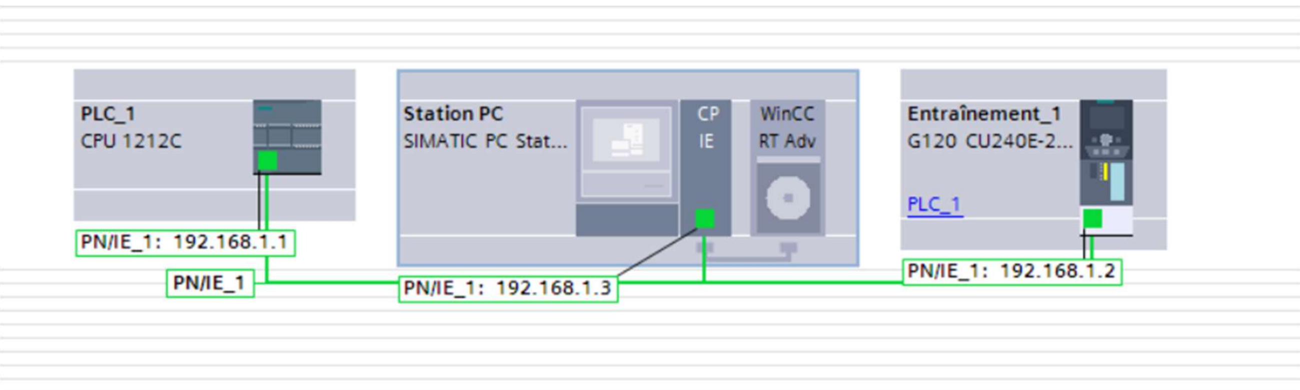
2. System Architecture Overview

2.1. Hardware Configuration & Network Setup :

Component Specifications:

Device	Model Example	Key Interfaces
PLC	S7-1215C DC/DC/DC	PROFINET Port (X1), 24V DC I/O
G120 CU	CU250S-2 PN (6SL3246-...)	PROFINET (X1 P1/P2), Digital I/O (X21)
Power Module	PM240-2 (e.g., 3kW)	3AC 400V Input, U/V/W Motor Output
HMI	WinCC KTP700 Basic	PROFINET, Touchscreen

Overview of Industrial Automation Devices and Their Key Interfaces



Network Configuration Diagram of a SIMATIC S7-1200 CPU, PC Station, and SINAMICS G120 Drive.

3. Wiring & Topology :

- PROFINET: Daisy-chain topology:
  PLC (X1) → G120 (X1 P1) → G120 (X1 P2) → HMI
  - Use shielded RJ45 cables (CAT5e+).
- Motor Connection :
  - G120 U1/V1/W1 → Motor terminals (PE grounded).
- STO Safety Circuit (Optional):
  - Wire emergency stop to G120 terminals (X21.3/4 for STO A/B).

4. TIA Portal Project Setup:

4.1.1. Device Integration

Add Devices:

- PLC: Select exact CPU model (e.g., 6ES7215-1AG40-0XB0).
- G120: Add SINAMICS G120 CU250S-2 PN under "Drives."
- HMI: Add KTP700 Basic PN (Resolution: 800x480).

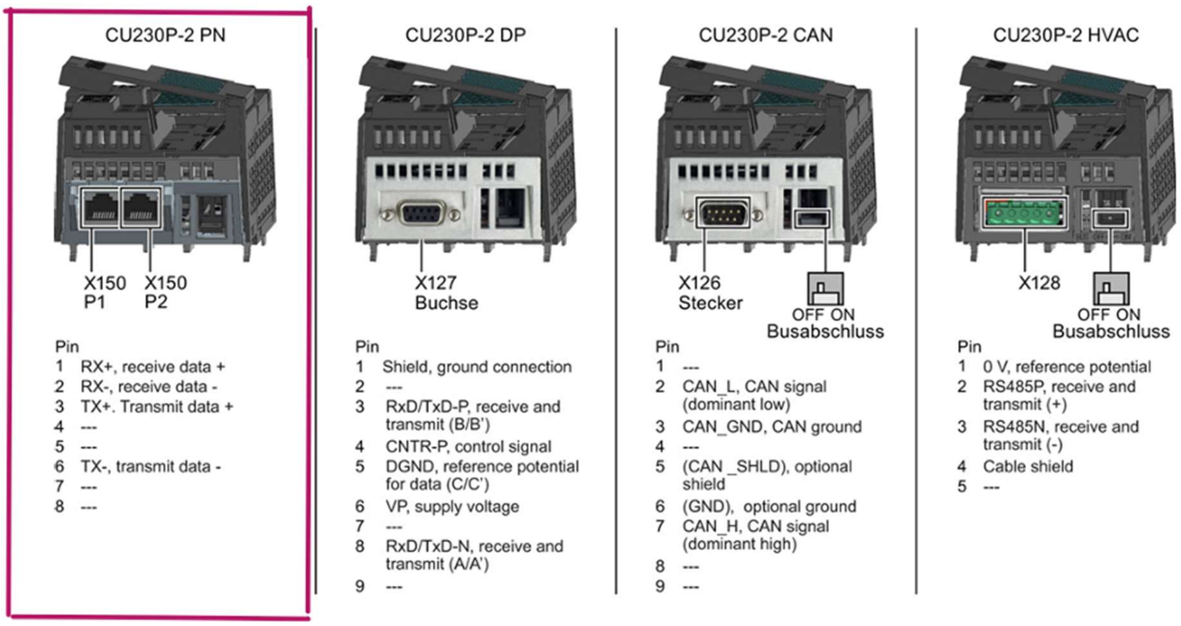


Figure 32 Interfaces at the lower side of the CU230P-2 Control Unit

5. PROFINET Configuration :

2.1. In Network View:

-Assign IPs: PLC (192.168.0.1), G120 (192.168.0.2), HMI (192.168.0.3)

-Set Device Name for G120 (e.g., drive_g120).

-Configure Real-Time (RT) class: Cycle time = 4 ms.

