DESIGN AND DEVELOPMENT OF PLC AND SCADA BASED CONTROL PANEL FOR CONTINUOUS MONITORING OF 3-PHASE INDUCTION MOTOR

Major Project Report

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ELECTRICAL ENGINEERING

(Power Electronics, Machines & Drives)

By

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Certificate

This is to certify that the Major Project Report entitled **"Design and Development of PLC and SCADA Based Control Panel for Continuous Monitoring of 3-Phase Induction Motor"** submitted by **Mrs.Jignesha B. Ahir (09MEE001)**, towards the partial fulfillment of the requirements for awards of degree in **Master of Technology (Electrical Engineering)** in the field of **Power Electronics, Machines & Drives)** of Nirma University is the record of work carried out by her under our supervision and guidance. The work submitted has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, have not been submitted to any other University or Institution for award of any degree or diploma.

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Abstract

Three phase squirrel cage induction motors are widely used motors in industry because of its rugged construction and negligible maintenance.To operate this kind of this motor star-delta starters are used .But ,because of its constant speed characteristics, many a times it is driven with the help of variable frequency drives.To have reliable operation its performance must be monitored continuosly. Design and fabrication of a monitoring and control system for 3-phase induction motor based on Programmable Logic Controller technology. Also the implementation of a hardware and software for speed control and protection with the result obtained from the test on induction motor performance is provided.The PLC corelates the operational parameters to the speed requested by the user and monitor the system during normal operational and under the trip conditions.Other performance parameters of three phase induction motors can also be monitored by the other control devices.Variable Frequency Drives (VFD) can also used to control the motor rotation direction and rotation speed of the three phase induction motor.All the required control and motor performance data will be taken to a personal computer via PLC for further analysis.Speed control from control side and protection from performance side will be priority.

Index Terms-Computer-controlled systems, computerized monitoring, electric drives, induction motors, programmable logic controllers (PLCs), variable frequency drives, voltage control, SCADA (Citect Software)

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Nomenclature/Abbreviations

PLC .... Programmable Logic controller
RDOL .... Reverse Direct On Line
SCADA .... Supervisory Control And Data Acquisition
PIC .... Programmable Integrated Circuit
ADC .... Analog to Digital Converter
VFD .... Variable Frequency Drive
XLPE .... Cross-Linked Polyethylene
PWM .... Pulse Width Modulation
CIV .... corona inception voltage
LAN .... Local Area Network

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Chapter 1

Introduction

1.1 General

Induction motors are the most widely used motors in the industrial applications because of their simple construction, low maintenance, no commutator, low price and moderate reliability.Since technology for motion control of electric drives became available, the use of programmable logic controllers (PLCs) with power electronics in electric machines applications has been introduced in the manufacturing automation. This use offers following advantages such as 1) lower voltage drop when turned on and the ability to control motors and other equipment with a virtually unity power factor. 2) Many factories use PLCs in automation processes to diminish production cost and to increase quality and reliability. 3) Fault or error detection and correction is easy. 4) It has very less amount of component. 5) Maintanance is easy. 6) Visualisation or indication of process. 7) Documentation is powerful. 8) Easy programming

Other applications include machine tools with improved precision computerized numerical control (CNC) due to the use of PLCs. To obtain accurate industrial electric drive systems, it is necessary to use PLCs interfaced with power converters, personal computers, and other electric equipment.Disadvantage of this method is that this makes the equipment more sophisticated, complex, and expensive.

Many applications of induction motors require besides the motor control functionality, the handling of several specific analog and digital I/O signals, home signals, trip signals, on/off/reverse commands. In such cases, a control unit involving a PLC must be added to the system structure. In this project presents a PLC-based monitoring and control system for a three-phase induction motor. It describes the design and implementation of the configured hardware and software. This configuration is interfaced on SCADA through PLC via RS232.

1.2 Problem identification

Protection of an induction motor (IM) against possible problems, such as overvoltage, overcurrent, overload, overtemperature, and undervoltage, occurring in the course of its operation is very important, because it is used intensively in industry as an actuator. IMs can be protected using some components, such as timers, contactors, voltage, and current relays. This method is known as the classical method that is very basic and involves mechanical dynamic parts. Computer and programmable integrated circuit (PIC) based protection methods have eliminated most of the mechanical components. However, the computer-based protection method requires an analog-to-digital conversion (ADC) card, and the PIC-based protection method does not visualize the electrical parameters measured. In this study, for IMs, a new protection method based on a programmable logic controller (PLC) has been introduced. In this method, all contactors, timers, relays, and the conversion card are eliminated. Moreover, the voltages, the currents, the speed, and the temperature values of the motor, and the problems occurred in the system, are monitored and warning messages are shown on the computer screen. PLC provides higher accuracy as well as safe and visual environment compared with the classical, the computer, and the PIC-based protection system.

1.2.1 Project at a glance

The undertaken project is based on physical model fabrication of PLC-SCADA operated control panel for monitoring and control of speed as well as direction of 3-phase induction motor. This model is a SMALL SCALE model with control panel having FR-E-540 (VFD of MITSUBISHI) drive to control speed and direction of a small three-phase induction motor with deployment of PLC and SCADA. This model also provides panel operated manual control

Chapter 2

Literature Survey

Literature survey plays a very important role in the project. Literature survey consists of the implementation of monitoring and control system for 3-phase induction motor based on programmable logic controller (PLC) technology is described.Also the implementation of hardware and software for the speed control and protection with the results obtained from tests on induction motor performance is provided. The PLC correlates the operational parameters to the speed requested by the user and monitors the system during normal operation and under trip conditions. Tests of the induction motor system driven by inverter and controlled by inverter and controlled by PLC related papers that includes different PLC as control system,control system of induction motor,hardware description,software description,PLC speed control software, control,monitor and control software, experiments results. Papers were taken from IEEE conference proceedings, journal proceedings and other standard publications.

1 **Maria G. Ioannides (S'85-M'86-SM'90) graduated from the Electrical Engineering Department of the National Technical University of Athens (NTUA), Athens, Greece. Currently, she is Professor of Electric Drives at NTUA. Her research interests include control of electric machines, renewable energy systems, small and special electric mo-**

tors, new materials Paper [1] This paper entitled "Design and implementation of PLC based monitoring control system for 3-phase induction motor.which provide detailed description of hardware and software of PLC based monitoring control system for 3-phase induction motor and control of electric machines.

2 **A.Daneels,W.Salter** In [2]This paper entitled"Technology Survey summary of Study Report"which gives detail of SCADA and advantages of SCADA.this paper also gives detail description of architecture of SCADA and SCADA program.

3 **R. Al-Ali, M. M. Negm, and M. Kassas, "A PLC based power factor controller for a 3-phase induction motor," in Proc. Conf. Rec. IEEE Industry Applications, vol. 2, 2000, pp. 1065-1072.** In [3] This paper gives information about the recent development in the Programmable Logic Controller (PLC) technology ,it has become widely used in most industrial application and utility plant.

4 **Kelvin Erickson, "Programmable logic controllers," IEEE Potentials, vol. 15, pp. 14-17, Feb./Mar. 1996.**

Paper[4] This paper entitled"Programmable Logic Controller"which gives information about PLC architectures and ladder logic.This paper also gives how to write the ladder language programme in ladder network and also gives detailed description of scan of PLC program.

Chapter 3

Control System of Induction Motor

In Fig.3.1 the block diagram of the experimental system is illustrated. The following configurations can be obtained from this setup.

1. A closed-loop control system for constant speed operation, configured with speed feedback and load current feedback. The induction motor drives a variable load, is fed by an inverter, and the PLC controls the inverter V/f output.

2. An open-loop control system for variable speed operation. The induction motor drives a variable load and is fed by an inverter in constant V/f control mode. The PLC is inactivated ..

3.The standard variable speed operation. The induction motor drives a variable load and is fed by a constant voltage-constant frequency standard three-phase supply. The open-loop configuration 2) can be obtained from the closed-loop configurati- on a) by removing the speed and load feedback. On the other hand , operation 3) . results if the entire control system is bypassed

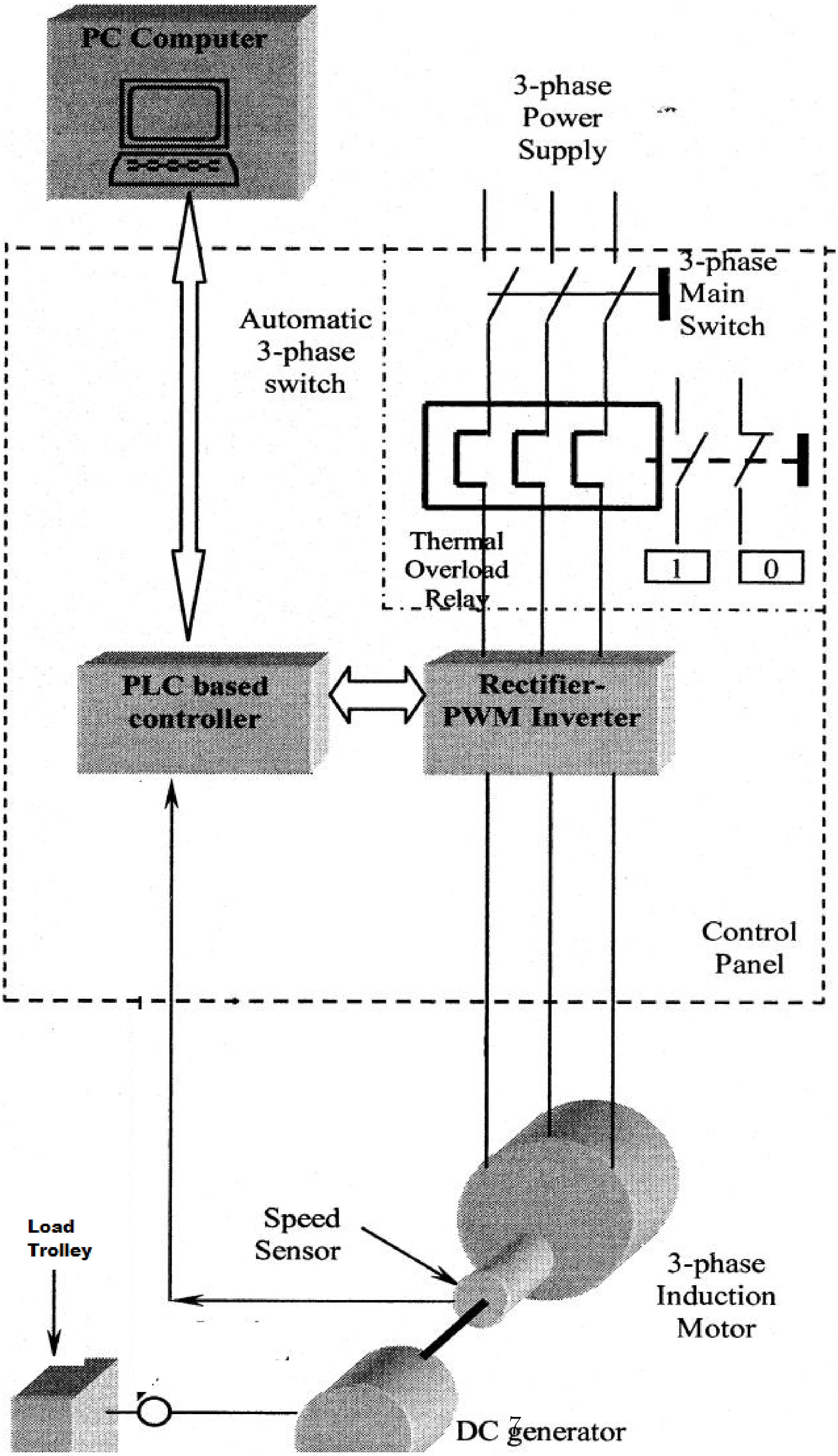


Figure 3.1: Power line diagram of experiment setup

3.1 Hardware Discription:

The control system is implemented and tested for a Squirrel cage induction motor, having the technical specifications given in Table I.The induction motor drives a dc generator, which supplies a variable R load. The three-phase power supply is connected to a three-phase main switch and then to 3 Phase thermal overload relay.which provides protection against current overloads. Then it is connected to variable frequency drives which control speed of motor and we change direction of motor through PLC and this is interface on SCADA via RS485 to USB communication cable.
A speed sensor is used for the speed feedback Thus,the feedback loops of the closed-loop system are setup by using the speed sensor, and the AIM.A Shaft encoder is used for speed sensing. The induction machine drives its shaft mechanically and an output voltage is produced, the magnitude of which is proportional to the speed of rotation. Polarity depends on the direction of rotation. The voltage signal from the encoder must match the specified voltage range of the AIM (05 V dc and 200-kOhm internal resistance). Other PLC external control circuits are designed using a low-voltage supply of 24 V dc.

Table 3.1: Induction Motor specification

Connection type	Delta
Input voltage	415 V
Input current	2.1 A
Rated Power	0.75 kW
Input frequency	50 Hz
Number of pole	4
Rated speed	1440

For the manual control, the scheme is equipped with start, stop, and trip push buttons, as well as with a forward and backward direction selector switch. As shown in Fig. 2, all of th described components: a main switch, an automatic three-phase switch, an automatic single phase switch, a three-phase thermal overload relay, a load automatic switch, signal lamps (forward, backward, start, stop, trip), push buttons (start, stop, trip), a selector switch (for the forward/backward direction of rotation), a speed selector, a gain selector, as well as the PLC modules and VFD is installed in a control panel. The program is downloaded into the PLC from a personal computer PC and an RS232 serial interface.

