Micro-Grid Control

Power Practicum Project
Master Document

PORTLAND STATE UNIVERSITY
MASEEH COLLEGE OF ENGINEERING & COMPUTER SCIENCE
DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

411 STUDENTS FALL2018
December 8, 2018

Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY

ECE 411
INDUSTRY DESIGN PROCESSES

Abstract

For the 2018 Fall class of ECE 411 in the Power Track, the class was assigned to design, build and test a micro-grid control and transmission network consisting of several subsystems with individual roles and tasks. Groups are divided as follows:

1. **Slack Group:**

   Tasked with developing a PI controller that maintains the *system frequency set-points*. The goal is to maintain a system frequency of 60Hz (zero steady state error) using an induction motor controlled by a VFD.

2. **Gen V Group:**

   Tasked with developing PI controllers that maintain the *bus voltage set-point* at both the PV and Slack Buses at a level between 0.80 and 1.20 per unit using synchronous machines to provide reactive power.

3. **Gen P Group:**

   Tasked with developing a PI controller that maintains the *real power set-point* of the PV bus that covers the full range of generator capability and driven by an induction motor via VFD.

4. **Load Q Group:**

   Tasked with developing a PI controller that maintains *reactive power load set-points* of the PQ bus. The range shall be sufficient to test the full reactive power range across positive and negative Q values of PV slack generators.

5. **Load P Group:**

   Tasked with developing a PI controller which maintains *real power load set-point* within a range sufficient to test the full range of real power provided by the PQ bus generator.

6. **InterCon Group:**

   Tasked with developing a control center which consists of an HMI that allows control over all elements of the system including *system frequency, slack & PV bus voltages, PV bus & real power, and PQ bus real & reactive power.*

   The InterCon Group is also responsible for developing the microgrid transmission / distribution infrastructure of 208-V 3-phase, three-bus ring bus with appropriate reactance for bus voltage variations and sufficient ampacity for the needed power transfer and monitor real and reactive power transfer.

7. **MPR Group:**

   Tasked with providing the proper protections at all system buses using modern digital relays to protect from time-inverse and instantaneous overcurrent conditions, over/undervoltage, reactive power, phase reversal, power-factor and loss of potential conditions.

Contents

1 Introduction

Micro-grids are an increasing phenomenon in modern power generation and distribution systems as communities and organizations find ways to use technology to become more independently sustainable away from the larger generation, distribution and transmission systems so dominant within current infrastructure.

This project seeks to provide understanding of the systems and subsystems involved with generating, distributing, monitoring and managing the real and reactive power requirements and synchronous dynamics of an independent AC distribution system.

Objectives include:

- Learn & apply modern engineering project management techniques
- Use industry standard controls, protection equipment, hardware and software
- Work in a team environment to realize specifications, Engage in a design review process and conduct learning outside of the classroom.
- Follow NFPA 70, NEMA and UL codes and standards.
- Produce engineering design documentation including schematics, layout drawings, Bill of Materials, points lists, project flow carts, state diagrams while tracking projected costs, components, consumables and hours.
- Create this detailed operator's manual.

2 Interconnect

2.1 Interconnect Overview

Overall System Command Control Center &
Interconnecting Distribution Network

The creation of a central command center that is capable of controlling the system frequency, slack and PV bus voltages, PV bus real power, PQ bus real and reactive load power as well as monitoring PV and PQ power between buses.

Development and construction of micro-grid infrastructure including a 208 V three-phase, three-bus ring bus with sufficient reactance between buses to allow for bus voltage variations, and with sufficient ampacity to handle power transfer between buses.Line reactance is provided by a three-phase drive reactor on each distribution line model #LR-23P0.

An ethernet network was created to establish communications between each subsystem's PLC H2-DM1E CPU to carry commands, inputs, outputs, control and monitor values between each panel and displayed at the InterCon CC HMI screen.

System frequency, slack and PV bus voltages, PV bus real power, PQ bus real and reactive load power can be set by the central control. Real and reactive power flow is monitored at all system buses.

2.2 Realized Specifications

1. *The InterCon group shall build a control center (CC) from which system set-points shall be controlled.*
   HMI control of PLC logic provides control over all appropriately adjustable setpoints within the system

2. *Either a DL205 AD PLC or an SEL 3530 RTAC shall be used as the CC controller.*
   A DL205 PLC H2D1ME CPU module is used to communicate with other PLCs via ethernet protocol.

3. *The Slack bus voltage set point shall be setable from the CC.*
   Slack bus voltage set-points are controllable via InterCon CC HMI.

4. *The PV bus voltage and real power set-points shall be setable from the CC.*
   PV bus voltage and real power set-points are controllable from the InterCon CC HMI.

5. *The PQ real and reactive power set-points shall be setable from the CC.*
   Real and reactive power set-points are adjustable from the InterCon CC HMI.

6. *Set-points issued by the CC shall override set-points from the local bus controllers.*
   InterCon HMI CC is capable of local lockout and can take over control of all bus subsystems within the micro-grid.

7. *The CC should use an HMI to receive inputs and show outputs.*
   All appropriate commands and status variables are displayed and controlled via CC HMI and shared across an encompassing ethernet network.

8. *The CC HMI should show real-time status of bus voltages, system frequency,and generator and load power flows.*
   All relevant information across all three buses is displayed on CC HMI.

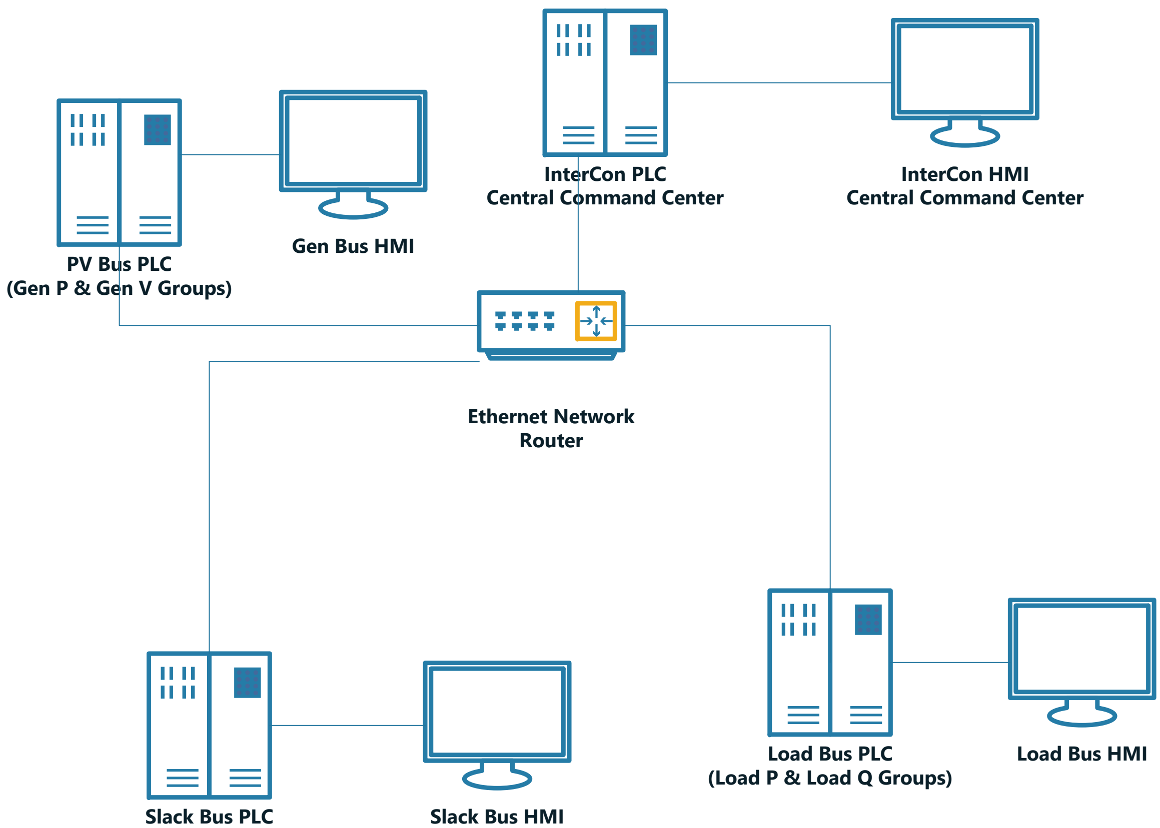
9. *The CC HMI might show real-time status of transmission line power flows.*
   Transmission Line currents and voltage is displayed on the CC HMI.

