# Automatic testing of drive fieldbus using OPC interface

Submitted in partial fulfillment of the requirements

for the degree of

Master of Technology

in

Electrical Engineering

(Power Electronics, Machine Drives)


Submitted By

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(18MEEP09)


NIRMA UNIVERSITY

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(POWER ELECTRONICS, MACHINE & DRIVES)

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# Certificate

This is to certify that the Major project entitled **Automatic testing of drive field-bus using OPC interface** submitted by **Patel Poojaben Yogeshkumar (Roll No: 18MEEP09)**, towards the partial fulfillment of the requirements for the award of degree of Master of Technology in Electrical Engineering (Power Electronics, Machine & Drives) of Nirma University, Ahmedabad, is the record of work carried out by her under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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# Statement of Originality

I, **Poojaben Y. Patel**, Roll. No. **18MEEP09**, give undertaking that the Research Seminar entitled "**Automatic testing of drive fieldbus using OPC interface**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Electrical Engineering (Power Electronics, Machine & Drives)** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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**- Poojaben Y. Patel**
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# Abstract

This project investigates automatic testing of medium voltage drive controller using OPC server interface. OPC is a standard software interface that allows program to communicate with industrial hardware devices. The control board of medium voltage drive consists of digital input signals, which are used to control the drive. PLC that serve as an overriding systems. In Visual Studio, it is possible to access the PLC symbol variables using OPC server interface and control the drive for application software functionality testing. PLC symbol variables are accessed by Automatic Testing Framework through OPC interface. This project describes the hardware setup, automatic testing of control software using OPC Server Interface. Test results proves the advantage of using OPC interface over conventional way of testing.

# Abbreviations

| | |
|---|---|
| **MVD** | MEDIUM VOLTAGE DRIVE. |
| **OPC** | OPEN PLATFORM COMMUNICATIONS.. |
| **FB** | FIELD BUS. |
| **CAN** | CONTROLLER AREA NETWORK. |
| **AI** | ANALOG INPUT. |
| **AO** | ANALOG OUTPUT. |
| **DI** | DIGITAL INPUT. |
| **DO** | DIGITAL OUTPUT. |
| **ATF** | AUTOMATIC TESTING FRAMEWORK. |
| **EMU** | EMULATOR. |
| **IGBT** | INSULATED GATE BIPOLAR TRANSISTOR. |

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# Contents

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# Chapter 1

# Introduction

## 1.1 Electric drive system

**Definition: Electric drive is defined as a form of machine equipment designs to convert electric energy in to mechanical energy and provides the electrical or electronics control of the system. This system use electrical power to drive system [2].**

## 1.2 Block diagram of electric drive system

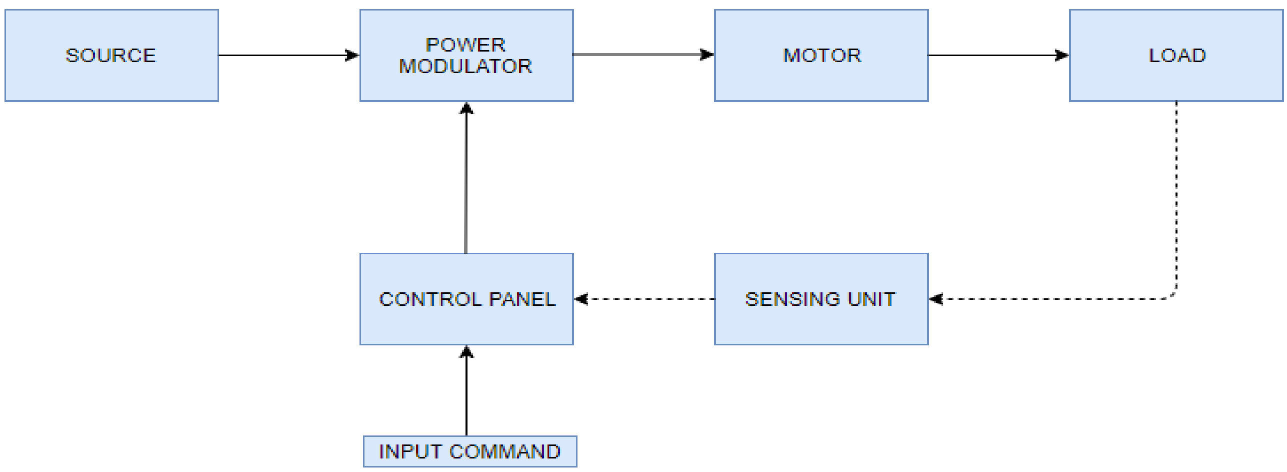


Figure 1.1: Block diagram of electric drive system.

### 1.2.1 Power modulator

Power modulators are the device which alter the nature of frequency as well as changes the intensity of power to control electrical devices. Roughly, power modulator can be classified into three types:

1. Converters
2. Variable impedance circuit
3. Switching circuits

In the electric drive system, these are the different type of converters and the power modulators can be any one of the following: Controlled rectifiers(ac to dc converters), Inverters (dc to ac converters), AC voltage controllers (ac to ac converters), DC choppers (dc to dc converters), Cycloconverters(frequency conversion). Since the electrical sources are normally uncontrollable, it is there- fore necessary to be able to control the flow of power to the motor. This is achieved using power processor or power modulator. With controllable sources, the motor can be reversed, brake or can be operated with variable speed. Conventional methods used, for example, variable impedance or relays, to shape the voltage or current that is supplied to the motor. These methods however are inflexible and inefficient. Modern electric drives normally used power electronics converters to shape the desired voltage or current supplied to the motor [3].

### 1.2.2 Motor

They convert energy from electrical to mechanical therefore can be regarded as energy converters. In braking mode, the flow of power is reversed. Depending upon the type of power converters used, it is also possible for the power converters used, it is also possible for the power to be the sources rather than dissipated as heat. There are several types of motors used in electric drives choice of type used depends on applications, cost, environmental factors and also the type of sources available.

### 1.2.3 Control unit

Choice of control unit depends upon the types of power modulator that is used. There are of many types like when semiconductor converters are used than the control unit of firing circuit.

## 1.3 Four Quadrant Operation of Drives

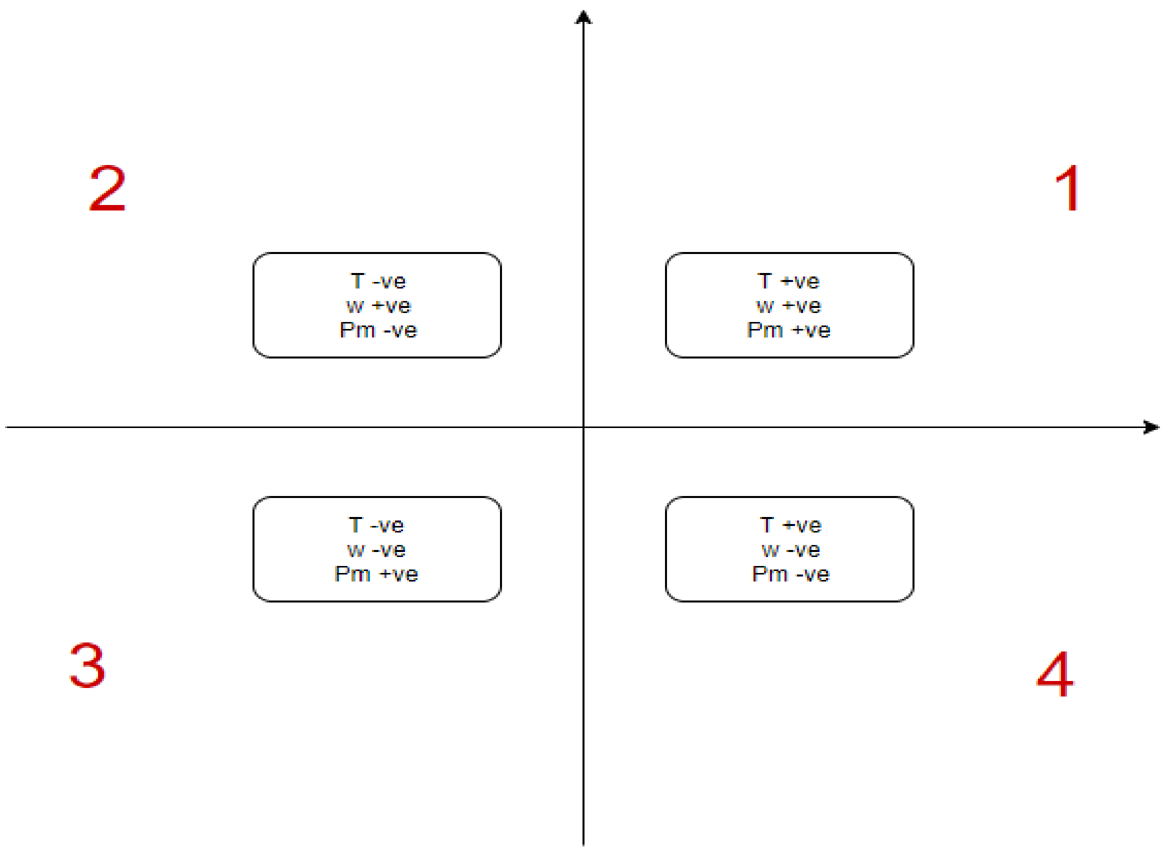


Figure 1.2: Four Quadrant Operation.

Quadrant Operation: The speed Vs. torque plot of a drive is a four quadrant operation where quadrant is identified based on the rotation of motor and direction of torque. Single quadrant drive operates in only one region either in quadrant I or quadrant III. Quadrant I is forward motoring. Here the direction of rotation and torque generated are in assistance with each other. The machine converts electrical energy into mechanical energy and support motion. Quadrant III is reverse motoring. It is achieved by reversing the direction of rotating magnetic field. The motor works in reverse direction.