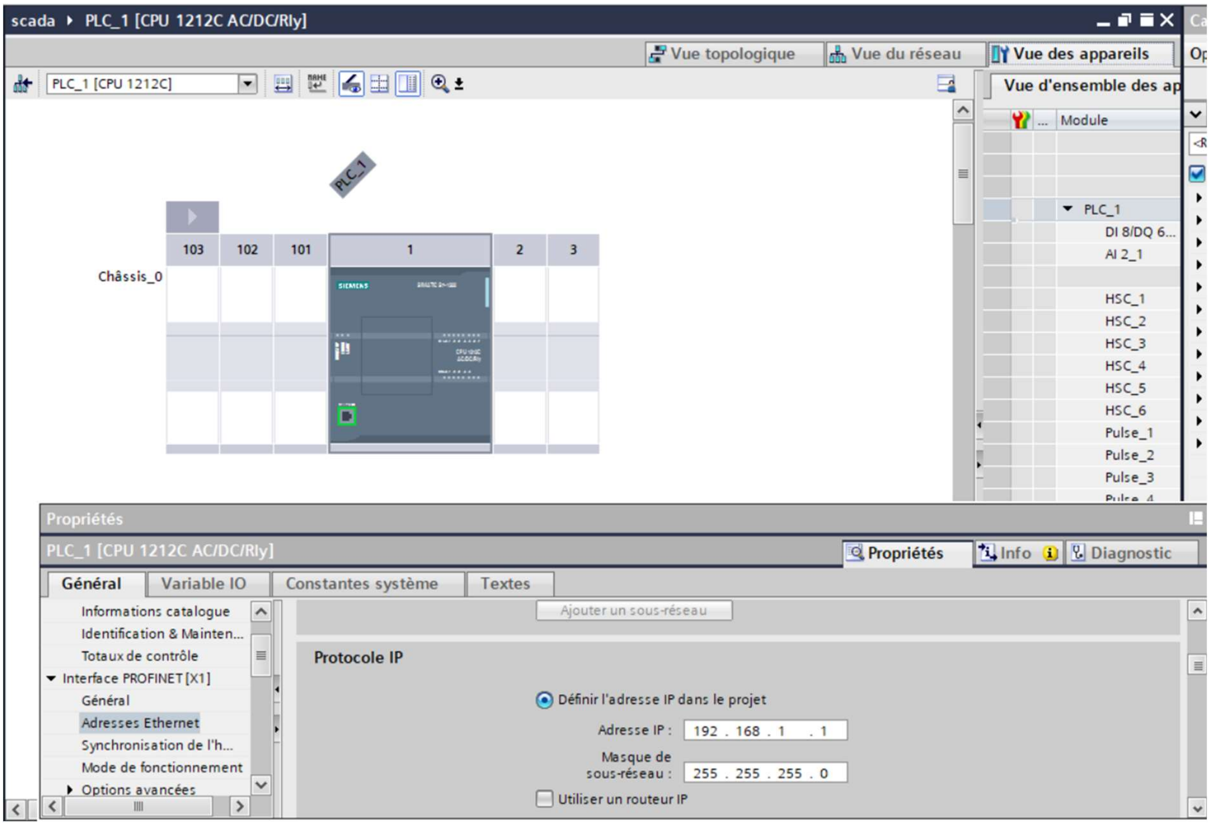


Figure 33 Portal Hardware Configuration for a SIMATIC S7-1200 PLC with PROFINETInterface Settings

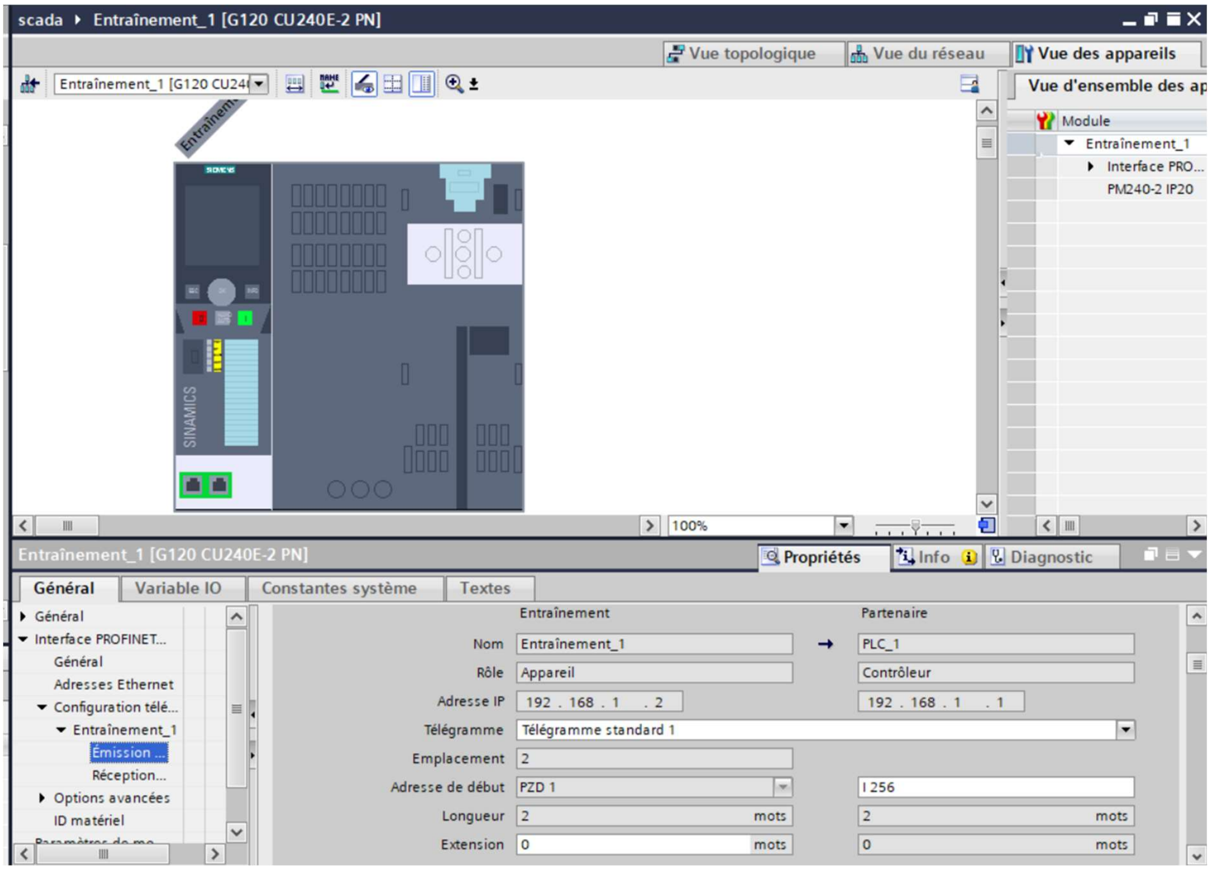


Figure 34 Siemens TIA Portal Hardware Configuration for a SINAMICS G120 CU240E-2 PLC with PROFINETInterface Settings