10. *The InterCon group shall build a 208 VAC three-bus ring bus distribution system.*
    Distribution lines carry current across the three bus ringbus system equipped with appropriate drive reactors model LR-23P0.

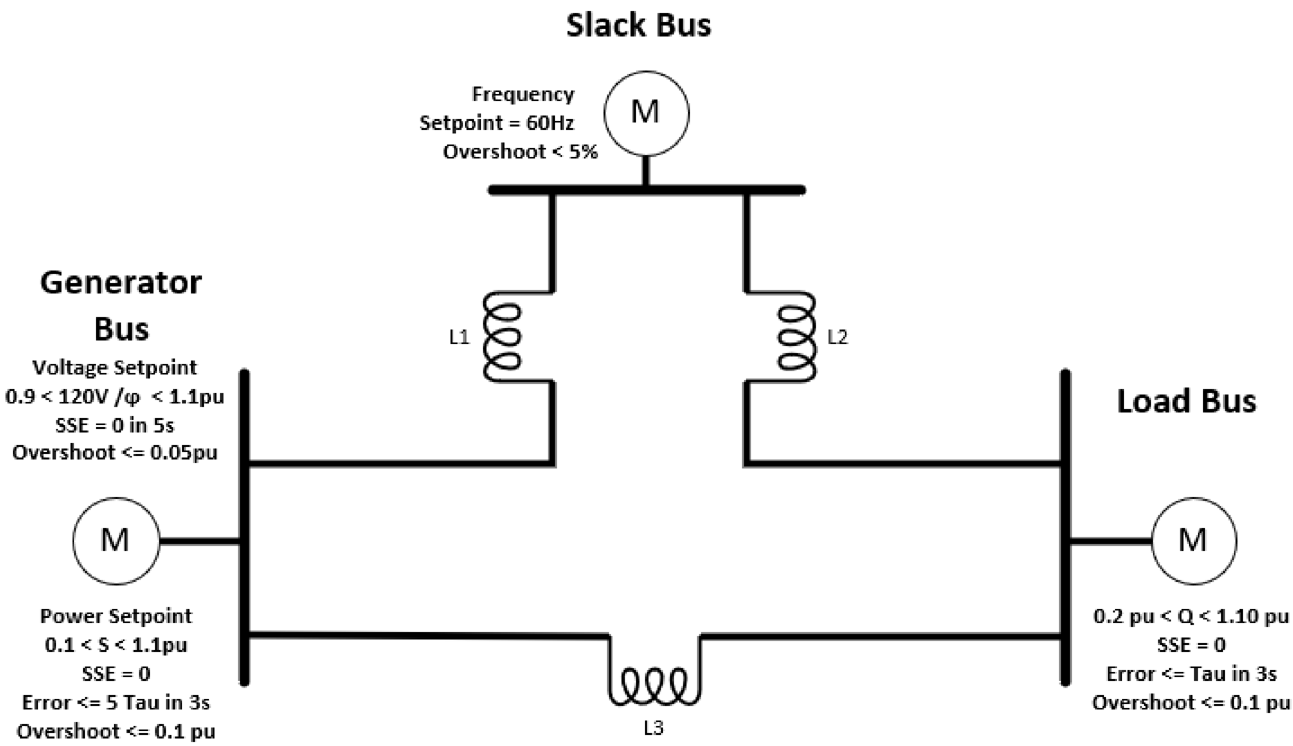
11. *Sufficient and appropriate impedance shall be introduced within the system distribution lines*
    Drive Reactors Model LR-23P0 are present on each three-phase line between all buses.

12. *Power flows within the distribution lines might be monitored.*
    All appropriate parameters are monitored and displayed on CC HMI.

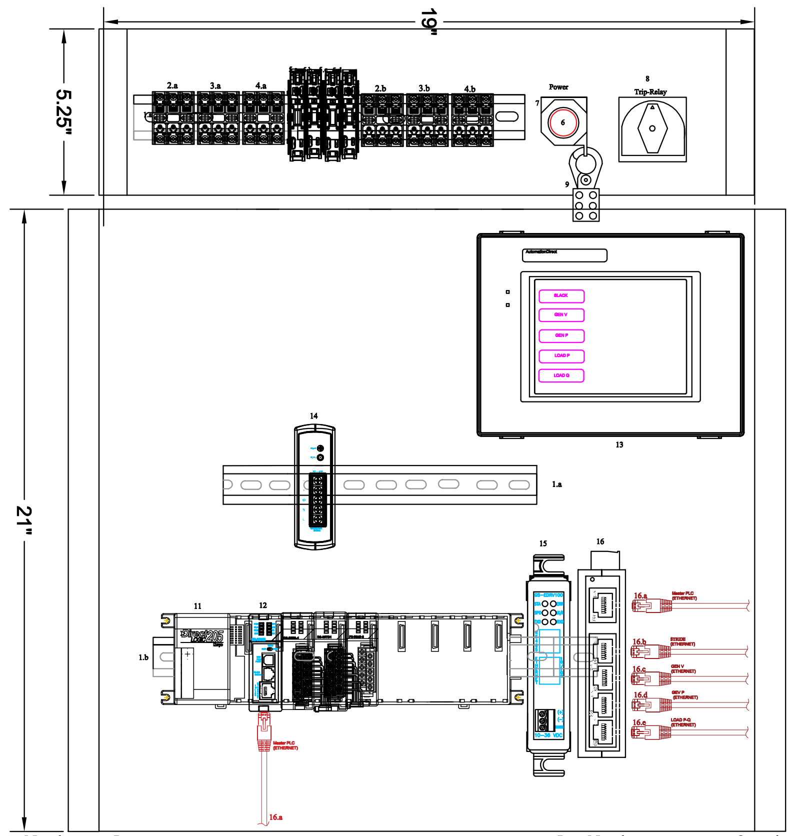
2.3 Network Diagram



2.4 System Bus Diagram



2.5 Panel CAD Drawing



Number	Item	Part Number	Quantity
1	Terminal Block Track 17"	980MH217	5
2	Terminal Block, DIN, 2 position, 4mm, 26-10AWG, Green	NSYTRV42GN	3
3	Terminal Block, DIN, 2 position, 4mm, 26-10AWG, White	NSYTRV42WH	3
4	Terminal Block, DIN, 2 position, 4mm, 26-10AWG, Red	NSYTRV42RD	3
5	Fuse Block, GRY 30A 20-6AWG, 300V	DN-F6MN	4
6	Push Button	13Z546	1
7	Push Button Safety Cover	3PDE5	1
8	Lock Out Relay	7601D	1
9	Safety Lockout Hasp	1U177	1
10	STRIDE industrial unmanaged Ethernet switch	SE-SW5U	1
11	DL205 X-Slot Base, 120 VAC PWR	D2-XXXX	1
12	Do-More CPU Module	H2-DM1E	1
13	C-More X inch Color Touch Screen Interface Panel	EA9-TXXX	1
14	RHINO switching power supply	PSB12-030-P	1
15	Ethernet communication module	GS-EDRV100	1
16	Cat5E straight-through patch cable	C5E-STPBK-S3	5