3.2 PID Control:

The PID Loop instruction (Proportional, Integral, Derivative loop) is provided by the S7-200 CPU to perform the PID calculation.

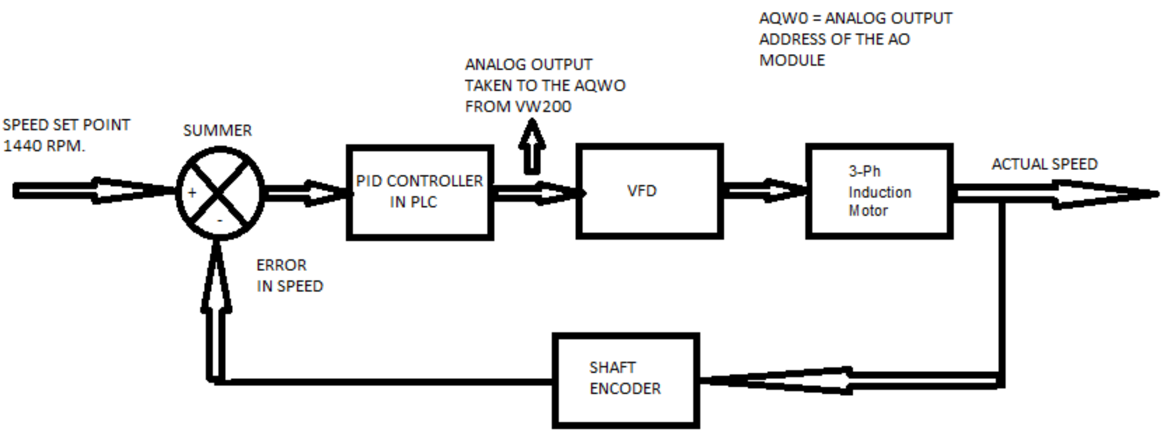


Figure 3.2: Block Diagram of PID Control

In steady state operation, a PID controller regulates the value of the output so as to drive the error (e) to zero. A measure of the error is given by the difference between the setpoint (the desired operating point), and the process variable (the actual operating point). The principle of PID control is based upon the following equation that expresses the output, M(t), as a function of a proportional term, an integral term, and a differential term:

$$M(t) = K_c * e + K_c \int_0^t e * dt + \frac{de}{dt} \tag{3.1}$$

where:

M(t) is the loop output as a function of time

Kc is the loop gain

E is the loop error (the difference between setpoint and process variable)

$M_{initial}$ = is the initial value of the loop output

In order to implement this control function in a digital computer, the continuous function must be quantized into periodic samples of the error value with subsequent calculation of the out-put. The corresponding equation that is the basis for the digital computer solution is:

$$M_n = K_c * e_n + K_I \sum_1^n + M_{initial} + K_D * (e_n - e_{n-1}) \tag{3.2}$$

where:

M_n is the calculated value of the loop output at sample time n

KC is the loop gain

e_n is the value of the loop error at sample time n

$en - 1$ is the previous value of the loop error (at sample time n - 1)

K_I is the proportional constant of the integral term

$M_{initial}$ is the initial value of the loop output

K_D is the proportional constant of the differential term

From this equation, the integral term is shown to be a function of all the error terms from the first sample to the current sample. The differential term is a function of the current sample and the previous sample, while the proportional term is only a function of the current sample. In a digital computer it is not practical to store all samples of the error term, nor is it necessary.

Since the digital computer must calculate the output value each time the error is sampled beginning with the first sample, it is only necessary to store the previous value of the error and the previous value of the integral term. As a result of the repetitive nature of the digital computer solution, a simplification in the equation that must be solved at any sample time can be made. The simplified equation is:

$$M_n = K_c * e_n + K_I * e_n + MX + K_D * (e_n - e_{n-1}) \tag{3.3}$$

Where

MX=Previous Value of integral term(at a sample time n-1)

The CPU uses a modified form of the above simplified equation when calculating the loop output value. This modified equation is:

$$M_n = MP_n + MI_n + MDn \tag{3.4}$$

Where

$M_n$is calculated Value of Loop output at sample time n

$MP_n$is the Value of the Proportional term of loop output at sample time n

MI_n is the Value of the integral term of loop output at sample time n

$MD_n$is the Value of the differential term of loop output at sample time n

3.2.1 Proportional Term

The proportional term MP is the product of the gain KC which controls the sensitivity of the output calculation, and the error (e), which is the difference between the setpoint (SP) and the process variable (PV) at a given sample time. The equation for the proportional term as solved by the CPU is:

$$MP_n = K_c * (SP_n - PV_n) \tag{3.5}$$

Where

$MP_n$is the value of the Proportional term of loop output at sample time n

$K_c$is Loop gain

$SP_n$is the value of the setpoint at sample time n

PV_n is the value of Process variable at sample time n

3.2.2 Integral Term

The integral term MI is proportional to the sum of the error (e) over time. The equation for the integral term as solved by the CPU is:

$$MI_n = K_c * \frac{T_s}{T_I} * (SP_n - PV_n) + MX \tag{3.6}$$

Where

$MI_n$is the Value of the integral term of loop output at sample time n

$T_s$is the Loop sample time

$T_I$is the integral time

The integral sum or bias (MX) is the running sum of all previous values of the integral term. After each calculation of MIn, the bias is updated with the value of MIn which may be adjusted or clamped . The initial value of the bias is typically set to the output value Minitial just prior to the first loop output calculation. Several constants are also part of the integral term, the gain KC , the sample time TS , which is the cycle time at which the PID loop recalculates the output value, and the integral time or reset TI , which is a time used to control the influence of the integral term in the output calculation.

3.2.3 Differential Term

The differential term MD is proportional to the change in the error. The equation for the differential term is:

$$MD_n = K_c * \frac{T_D}{T_S} * (SP_n - PV_n) - (SP_{n-1} - PV_{n-1}) \tag{3.7}$$

To avoid step changes or bumps in the output due to derivative action on setpoint changes, this equation is modified to assume that the setpoint is a constant SPn=SPn-1 . This results in the calculation of the change in the process variable instead of the change in the error as shown:

$$MD_n = K_c * \frac{T_D}{T_S} * (PV_{n-1} - PV_n) \tag{3.8}$$

Where
$MD_n$is the Value of the differential term of loop output at sample time n
SP_n is the value of the setpoint at sample time n
$SP_{n-1}$is the value of the setpoint at sample time n-1
$PV_n$is the value of the Process variable at sample time n
$PV_{n-1}$is the value of the Process variable at sample time n-1

3.2.4 Converting and Normalizing Loop Output

A loop has two input variables, the setpoint and the process variable. The setpoint is generally a fixed value such as the speed setting on the cruise control in your automobile. The process variable is a value that is related to loop output and therefore measures the effect that the loop output has on the controlled system. In the example of the cruise control, the process variable would be a tachometer input that measures the rotational speed of the tires.

Both the setpoint and the process variable are real world values whose magnitude, range, and engineering units may be different. Before these real world values can be operated upon by the PID instruction, the values must be converted to normalized, floating-point representations.

The first step is to convert the real world value from a 16-bit integer value to a floating-point or real number value. The following instruction sequence is provided to show how to convert from an integer value to a real number.

ITD AIW0, AC0 //Convert an input value to a double word DTR AC0, AC0 //Convert the 32-bit integer to a real number. The next step is to convert the real number value representation of the real world value to a normalized value between 0.0 and 1.0. The following equation is used to normalize either the setpoint or process variable value:

$$R_{norm} = (\frac{R_r aw}{Span} + Offset) \tag{3.9}$$

where

R_{norm} =normalised,real number value representation of real word value

R_{raw} =un-normalized or raw ,real number value representation of real word value

Offset=0.0 for unipolar value and 0.5 for bipolar value

Span=maximum possible value minus minimum possible value

=32000 for unipolar value

=64000 for bipolar value

3.2.5 PID Loop Definition Table

Eighty (80) bytes are allocated for the loop table from the starting address you enter for Table (TBL) in the PID instruction box.

The PID instruction for the S7-200 references a loop table that contains the loop parameters. This table was originally 36 bytes long. With the addition of PID autotuning the loop table has been expanded and is now 80 bytes long.

If you use the PID Tuning Control Panel, all interaction with the PID loop table is handled for you by the control panel. If you need to provide auto-tuning capability from an operator panel, your program must provide the interaction between the operator and the PID loop table to initiate, and monitor the auto-tuning process, and then apply the suggested tuning values.

Table 3.2: PID Loop Defination Table

Offset	Field	Format	Type	Description
0	PVn	Double word - REAL	In	Contains the process variable, which must be scaled between 0.0 and 1.0.
4	SPn	Double word - REAL	In	Contains the setpoint, which must be scaled between 0.0 and 1.0.
8	Mn	Double word - REAL	In/Out	Contains the calculated output, scaled between 0.0 and 1.0.
12	Kc	Double word - REAL	In	Contains the gain, which is a proportional constant. Can be a positive or negative number.
16	T_S	Double word - REAL	In	Contains the sample time, in seconds. Must be a positive number.
20	T_I	Double word - REAL	In	Contains the integral time or reset, in minutes. Must be a positive number.
24	T_D	Double word - REAL	In	Contains the derivative time or rate, in minutes. Must be a positive number.
28	MX	Double word - REAL	In/Out	Contains the bias or integral sum value between 0.0 and 1.0.
32	PV_{n-1}	Double word - REAL	In/Out	Contains the previous value of the process variable stored from the last execution of the PID instruction

Chapter 4

Variable Frequency Drive

4.1 Variable Frequency Drive

Due to its versatility and compact dimensions the FR-E 500 EC is a frequency inverter solving most effectively your individual drive tasks. Its extensive functions allow flexible applications. The outstanding drive features of the FR-E 500 EC suits various needs:

- Textile machines such as spinning machines, knitting machines, weaving looms
- Material transport systems such as chain, belt, and screw conveyors
- Door and gate drives
- Machines for working of metal, stone, wood, and plastics
- Material-handling technology
- Pumps and ventilator

Undertaken project has utilized a small rated VFD model whose specifications are shown in Table I.:

Table 4.1: Small scale VFD specification

Model	FR-E540EC
Make	Mitsubishi Electric Corporation
Power	0.75kW
Input	4.1A,3-PH AC380-480 V,50Hz
Output	2.1A,3-PH AC380-480 V,0.2-400Hz

4.1.1 Available rating of VFD

FR-E520 series-0.4kW, 0.75kW,1.5kW,2.2kW

FR-E540 series-0.4kW, 0.75kW,1.5kW,2.2kW,3.7kW,5.5kW,7.5kW

Displayed option

Operating state-Output frequency, motor current, output voltage, frequency setting value, operating speed

Alarm state-Error messages are displayed after protective function is activated. Up to 4 error codes can be stored.

Protection

Overcurrent cutoff,regenerative overvoltage cutoff,instantaneous power failure, overload cutoff, ground fault overcurrent,output short-circuit, overload warning, parameter error, PU connection error, output phase error.

Cooling

Self cooling ,fan cooling

Note:

Not valid for the inverter FR-E540-0.4k ,0.75k EC and FR-E520-0.1k to 0.4k EC which are not equipped with cooling fan