6 G120 Commissioning :

PARAMETER	PATH IN TIA PORTAL	VALUE	DESCRIPTION
MOTOR RATED POWER	Drive > Configuration > Motor	Δ : 0.37KW γ : 0.37KW γ : 0.43KW	From motor nameplate
MOTOR RATED CURRENT	Drive > Configuration > Motor	Δ : 1.84A γ : 1.84A γ : 0.98A	From motor nameplate
MOTOR RATED VOLTAGE	Drive > Configuration > Motor	Δ : 230V γ : 400V γ : 460V	From motor nameplate

MOTOR SPEED	Drive > Configuration > Motor	Δ : 2755 tr /min γ : 2755 tr /min γ : 3355 tr /min	From motor nameplate
CONTROL MODE	Drive > Configuration > Setpoints	SLVC (Sensorless VC)	For torque-sensitive apps
PROFINET TELEGRAM	Drive > Communication > Telegram	Telegram 1 (PZD-2/2)	4-byte I/O (2 words in/out)
ACCELERATION RAMP	Drive > Function Modules > Setpoints	P1120 = 10.0 s	0→50 Hz in 10 sec
STO ENABLE	Drive > Safety Integrated	P9601 = 1	Safe Torque Off via terminals

Key Parameters for SINAMICS G120 Commissioning

8 PLC Programming (S7-1200) :

7.1 I/O Mapping for G120:

G120 Data	**PLC Address**	**Data Type**	**Scaling**
Control Word (STW)	QB256	WORD	Bitwise control (see table below)
Speed Setpoint	PQW258	INT	0–16384 = 0–50 Hz
Status Word (ZSW)	IB256	WORD	Bitwise status
Actual Speed	PIW260	INT	0–16384 = 0–50 Hz

I/O Mapping for SINAMICS G120 Drive Control and Status

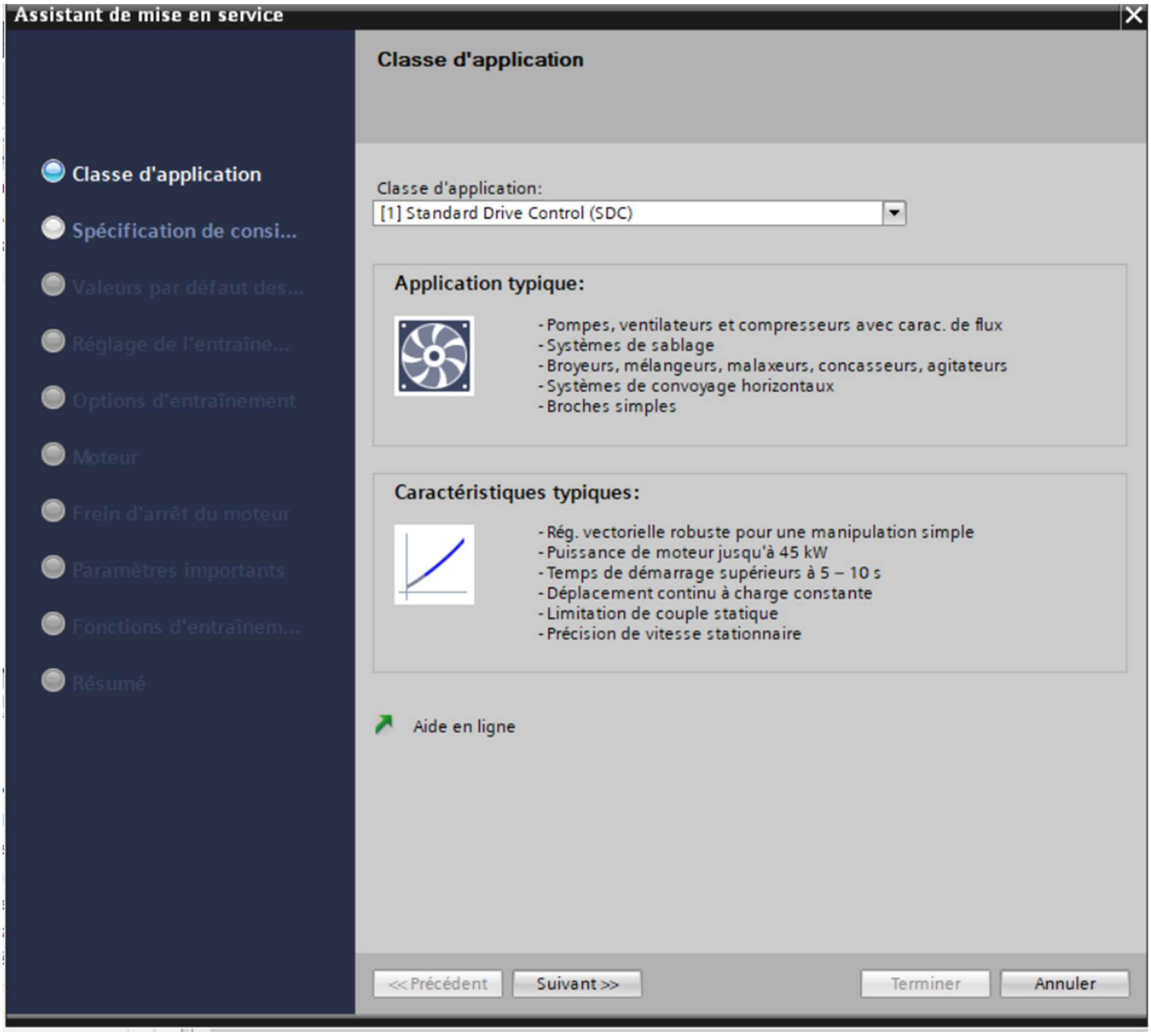


Figure 35 SINAMICS G120 Commissioning Assistant: Application Class Selection (Standard Drive Control¬¬¬¬¬)