Four Quadrant operation: Torque in machine always act to make the rotor to run towards the synchronous speed. If for any reason the synchronous speed of machine is suddenly reduced, a negative torque is developed in machine. So the motor acts like a generator in this case and converts the mechanical power from motor shaft into electrical power. This is returned to the main ac supply of drive. Braking happens in quadrants II an IV [4].

## 1.4 Classification of Induction Motor Drives [1]

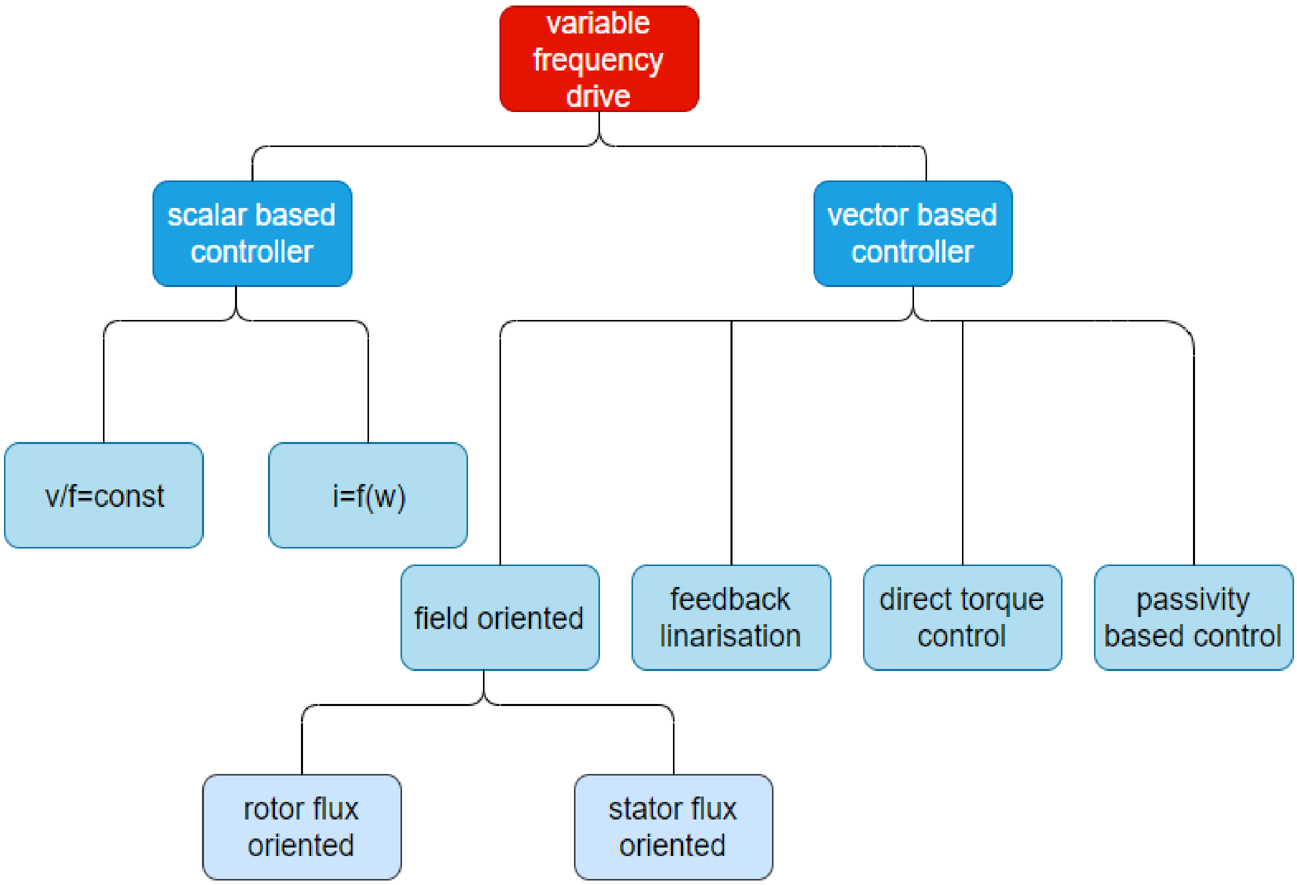


Figure 1.3: Classification Of Induction Motors Drives.

## 1.5 Speed Control of Induction Motors

**AC Machines: The speed of AC motors generally depends on the frequency of the supply voltage and the number of magnetic poles per phase in the stator. However for speed control in induction motors the supply voltage must vary in unison with the frequency. This requires a Volts/Hertz controller.**

**Torque Control: In torque control direct control of motor torques is done rather than controlling the speed. In simple machines this is achieved by controlling the motor current. The motor current is proportional to the torque. So the speed control loop is can be completely omitted in torque control making it a faster and more accurate control technique.**

**Current Control: Usually adopted method is to control voltage of the motor. But in many applications like of high inductive load the motor current may lag the supply voltage by a considerable angle. So in these cases it is often desirable to control current directly rather than voltage to obtain a precise and faster control current and in turn the torque of machine. The difference between the actual and reference currents is used in a high gain feedback loop to provide the necessary current regulation.**

**Cycloconverter: It converts AC supply with fixed frequency directly to a variable frequency AC without the intermediate DC link stage. The system is very complex. It works by sampling the voltage of each phase of the AC supply and switching the switches to synthesizing the desired output waveform. In these switching the load is switched to ac supply for the duration of the sampling period. The output waveform is severely distorted. The induction motor is incapable to cope with very high harmonic content in its supply. This limits the maximum frequency for which the cycloconverter can be used for induction motor. It is only suitable for very low frequencies, up to 30% of the input frequency.**

**Volts-per-Hertz Control: The area within each pulse is the power delivered to the motor in volt-microseconds. The speed of an induction motor can be controlled by varying supply frequency. Supply voltage is proportional to the product of frequency (f) and air gap flux (if stator drop is neglected). If we reduce supply frequency and keep terminal voltage fixed, air gap flux increases. This results in saturation. The magnetizing current will increase and distort the line current, volt- age and increase core copper losses. So both Supply voltage and supply frequency are varied simultaneously to keep their ratio constant. It is performed below rated speeds (beyond rated speed it may cause decrease in flux affect torque capability of motor).**

**Vector Control: Flux or Field Oriented Control (FOC) : In a brushed DC motor, the magnetizing current and Torque producing currents are fed to two different windings. The magnetizing current is fed to the stator or field winding and the torque producing current is fed to the rotor winding. This allows independent control of both the stator and the rotor fields. This concept can be employed to induction with help of some transformations. The stator current of induction motor can be expressed as a vector sum of two current vectors. First one is the inductive magnetizing current vector which is phase delayed and generates the air gap flux. The second one is in phase, torque producing current. If we want to change the torque of motor we need to change the in phase current, but in this process the air gap flux should remain constant i.e. the magnetizing current should not change.**

**Thus these two currents should be 90 degrees phase apart to achieve their independent control. Field oriented control is a method of independently controlling the magnitudes and phases of stator current vectors to adapt according to change in instantaneous speed or torque demands of motor. It allows changing the parameters over which direct control is not possible by changing the parameters which can be measured and controlled [5].**

## 1.6 Direct Torque Control

DTC is a revolutionary technology developed by ABB. In this control field orientation is achieved without the help of feedback. DTC uses advanced motor theory to calculate the motor torque directly and without using modulation. The controlling variables are motor magnetizing flux and motor torque.

In DTC there is no need of modulator and tachometer or position encoder to get the feedback speed or position of shaft of motor [6].

DTC uses the fastest digital signal processing hardware and advanced mathematical understanding of how a motor works.

The drive with DTC gives torque response that is around 10 times faster than any AC or DC drive. The dynamic speed accuracy of DTC drives is 8-9 times better than any open loop AC drives and is comparable to a DC drive with feedback.

## 1.7 Application of medium voltage drive

The purpose MV drives operating at higher supply voltages is to get lower losses, better drive efficiency and lower system cost. The capability of Medium-voltage(MV) ac drives for producing power output much more than their smaller, low-voltage(LV) drives. Application wise used in power stations, metal processing plants motors, controlling pumps, many other applications like conveyors and mixers(variable and constant torque).[7].

MV drives also provides flexibility in choosing the size. Other factors also affect the choice for specific applications like harmonic content. Every industry has MV drives of different rating like for motor drives it various from 600V to 15kV. MV drive has inputs of 2.3 and 4.16kV used in America, while commonly used drive prefers 3.3 to 6.6 kV.

**The biggest advantage of MV as compared to LV drives is that the amount of lower current flow for a given power output is less as compared to LV drives, observe from the basic relationship equation that power equals voltage x current (P=VI). Because of insulation requirements MV cable construction is a more costly, but the content of copper present is less. This will result in lower potential drops and smaller cable size.**

**MV-VFDs serve as huge power source nearer to the distribution voltage most of the time they are enforce to add harmonics reduction in their designs**

Figure 1.4: Induction Motor Drive.

**Obliviously low harmonic distortion draws more attention, around 20 percent of LV drives specifically integrates harmonic mitigation, whereas almost all MV drives engaged it.**

**The design of MV drive depends on a multi-pulse transformer .For minimizing line-current harmonics the input transformer and multi-pulse rectifier**

section of the drive worked together which generates cancelling waveform to reduce its effect.

Cutting down the harmonic is part of the basic design. Phase-shifted transformers are used to provide shape to the output wave forms and input isolation. Cutting down of Harmonic then also depend on configuration of the rectifier circuits and windings. Moreover, for high-performance applications, MV drives include an active front end to make sure that harmonic content is in control.