4.2 Terminal connection of VFD

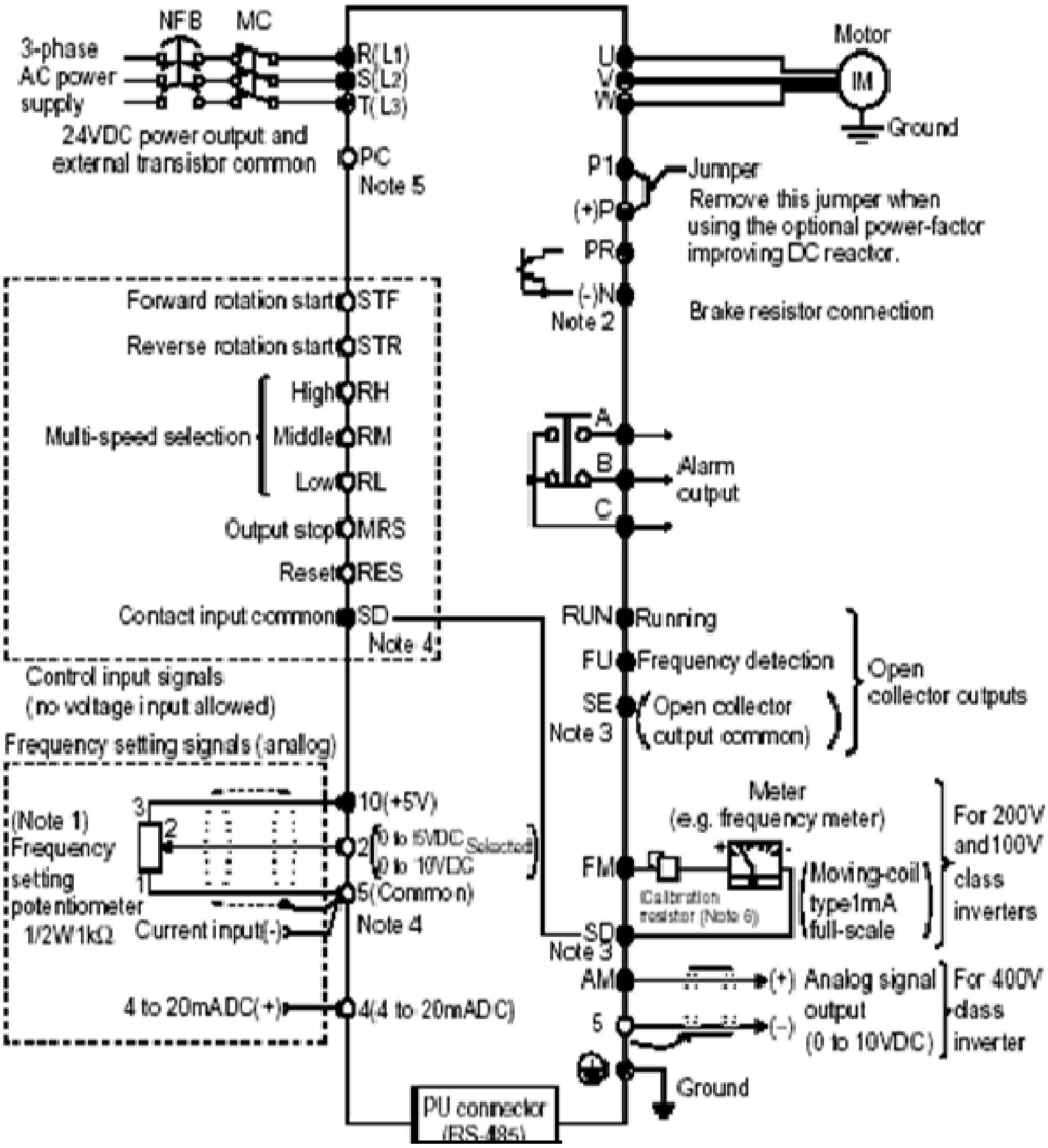


Figure 4.1: Power line diagram of experiment setup

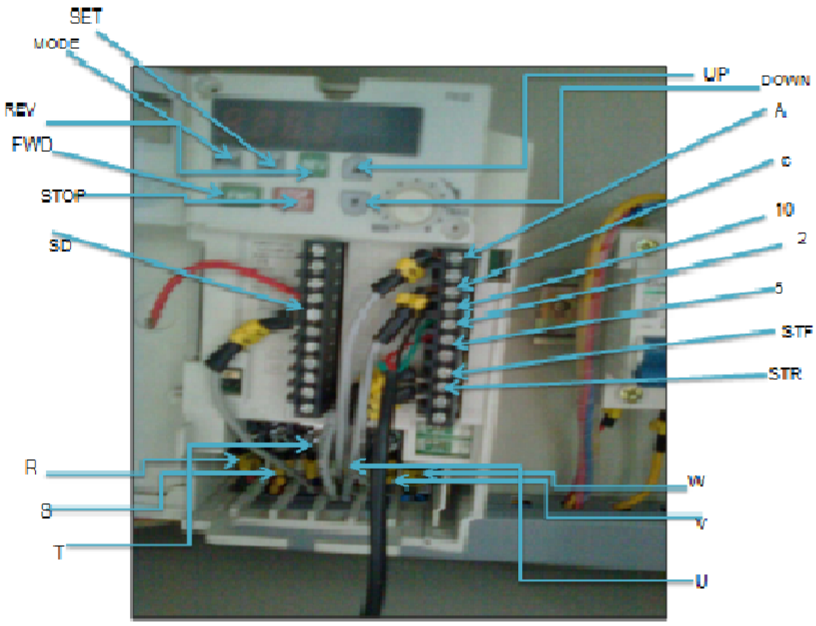


Figure 4.2: terminal connection of VFD

Note: When terminal PC-SD are used as 24Vdc power supply, be care full not to short them these terminals. If they are shorted, the inverter will be damaged.

Table 4.2: Description of Main circuit terminals

Symbol	*Terminal name*	*Description*
R,S,T(L1,L2,L3)	Ac power input	Connect to the commercial
U,V,W	Inverter output	connect to the squirrel cage induction motor
P(+),PR	Brake resistor connection	Connect the optional brake resistor across the terminals P-PR
P(+),N(-)	Brake unit connection	Connect optional brake unit or high power factor converter
P(+),P1	Power factor improving DC reactor connection	Disconnect the jumper from the terminals P-P1(+ - P1) and connect the optional power factor improving DC reactor

Table 4.3: Description of Control circuit terminals

Symbol	*Terminal name*	*Description*
STF	Forward rotation start	Turn on the STF signal to start forward rotation and turn it off to stop.
STR	Reverse rotation start	Turn on the STR signal to start reverse rotation and turn it off to stop.
RH,RM,RL	Multi-speed selection	Combined the RH, RM and RL signal as appropriate to select multiple speeds.
MRS	Output stop	Turn on the MRS signal (20ms or longer) to stop the inverter output.Used to shutoff the inverter output to bring the motor to a stop by electromagnetic brake.
RES	Reset	Used to reset the protective circuit activated. Turn on the RES signal for more than 0.1 second then turn it off.
SD	Contact input common (sink)	Common to the contact input terminal and terminal FM. Common output terminal for 24VDC 0.1A power output.
PC	Power output and external transistor common .Contact input common (source)	When transistor output(open collector output)such as programmable controller (PLC) is connected, connect the external power supply common for transistor output to this terminal to prevent a fault caused by undesirable current. this terminal can be used as a 24VDC 0.1 A power output.
10	Frequency setting power supply	5V,permissible load current 10 mA
2	Frequency setting(voltage)	By entering 0 to 10VDC, the maximum output frequency is reached at 10V and I/O are proportional. Use Pr.73 to switch between 0 to 5VDC and 0to 10V, input resistance 10Kohm.maximum permissible voltage 20V
4	Frequency setting (current)	By entering 4 to 20mA DC, the maximum output frequency is reached at 2mA and I/O are proportional. This input signal is valid only when AU signal is on.Input resistance 250 ohm. Maximum permissible current 30mA

Symbol	*Terminal name*	*Description*
5	Frequency setting input common	Common to frequency setting signal(terminal 2,1 or 4). Do not connect to the earth.
A,B,C (contact)	Alarm output	Contact output indicating that output has been stopped by the inverter protective function activated.230V AC0.3A,30V DC 0.3A
Output signal run	Inverter running	Switched low when inverter output frequency is equal to or higher than the starting frequency (factory set 0.5 Hz variable).Switched high during stop or DC injection brake operation
FU	Frequency detection	Switched low when output frequency has reached or exceed the detection frequency set as appropriate. Switched high when below the detection frequency
SE	open collector output common.	Common to RUN and FU terminal
FM AM	For meter Analog signal output	One selected from output frequency, motor current and output voltage is output. The output signal is not proportional to magnitude of each monitoring item. 1) factory setting of the output item : Frequency, Permissible load current 1mA 1440 pulses/s at 60Hz 2) factory setting of the output item : Frequency output signal 0 to 10 VDC
RS485	PU connector	With control panel connector , communication can be made using RS485

4.3 Control diagram

4.3.1 VFD control diagram

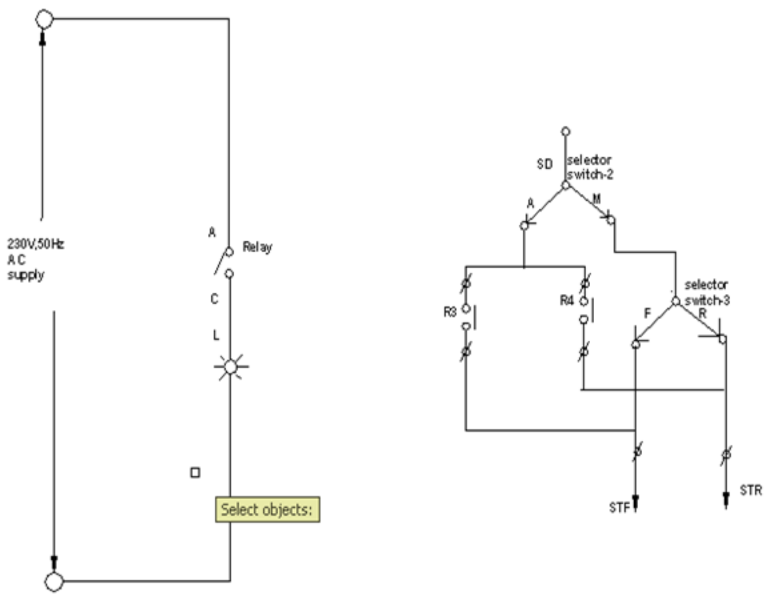


Figure 4.3: VFD control wiring

The circuit shown in fig.4.2 is control the direction of rotation and speed of 3-phase induction motor by using VFD.230 V,50Hz,1-Phase supply is given across NO contact of relay(terminal A and C of VFD) Terminal SD is Common to the contact input terminal and terminal FM.Common output terminal for 24VDC 0.1A power output.SD terminal is connected to the selector switch 1. Terminal R,S,T is used as input and U,V,W is used as output which is connected to motor. In this there are two control method(1) control by Auto (2) Control by Manually.In manually control,selector switch2 is connected across STF and STR terminal of VFD which is used for changing direction of rotation.1W2Kohm frequency setting potentiometer is connected across terminal 10,2,5 of VFD which is used to adjust input voltage and frequency setting of inverter. In In automatic control we push the start forward push button on SCADA,relay R3 is energized and motor rotate in forward direction and pushing start reverse button on SCADA ,relay R4 is energized and motor rotate in reverse direction.Speed of motor is control by analog output of PLC.

4.4 Parameter setting

Table 4.4: Basic parameter setting

Name	*Parameter number*	*setting*
Accelaration time	Pr.7	10 sec
Decelaration time	Pr.8	10 sec
Operation mode selection	Pr.79	2
Motor capacity	Pr.80	0.75 kW
Rated voltage	Pr.83	415 V
Rated frequency	Pr.84	50 Hz

1) Pr.7 and Pr.8 is set at 10sec

Used to set motor acceleration/deceleration time.Set a larger value for a slower speed increase/decrease or a smaller value for a faster speed increase/decrease

2)Pr.79 Operation mode selection

Used to select the operation mode of the inverter.The inverter can be run from the control panel or parameter unit (PU operation), with external signals (external operation), or by combination of PU operation and external operation (external/PU combined operation).When power is switched on (factory setting), the External operation mode is selected Selected range 0 to 4 and 6 to 8 Pr.79=2-External operation mode

Chapter 5

Programmable logic controller

5.1 PLC as system controller

A PLC is a microprocessor-based control system, designed for automation processes in industrial environments. It uses a programmable memory for the internal storage of user-orientated instructions for implementing specific functions such as arithmetic, counting, logic, sequencing, and timing. A PLC can be programmed to sense, activate, and control industrial equipment and, therefore, incorporates a number of I/O points, which allow electrical signals to be interfaced. Input devices and output devices of the process are connected to the PLC and the control program is entered into the PLC memory.

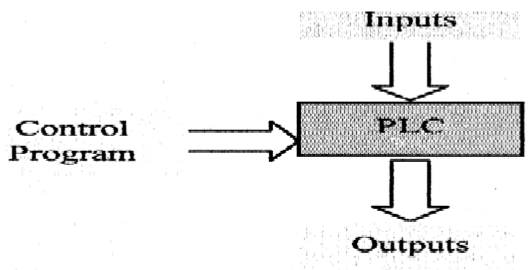


Figure 5.1: Control action of PLC

In our application, it controls through analog and digital inputs and outputs the varying load-constant speed operation of an induction motor. Also, the PLC continuously monitors the inputs and activates the outputs according to the control program. This PLC system is of modular type composed of specific hardware building blocks (modules), which plug directly into a proprietary bus: a central processor unit (CPU), a power supply unit, input-output modules I/O, and a program terminal. Such a modular approach has the advantage that the initial configuration can be expanded for other future applications such as multimachine systems or computer linking.PLC configuration is shown in table III

Table 5.1: PLC configuration

Make	Siemens PLC, S7-200 series CPU 224 with an analog expansion module
Operating voltage	24 V DC
Digital input	14
Digital output	10
Analog input	4
Analog output	1

5.1.1 Some major specifications of PLC

- Easily programmed and reprogrammed, preferably in-plant to alter its sequence of operations.
- Easily maintained and repaired preferably with plug-in modules.
- Capable of operation in a plant environment.
- Smaller than relay equivalent.
- Capable of communicating with central data collection system.
- Cost-competitive with solid-state and relay logic systems then in use.