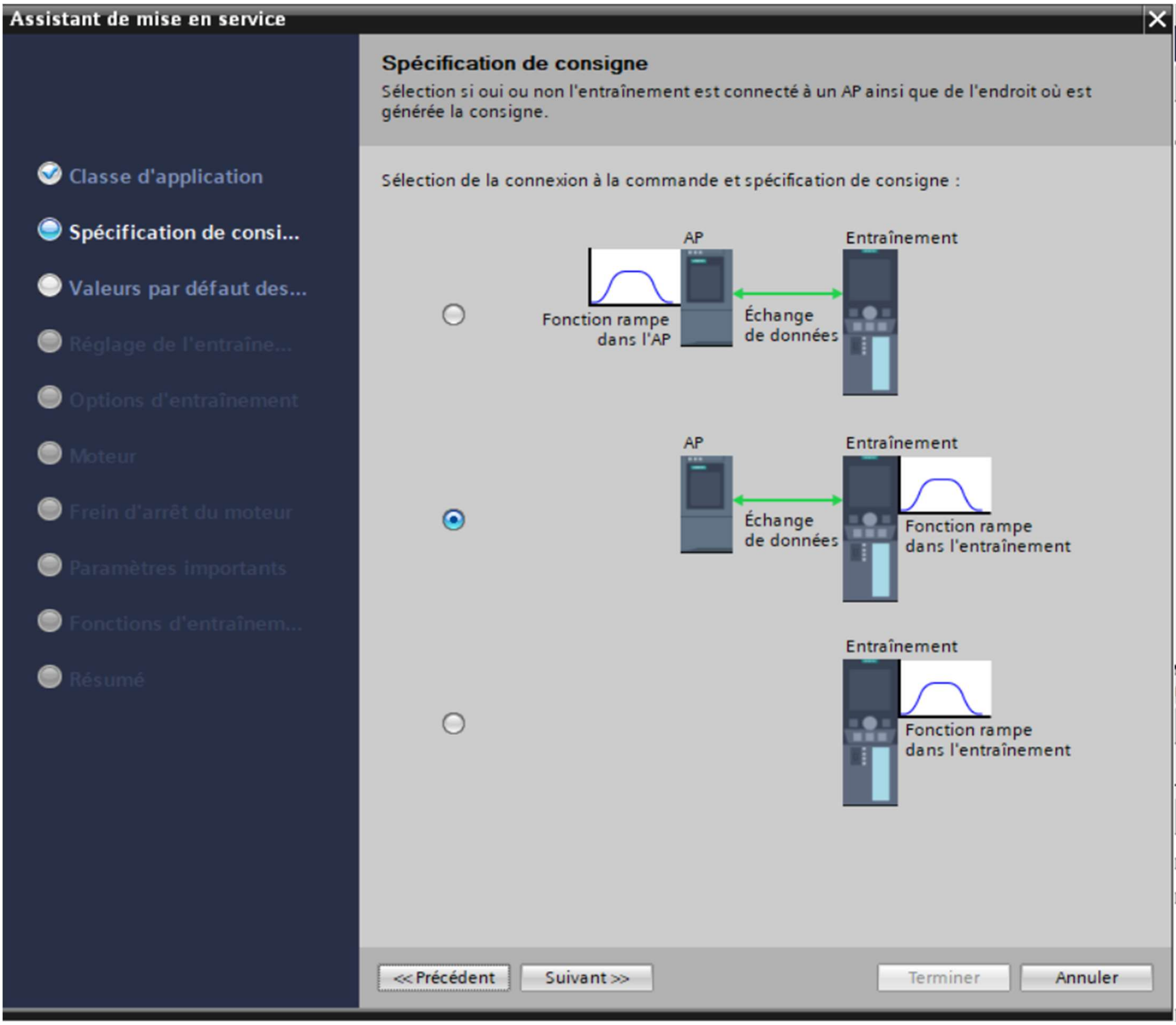


Figure 36 SINAMICS G120 Commissioning Assistant: Setpoint Specification and Ramp Function Location

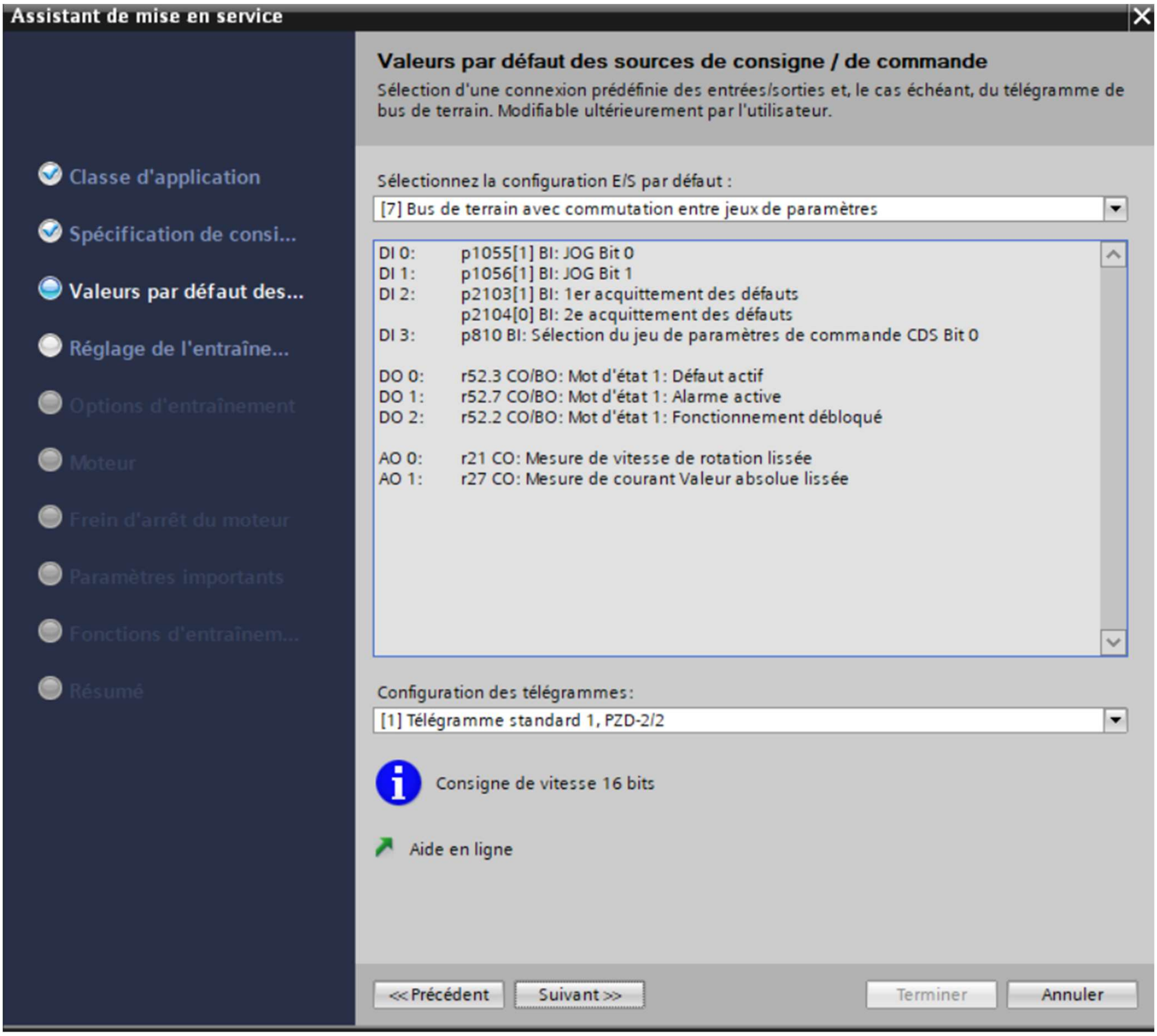


Figure 37 SINAMICS G120 Commissioning Assistant: Default I/O and Telegram Configuration for Drive Control