## 1.8 General block diagram

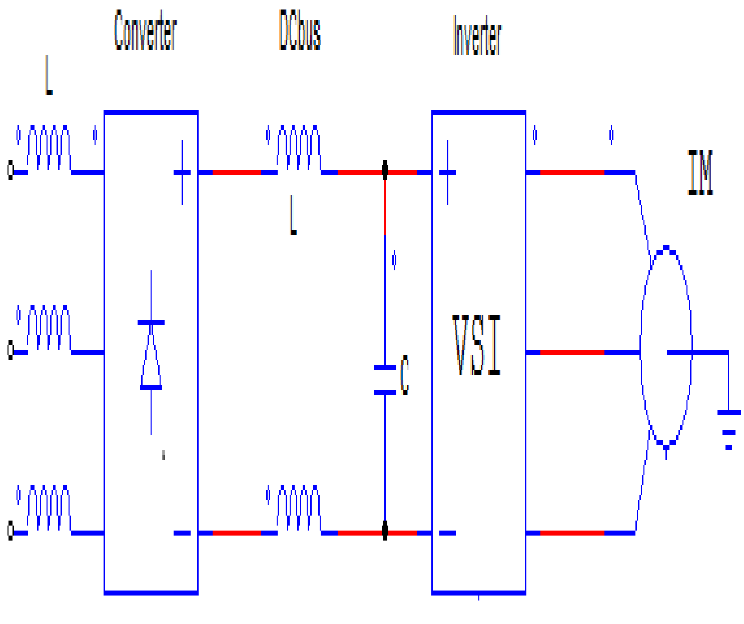


Figure 1.5: Medium Voltage Drive.

The main part of MV drive is represented; in the figure [1.5] are rectifier, line- side filter, transformer, dc filter, inverter and motor-side filter. The selection of motor side filters will be varied according to need of the system; rectification topology and inverter topology Medium voltage level of 2.3kV to

13.8kV are used for MV drive.

The major high power drive users use the pulse diode rectifier techniques. The specific choice of using the multi pulse diode-rectifier is to decrease harmonic content in output voltage waveform. The six pulse rectifiers used to cancel out the lower order harmonics such as 5th and 7th. The percentage of THD in the line current, also along with the decrease by increasing the pulse number of diode rectifier. 12-pulse diode-rectifiers have better harmonic profile compared to the to six-pulse diode rectifiers [8].

Presently in this drive, 18-pulse and 24-pulse diode-rectifiers are used as front end rectifiers which results in better harmonic profile comparatively. The phase shifting transformers are specifically used to generate phase displacement for deduction in cancellation of harmonics, proper secondary voltage and an electrical isolation is given in between rectifier and utility supply.

In the case of voltage source converters the dc filter capacitor helps to provide, constant dc voltage to the inverter but for the current source converters the dc filter.

It can be used as inductor helps to reduce the amount of ripple present in dc current output waveform.

The inverter used to convert fixed dc supply into adjustable magnitude of ac. The inverters for MV drives are classified into current source inverter (CSI) and voltage source inverter (VSI). The task for VSI is to convert dc voltage into a three-phase ac voltage with adjustable magnitude and frequency. The typologies used MV drive for voltage source inverter which are neutral point clamped (NPC), flying capacitor (FC) and cascaded H-bridge (CHB) topologies.

# Chapter 2

# Literature Survey

## 2.1 ABB drives

### 2.1.1 Medium Voltage Drives Offered by ABB

ABB offers medium voltage drives in the range of 250 kW to more than 100 MW. ABB supplies medium voltage variable speed drives for a wide range of applications in the cement, mining and minerals; power; water; metals; marine and chemical, oil and gas industries. Based on the voltage output of the electric drives it can be Low voltage drives or Medium voltage drives. This drive has the Rectifier and inverter. Some advanced drive will use the active rectifier Unit which have some advanced feature like regeneration, power quality management etc. The Multilevel inverters are used in advanced drives. By using the multilevel inverters, the voltage blocking capability of switch can be reduced. And also the different voltages we can able to get by using multilevel inverters. The ABB provides the drive for the application in which induction, synchronous and permanent magnet motors are used [9].

## 2.2 ACS 580MV

### 2.2.1 Applications of ACS 580MV drive.

Application of ACS 580MV is controlling pumps, fans and many other applications like conveyors and mixers (variable and constant torque).

### 2.2.2 Features of ACS 580MV drive

- **Reliability and efficiency throughout the whole life cycle**
- **Built-in energy calculators ensure optimal energy use**
- **Performance-based reliability thanks to the power loss ride-through and automatic restart function**
- **Simple to operate, safe to use**
- **User-friendly, intuitive control panel**
- **Startup and maintenance tool**
- **Communication with all major automation networks**
- **Advanced diagnostics and warning system enables users to effectively analyze and resolve issues**
- **Power range 200 kW up to 5.6 MW**

### 2.2.3 Rating of ACS 580MV drive

- **Input voltage: 6 to 11 kV +/- 10**
- **Output voltage: 6 to 11 kV**
- **Input power factor: 0.96**
- **Power range: 200 kW up to 5.6 MW ( 6 kV 200 to 3550 kw, 6.3 kV 200 to 3500 kW, 6.6 kV 200 to 4000 kW )**
- **Motor control: scalar and vector control**

# Chapter 3

# Technology Adopted

## 3.1 Technology Adopted

- **Block diagram of Emulator setup for MV Drive**

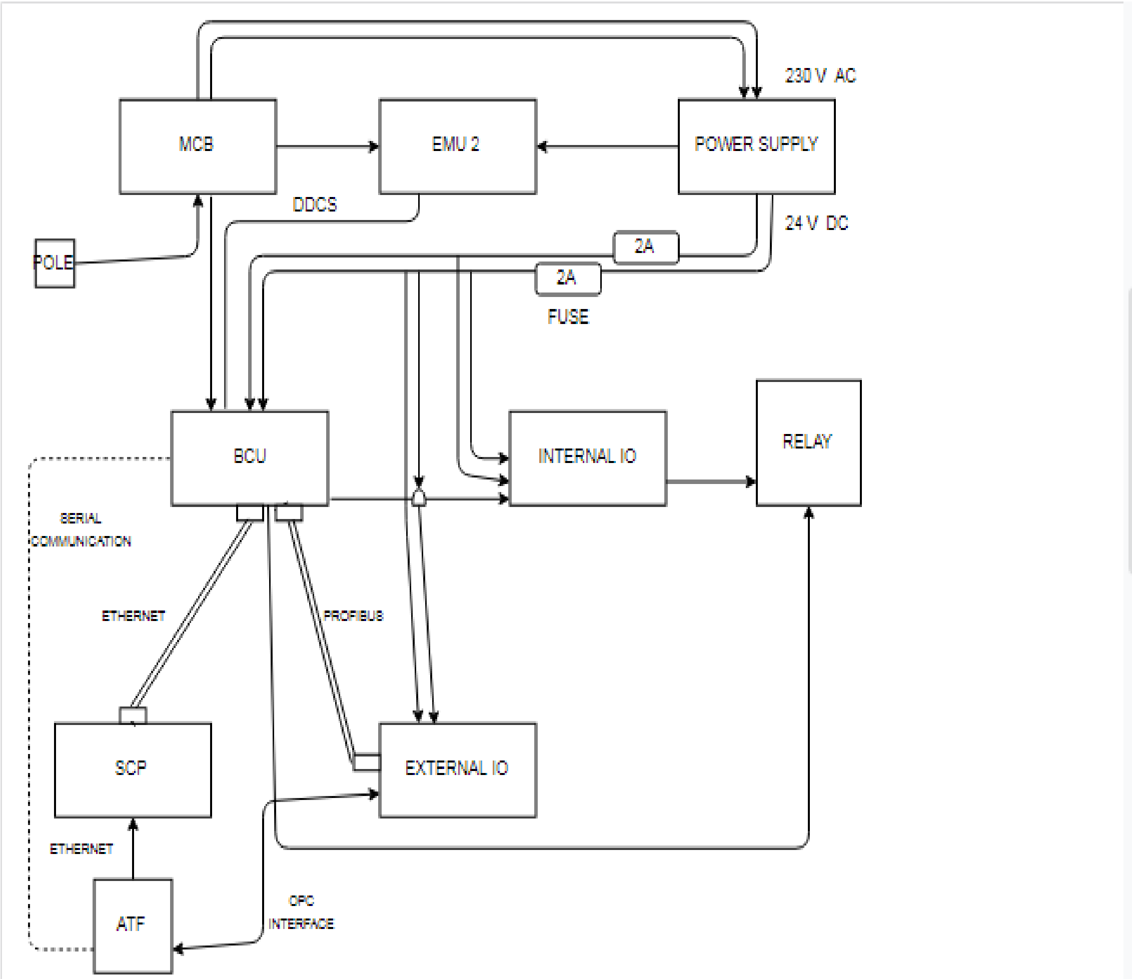


Figure 3.1: Block diagram of Emulator setup for MV Drive

### 3.1.1 Overview diagram of ACS 580 MV drive

- ABB medium voltage drive has many applications in Which High Power & Dynamic response are required. It is necessary to test Control Software before releasing it to Market. However it is not that easy to test Control software on actual Drive System as very high cost of Drive, Space Risk of High Voltage is involved. Therefore Emulator Controller is developed where a Constant DC link Voltage Motor Currents are given to Drive Controller through Emulator Controller.

- An Emulator Setup Provides Constant DC Link Voltage & Motor current feedback to the Drive Controller. Here in Emulator, there is Motor model is present. Required Motor Parameters are entered to the Emulator System Parameters file. Drive Configuration, Drive Power Rating Other parameters are configured in the Emulator Controller.

- A Virtual testing environment is created where Controller behaves like Real time field conditions. For Input Output Modules, it is possible to utilize Setups like OPC [Object Linking and Embedding (OLE) for process control (OPC)] National Instruments setup.

- Object Linking and Embedding (OLE) for process control (OPC) is a set of standards developed by a joint collaboration of leading automation industry suppliers. OPCs primary mission is to define a uniform interface for use with any organization OR Custom software package.

- National Instruments modules are 24 V DC Input Output Modules without a Programming Controller. NI Output module can be triggered on off with NI MAX Measurement & Automation Explorer tool. NI modules are faster in terms of processing than other PLC setup. NI modules are costly compared to PLC.