5.2 Flow Chart of Speed Control Software

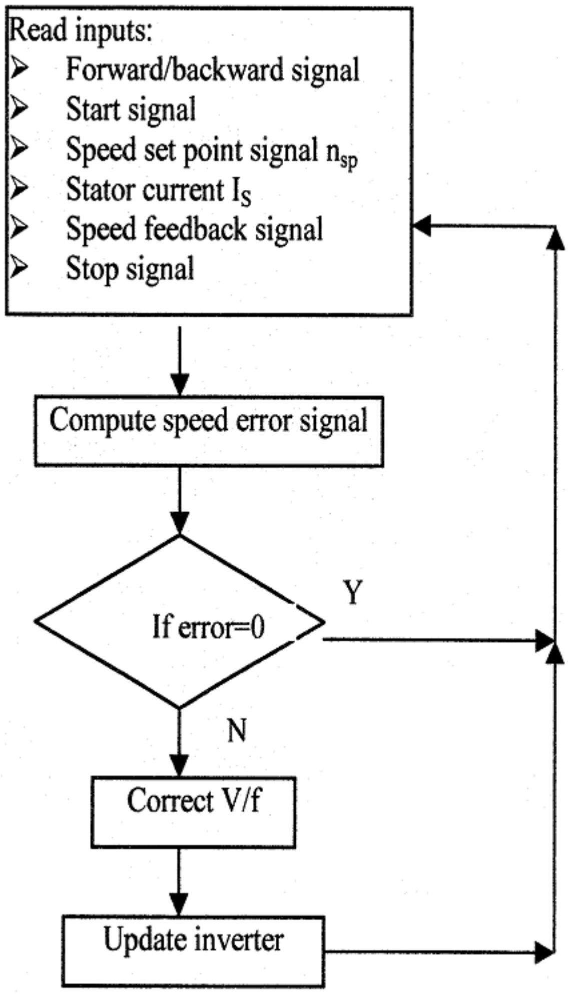


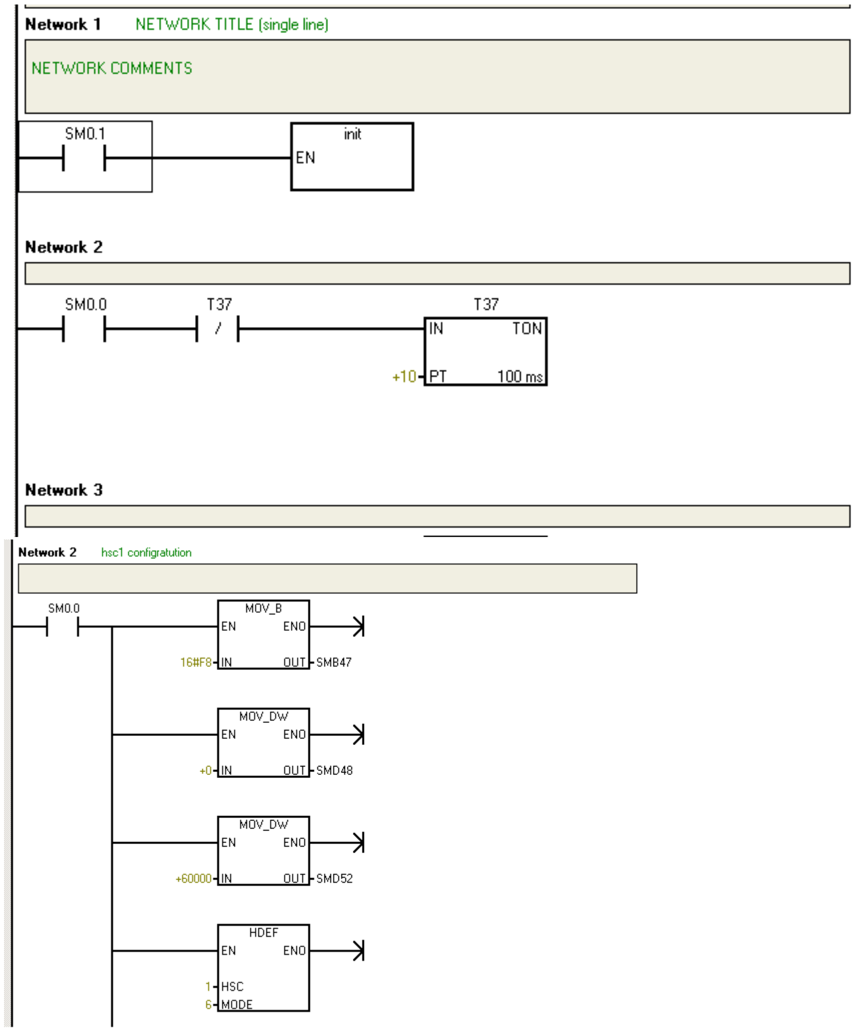
Figure 5.2: Flowchart of Speed Control Software

In Fig. 2, the flowchart of the speed control software is illustrated.The software regulates the speed and monitors the constant speed control regardless of load variation. The inverter being the power supply for the motor executes this while, at the same time, it is controlled by PLC's software. The inverter alone cannot keep the speed constant without the control loop with feedback and PLC. From the SCADA, the operator selects the speed setpoint and the forward/backward direction of rotation. Then, by pressing the start button, the motor begins the rotation. If the stop button is pushed, then the rotation stops. The corresponding input signals are interfaced to the DI and the output signals to the DO.

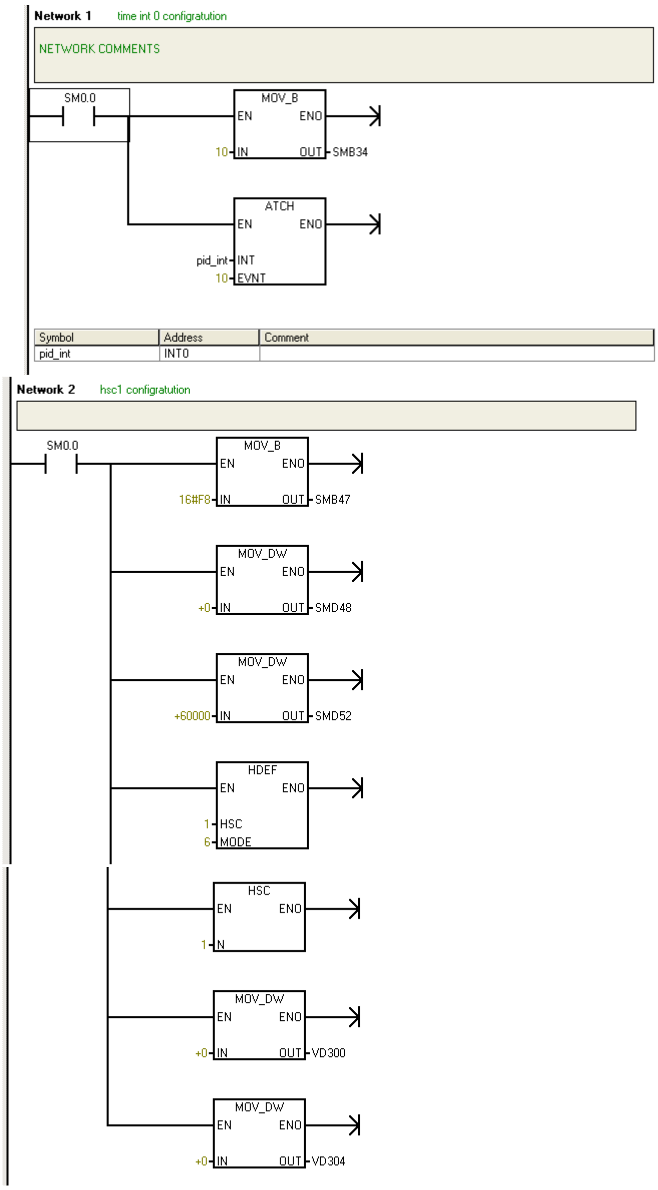
The AIM receives the speed feedback signal from the tachogenerator, and the signal from the control panel. In this way, the PLC reads the requested speed and the actual speed of the motor. The difference between the requested speed by the operator and the actual speed of the motor gives the error signal. If the error signal is not zero, but positive or negative, then the PLC according to the computations carried out by the CPU decreases or increases the of the inverter and, as a result, the speed of the motor is corrected The implemented control is of proportional and integral (PI) type (i.e., the error signal is multiplied by gain Kp , integrated, and added to the requested speed). As a result, the control signal is sent to the DOM and connected to the digital input of the inverter to control V/f variations. At the beginning, the operator selects the gain Kp by using SCADA programming and the AIM receives its voltage drop as controller gain signal (0-10 V). The requested speed is selected using SCADA programming and the AIM reads this signal. Its value is sent to the AOM and displayed at the control panel (speed set point display). Another display of the control panel shows the actual speed computed from the speed feedback signal

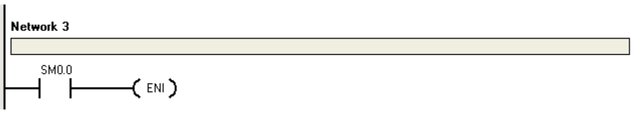
5.3 PLC programming

Ladder logic language is used in PLC programming.This program is download in S7-200 PLC via RS232 communication port.

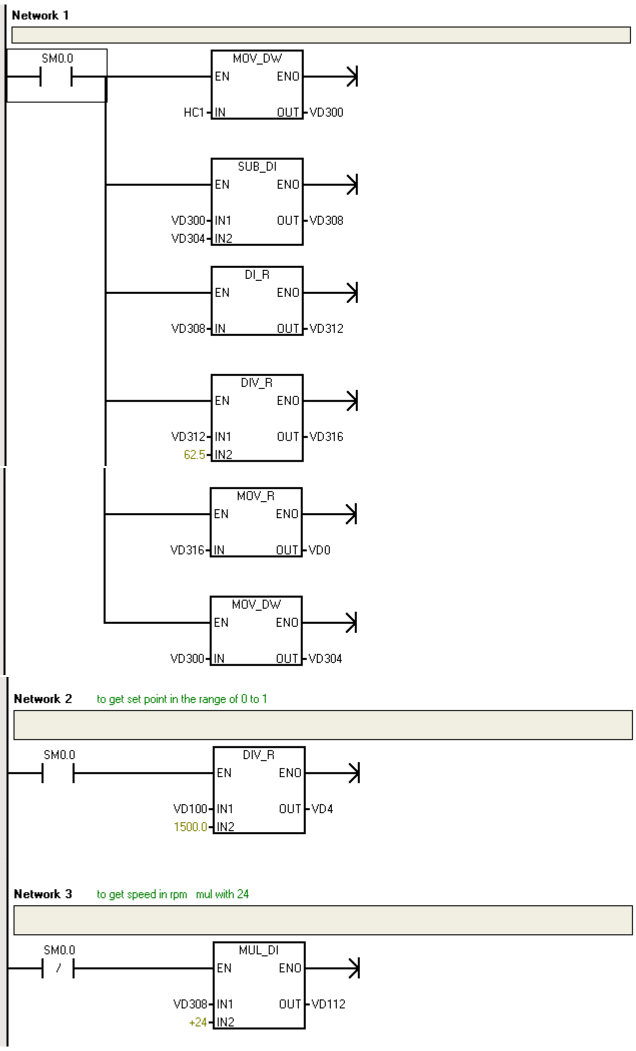


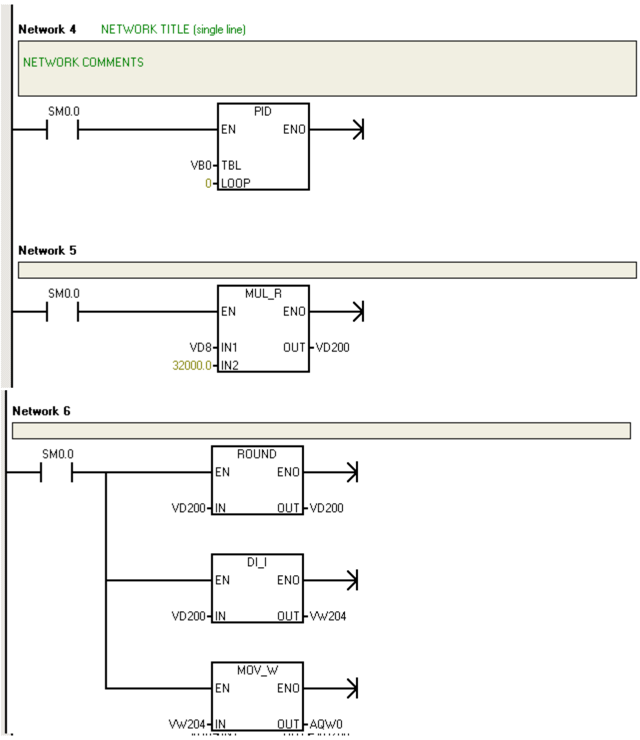
5.3.1 Subroutine





5.3.2 Intruupt Routine




Network 4
NETWORK TITLE (single line)
NETWORK COMMENTS
SM0.0
PID
EN
ENO
VB0
TBL
0
LOOP
Network 5
SM0.0
MUL_R
EN
ENO
VD8
IN1
OUT
VD200
32000.0
IN2
Network 6
SM0.0
ROUND
EN
ENO
VD200
IN
OUT
VD200
DI_I
EN
ENO
VD200
IN
OUT
VW204
MOV_W
EN
ENO
VW204
IN
OUT
AQW0

Chapter 6

SCADA

6.1 Supervisory Control And Data Acquisition(SCADA) system

SCADA stands for Supervisory Control And Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. As such, it is a purely software package that is positioned on top of hardware to which it is interfaced, in general via Programmable Logic Controllers (PLCs), or other commercial hardware modules. SCADA systems are used not only in most industrial processes: e.g. steel making, power generation (conventional and nuclear) and distribution, chemistry, but also in some experimental facilities such as nuclear fusion. The size of such plants range from a few 1000 to several 10 thousands input/output (I/O) channels.