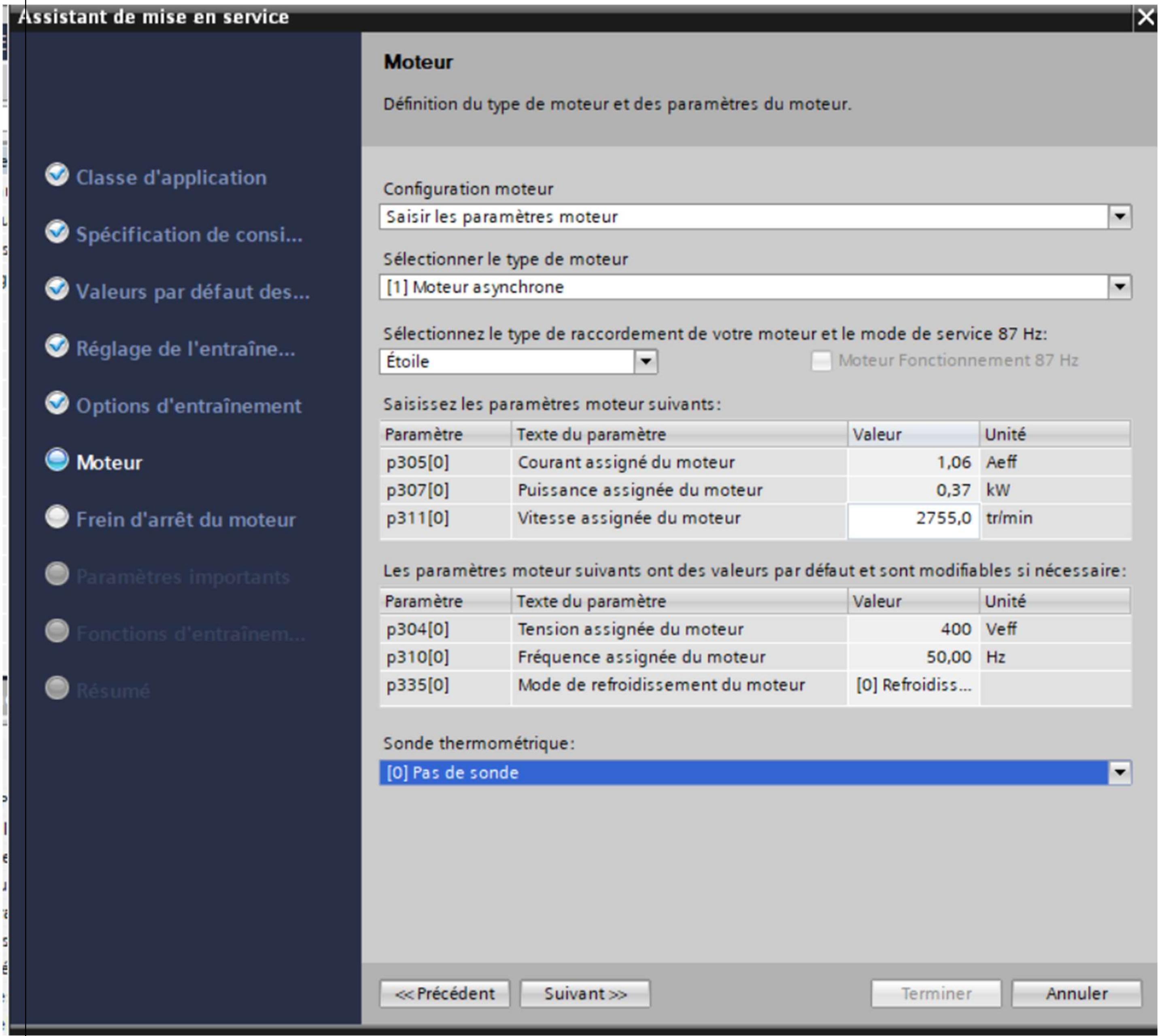


Figure 38 SINAMICS G120 Commissioning Assistant: Motor Parameter Configuration (Asynchronous Motor)

Bit	Function	Description
0	**ON/OFF1**	**1=Start, 0=Coast stop**
1	**OFF2**	**0=Emergency stop**
2	**OFF3**	**0=Fast stop**
3	**Enable Operation**	**Always 1**
7	**Fault Reset**	**Rising edge resets faults**
8/9	**Reserved**	**Currently not used in Telegram 20; reserved for future or specialized use.**
10	**Control via PLC**	0 = No control via PLC: Inverter ignores fieldbus commands. 1 = Control via PLC: Inverter accepts commands from the PLC via PROFINET/fieldbus. Signal Mapping: p0854[0] = r2090.10
11	**Direction Reversal**	1 = Reverse: Inverts the motor direction based on setpoint sign. Signal Mapping: p1131[0] = r2090.11
12	**Not used**	**This bit has no defined function in Telegram 20.**
13	**Motorized Potentiometer (MOP Up)**	1 = MOP up: Increases the setpoint stored in the motorized potentiometer. Signal Mapping: p1035[0] = r2090.13
14	**Motorized Potentiometer (MOP Down)**	• 1 = MOP down: Decreases the setpoint stored in the motorized potentiometer. • Signal Mapping: p1036[0] = r2090.14

Bit	Function	Description
15	**CDS (Command Data Set) Selection**	• Reserved: Used to switch between different command datasets (presets) if configured. • Signal Mapping: p0810 = r2090.15

9 Control Word (STW) Bit Assignment:

Col1	Bit 0	Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8	Bit 9	Bit 10	Bit 11	Bit 12	Bit 13	Bit 14	Bit 15
STOP	0	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0
Forward run	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0
Reverse run	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0
Fault acknowledgment	0	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0
Control Local/Remote	1	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0
HEX																
STOP	E				7			4				0				
Forward run	F				7			4				0				
Reverse run	F				7			C				0				
Fault acknowledgment	E				F			C/4				0				
Control Local/Remote	E				F			8/0				0				