# Chapter 4

# Communication Protocols

## 4.1 OPC interface

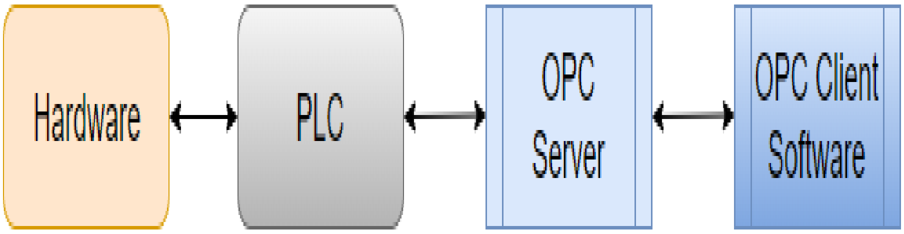


Figure 4.1: OPC interface

**OPC interface full form is open platform communications. It is a series of standards. OPC interface is a specification for industrial communication system. A standard that defines the communication of data between devices from different manufactures. Requires an OPC server that communicates with the OPC client. OPC allows plug - and - play, gives benefits as reduces installation time and opportunity to choose products from different manufactures. Different standards: real - time data (OPC DA), Historical data (OPC HAD), alarm event data (OPC AE), etc.**[10]

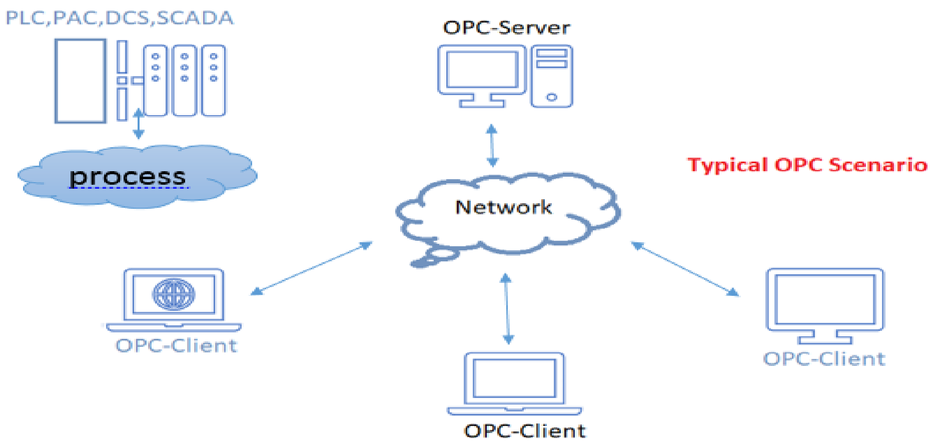


Figure 4.2: Network of OPC interfaces

## 4.2 Different protocols of communication system

### 4.2.1 Different types of protocols used in ACS 580MV drive:

1. Modbus
2. Profibus
3. Profinet
4. DeviceNet
5. CAN

### 4.2.2 Fieldbus communication system

- Fieldbus networks is having following topologies:
    1. Ring
    2. Branch
    3. Star
    4. Daisy chain
- Fieldbus allows no. of instruments into a single cable in place of multiple cables. This type of communication system saves significant amount of man- power and cost of cables. This type of segment is in form of single

**pair. [11]Fieldbus protocol type of segment carries both dc power and digital signals. In one segments of it capable to connect up to 32 devices in it.**

- **Advantages of fieldbus communication system :**
  1. **Reduced the wiring between remote field related industrial instruments and panel.**
  2. **Requires less space for this communication system.**
  3. **Less inspection required for customer side like meggering, continuity, loop tests.**
  4. **Reduced work related to engineering drawing or designing side.**
  5. **Multiple variable access in one drive like ACS 580 MV drive.**
  6. **Control system is available in field level.**
  7. **Devices of different manufactures can integrated easily.**
- **Feature**
  - **[11]Foundation fieldbus system is all digital, serial, two way, multi drop communication system designed to interconnect smart field bus devices(sensor, actuators, other i/o)to control system.**
  - **Foundation fieldbus replaces 4 to 20 mA technology and complex wiring system.**
  - **Intrinsically safe wiring option is available in FF system to reduce the in hazardous environments.**
  - **Smart field devices not only convert the sensor data but they can also have a rich set of function blocks and control algorithms.**
  - **Enhanced data availability a devices may be source and/or destination of many control variables.**
  - **Time sharing of control parameters performed in field devices and coupled to control data to optimize operating performance.**
  - **FF provide high speed and reliable data communication in harsh environment.**

– Integrating control and monitoring function is also possible in filed mounting devices which free up space in central controller.

– There are two types of foundation fieldbus implementations-

1. foundation fieldbus H1
2. HSE(high-speed Ethernet)

### 4.2.3 Modbus

- Modbus communication protocol is developed by modicon systems. Modbus an open, serial(RS-232 OR RS-485) protocol derived from the master/slave architecture. It is widely used protocol because of its ease of use and reliability. In a standard Modbus network, there is one master and up to 247 slaves, each with a unique slave address from 1 to 247. The master can also write information to the slaves[12].

- Modbus is available in two version:

1. Modbus RTU: Modbus RTU is most commonly used Modbus is sending data using binary coding and CRC error-checking.
2. Modbus ASCII: Modbus ASCII is less efficient. ASCII mode uses ASCII characters to begin and end messages.

- Function code of Modbus:

| Function Code | Action | Table Name |
|---|---|---|
| 01 (01 hex) | Read | Discrete Output Coils |
| 05 (05 hex) | Write single | Discrete Output Coil |
| 15 (0F hex) | Write multiple | Discrete Output Coils |
| 02 (02 hex) | Read | Discrete Input Contacts |
| 04 (04 hex) | Read | Analog Input Registers |
| 03 (03 hex) | Read | Analog Output Holding Registers |
| 06 (06 hex) | Write single | Analog Output Holding Register |
| 16 (10 hex) | Write multiple | Analog Output Holding Registers |

Figure 4.3: Function code of Modbus

### 4.2.4 Profibus

Profibus(process field bus) is standard fieldbus communication standard used in industrial automation. Profibus is used to interface controller, repeaters, sensors, HMI, actuators same as Profinet. Profibus is based on RS-485 and compatible with European standard EN-50170. [13]Profibus communicate over 2 crore twisted, shielded cable. There are two variants in Profibus named Profibus DP and Profibus AP. Profibus DP(decentralised peripherals) is used to operate sensors and actuators through a decentralized controller. Data transfer speed varies from 9.6 Mbit/s. A particular speed can be chosen for a particular network to give sufficient time for communication for all devices. ON PROFIBUS DP 32 devices can be connected. Profibus AP(process automation) is used to monitor process measuring equipment through process control system. Profibus AP is slower than Profibus DP. It runs on 32 Kb/s fixed speed of 32 kb/s. The devices connected to AP is limited. Both AP and DP works on same protocol and uses 2 core cable.

### 4.2.5 Profinet

Profinet is standard industrial communication protocol used world wide. [14]Profinet is a kind of industrial Ethernet. Profinet is 100% Ethernet compatible as defined in IEEE standard (IEEE 802.3). Profinet and Profibus both are developed by organization Profibus international(PI). Profinet uses consumer/provider model. That is why it provides the faster speed of data communication as compared to Profinet. The maximum number of devices in Profinet network may be at 256. Profinet provide 100 mbps or 1Gbit/s communication speed. Profinet is faster with more bandwidth and provide larger massage space. Profinet can communicate with multiple industrial devices.

Advantages of Profinet

- speed: Profinet provides high speed data exchange between controller and devices, suitable for fast motion control applications.

- precision: Profinet is highly precise as provides ¡ 1 us precision cycle.It precision make it high performance techanique.
- Large quantity structures: With Profinet 256 devices can be controlled.
- seamless redundancy: Profinet provides the seamless redundancy for critical applications.
- flexible topologies: Profinet enables the use of star, tree and ring topologies in addition to the linear topology.
- open standard
- expand ability: Profinet network can be expanded as desired.

# Chapter 5

# Communication between ATF and Drive

## 5.1 Proposed Test Set up

**In existing testing environment, National Instrument(NI) input output modules are used for drive control. National Instruments(NI) modules are 24V DC Input and Output modules without a programming controller. NI modules are costly when compared to the PLC modules. PLC is used by user as per requirement. Thus a PLC with OPC interface communication provides an economic solution with additional features. In improved testing, PM592 PLC is used for testing. Input and output variables are defined by analog and digital connections. These type of connections are defined in the CoDeSys application program as global variables. Fig.5.1 shows the overall block diagram of the proposed set up with OPC interface.**