File No. *.DWG file name Sheet 3 of 3

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Panel View InterCon
Bottom

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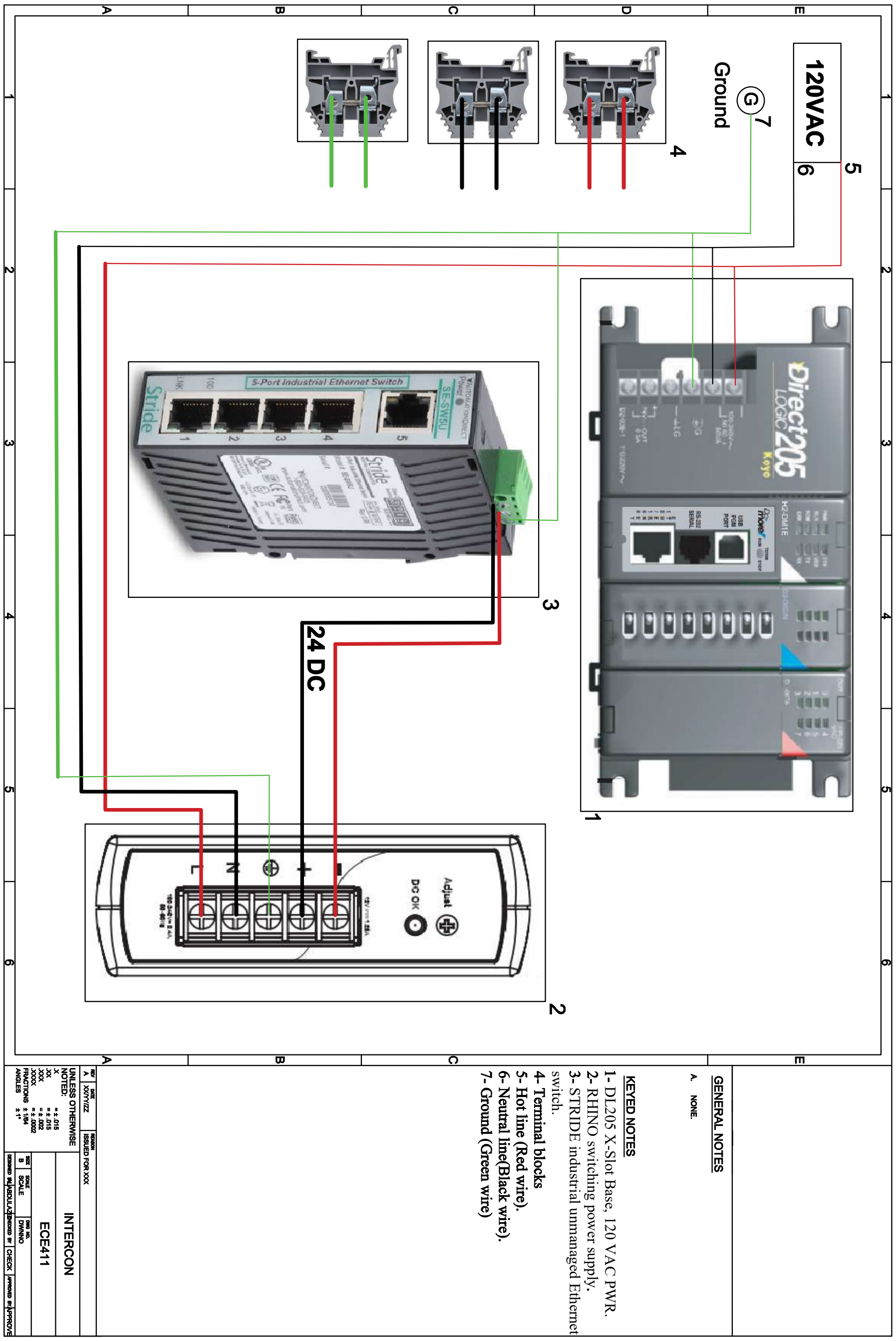
Designed Group 6 4/20/18
Drawn person date
Checked
Approved Date
Title

2.6 Wiring Diagram



2.7 Ladder Logic

2.8 Bill of Materials

2.9 Points List

	SESW-5U	PC	EA9-T8CL	Line Reactor
InterCon H2-DM1E	Ethernet	USB	Serial	NA
Gen Bus H2-DM1E	Ethernet	USB	Serial	to Load & Slack
Load Bus H2-DM1E	Ethernet	USB	Serial	to Gen & Slack
Slack Bus H2-DM1E	Ethernet	USB	Serial	to Gen & Load

2.10 Credits (InterCon)

This section of the system and report was designed, built and completed by:

- **Benjamin Evans:**
  - Procured drive reactors for distribution lines.
  - Helped to design and configure networking logic.
  - Created Points List, Network Diagram and Ring-Bus diagram.
  - Assembled and compiled class report while coordinating with groups to aggregate deliverables.

- **Aqeel Almousawi:**
  - Developed networking strategy.
  - Designed, created and executed the ladder logic for the network.
  - Configured WX & RX write/read protocol for Do-More Logic.
  - Relayed logic information between groups.

- **Mohammed Alabdulaziz:**
  - Created C-More HMI screen and coordinated functionality between groups.
  - Created AutoCAD drawings
  - Created Bill of Materials
  - Realized Specifications
  - Wiring Diagram

3 Slack

3.1 Slack Overview

The Slack Generator group provides a reference generator for a micro grid and is responsible for setting the frequency of the grid at 60HZ.

The Slack Generator group employs a PLC to read the frequency of the micro grid via a schmitt trigger and uses a PI controller to automatically adjust the frequency of the grid to the set point of 60 HZ.

The PI controller outputs a desired frequency to a VFD which controls a prime mover to drive the slack generator that provides power for the micro grid.

The system was testing using a 4 pole squirrel cage motor as the prime mover and another 4 pole squirrel cage motor mechanically linked to a dynamometer that was used to change the load of the system.

3.2 Realized Specifications

1. *A DL205 AD PLC shall be used as the controller for the Slack Generator.*
   The DL205 PLC is used to control the Slack generator via the Do-More software.

2. *The controller should use an HMI to receive inputs and show outputs.*
   The HMI is used to display outputs and receive inputs using C-More, controlled by the PLC and Do-More

3. *The controller shall communicate with Central Control via a local TCP/IP network.*
   The PLC is connected the TCP/IP network via an Ethernet cable and specified control commands in Do-More.

4. *The Slack group shall coordinate with the Gen V Group to implement the voltage controller specifications within the slack generator PLC.*
   The Gen V group implemented their Do-More code into the slack bus PLC controller.

5. *The Slack group shall work with the MPR group to provide the applicable IEEE Std C37.2-2008 protective relays at the PQ bus.*
   The MPR provides protection through protective relays between the Lab-Volt power supply and the slack bus control rack.