Table 6 PROFIdrive Control Word Bit Assignments and Hexadecimal Representation for Drive Commands

9 PLC Programming blocks « OB » :

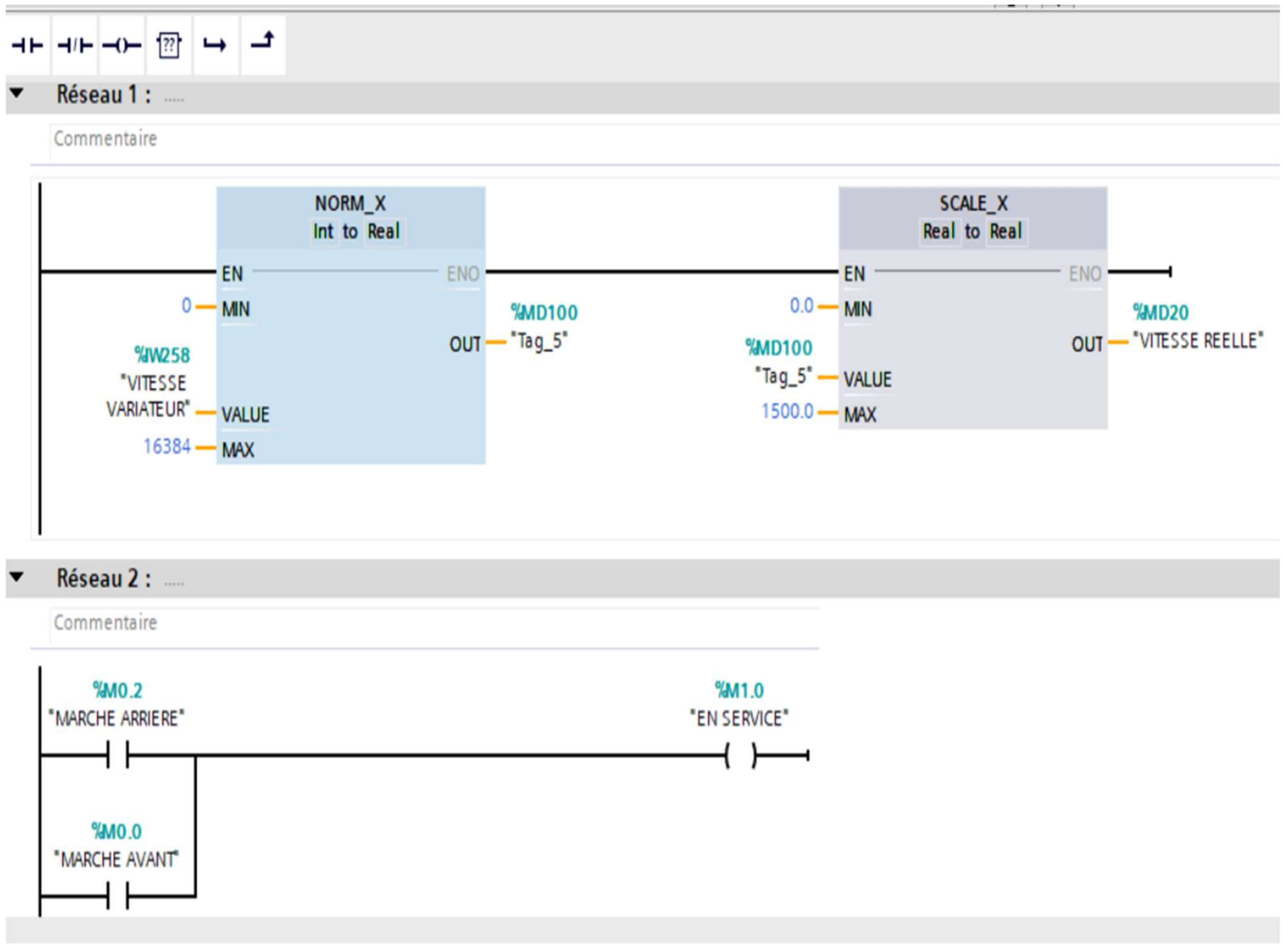
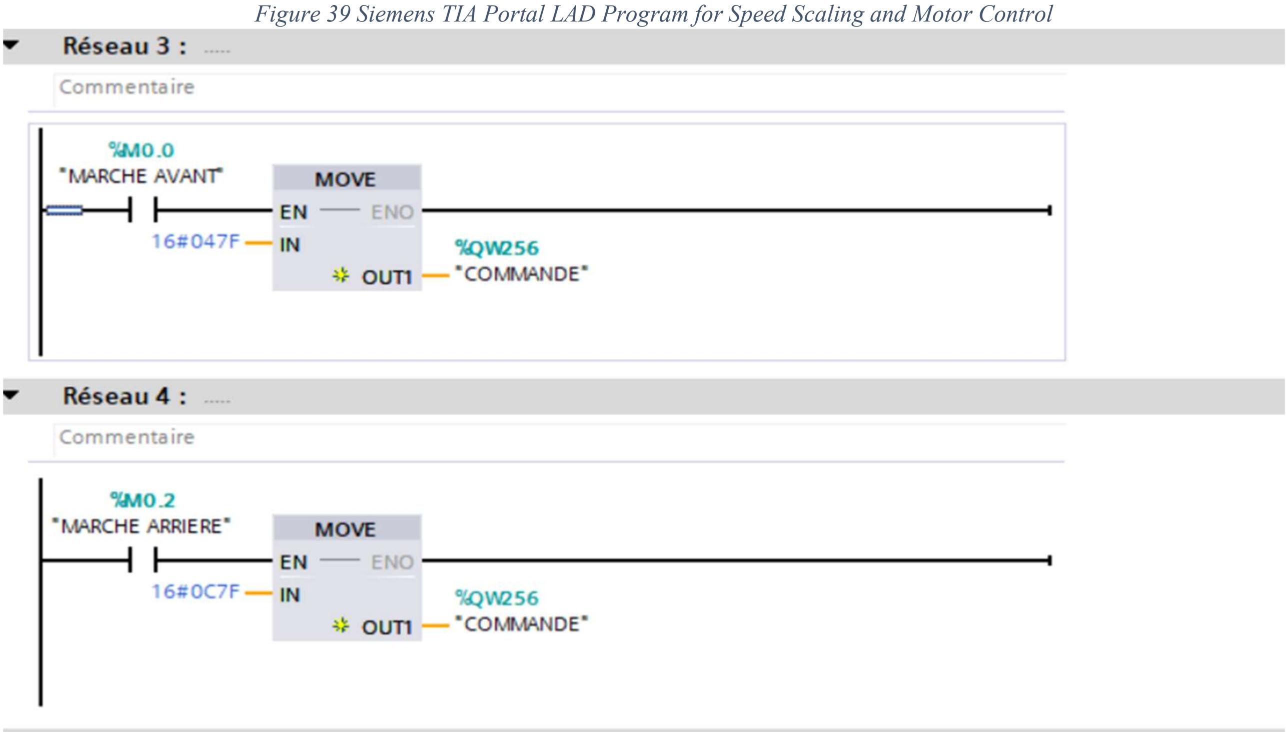