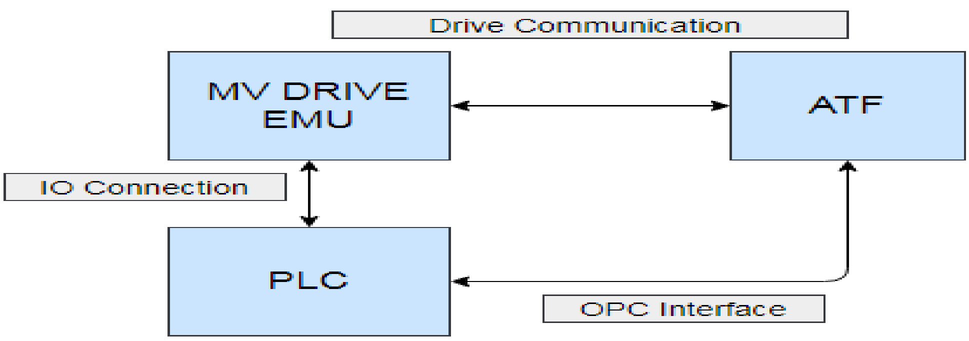


Figure 5.1: Proposed test set up with PLC and OPC interface

## 5.2 OPC interface with visual studio

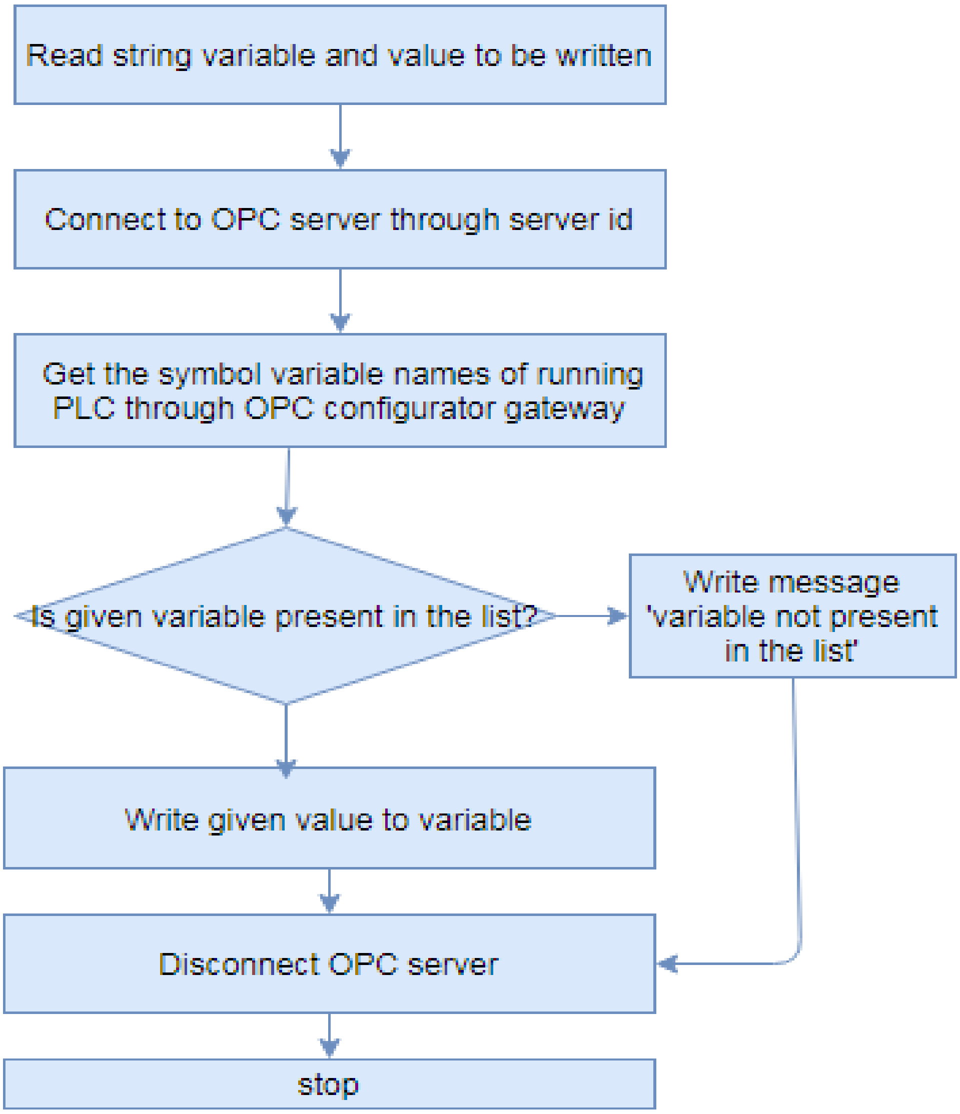


Figure 5.2: OPC interface with visual studio

**Visual studio uses OPCdotNETLib.dll library to connect to OPC server using OPC configurator as a gateway. Variables can be accessed through read and write methods of this library. When write command is executed visual studio connect to OPC server using server id. This server id can be obtained through OPC client. Once a desired symbol variable found in list, given value is written in this variable. In case if variable is not found in the symbol list corresponding message is printed and OPC server gets disconnected. Flowchart of the OPC interface and visual studio is shown above.**

## 5.3 ATF flowchart with OPC interface

### 5.3.1 Test case 1 : FB speed reversal

This test will verify positive negative speed functionality by fieldbus.

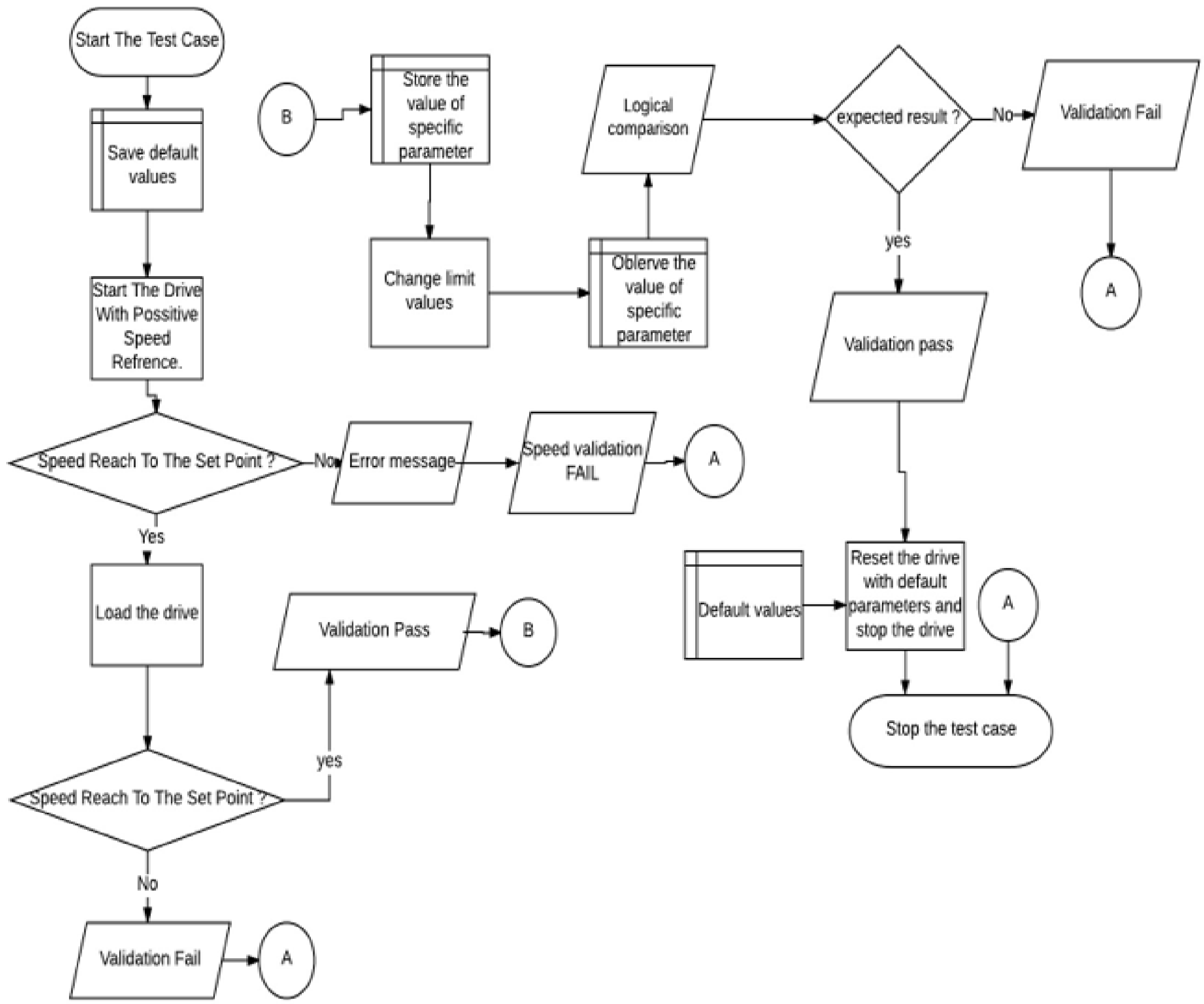


Figure 5.3: Flowchart of FB speed reversal

### 5.3.2 Test case 2 : Emergency off function test case

This test will verify that drive isnot started when EM STOP is on, neither in local nor in remote mode[15].

Fig.5.3 explains the complete ATF flowchart with OPC interface. OPC interface is developed by the OPC foundation. It is server-client based interface, where the server is vendor-specific and the client is general. OPC includes