6. *The frequency controller shall use PI compensation.*
   The frequency controller uses a PI controller via Do-More code on the PLC

7. *The frequency controller shall have a set point of 60 Hz at all times.*
   The PI controller uses a set point reference of 60 Hz to maintain the desired frequency

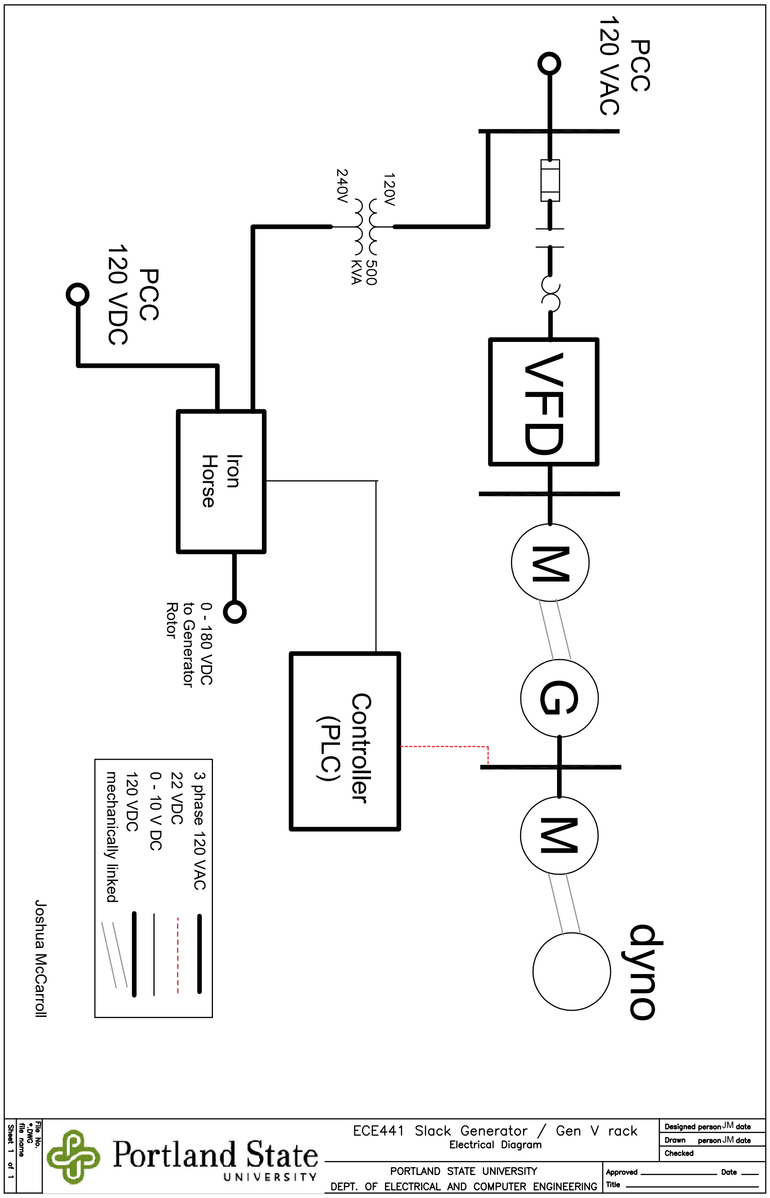
8. *Steady-state error should be zero within 2 seconds.*
   The PI controller responds, and corrects the frequency within 2 seconds by adjusting the control variable in the Variable Frequency Drive

9. *Overshoot should not exceed 5%.*
   The overshot does exceed 63Hz when VFD adjusts the frequency by setting the PI controller to an acceptable boundary value.

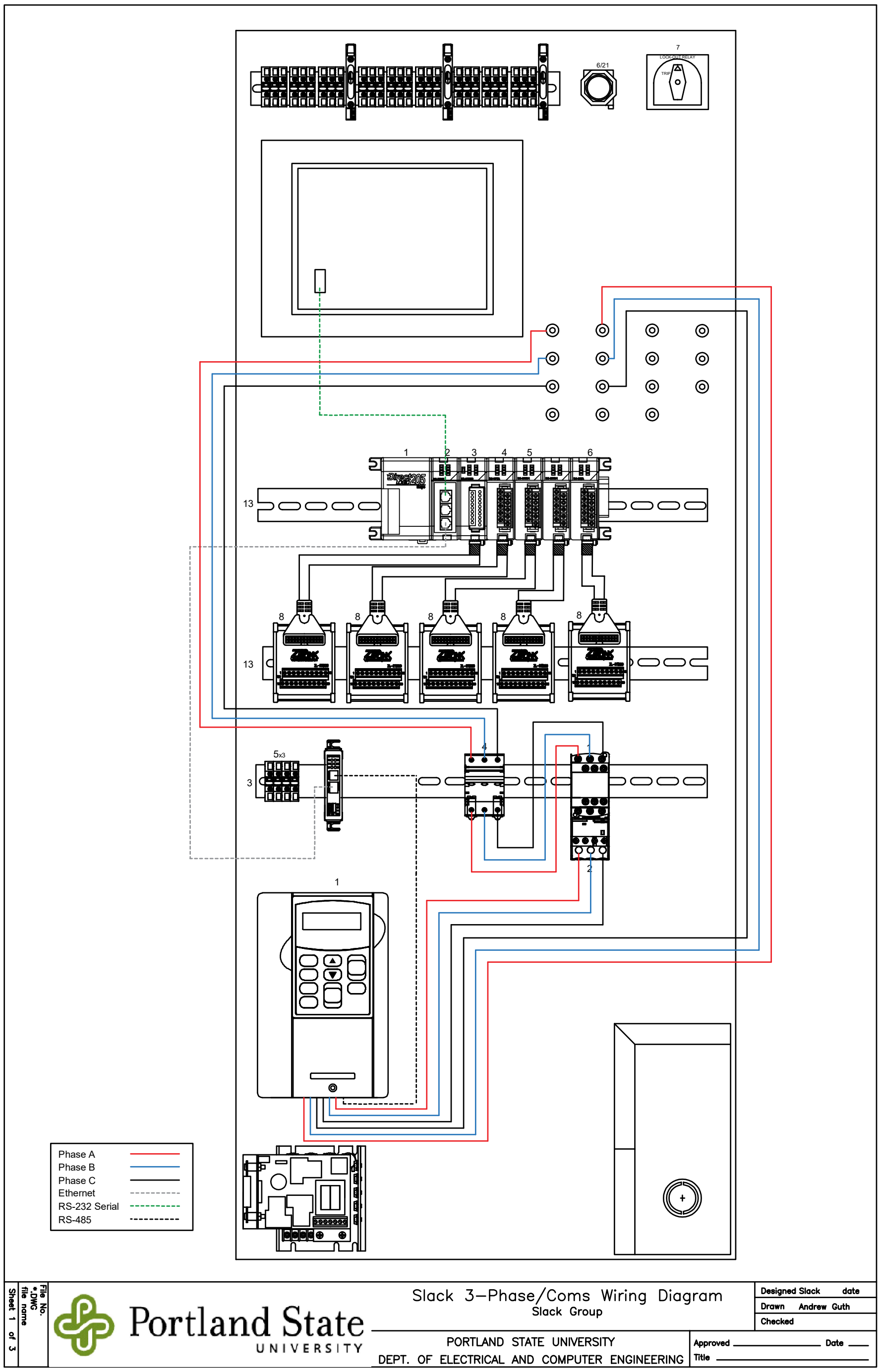
10. *The prime mover for the slack generator should be an induction motor.*
    The prime mover used is a 4-pole squirrel cage induction motor in the Lab-Volt 8221-00.