Figure 39 Siemens TIA Portal LAD Program for Speed Scaling and Motor Control



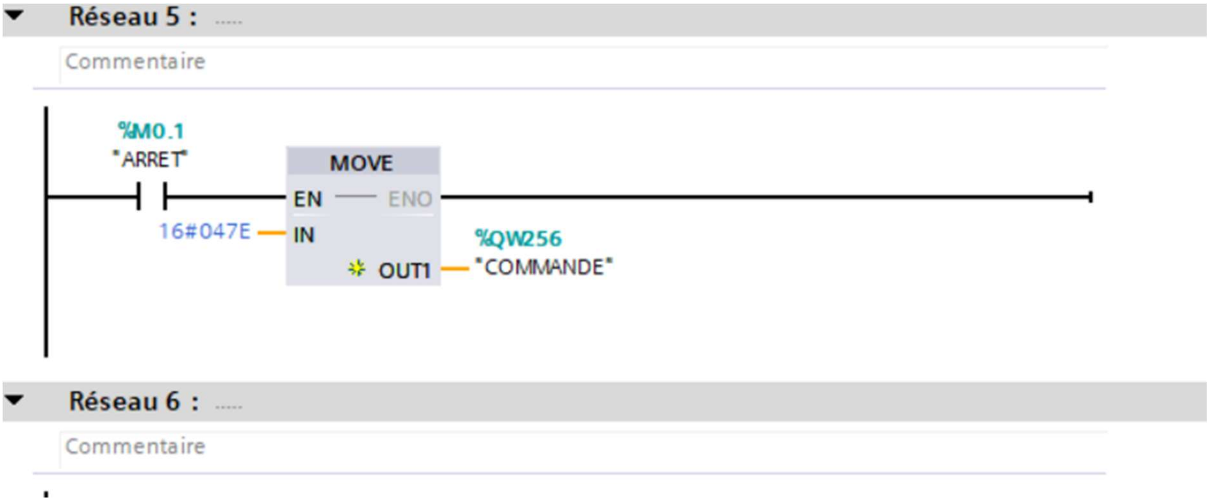


Figure 40 Siemens TIA Portal LAD Program for Motor Forward/Reverse Control using MOVE Instructions

Figure 41 Siemens TIA Portal LAD Program for Motor Stop and SCADA Setpoint Control

9.WinCC HMI Development :

9.1 Screen Design

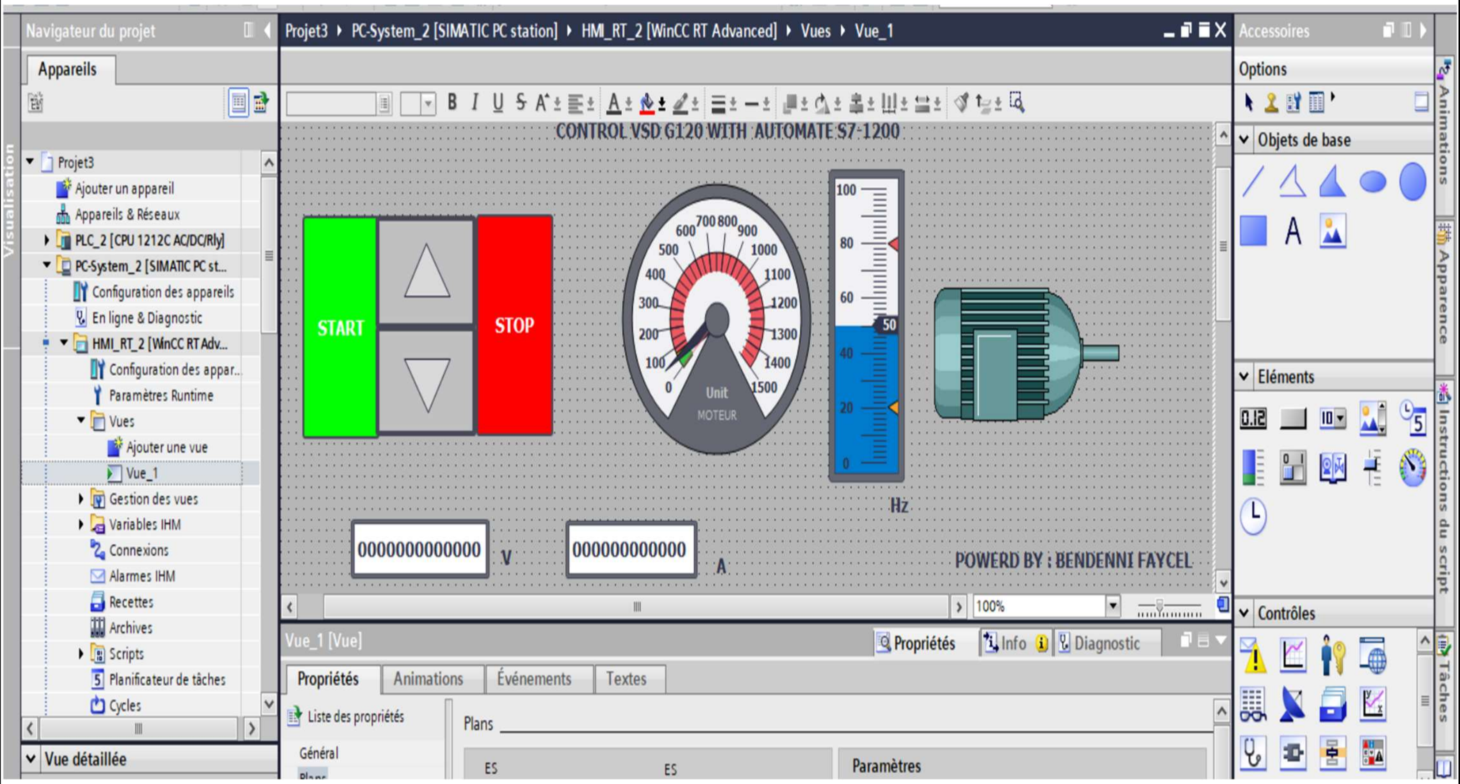


Figure 42 Siemens WinCC RT Advanced HMI for VSD G120 Control with SIMATIC S7-1200 PLC