6.2 Hardware architecture

One distinguishes two basic layers in a SCADA system: the "client layer" which caters for the man machine interaction and the "data server layer" which handles most of the process data control activities. The data servers communicate with devices in the field through process controllers. Process controllers, e.g. PLCs, are connected to the data servers either directly or via networks or fieldbuses that are proprietary (e.g.Siemens H1), or non-proprietary (e.g. Profibus). Data servers are connected to each other and to client stations via an Ethernet LAN.

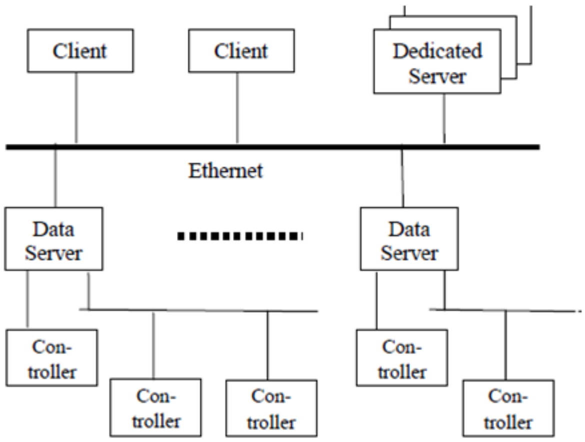


Figure 6.1: Hardware architecture

Many industrial and infrastructure-scale enterprises depend on equipment located at multiple sites dispersed over a large geographical area. A vast majority of large infrastructure and industrial-scale ventures use Supervisory Control and Data Acquisition (SCADA) systems. According to Newton-Evans, the power utility industry alone uses SCADA at more than 50SCADA systems provide monitoring, control, and automation functions that allow the enterprise to improve operational reliability, reduce costs through eased work force requirements, enhance overall Quality of Service (QoS), or meet expected QoS or other key performance factors as well as boost employee and customer safety.

6.3 Features of SCADA

1) Access Control Users are allocated to groups, which have defined read/write access privileges to the process parameters in the system and often also to specific

Table 6.1: SCADA specification

Make	Citech
single user	Trial version
Number of Tags	100
Facilities	Report, Alarm, Graphic display, Real-time trending

product functionality

2) Trending The products all provide trending facilities and one can summarise the common capabilities as follows:

• the parameters to be trended in a specific chart can be predefined or defined on-line

• a chart may contain more than 8 trended parameters or pens and an unlimited number of charts can be displayed
(restricted only by the readability)

• real-time and historical trending are possible, although generally not in the same chart

• historical trending is possible for any archived parameter

• zooming and scrolling functions are provided

• parameter values at the cursor position can be displayed

The trending feature is either provided as a separate module or as a graphical object (ActiveX), which can then be embedded into a synoptic display. XY and other statistical analysis plots are generally not provided.

3) Alarm Handling

Alarm handling is based on limit and status checking and performed in the data servers. More complicated expressions (using arithmetic or logical expressions) can be developed by creating derived parameters on which status or limit checking is then performed. The alarms are logically handled centrally, i.e., the information only exists in one place and all users see the same status (e.g., the acknowledgement), and multiple alarm priority levels (in general many more than 3 such levels) are supported.

4) Report Generation

One can produce reports using SQL type queries to the archive, RTDB(real time database) or logs. Although it is sometimes possible to embed EXCEL charts in the report, a "cut and paste" capability is in general not provided. Facilities exist to be able to automatically generate, print and archive reports.

6.4 The General Block Diagram For the VFD,PLC and SCADA Hardware Interfacing System:-

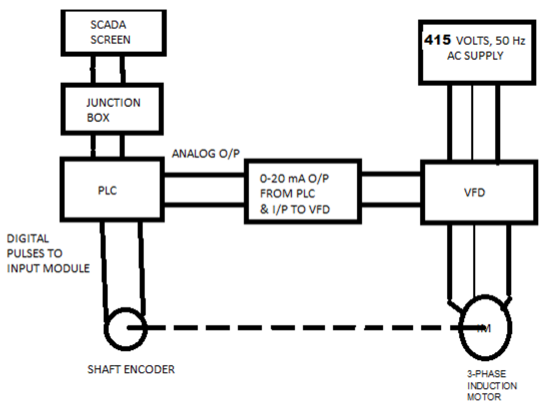


Figure 6.2: Block diagram of VFD,PLC and SCADA hardware interfacing system

The diagram shown above is the general diagram of the entire system. Here the actual set speed of the motor is 1440 RPM. Which is stored in one of the "V memory register." Let us say VW100. Now PLC is providing an output in the form of 0-20 mA. Hence when the output of PLC is 20 mA at that time the speed of the motor is 1440 RPM. If the output of the PLC is 10 mA, then the speed of the induction motor will be 720 RPM. Hence In this manner the scaling of the motor's speed w.r.t the o/p of the PLC current is done. Now the feedback is taken from the shaft encoder. It provides an o/p In the form of train of pulses. Now these pulses are given to digital input module of the PLC. As the train of pulses are act as a digital input signal. Now these pulses are connected with say I0.7th bit of the digital input module. Now by while building the logic diagram we have to use "HIGH SPEED COUNTER". The High Speed Counter is made to use only this kind inputs. Like counting of pulses coming from the shaft encoder which are approximately 24-25 pulses coming per second. And hence the contact of I0.7th bit will be directly connected to the High Speed Counter. Hence now with help of this counting we can derive that what is the actual speed of the motor at any instant of time. Now the set speed is defined in the register of the PLC memory that was VW100. It is a 16 bit memory address. Now the pulses taken from the shaft encoder is now converted in the form of the RPM by developing the logic in PLC that will be stored in the VW110. The difference occurs in a speed of set speed and actual speed will be given to the built in PID controller in PLC and hence PID controller will take necessary action to reduce that error.

Now PLC is having the built in PID controller. In this PID controller following settings should be done.

• We have to configure PID loop first of all. It is having a value of 0 to 7, among this value we can select any loop number according to the requirement.

• Loop set point scaling is done.(i.e. 0-100)

• Loop parameters setting will be done. (i.e. loop gain, sample time, integral time, derivative time should be mentioned.)

• Loop input options should be configure. (i.e. low range(0) and high range (32000) is set.)

• Loop output options should be configure. (i.e. output type(analog), scaling i.e. low range(0) and high range (32000) is set.)

• Now the PID loop is configured, now the output from the PID loop will be stored in specified address set by the user. So let us give an address VW204.

• Hence VW204 will have the counts starts from 0 to 32000. Will be given directly to the analog output module. Now these counts are the output of the PID controller. Which will be given to the VFD. Now VFD will vary its speed according to the output data of the PID controller.

6.5 Monitoring Energy Meter Data on SCADA Screen

The SCADA is always used to monitor the different types of functions, variables quantities which are varying in the process field. The data of the variable quantities and different functions can be directly shown on the computer screen by using SCADA. SCADA systems are normally placed in the control room. By defining or configuring different kind of variable tags with the I/O addresses defined in PLC memory we can visualise the exact condition of any variable during that time. SCADA provides the facility to provide an input directly from the SCADA screen. It means that from SCADA screen you can give the input/set point to the control element. To gather the data from the field by sitting in the control room itself we can retrieve all the field data..hence SCADA performs very useful operation.

6.5.1 Harware Interfacing of SCADA , PLC and Energymeter

• To make an interface of PLC and SCADA, we have to connect a Multi-Master Cable. In this communication, PLC is supporting RS 485 port and SCADA which is inside the PC, hence PC is supporting the RS 232 port.
• Normally in this kind of conditions when both ports of the two communication systems are different at that time to make possible a communication possible between these two we have to use "JUNCTION BOX".
• With the help of junction box like RS232/RS485, we can easily send and receive

the data from and to both the systems.

• The energy metering system under test was connected to a three phase induction motor (load) through CTs. The energy consumption pattern of the motor (load) is accessed by the meter and data is acquired in SCADA system using SCADA software (Citech) through RS485 to RS232 converter. The modbus communication protocol of energy meter is utilized for transfer data from energy meter. The presentation of data are made in SCADA system. The necessary LADDER programming is done by PLC software (Step 7 Microwin) to control the operation of load from SCADA. PLC has a Ethernet communication with SCADA

• The SCADA based energy monitoring system developed in the present work comprises of following devices.

• In this system Energy meter work as Slave and SCADA work as Master

" **Master:** A device that is a master on a network can initiate a request to another device on the network. A master can also respond to requests from other masters on the network. Typical master devices include STEP 7–Micro/WIN, human-machine interface devices such as a TD 200, and S7-300 or S7-400 PLCs. The S7-200 functions as a master when it is requesting information from another S7-200 (peer-to-peer communications).

" **Slave:** A device that is configured as a slave can only respond to requests from a master device; a slave never initiates a request. For most networks, the S7-200 functions as a slave. As a slave device, the S7-200 responds to requests from a network master device, such as an operator panel or STEP 7–Micro/WIN.

Communication Detail of Energymeter

- Protocol : MODBUS

- Mode : RTU
- The Character Format : A) 1 Start bit

B) 8 Data bits

C) Even Parity bits

D) 1 Stop bit

- Baud Rate : 9600 Bits / Sec.

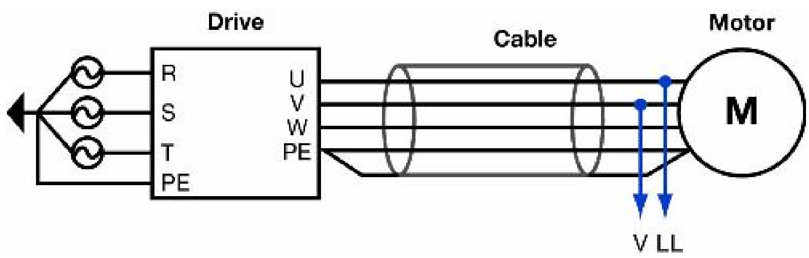
  - Public Functions Supported:

A) 01h = Read Coils

B) 03h = Read Holding Register

Chapter 7

Effect of Cable Length on Operation of 3-Phase Induction Motor While Used with VFD



VFDs offer many benefits; principal among them the ability to save a substantial amount of energy during motor operation. Other benefits include the ability to:

- maintain torque at levels to match the needs of the load
- improve process control
- reduce mechanical stress on 3-phase induction motors by providing a "soft start"
- improve an electrical system's power factor

The way in which VFD-based systems are constructed and operated will have an impact on both the longevity and reliability of all the components of the system, as well as nearby or adjacent systems. This article focuses on the motor-supply cable in the VFD/motor system. It looks at some fundamental cable design considerations, and presents suggestions for installation.

7.1 Evalution of Cable Types Used for VFDs

The most commonly recommended cables for VFD applications have been studied by Belden, in both a lab and a working application. [1]
An exception to this exclusion was the use of PVC-Nylon insulated, PVC jacketed tray cables. These cables are the most commonly installed type of industrial control cable, and though they are often misapplied for use in VFD applications, they were included in the tests for purposes of comparison.
In the testing, the following five cable designs were evaluated:
XLPE (cross-linked polyethylene) insulated, foil/braid (85XLPE insulated, dual-copper tape shielded, Industrial PVC jacketed cable designed for VFD applications (600V Rated)
XLPE insulated, continuously welded aluminum armored, Industrial PVC jacketed cable designed for VFD applications (600V MC Rating)
PVC-Nylon/PVC Type TC (unshielded)
PVC-Nylon/PVC Foil Shield Type TC
The cables investigated were used to interconnect a VFD to the AC motor. All testing was conducted using a current generation, IGBT-based, 480VAC, 5HP VFD, an inverter-duty rated AC motor, and relevant lab equipment, such as an oscilloscope to make voltage measurements.

7.2 Impact of Cable Design on Motor and Cable Life

Reflected waves caused by a cable-to-motor impedance mismatch are prevalent in all AC VFD applications. The magnitude of the problem depends on the length of the cable, the rise-time of the PWM (pulse width modulated) carrier wave, the voltage of the VFD, and the magnitude of the impedance difference between the motor and cable.

Under the right conditions, a pulse from the VFD can add to a pulse reflected back from the motor resulting in a doubling of voltage level, which could damage the cable or the components inside the drive. A solution is the use of XLPE cable insulation, a material with high impulse voltage breakdown levels. This makes the system more immune to failure from reflected wave and voltage spikes in a VFD application than a PVC material which is not recommended in these applications.

The impedance of the cable relative to the motor will be the primary mechanism outlined in this article. This is done because cable length is mostly determined by the layout of the application, rise times vary with the VFD output semiconductor and the voltage of the VFD is determined by the application.

Estimated motor impedance relative to motor size in HP over a range of horsepower ratings, as indicated in Figure 2. Note that the cable impedance for 1HP motor/drive combinations would need to be roughly 1,000 ohms to match the corresponding motor's impedance. Unfortunately, a cable with such high characteristic impedance would require conductor spacing in excess of several feet. Obviously, this would be both impractical and very expensive.

In addition to other benefits, such as reduced capacitance, a more closely matched impedance can improve motor life. Table 1 lists the observed line-to-line peak motor terminal voltages, as well as the impedance of the cables under test. The voltage measurements were taken using 120 ft. cable lengths.