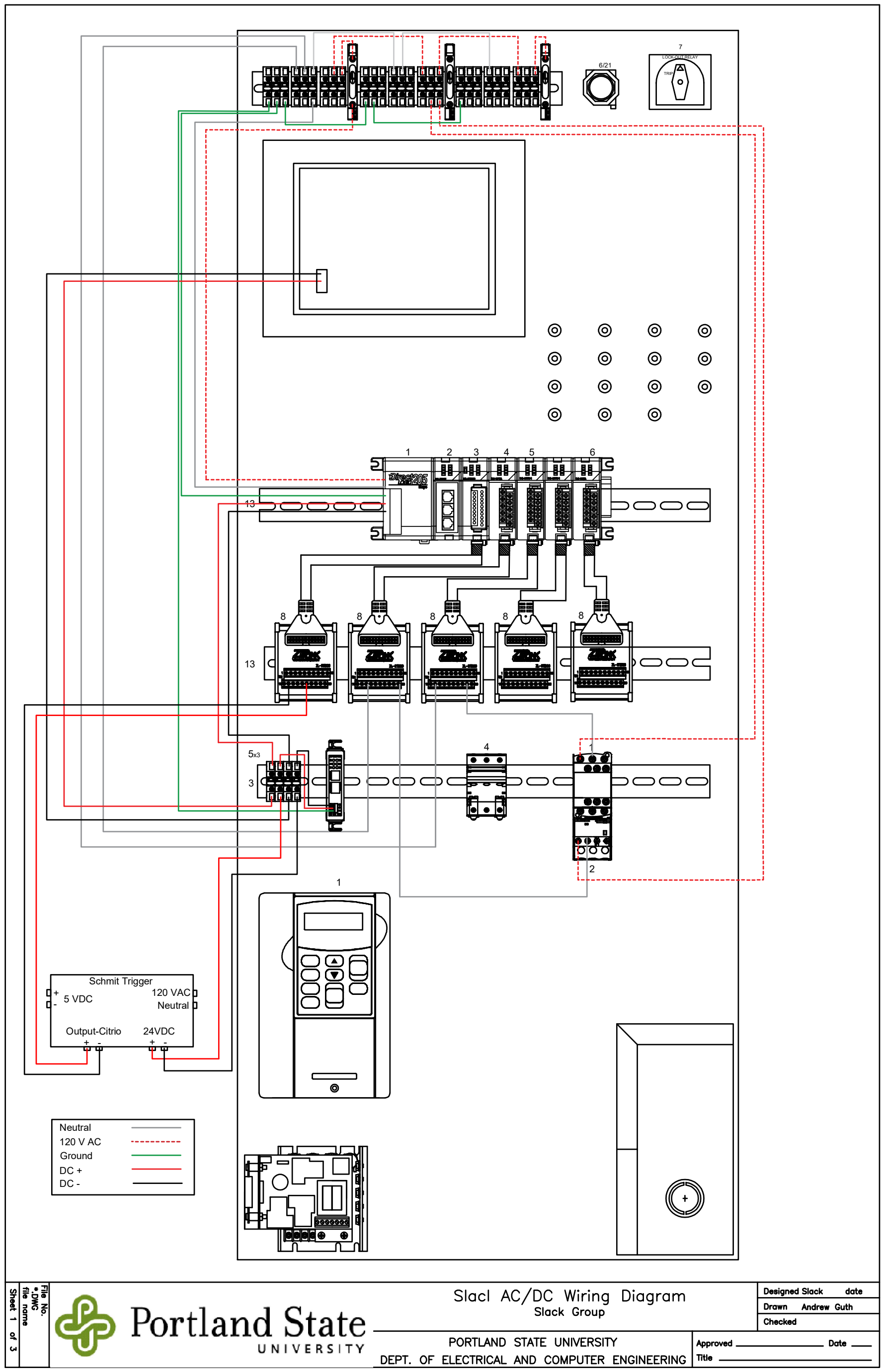
11. *The PM induction motor should be controlled using a VFD*
    A VFD is used to set and control the frequency in the Micro grid, supplying the 3 Phase power to the induction motor prime mover.

3.3 Slack Electrical Diagram



3.4 Slack Wiring Diagrams





Schmit Trigger
5 VDC
120 VAC
Neutral
Output-Citrio
24VDC
Neutral
120 V AC
Ground
DC +
DC -
Slacl AC/DC Wiring Diagram
Slack Group
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Designed Slack date
Drawn Andrew Guth
Checked
Approved
Date
Title
File No.
file name
Sheet 1 of 3
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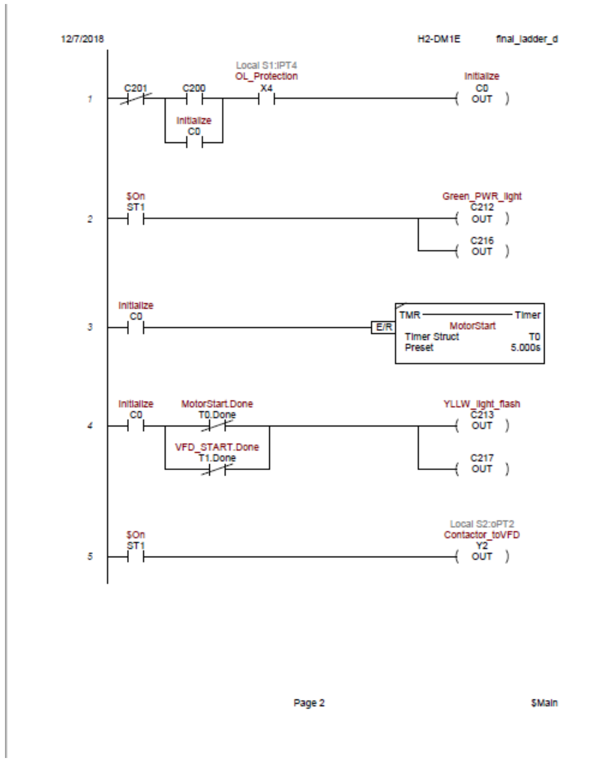
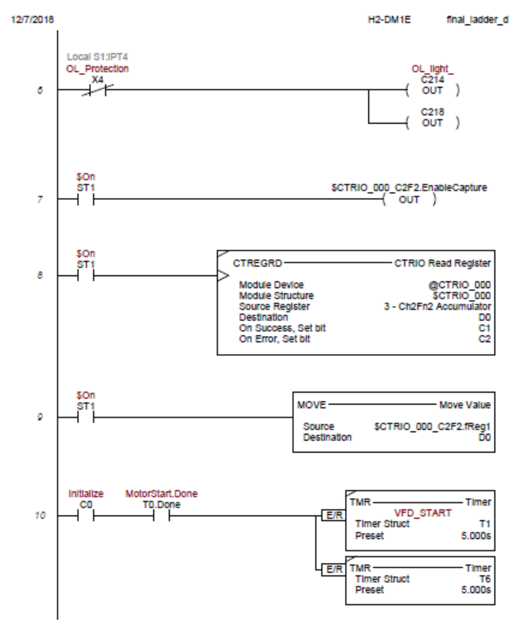
3.5 Ladder Logic