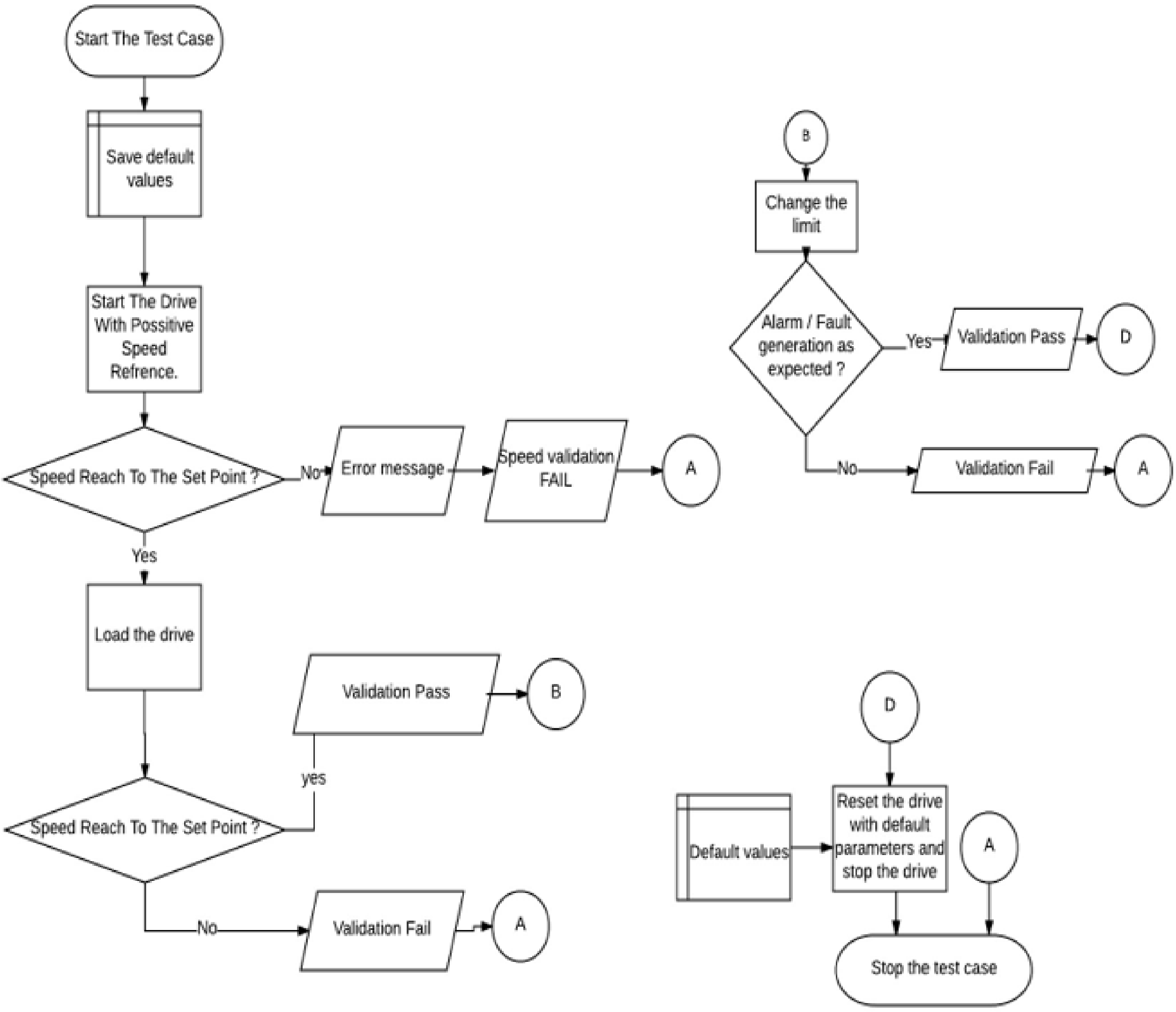


Figure 5.4: Flowchart of Emergency off function test case

**several specifications that contain information about how the server/client should exchange data. First specification is OPC DA that makes it possible for any OPC DA client to access data from an OPC DA server that fulfils the same specification. OPC DA is accessed to move real-time data from communication devices to Microsoft Windows applications. The OPC DA is based on Computer Object Model (COM) and Distributed Component Object Model (DCOM), which is a Microsoft technology. OPC has the problem with firewalls especially when the OPC client and server are located on different machines.**