Table 1 shows typical impedance values for 12 AWG circuit conductors and is based

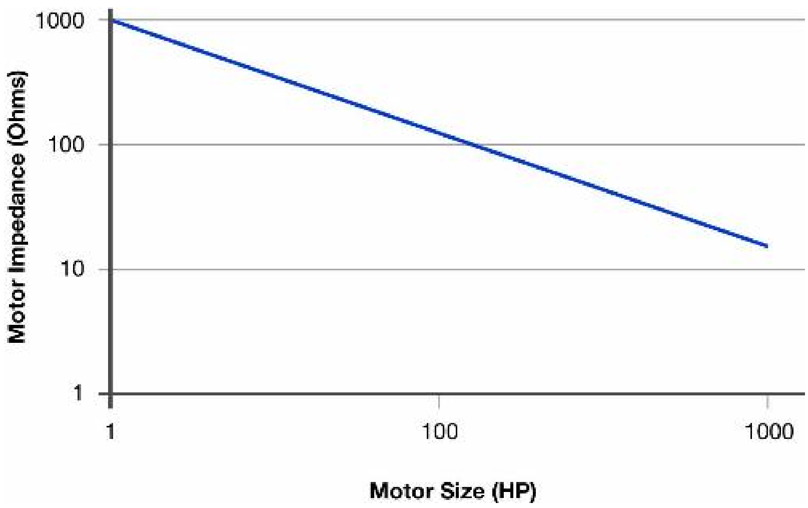


Figure 7.1: Motor Impedance relative to Motor size

on actual data. Cable impedance is influenced both by its geometry and materials used in its manufacture. The characteristic impedance of a cable is calculated using the following formula, where Zc = characteristic impedance, L = cable inductance, and C = cable capacitance: Zc = vL / C

Table 7.1: Impedance impact on Motor terminal voltage using 120ft of cable

Cable Type	Impedance(Ohm)	Voltage at Motor Terminal
Continuous Aluminum Armored Cable	87	1080 V
Belden Foil/Braid VFD cable 2950X series	78	1110 V
Cu-Tape Shielded Belden VFD cable	58	1150V
Unshielded PVC -Ny/PVC	58	1150 V
Shielded PVC-Ny/PVC	38	1150 V

Also in Table 1, note the inversely proportional relationship between the cable's impedance and the peak motor terminal voltage: cables with higher impedance tended to result in lower peak motor terminal voltages. A cable's design for impedance also impacts its useful life. Lower voltages across the motor terminals translate into the cable being exposed to lower voltages, increasing its life expectancy.

In addition, this reduces the likelihood of either the cable or the motor reaching its corona inception voltage (CIV). That's the point at which the air gap between two conductors in the cable, or two windings on the motor, breaks down via‘ arcing or a spark under the high potential difference. If the CIV is reached, insulation failure can occur in the windings of the motor. Corona discharge occurring between conductors of the cable can produce very high temperatures. If the insulation system of the cable is a thermoplastic material such as PVC, the phenomenon can cause premature cable burn-out or a short circuit due to a gradual, localized melting of the insulation. For this reason alone, thermoplastic insulations should not be used for VFD applications. On the other hand, thermoset insulation systems such as those based on XLPE are ideal materials for these applications because of the high temperature stability they exhibit. In their case, the heat generated from corona forms a thermally-isolating charred layer on the surface of the insulation, preventing further degradation. All cables used for VFDs should use a thermoset insulation system as a precautionary measure.

7.3 Understanding Radiated Noise in VFD Application

Noise radiated from a VFD cable is proportional to the amount of varying electric current within it. As cable lengths grow, so does the magnitude of reflected voltage. This transient over voltage, combined with the high amplitudes of current associated with VFDs, creates a significant source of radiated noise. By shielding the VFD cable, the noise can be controlled.

In the tests presented in this paper, relative shielding effectiveness was observed by noting the magnitude of noise coupled to 10 ft. of parallel unshielded instrumentation cable for each VFD cable type examined. The results of the shielding effectiveness testing are documented in Figure 7.2

As demonstrated by its trace in that figure, foil shields are simply not robust enough

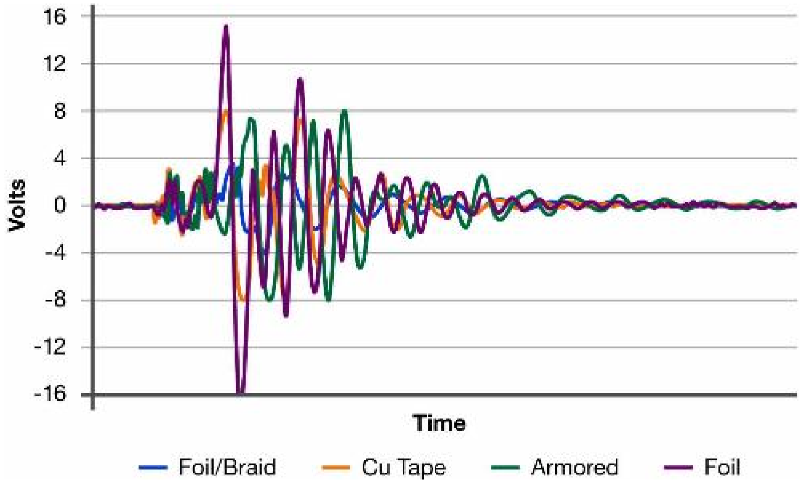


Figure 7.2: Noise Coupled from VFD cable to unshielded instrumentation

to capture the volume of noise generated by VFDs. Unshielded cables connected between a VFD and a motor can radiate noise in excess of 80V to unshielded communication wires/cables, and in excess of 10V to shielded instrumentation cables. Moreover, the use of unshielded cables in conduits should be limited, as the conduit is an uncontrolled path to ground for the noise it captures.

Any equipment in the vicinity of the conduit or conduit hangers may be subject to an injection of this captured, common-mode noise. Therefore, unshielded cables in conduit are also not a recommended method for connecting VFDs to motors. If radiated noise is an issue in an existing VFD installation, care should be taken when routing instrumentation/control cables in the surrounding area. Maintain as much separation as possible between such cables and VFD cables/leads. A minimum of one foot separation for shielded instrumentation cables, and three feet for unshielded instrumentation cables, is recommended. If the cables must cross paths, try to minimize the amount of parallel runs, preferably crossing the instrument cable perpendicularly with the power/VFD cable.

If noise issues persist after these precautions are taken, use a non-metallic, verticaltray flame rated fiber optic cable and media-converters or direct-connect fiber communication equipment for the instrumentation circuit. Other mitigation techniques may also be required, such as, but not limited to, use of band-pass filters/chokes, output reactors, motor terminators, and metallic barriers in cable trays or raceways.

7.4 Impact of Common Mode Noise in VFD Application

Radiated noise from a VFD cable is a source of interference with adjacent systems that is often easier to identify and rectify than common mode noise. In the latter, high levels of noise across a broad frequency range, often from 60 Hz to 30 MHz, can capacitatively couple from the windings of the motor to the motor frame, and then to ground.

Common-mode noise can also capacitatively couple from unshielded motor leads in a conduit to ground via conduit ground straps, supports or other adjacent, unintentional grounding paths. This common-mode ground current is particularly troublesome because digital systems are susceptible to the high-frequency noise generated by VFDs. Signals susceptible to common-mode noise include those from proximity sensors, and signals from thermocouples or encoders, as well as low-level communication signals in general. Because this type of noise takes the path of least resistance, it finds unpredictable grounding paths that become intermittent as humidity, temperature, and load change over time.

One way to control common-mode noise is to provide a known path to ground for noise captured at the motor's frame. A low-impedance path, such as a properly designed cable ground/shield system, can provide the noise with an easier way to get back to the drive than using the building ground grid, steel, equipment, etc.

In the study presented here, tests were conducted on the five cable types to deter-

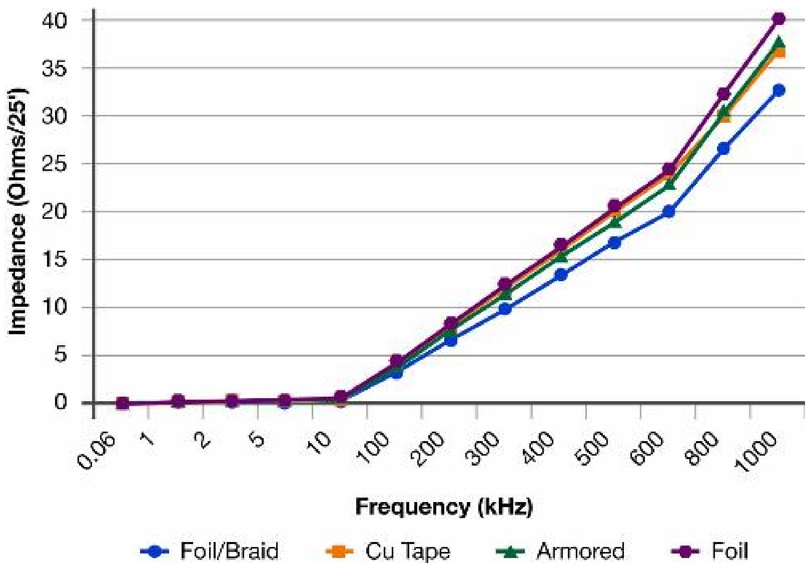


Figure 7.3: Impedance Vs Broad frequency spectrum

mine the ground path impedance of the shield and grounding system of each cable. The tests were conducted across a broad frequency spectrum. Results are outlined in Fig7.3 Lower impedance implies a more robust ground path, and therefore relatively lower noise coupled to the building ground.

From fig Foil/Braid is most appropriate for VFD application compared to other four type cable because of the low impedance path they provide for common-mode noise to return to the drive.

Lower building ground noise means a reduced need for troubleshooting of nearby adjacent systems and components.

Cable Selection Is Key to VFD Performance and Reliability

From this testing we can conclude that a cable should never be the weak link in a VFD system. The cable must be able to stand up to the operating conditions, and maintain the life of other components in the system. Selecting an appropriate VFD cable can improve overall drive system longevity and reliability by mitigating the impact of reflected waves.

Chapter 8

Results

8.1 Experimental Results

The system was tested during operation with varying loads including tests on induction motor speed control performance. The PLC monitors the motor operation and correlates the parameters according to the software. At the beginning, for reference purposes, the performance of induction motor supplied from a standard 415 V, 50-Hz network is measured. Then, the experimental control system is operated between no load and full load in the two different modes.

a) induction motor fed by the inverter and with PLC control;

b) induction motor fed by the inverter.

The results show that configuration b) operates with varying speed-varying load torque characteristics for different speed setpoints as shown in fig 8.1 and fig 8.3 .Configuration a) operates with constant-speed-varying load characteristics in the speed range 01400 r/min and 0100 percentage loads as shown in fig.8.2 and fig. 8.4. However, in the range of speeds higher than 1400 r/min and loads higher than 70 percentage, the system operates with varying-speed-varying-load and the constant speed was not possible to be kept. This fact shows that PI control for constant speed as implemented by the software with PLC is effective at speeds lower than 93 percentage of the synchronous.

8.1.1 Control Without PID Tuning

Generator Voltage=230 V

Rated Current=2.1 A

Frequency Setpoint=30Hz

Speed Setpoint(rpm)	Voltage (volts)	Current (A)	Percentage Loading of Genrator	Percentage Loading of Motor	Actual speed (rpm)
900	104.6	0.43	9.3122	8.3809	889.5
900	102.8	0.62	13.1958	11.8762	885.1
900	98.3	1.07	21.7766	19.5989	877.4
900	94.6	1.43	28.6078	25.7470	868.2
900	90.8	1.8	33.838	30.4542	855.5

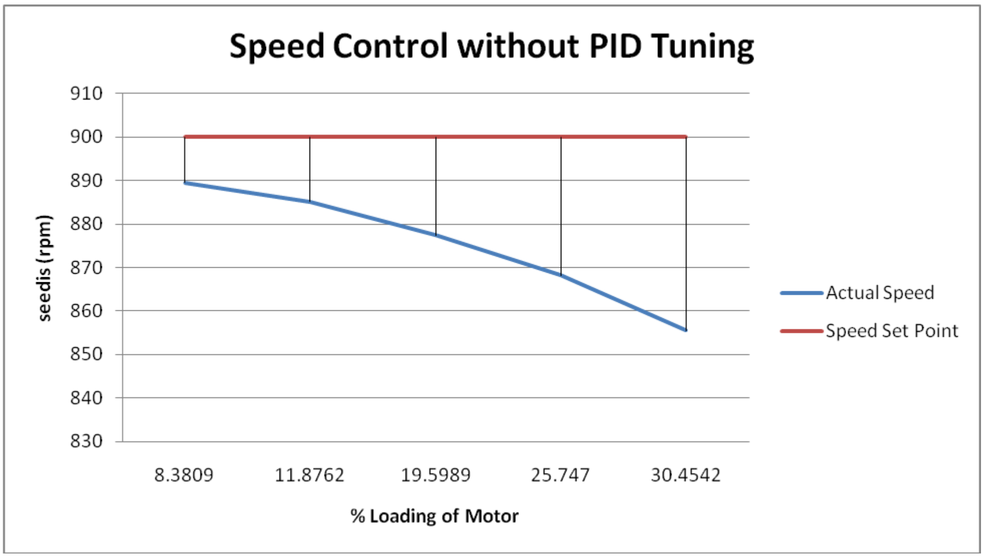


Figure 8.1: Control Without PID Tuning at Speed Setpoint 900rpm

8.1.2 Control With PID Tuning

Speed Setpoint(rpm)	Voltage (volts)	Current (A)	Percentage Loading of Genrator	Percentage Loading of Motor	Actual speed (rpm)
900	106.9	0.43	9.5169	8.5652	900
900	105.2	0.62	13.7217	12.3495	900
900	101.5	1.10	23.1159	20.8042	900
900	98.6	1.48	30.2128	27.1952	900
900	95.4	1.89	37.330	33.597	900