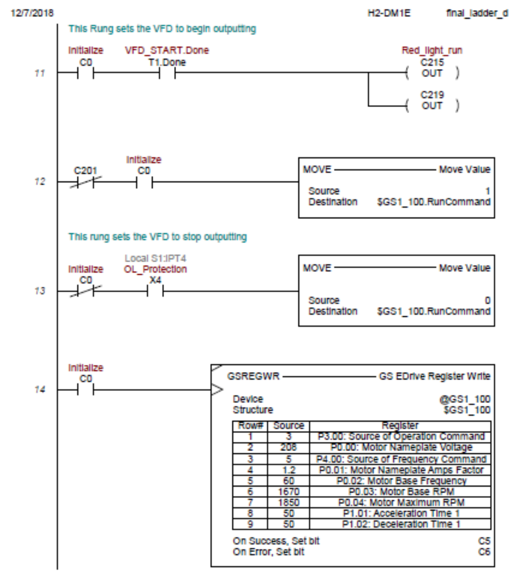
12/7/2018 H2-DM1E final_ladder_d

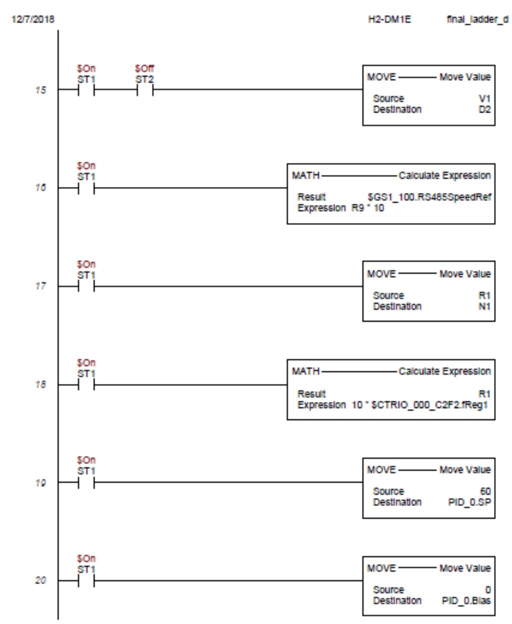
Project Path: C:\Users\josh\Desktop\XXX\final_ladder_d.dmd
Save Date: 12/07/18 01:36:09
Creation Date: 12/07/18 01:36:08
PLC Type: H2-DM1E
Class ID: Do-more H2 Series
Link Name: H2-DM1E 38:6D
Do-more Technology Version: 2.3
Description:
Version:
Company:
Department:
Programmer:

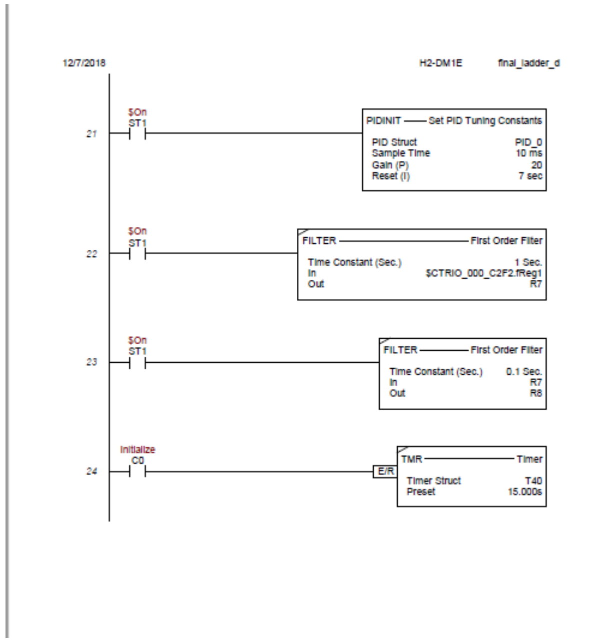
Page 1

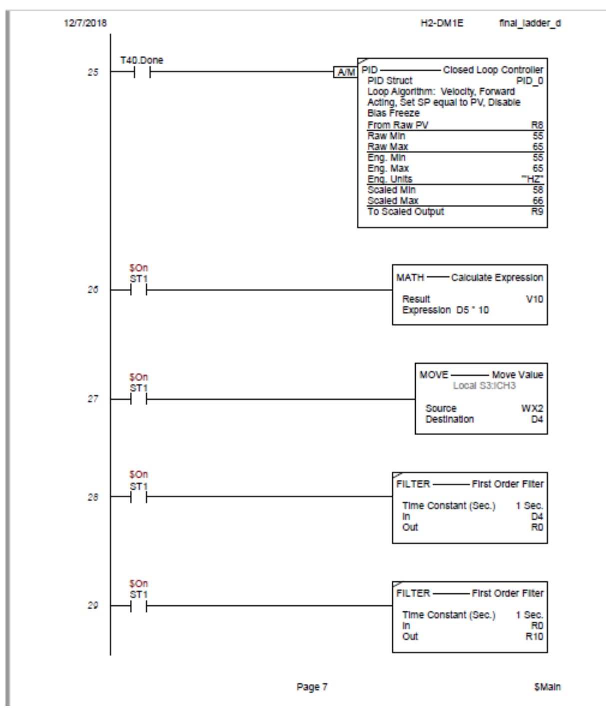

12/7/2018
H2-DM1E
final_ladder_d
1
C201
C200
Initialize
C0
Local S1:IPT4
OL_Protection
X4
Initialize
C0
OUT
2
$On
ST1
Green_PWR_light
C212
OUT
C216
OUT
3
Initialize
C0
E/R
TMR
Timer
MotorStart
Timer Struct
T0
Preset
5.000s
4
Initialize
C0
MotorStart.Done
T0.Done
VFD_START.Done
T1.Done
YLLW_light_flash
C213
OUT
C217
OUT
5
$On
ST1
Local S2:oPT2
Contactor_toVFD
Y2
OUT
Page 2
$Main

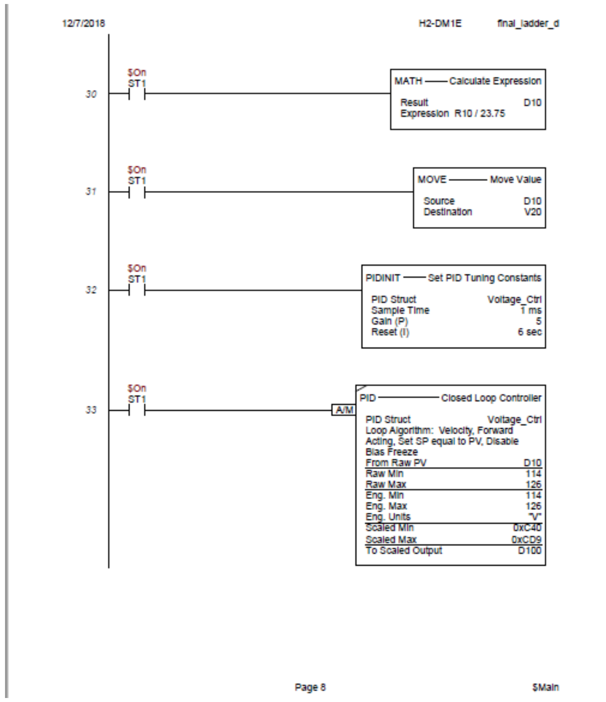

12/7/2018
H2-DM1E
final_ladder_d
6
Local S1:IPT4
OL_Protection
X4
OL_light_
C214
OUT
C218
OUT
7
$On
ST1
$CTRIO_000_C2F2.EnableCapture
OUT
8
$On
ST1
CTREGRD
CTRIO Read Register
Module Device
@CTRIO_000
Module Structure
$CTRIO_000
Source Register
3 - Ch2Fn2 Accumulator
Destination
D0
On Success, Set bit
C1
On Error, Set bit
C2
9
$On
ST1
MOVE
Move Value
Source
$CTRIO_000_C2F2.fReg1
Destination
D0
10
Initialize
C0
MotorStart.Done
T0.Done
E/R
TMR
Timer
VFD_START
Timer Struct
T1
Preset
5.000s
E/R
TMR
Timer
Timer Struct
T6
Preset
5.000s