## 5.4 Programming in PLC

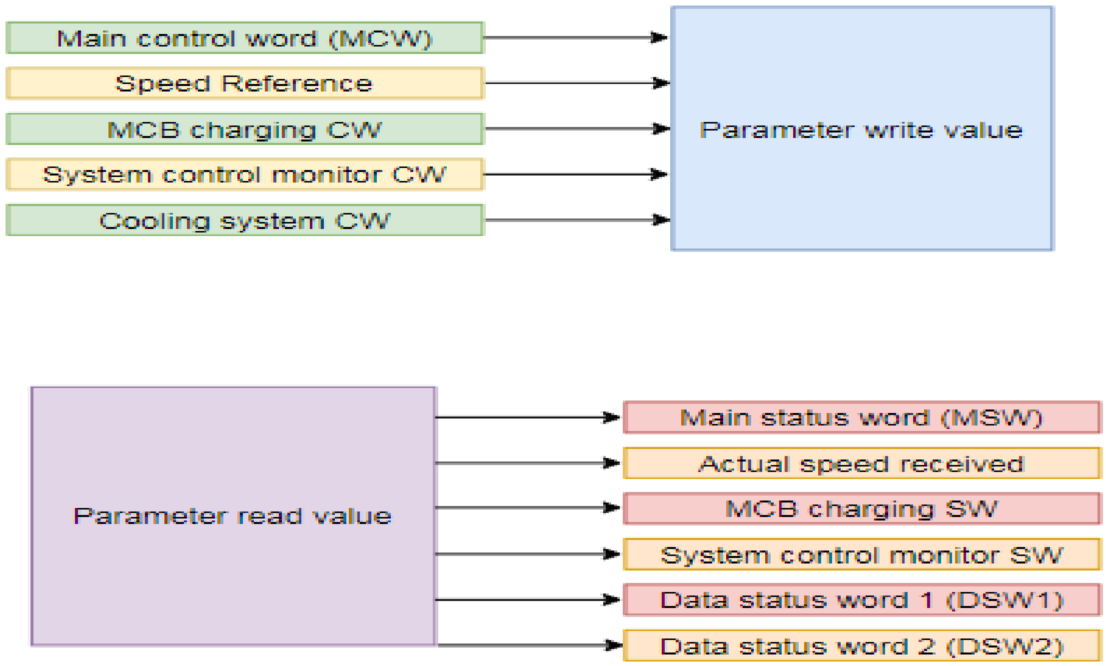


Figure 5.5: Data interface program

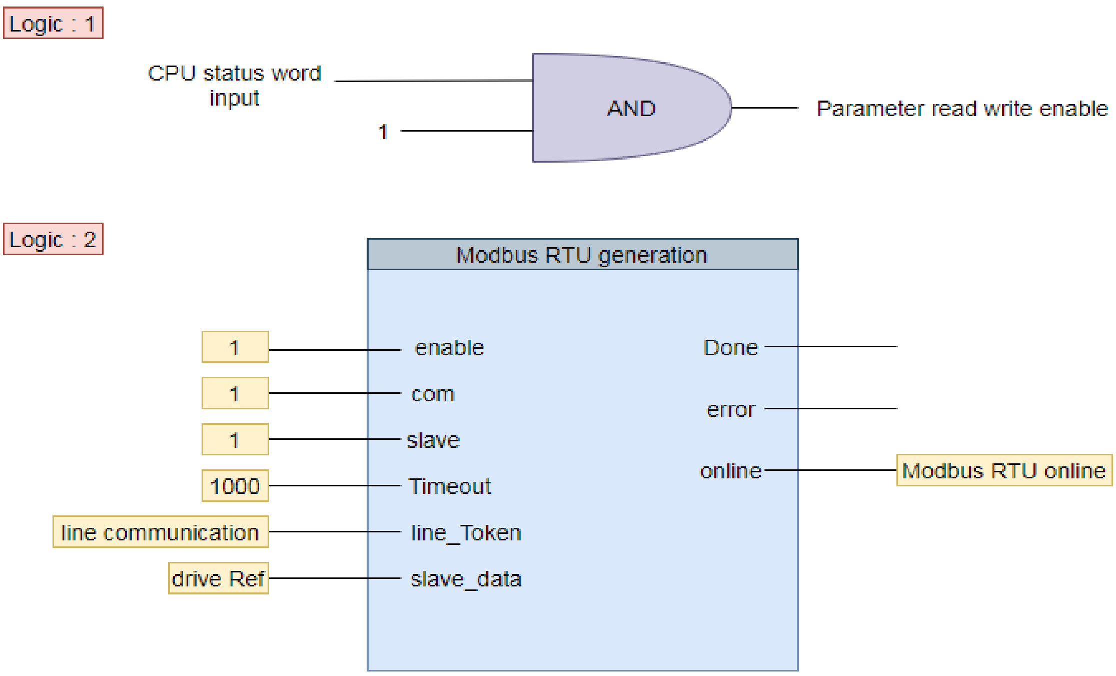


Figure 5.6: Modbus communication Master

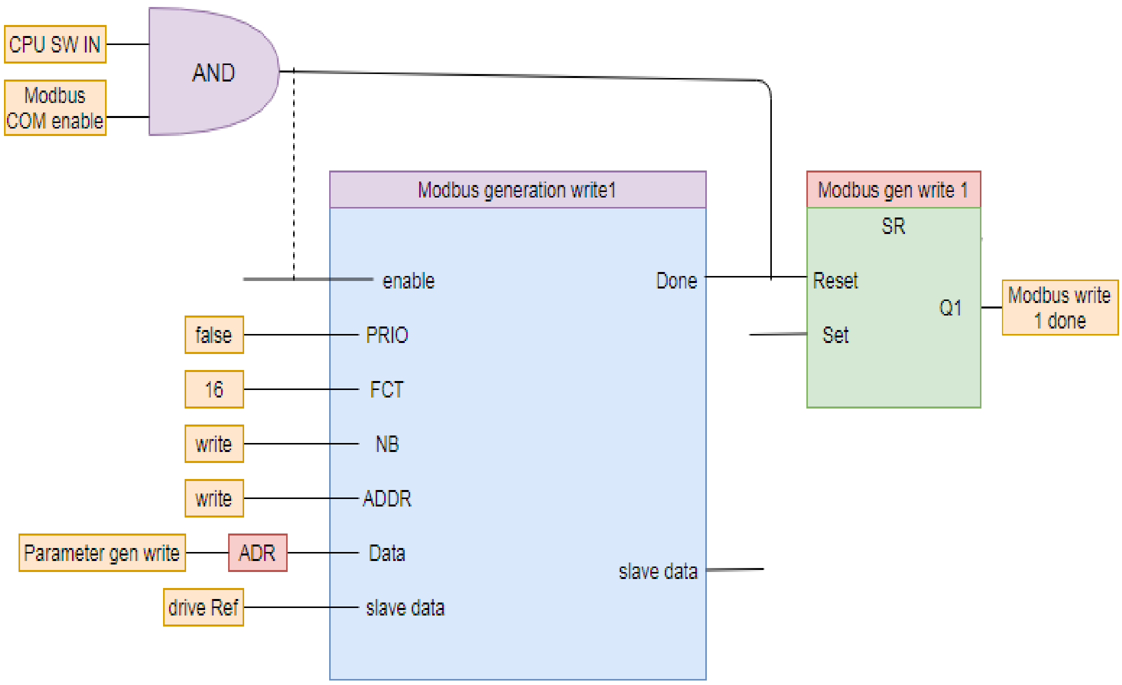


Figure 5.7: Modbus communication Read Write data

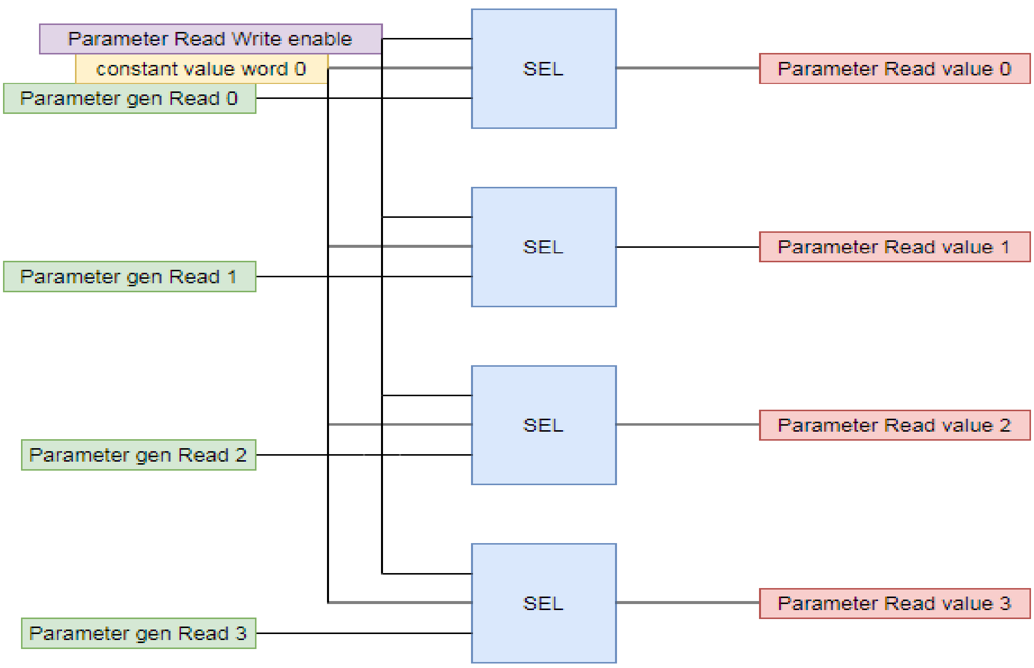


Figure 5.8: Modbus communication Read Write data from BCU

**Analog input signal scaling for -10V to +10V is available. These global variables are to be accessed as symbol variable in OPC server client. This PLC program is downloaded in PLC controller after rebuild. Inside setting option in CoDeSys tool download symbol file option needs to be activated. This**

symbol file which is consists of all global variables is created and downloaded in the PLC controller along with application program[16].

## 5.5 Results

The actual test was carried out using AC500 ABB make PLC and MV drive under test emulator test rack with induction motor model. The OPC interface read and writes methods are written in C language in visual studio script using OpcServer.dll library available in .net framework.

An Emergency Stop test case is explained here as an example to test OPC server interface. Drive start and stop command is given by through by switching on and off a digital input(DI1). Speed reference is given through analog input. An emergency off is triggered through another digital input(DI6). Thus from the Fig.5.4 it clear that automatic testing of the medium voltage drive using OPC interface is carried out successfully.

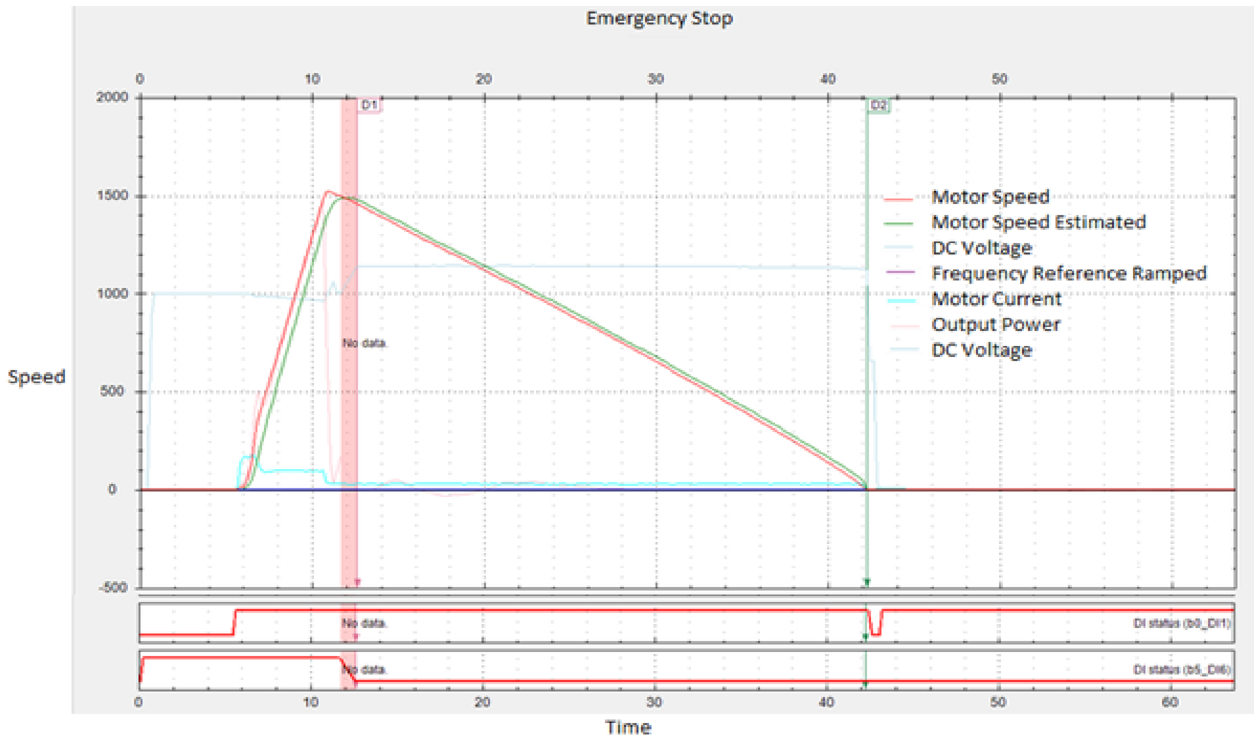


Figure 5.9: Emergency off function test case trend output

Another test case of speed reversal functionality is explained as shown in Fig.5.10 Drive start command is given using digital input 1(DI1). Drive speed reversal command is given using digital input 2(DI2).

Digital input 3 is used for stopping the drive. Drive stop command is active low i.e. input should be always high while motor is running. Motor stops when digital input 3(DI3) goes low. Motor speed reference ramp output reaches to nominal speed of 1500 rpm with DI1 edge trigger and reverses direction to negative nominal speed reference of -1500 rpm with DI2 edge trigger. All digital inputs are trigger using OPC server interface.

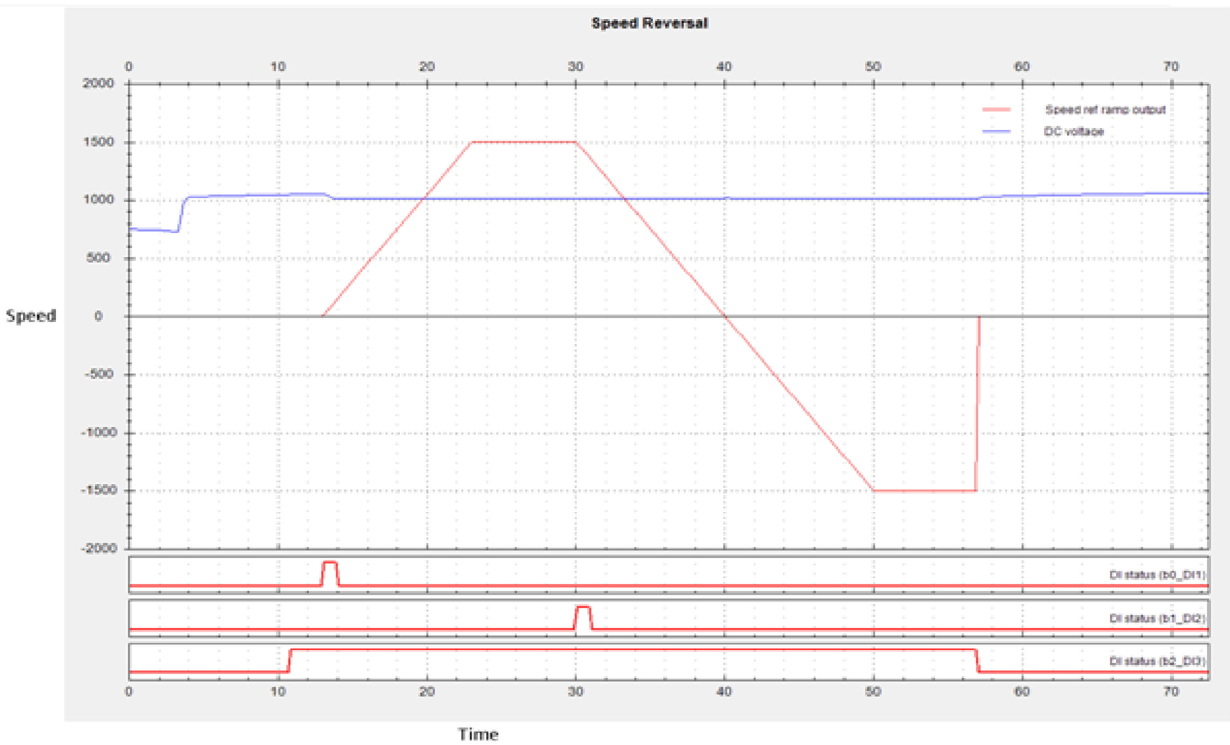


Figure 5.10: Speed Reversal test case trend output

# Chapter 6

# Communication between ATF and PLC

## 6.1 Manual Testing Environment

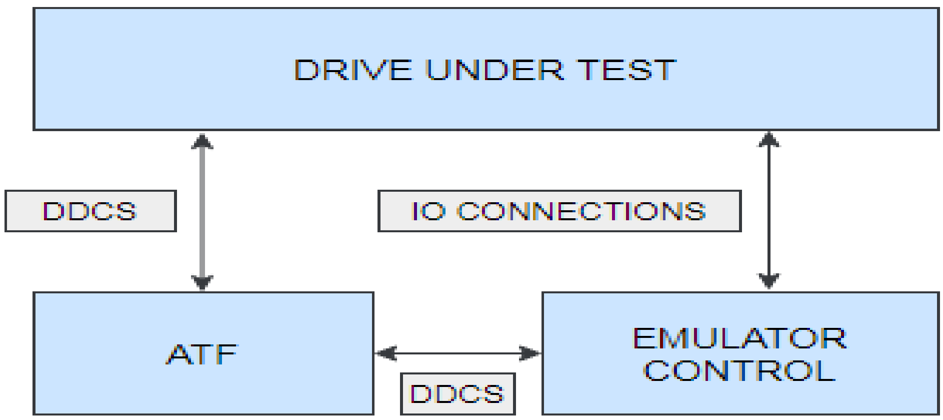


Figure 6.1: Medium Voltage Drive Emulator Set up

PLC library can contain many function blocks. Each function block is written to carry out certain function. Most of the time these functions blocks works standalone. In other words the function block should be self sufficient to carry out desired function and gives some logical outputs to the given set of input variable values. Hence it is of almost importance to test each function block thoroughly for each functionality as well as various possible input variable values.