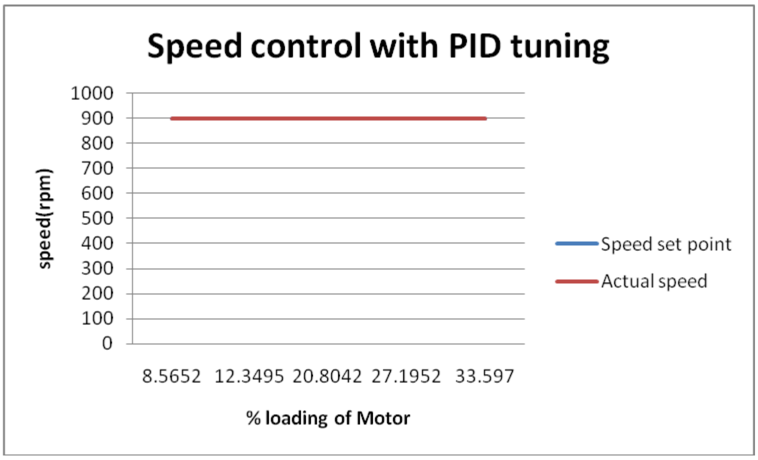


Figure 8.2: Control With PID Tuning at Speed Setpoint 900rpm

8.1.3 Control Without PID Tuning

speed setpoint=40Hz

Speed Setpoint(rpm)	Voltage (volts)	Current (A)	Percentage Loading of Genrator	Percentage Loading of Motor	Actual speed (rpm)
1200	141.1	0.58	16.9436	15.2493	1186
1200	139.4	0.84	24.2434	21.8192	1180
1200	128	1.45	38.4265	34.5839	1162
1200	127.5	1.92	50.6832	45.6149	1152

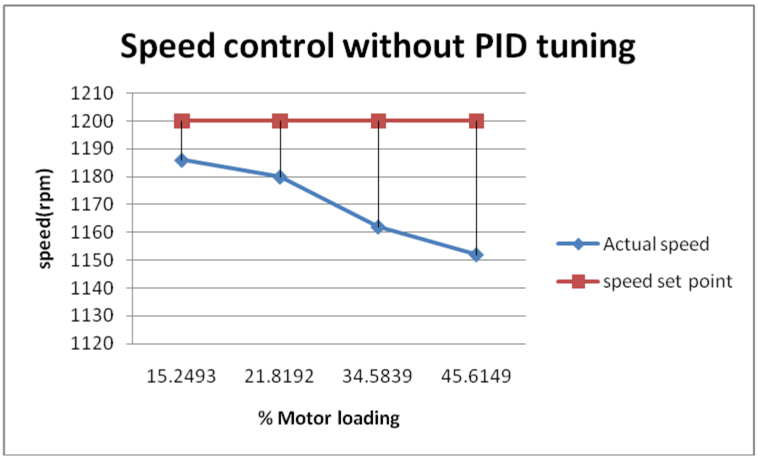


Figure 8.3: Control Without PID Tuning at Speed Setpoint 1200rpm

8.1.4 Control With PID Tuning

Speed Setpoint(rpm)	Voltage (volts)	Current (A)	Percentage Loading of Genrator	Percentage Loading of Motor	Actual speed (rpm)
1200	142.4	0.58	17.0997	15.3898	1200
1200	139.8	0.85	24.6024	22.1422	1200
1200	136.3	1.48	41.7648	37.5883	1200
1200	131.6	1.98	53.9478	48.5530	1200

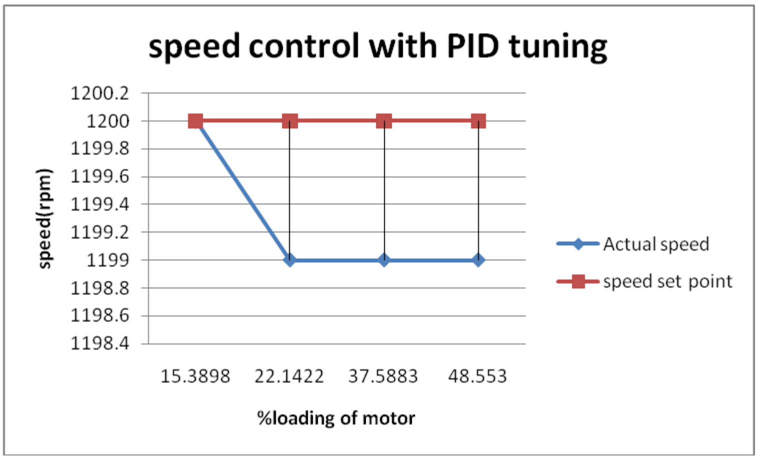


Figure 8.4: Control with PID Tuning at Speed setpoint 1200rpm

8.2 Result on SCADA Screen

Speed setpoint=900rpm Speed setpoint =1200rpm

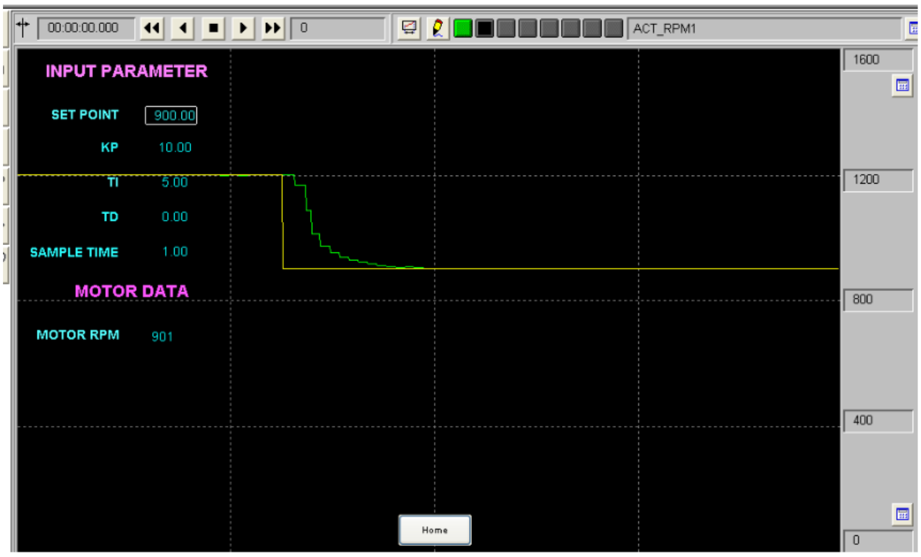


Figure 8.5: Speed control with PID tuning at speed set Pt.900rpm

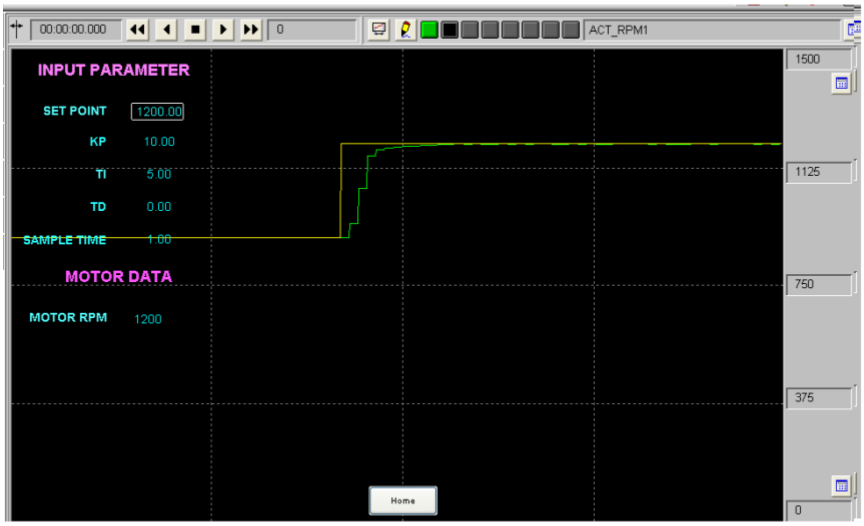
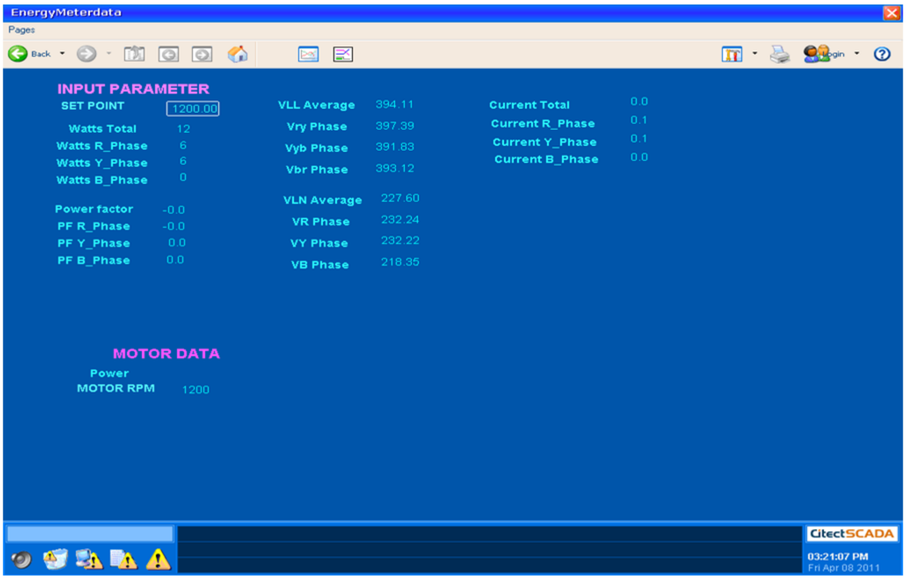
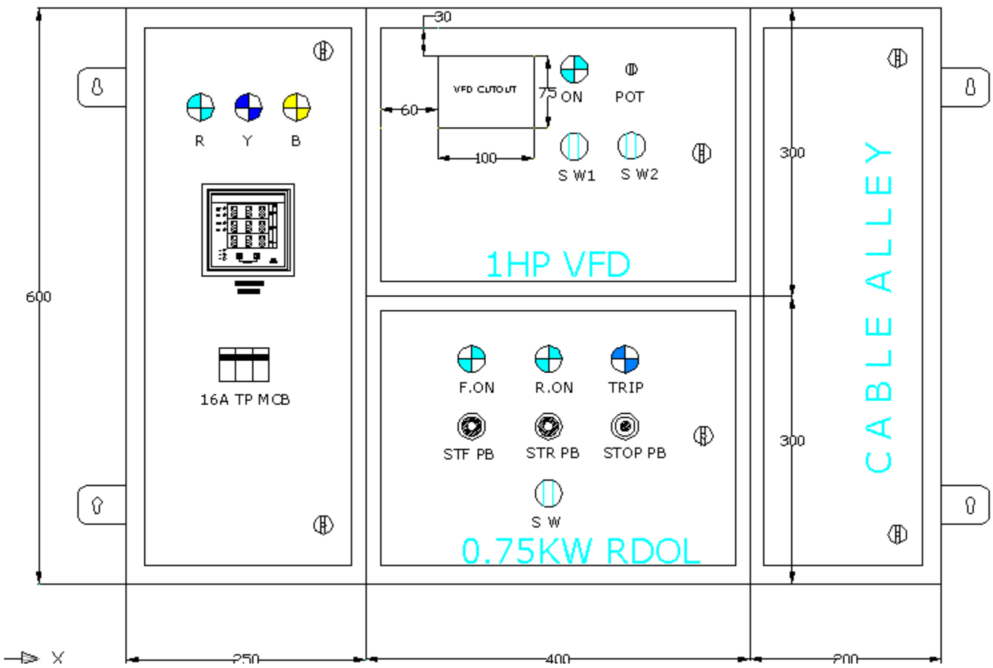


Figure 8.6: Speed control with PID tuning at speed set Pt.1200rpm

8.3 Monitoring Data on SCADA Screen



8.3.1 General arrangement diagram



8.4 Views of Panel

Figure 8.7: VFD view

Figure 8.8: Complete panel body

Chapter 9

Conclusion

9.1 Conclusion

With the use of PLC, motor speed is kept constant irrespective of loading condition. Here in the PLC program, PID controller is implemented and speed error remains zero. With the use of PLC external hardware required for PID control is eliminated. In addition to this it helps to automate the process for better stability and easy control. Despite the simplicity of the speed control method used, this system presents:

- constant speed for changes in load torque;
- full torque available over a wider speed range;
- very good accuracy in closed-loop speed control scheme;
- higher efficiency;
- overload protection.

Thus, the PLC proved to be a versatile and efficient control tool in industrial electric drives applications.