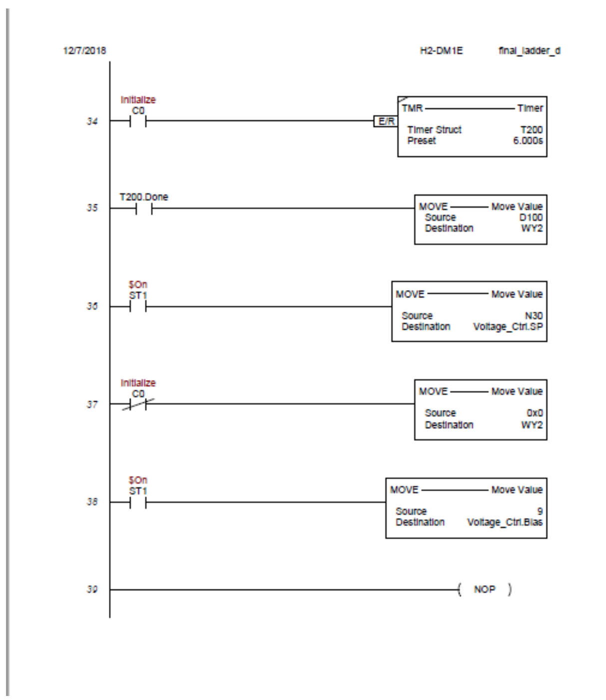

12/7/2018
H2-DM1E
final_ladder_d
This Rung sets the VFD to begin outputting
Initialize
C0
VFD_START.Done
T1.Done
Red_light_run
C215
OUT
C219
OUT
11
C201
Initialize
C0
12
MOVE
Move Value
Source 1
Destination $GS1_100.RunCommand
This rung sets the VFD to stop outputting
Initialize
C0
Local S1:IPT4
OL_Protection
X4
13
MOVE
Move Value
Source 0
Destination $GS1_100.RunCommand
Initialize
C0
14
GSREGWR
GS EDrive Register Write
Device @GS1_100
Structure $GS1_100
Row# Source Register
1 3 P3.00: Source of Operation Command
2 208 P0.00: Motor Nameplate Voltage
3 5 P4.00: Source of Frequency Command
4 1.2 P0.01: Motor Nameplate Amps Factor
5 60 P0.02: Motor Base Frequency
6 1670 P0.03: Motor Base RPM
7 1850 P0.04: Motor Maximum RPM
8 50 P1.01: Acceleration Time 1
9 50 P1.02: Deceleration Time 1
On Success, Set bit C5
On Error, Set bit C6


12/7/2018
H2-DM1E
final_ladder_d
$On
ST1
$Off
ST2
15
MOVE
Move Value
Source V1
Destination D2
$On
ST1
16
MATH
Calculate Expression
Result $GS1_100.RS485SpeedRef
Expression R9 * 10
$On
ST1
17
MOVE
Move Value
Source R1
Destination N1
$On
ST1
18
MATH
Calculate Expression
Result R1
Expression 10 * $CTRIO_000_C2F2.fReg1
$On
ST1
19
MOVE
Move Value
Source 60
Destination PID_0.SP
$On
ST1
20
MOVE
Move Value
Source 0
Destination PID_0.Bias

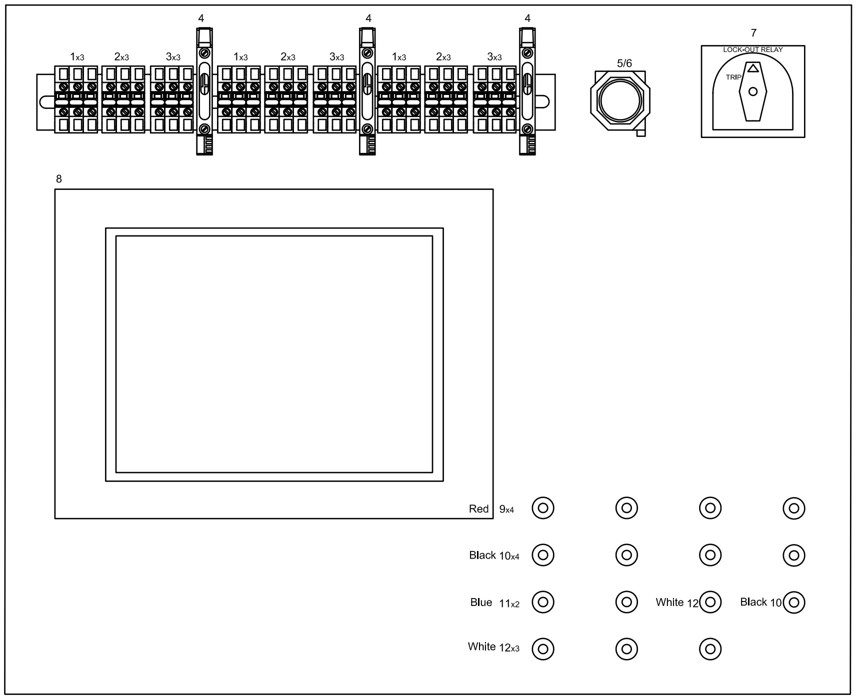

12/7/2018
H2-DM1E
final_ladder_d
21
$On
ST1
PIDINIT —— Set PID Tuning Constants
PID Struct PID_0
Sample Time 10 ms
Gain (P) 20
Reset (I) 7 sec
22
$On
ST1
FILTER —— First Order Filter
Time Constant (Sec.) 1 Sec.
In $CTRIO_000_C2F2.fReg1
Out R7
23
$On
ST1
FILTER —— First Order Filter
Time Constant (Sec.) 0.1 Sec.
In R7
Out R8
24
Initialize
C0
E/R
TMR —— Timer
Timer Struct T40
Preset 15.000s


12/7/2018
H2-DM1E
final_ladder_d
25
T40.Done
A/M
PID —— Closed Loop Controller
PID Struct PID_0
Loop Algorithm: Velocity, Forward Acting, Set SP equal to PV, Disable Bias Freeze
From Raw PV R8
Raw Min 55
Raw Max 65
Eng. Min 55
Eng. Max 65
Eng. Units "HZ"
Scaled Min 58
Scaled Max 66
To Scaled Output R9
26
$On
ST1
MATH —— Calculate Expression
Result V10
Expression D5 * 10
27
$On
ST1
MOVE —— Move Value
Local S3:ICH3
Source WX2
Destination D4
28
$On
ST1
FILTER —— First Order Filter
Time Constant (Sec.) 1 Sec.
In D4
Out R0
29
$On
ST1
FILTER —— First Order Filter
Time Constant (Sec.) 1 Sec.
In R0
Out R10
Page 7
$Main


12/7/2018
H2-DM1E
final_ladder_d
$On
ST1
30
MATH Calculate Expression
Result D10
Expression R10 / 23.75
$On
ST1
31
MOVE Move Value
Source D10
Destination V20
$On
ST1
32
PIDINIT Set PID Tuning Constants
PID Struct Voltage_Ctrl
Sample Time 1 ms
Gain (P) 5
Reset (I) 6 sec
$On
ST1
33
A/M
PID Closed Loop Controller
PID Struct Voltage_Ctrl
Loop Algorithm: Velocity, Forward Acting, Set SP equal to PV, Disable Bias Freeze
From Raw PV D10
Raw Min 114
Raw Max 126
Eng. Min 114
Eng. Max 126
Eng. Units "V"
Scaled Min 0xC40
Scaled Max 0xCD9
To Scaled Output D100
Page 8
$Main