- **Main Screen:**
  -
  - **Buttons:**
    - Start (Green): Sets Start_Button = 1.
    - Stop (Red): Sets Start_Button = 0.
  - **Data Visualization:**
    - I/O Field: Linked to Speed_Setpoint (min=0.0, max=50.0).
    - Bar Graph: Shows Actual_Speed (0–1500 RPM).
    - Alarm Indicator: Flashing when Drive_Fault = 1.
- **Diagnostics Screen:**
  - Trend view for Actual_Speed and motor current (using WinCC historization).

10. PROFINET Communication Validation

10.1 Diagnostic Tools

- TIA Portal Online Diagnostics:

  - Monitor PROFINET cycle time (< 4 ms).
  - Check device status (green = OK, red = fault).
- G120 Diagnostics:
- Parameter r0947: Last fault code (e.g., F07900 = PROFINET comm loss).
  - Trace actual speed (r0021) vs. setpoint (r0062).

11. Conclusion:

This chapter demonstrated how the TIA Portal V16 environment facilitates the integration of a three-phase motor control system using Siemens automation hardware. The project covered configuration of the S7-1200 PLC, SINAMICS G120 VSD, and an HMI interface, all networked through PROFINET. This practical application showcases how industrial automation systems can be designed and implemented with modern tools to ensure efficient, safe, and user-friendly control of electrical machines.

General Conclusion

This graduation thesis has presented the complete development and implementation of a sensorless control system for a three-phase asynchronous motor using Siemens automation technologies, including the S7-1200 PLC, SINAMICS G120 variable speed drive (VSD), and a WinCC HMI panel, all integrated through the TIA Portal environment and communicating via PROFINET.

The study began with a detailed theoretical overview of asynchronous motor operation, sensorless control techniques, and variable speed drive principles. This foundation enabled the design of a robust and cost-effective motor control system that eliminates the need for mechanical sensors while maintaining precise control over motor speed and direction.

The integration of the Siemens S7-1200 PLC and SINAMICS G120 VSD, configured through PROFINET, allowed for flexible and reliable communication between control devices. The use of standard telegrams and control words enabled accurate command execution and status monitoring in real-time. Additionally, the development of a user-friendly HMI interface provided intuitive supervision and parameter adjustment, enhancing operational safety and usability.

The practical implementation demonstrated in this work validates the performance, scalability, and industrial relevance of the proposed architecture. The system achieved the intended goals of:

- Cost reduction through sensorless control,
- Enhanced system reliability and flexibility,
- Real-time monitoring and diagnostics via HMI,
- Smooth motor operation and dynamic speed control through precise parameter tuning.

This project not only showcases the capabilities of modern industrial automation tools but also reflects the ongoing transition toward smart, interconnected control systems aligned with Industry 4.0 objectives.

In conclusion, this work contributes to the advancement of efficient and intelligent motor control systems, and opens pathways for future enhancements such as remote diagnostics, energy optimization, and integration with IoT platforms.

Summary:

This project aims to design and implement a sensorless automatic control system for a three-phase motor using an S7-1200 programmable logic controller (PLC), a SINAMICS G120 variable speed drive (VSD), and an HMI interface, all programmed through TIA Portal and communicating via the PROFINET protocol. The system enables precise control of motor speed and direction without the need for a mechanical sensor, reducing costs and increasing reliability. The system was successfully tested in practice and has potential for future development.

Keywords:

VSD (Variable Speed Drive):
A device that controls the speed and torque of an electric motor by adjusting the frequency and voltage.
SINAMICS G120:
A Siemens variable speed drive used to control three-phase motors with modular design and PROFINET support.
PLC S7-1200:
A compact Siemens controller used to automate machines and processes in industrial systems.
HMI (Human-Machine Interface):
A screen that allows operators to monitor and control machines through a graphical interface.
TIA Portal:
Siemens software that integrates programming of PLCs, HMIs, and drives in one engineering environment

ملخص :

هذا المشروع يهدف إلى تصميم وتنفيذ نظام تحكم أوتوماتيكي بدون مستشعر لمحرك ثلاثي الطور باستخدام وحدة تحكم منطقية قابلة للبرمجة **(PLC)** من نوع S7-1200ومحول سرعة متغيرة **SINAMICS G120**، وواجهة **HMI**، جميعها مبرمجة عبر **TIA Portal** وتتواصل باستخدام بروتوكول **PROFINET**. يتيح هذا النظام تحكمًا دقيقًا في سرعة واتجاه المحرك دون الحاجة لمستشعر ميكانيكي، مما يقلل التكاليف ويزيد من الموثوقية. تمت تجربة النظام بنجاح عمليًا مع إمكانية تطويره مستقبلاً

الكلمات المفتاحية :

VSD جهاز التحكم في السرعة المتغيرة :
جهاز يُستخدم للتحكم في سرعة وعزم دوران المحرك الكهربائي من خلال تعديل التردد والجهد الكهربائي.
SINAMICS G120 :
جهاز تحكم في السرعة من شركة سيمنس يُستخدم للتحكم في محركات التيار الثلاثي، يتميز بتصميمه المُعياري ودعمه لبروتوكول PROFINET.
:PLC S7-1200
وحدة تحكم مبرمجة مدمجة من سيمنس تُستخدم لأتمتة الآلات والعمليات في الأنظمة الصناعية.
HMI واجهة الإنسان والآلة:
شاشة تفاعلية تتيح للمشغلين مراقبة الأجهزة والتحكم فيها من خلال واجهة رسومية.
:TIA Portal:
برنامج من شركة سيمنس يُستخدم لتكوين وبرمجة وحدات التحكمPLC ، وشاشاتHMI ، وأجهزة التحكم في السرعة، ضمن بيئة هندسية موحدة.
PROFINET
هو بروتوكول صناعي من شركة سيمنس يُستخدم لتبادل البيانات بسرعة وفعالية بين أجهزة الأتمتة مثل PLC و HMIوVSD، ويعتمد على شبكة الإيثرنت.

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