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Appendix A

Introduction of FR-E500 series Mitsubishi VFD

Parameter Number	Name	Application
1	Maximum frequency	Used to set the maximum and minimum output frequencies.
2	Minimum frequency	
7	Acceleration time	Used to set the acceleration and deceleration times.
8	Deceleration time	
9	Electronic thermal O/L relay	Used to set the current of the electronic overcurrent protection to protect the motor from overheat.
14	Load pattern selection	Used to select the optimum output characteristics which match the application and load characteristics.
71	Applied motor	Used to set the thermal characteristics of the electronic overcurrent protection according to the motor used.
73	0-5V/0-10V selection	Used to select the specifications of the frequency setting signal entered across terminal 2-5 to perform operation with the voltage input signal.
900	FM terminal calibration	Used to calibrate the meter connected across terminals FM-SD.
901	AM terminal calibration	Used to calibrate the meter connected across terminals AM-5.
902	Frequency setting voltage bias	Used to set the magnitude (slope) of the output frequency relative to the frequency setting signal (0 to 5V, 0 to 10V or 4 to 20mA DC) as desired.
903	Frequency setting voltage gain	
904	Frequency setting current bias	
905	Frequency setting current gain	

Function	Parameter Number	Name	Setting Range	Minimum Setting Increments	Factory Setting	Refer To:	Customer Setting
Basic functions	0	Torque boost (Note 1)	0 to 30%	0.1%	6%/4% (Note 11)	72	
	1	Maximum frequency	0 to 120Hz	0.01Hz (Note 3)	120Hz	73	
	2	Minimum frequency	0 to 120Hz	0.01Hz (Note 3)	0Hz	73	
	3	Base frequency (Note 1)	0 to 400Hz	0.01Hz (Note 3)	60Hz	74	
	4	Multi-speed setting (high speed)	0 to 400Hz	0.01Hz (Note 3)	60Hz	75	
	5	Multi-speed setting (middle speed)	0 to 400Hz	0.01Hz (Note 3)	30Hz	75	
	6	Multi-speed setting (low speed)	0 to 400Hz	0.01Hz (Note 3)	10Hz	75	
	7	Acceleration time	0 to 3600 s/ 0 to 360 s	0.1 s/0.01 s	5 s/10s (Note 4)	76	
	8	Deceleration time	0 to 3600 s/ 0 to 360 s	0.1 s/0.01 s	5 s/10s (Note 4)	76	
	9	Electronic thermal O/L relay	0 to 500A	0.01A	Rated output current (Note 5)	78	
Standard operation functions	10	DC injection brake operation frequency	0 to 120Hz	0.01Hz (Note 3)	3Hz	79	
	11	DC injection brake operation time	0 to 10 s	0.1 s	0.5 s	79	
	12	DC injection brake voltage	0 to 30%	0.1%	6%	79	
	13	Starting frequency	0 to 60Hz	0.01Hz	0.5Hz	80	
	14	Load pattern selection (Note 1)	0 to 3	1	0	81	
	15	Jog frequency	0 to 400Hz	0.01Hz (Note 3)	5Hz	82	
	16	Jog acceleration/ deceleration time	0 to 3600 s/ 0 to 360 s	0.1 s/0.01 s	0.5 s	82	
	18	High-speed maximum frequency	120 to 400Hz	0.1Hz (Note 3)	120Hz	73	
	19	Base frequency voltage (Note 1)	0 to 1000V, 8888,9999	0.1V	9999	74	
	20	Acceleration/deceleration reference frequency	1 to 400Hz	0.01Hz (Note 3)	60Hz	76	
	21	Acceleration/deceleration time increments	0, 1	1	0	76	
	22	Stall prevention operation level	0 to 200%	0.1%	150%	83	
	23	Stall prevention operation level compensation factor at double speed (Note 6)	0 to 200%, 9999	0.1%	9999	83	
	24	Multi-speed setting (speed 4)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	25	Multi-speed setting (speed 5)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	26	Multi-speed setting (speed 6)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	27	Multi-speed setting (speed 7)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	

Function	Parameter Number	Name	Setting Range	Minimum Setting Increments	Factory Setting	Refer To:	Customer Setting
Standard operation functions	29	Acceleration/deceleration pattern	0, 1, 2	1	0	85	
	30	Regenerative function selection	0, 1	1	0	86	
	31	Frequency jump 1A	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	32	Frequency jump 1B	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	33	Frequency jump 2A	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	34	Frequency jump 2B	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	35	Frequency jump 3A	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	36	Frequency jump 3B	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	87	
	37	Speed display	0, 0.01 to 9998	0.001 r/min	0	88	
	38	Frequency at 5V (10V) input	1 to 400Hz	0.01Hz (Note 3)	60Hz (Note 2)	89	
	39	Frequency at 20mA input	1 to 400Hz	0.01Hz (Note 3)	60Hz (Note 2)	89	
Output terminal functions	41	Up-to-frequency sensitivity	0 to 100%	0.1%	10%	90	
	42	Output frequency detection	0 to 400Hz	0.01Hz (Note 3)	6Hz	90	
	43	Output frequency detection for reverse rotation	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	90	
Second functions	44	Second acceleration/deceleration time	0 to 3600 s/ 0 to 360 s	0.1 s/0.01 s	5s/10s (Note 12)	76	
	45	Second deceleration time	0 to 3600 s/ 0 to 360 s, 9999	0.1 s/0.01 s	9999	76	
	46	Second torque boost (Note 1)	0 to 30%, 9999	0.1%	9999	72	
	47	Second V/F (base frequency) (Note 1)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	74	
	48	Second electronic overcurrent protection	0 to 500A, 9999	0.01A	9999	78	
Display functions	52	Control panel/PU main display data selection	0, 23, 100	1	0	92	
	54	FM terminal function selection (Note 9)	0, 1, 2	1	0	92	
	55	Frequency monitoring reference	0 to 400Hz	0.01Hz (Note 3)	60Hz	94	
	56	Current monitoring reference	0 to 500A	0.01A	Rated output current	94	
Automatic restart functions	57	Restart coasting time	0 to 5 s, 9999	0.1 s	9999	95	
	58	Restart cushion time	0 to 60 s	0.1 s	1.0 s	95	

Function	Parameter Number	Name	Setting Range	Minimum Setting Increments	Factory Setting	Refer To:	Customer Setting
Additional function	59	Remote setting function selection	0, 1, 2	1	0	97	
Operation selection functions	60	Shortest acceleration/ deceleration mode	0, 1, 2, 11, 12	1	0	99	
	61	Reference I for intelligent mode	0 to 500A, 9999	0.01A	9999	99	
	62	Ref. I for intelligent mode accel	0 to 200%, 9999	1%	9999	99	
	63	Ref. I for intelligent mode decel	0 to 200%, 9999	1%	9999	99	
	65	Retry selection	0, 1, 2, 3	1	0	101	
	66	Stall prevention operation level reduction starting frequency (Note 6)	0 to 400Hz	0.01Hz (Note 3)	60Hz	83	
	67	Number of retries at alarm occurrence	0 to 10, 101 to 110	1	0	101	
	68	Retry waiting time	0.1 to 360 s	0.1 s	1 s	101	
	69	Retry count display erasure	0	1	0	101	
	70	Special regenerative brake duty	0 to 30%	0.1%	0%	86	
	71	Applied motor (Note 6)	0, 1, 3, 5, 6, 13, 15, 16, 23, 100, 101, 103, 105, 106, 113, 115, 116, 123	1	0	103	
	72	PWM frequency selection	0 to 15	1	1	104	
	73	0-5V/0-10V selection	0, 1	1	0	105	
	74	Filter time constant	0 to 8	1	1	106	
	75	Reset selection/ disconnected PU detection/ PU stop selection	0 to 3,14 to 17	1	14	106	
	77	Parameter write disable selection	0, 1, 2	1	0	108	
	78	Reverse rotation prevention selection	0, 1, 2	1	0	109	
	79	Operation mode selection (Note 6)	0 to 4,6 to 8	1	0	110	
General-purpose Magneticflux vector control	80	Motor capacity (Note 6)	0.1 to 7.5kW, 9999 (Note 8)	0.01kW	9999	113	
	82	Motor exciting current	0 to 500A, 9999	0.01A	9999	115	
	83	Rated motor voltage (Note 6)	0 to 1000V	0.1V	200V/ 400V	115	
	84	Rated motor frequency (Note 6)	50 to 120Hz	0.01Hz (Note 3)	60Hz	115	
	90	Motor constant (R1)	0 to 50Ω, 9999	0.001Ω	9999	115	
	96	Auto-tuning setting/status (Note 6)	0, 1	1	0	115	

Function	Parameter Number	Name	Setting Range	Minimum Setting Increments	Factory Setting	Refer To:	Customer Setting
Communication functions	117	Station number	0 to 31	1	0	121	
	118	Communication speed	48, 96, 192	1	192	121	
	119	Stop bit length	0, 1 (data length 8) 10, 11 (data length 7)	1	1	121	
	120	Parity check presence/absence	0, 1, 2	1	2	121	
	121	Number of communication retries	0 to 10, 9999	1	1	121	
	122	Communication check time interval	0, 0.1 to 999.8 s, 9999	0.1 s	9999	121	
	123	Waiting time setting	0 to 150, 9999	1	9999	121	
	124	CR·LF presence/absence selection	0, 1, 2	1	1	121	
PID control	128	PID action selection	0, 20, 21	1	0	134	
	129	PID proportional band	0.1 to 1000%, 9999	0.1%	100%	134	
	130	PID integral time	0.1 to 3600 s, 9999	0.1 s	1 s	134	
	131	Upper limit	0 to 100%, 9999	0.1%	9999	134	
	132	Lower limit	0 to 100%, 9999	0.1%	9999	134	
	133	PID action set point for PU operation	0 to 100%	0.01%	0%	134	
	134	PID differential time	0.01 to 10.00 s, 9999	0.01 s	9999	134	
Additional function	145	Parameter for option (FR-PU04).					
	146	Parameter set by manufacturer. Do not set.					
Current detection	150	Output current detection level	0 to 200%	0.1%	150%	142	
	151	Output current detection period	0 to 10 s	0.1 s	0	142	
	152	Zero current detection level	0 to 200.0%	0.1%	5.0%	143	
	153	Zero current detection period	0.05 to 1 s	0.01 s	0.5 s	143	
Sub function	156	Stall prevention operation selection	0 to 31,100	1	0	144	
	158	AM terminal function selection (Note 10)	0, 1, 2	1	0	92	
Additional function	160	User group read selection	0, 1, 10, 11	1	0	146	
	168	Parameters set by manufacturer. Do not set.					
	169						
Initial monitor	171	Actual operation hour meter clear	0	——	0	148	

Function	Parameter Number	Name	Setting Range	Minimum Setting Increments	Factory Setting	Refer To:	Customer Setting
User functions	173	User group 1 registration	0 to 999	1	0	146	
	174	User group 1 deletion	0 to 999,9999	1	0	146	
	175	User group 2 registration	0 to 999	1	0	146	
	176	User group 2 deletion	0 to 999,9999	1	0	146	
Terminal assignment functions	180	RL terminal function selection (Note 6)	0 to 8, 16, 18	1	0	148	
	181	RM terminal function selection (Note 6)	0 to 8, 16, 18	1	1	148	
	182	RH terminal function selection (Note 6)	0 to 8, 16, 18	1	2	148	
	183	MRS terminal function selection (Note 6)	0 to 8, 16, 18	1	6	148	
	190	RUN terminal function selection (Note 6)	0 to 99	1	0	150	
	191	FU terminal function selection (Note 6)	0 to 99	1	4	150	
	192	A, B, C terminal function selection (Note 6)	0 to 99	1	99	150	
Multi-speed operation	232	Multi-speed setting (speed 8)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	233	Multi-speed setting (speed 9)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	234	Multi-speed setting (speed 10)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	235	Multi-speed setting (speed 11)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	236	Multi-speed setting (speed 12)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	237	Multi-speed setting (speed 13)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	238	Multi-speed setting (speed 14)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
	239	Multi-speed setting (speed 15)	0 to 400Hz, 9999	0.01Hz (Note 3)	9999	75	
Sub functions	240	Soft-PWM setting	0, 1	1	1	104	
	244	Cooling fan operation selection	0, 1	1	0	151	
	245	Rated motor slip	0 to 50%, 9999	0.01%	9999	152	
	246	Slip compensation response time	0.01 to 10 s	0.01 s	0.5 s	152	
	247	Constant-output region slip compensation selection	0, 9999	1	9999	152	
	249	Ground fault detection at start (Note 9)	0, 1	1	0	153	
Stop selection function	250	Stop selection	0 to 100 s, 1000 to 1100 s, 8888, 9999	1	9999	154	
Additional function	251	Output phase failure protection selection	0, 1	1	1	155	
	342	E^2PROM write selection (Note 10)	0, 1	1	0	121	

Function	Parameter Number	Name	Setting Range		Minimum Setting Increments	Factory Setting		Refer To:	Customer Setting
Calibration functions	900	FM terminal calibration (Note 9)	——		——	——		156	
	901	AM terminal calibration (Note 10)	——		——	——		158	
	902	Frequency setting voltage bias	0 to 10V	0 to 60Hz	0.01Hz	0V	0Hz	160	
	903	Frequency setting voltage gain	0 to 10V	1 to 400Hz	0.01Hz	5V	60Hz	160	
	904	Frequency setting current bias	0 to 20mA	0 to 60Hz	0.01Hz	4 mA	0Hz	160	
	905	Frequency setting current gain	0 to 20mA	1 to 400Hz	0.01Hz	20 mA	60Hz	160	
	990	Parameter for option (FR-PU04).							
	991								