[17]However sometimes some of the outputs of one function blocks are connected to input of the another function block. It means that few function blocks will work together to carry out certain functionality collectively. Hence these function blocks needs to be tested collectively at the same time.

Each function block needs to be tested for following different tests

- Unit test: this test is carried out by developer to test basic functionality
- Limit test: this test is carried out to validate input variable values.
- Function test: in this test more than one variable values are changed to check collective effect on the output variables
- System test: more than one functions blocks are tested collectively to check over all functionality of the library

Limit testing or black box testing is one of the major as well as time consuming manual testing. Each Function block has several inputs and output variables. In limit testing each input variable is tested five different values. This is also called boundary value analysis.

1. Minimum value (boundary limit)
2. Maximum value (boundary limit)
3. Intermediate value (default value)
4. Less than minimum value (out of boundary limit)
5. More than maximum value (out of boundary limit)

Also while testing one variable all other variables are set to default value. This testing is unique way to understand effect of one input variable to the output variables, when all remaining variables are set to default value.

Due to this tester can derive expected output variables values from the design document for the given input variable under test. So tester will have expected result before stating the test. Once test is over, this expected result is compared with actual result and accordingly test will be passed or failed.

However each function block has several input variables, normally 8-10 inputs. It means for each variable tester will have to test 5 different values. So total 50 different test cases and combination will be needed to test any function block.

## 6.2 Diagram of the water control level in storage tank

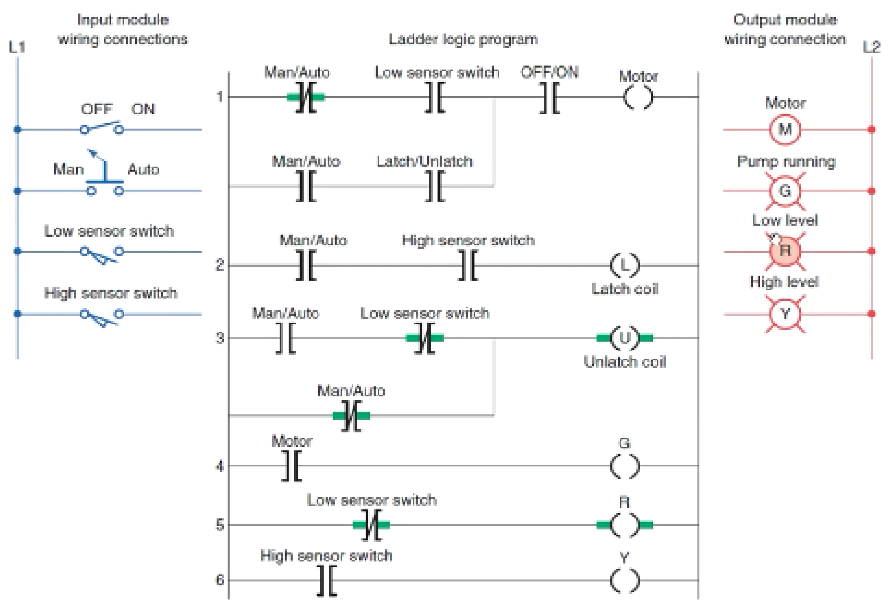


Figure 6.2: Diagram of the water control level in storage tank

The operation of the program that can be summarized as follows:

- The rung 1 examines on instruction addressed to the on/off switch prevents the pump motor from starting under any condition when in the off state.
- In the MAN mode, the rung 1 Examine-on instruction addressed to the

**low sensor switch allows the pump motor to operate only when the low level sensor switch is closed.**

- **In the AUTO mode, whenever the high sensor switch is momentarily closed the Examine-on instruction of rung 1 addressed to it will energize the latch coil. The pump will begin running and continue to operate until the unlatch coil is energized by the rung 3 Examine-off instruction addressed to the low sensor switch.**

- **The pump running status light is controlled by the rung 4 Examine-on instruction addressed to the motor output [18].**

## 6.3 Declaration of the Global Variables

```
VAR_GLOBAL
    Motor: BOOL;
    Green: BOOL;
    Red: BOOL;
    Yellow: BOOL;
    Low_Sensor_Switch: BOOL;
    Man_Auto: BOOL;
    On_Off: BOOL;
    High_Sensor_Switch: BOOL;
    Set_Coil: BOOL;
    Internal_Relay: BOOL;
    Reset_Coil: BOOL;
    _Relay: BOOL;
    Internal: BOOL;
    Internalrelay: BOOL;
END_VAR
```

Figure 6.3: Declaration of the Global Variables

**Motor, Low_Switch_Sensor, Man_Auto, On_Off, High_Sensor_Switch, Set_Coil, Internal_Relay, Rest_Coil are the variables which is used in ladder diagram. This type of variables is in boolean structure type and variables are declared in globally in global variables. These types of global variables are used in OPC configurator and OPC configurator makes interface between the PLC to ATF. All global variables are in the form of structure text in CoDesys as shown in Fig.6.3.**

## 6.4 OPC Configurator Settings

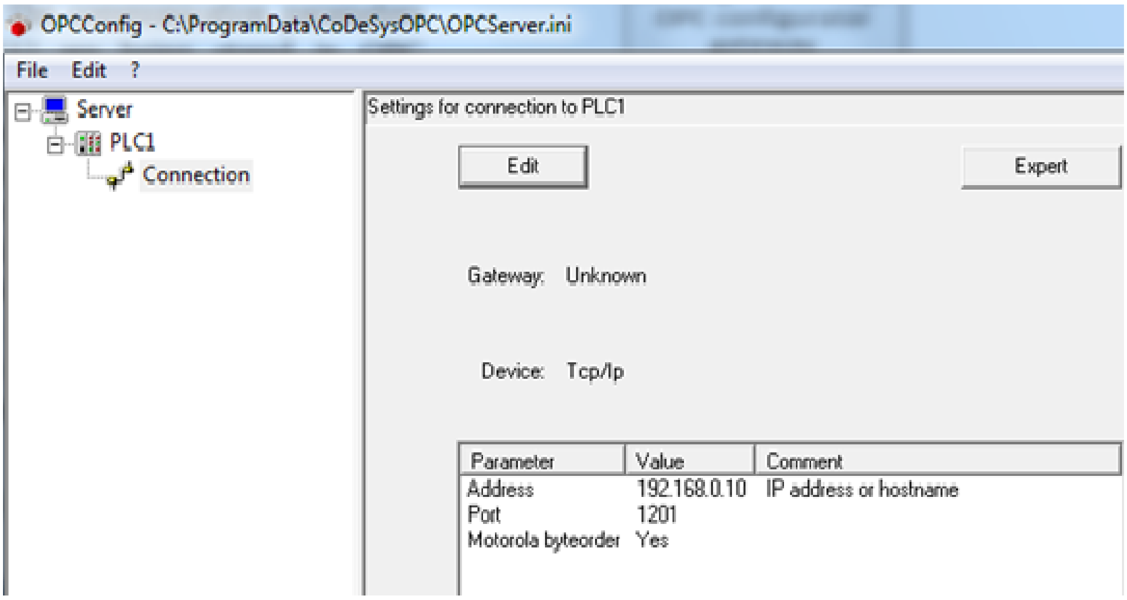


Figure 6.4: OPC Configurator Settings

**Visual studio uses OPCdotNETLib.dll library to connect to OPC server. [18]The library consists of methods to write to PLC variables or to read the status of the PLC variables. These variables are accessible through read and write methods of this library.**

## 6.5 Results


Figure 6.5: Results for passing condition

**Another test case of speed reversal functionality is explained as shown in**

. **Drive start command is given using digital input 1 i.e. DI1. Drive speed reversal command is given using digital input 2 i.e. DI2[19].**


Figure 6.6: Results for failing condition

**Digital input 3 is used for stopping the drive. Drive stop command is active low i.e. input should be always high while motor is running. Motor stops when digital input 3 i.e. DI3 goes low. Motor speed reference ramp output reaches to nominal speed of 1500 rpm with DI1 edge trigger and reverses direction to negative nominal speed reference of -1500 rpm with DI2 edge trigger. All digital inputs are triggered using OPC server interface.**

# Chapter 7

# Conclusion and Future Work

- **In this report automatic testing of medium voltage drive emulator using OPC server interface has been discussed. In this fieldbus testimg, Modbus communication is established between controller to PLC and automated it with the use of ATF. The OPC server interface can be used to start, stop and give speed reference to the drive. Therefore the drive commands are given through external controller where actual field scenario is created. Automatic system testing for medium voltage drive using PLC with the use of automation builder tool. The results prove that ATF is a powerful tool which can be used for testing of application software of control devices. Thus the project proves the use of OPC server as an automation tool for testing drive functionalities.**
- **Test code can be further made modular so that single code can be used for the different types of drives. Code can be constructed in such a way that it can be used for different motors with various ratings.**

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