12/7/2018
H2-DM1E
final_ladder_d
Initialize
C0
34
E/R
TMR Timer
Timer Struct T200
Preset 6.000s
T200.Done
35
MOVE Move Value
Source D100
Destination WY2
$On
ST1
36
MOVE Move Value
Source N30
Destination Voltage_Ctrl.SP
Initialize
C0
37
MOVE Move Value
Source 0x0
Destination WY2
$On
ST1
38
MOVE Move Value
Source 9
Destination Voltage_Ctrl.Bias
39
NOP

3.6 Panel CAD Drawings



Item Number	Description	Quantity
1	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Green	9
2	Terminal block, DIN, 2 position, 4mm, 26-10AWG, White	9
3	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Red	9
4	Fuse block, GRY 30A 20-6 AWG, 300V	3
5	Push Button	1
6	Push Button Safety Cover	1
7	Lock Out Relay (Series 24)	1
8	C-More 9 inch Color Touch Screen Interface Panel	1
9	Red Banana Jack, Tip	4
10	Black banana Jack, Tip	5
11	Blue banana Jack, Tip	2
12	White Banana Jack, Tip	4

1in
2in

Sheet 1 of 3
File No. *.DWG file name

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Micro Grid Slcak Top Panel layout
Slack Group

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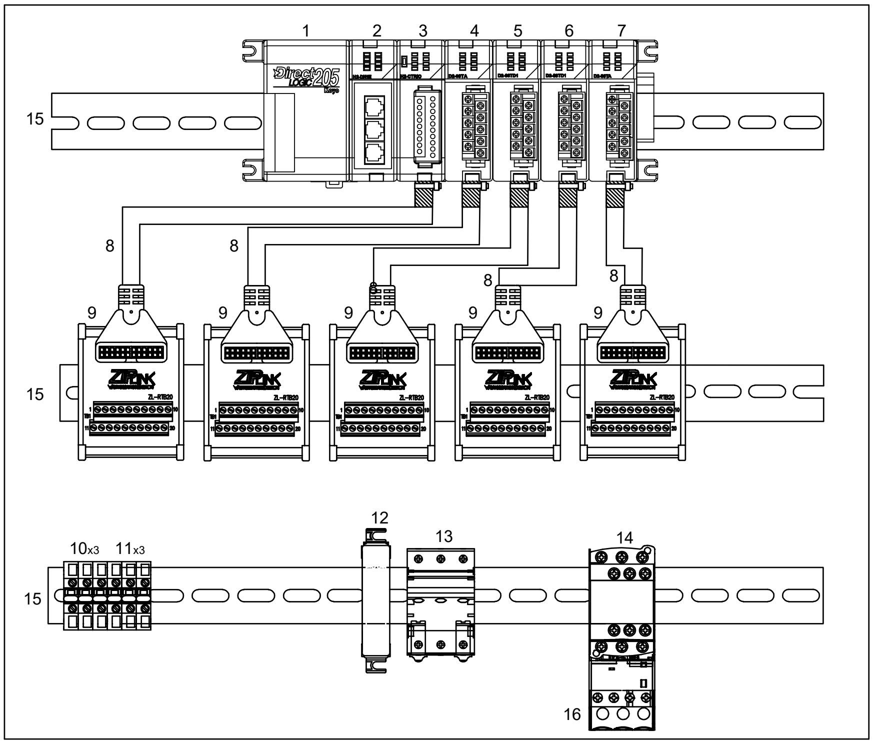
Designed Slack	date	
Drawn	Andrew Guth	
Checked		
Approved		Date
Title		



Item Number	Description	Quantity
1	DL205 X-Slot Base, 120 VAC PWR	1
2	Do-more CPU Module	1
3	High-speed Counter Interface Module	1
4	8 PT 110 VAC Input Module	1
5	18-220 VAC Output Module	1
6	8 Channel Analog Input	1
7	8PT 12-24 VDC Sink Output Module	1
8	Cable 10-term/24-pin 0.5m Ziplink for Dl205	5
9	ZipLink 20-pole feed through module	5
10	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Black	3
11	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Red	3
12	Ethernet Communication Module	1
13	Fuse holder, 3 phase, 32A w/ indicator	1
14	Contactor, 18A, 3 pole, 120VAC coil	1
15	Terminal Block Mounting Track, 17"	3
16	Thermal Overload relay, 1 to 1.6A	1

1in
2in

File No. *.DWG file name Sheet 2 of 3

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Micro Grip Slack Middle Panel layout
Slack Group

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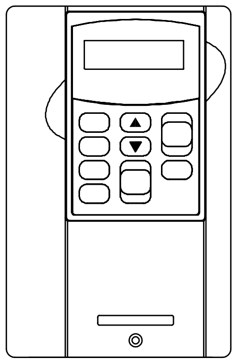
Designed Slack date
Drawn Andrew Guth
Checked
Approved Date
Title

1

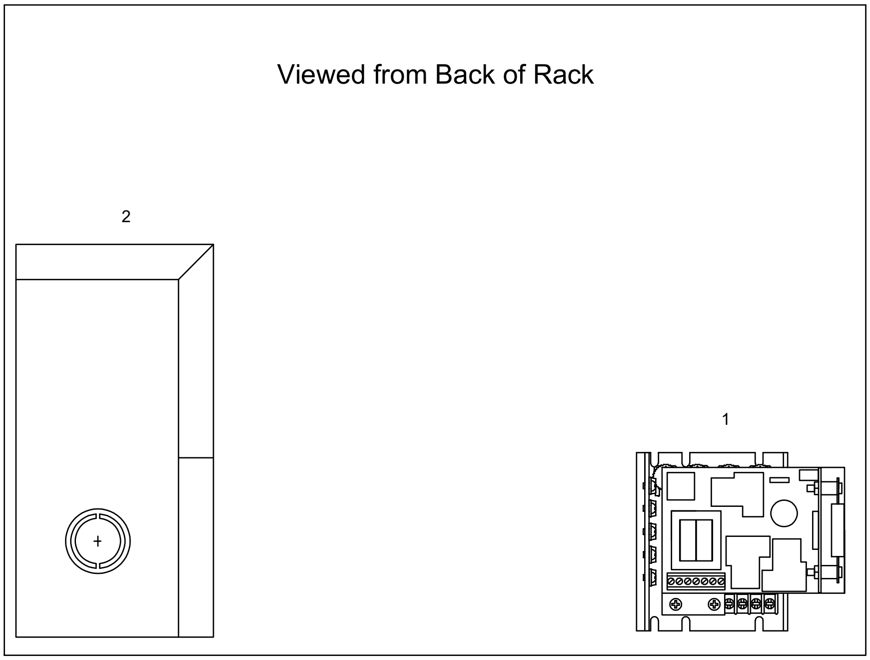


Item Number	Description	Quantity
1	Variable Frequency Drive	1

1in
2in

Sheet 3 of 3	File No. *.DWG file name	Portland State UNIVERSITY	Micro Grid Slack Bottom Panel Slack Group
			PORTLAND STATE UNIVERSITY DEPT. OF ELECTRICAL AND COMPUTER ENGINEERING

Designed Slack date
Drawn Andrew Guth
Checked
Approved Date
Title



Item Number	Description	Quantity
1	Iron horse	1
2	Transformer	1

1in
2in

File No.
*.DWG
file name
Sheet 3 of 3

Portland State UNIVERSITY

Micro Grid Slack Bottom Panel (back view)
Slack Group

PORTLAND STATE UNIVERSITY
DEPT. OF ELECTRICAL AND COMPUTER ENGINEERING

Designed Slack date
Drawn Andrew Guth
Checked
Approved Date
Title

3.7 Bill of Materials

Description	Vendor	Part NO.	Quan.	Total Cost
0.5A,250V,1-1/4*1/4-inch,Slow-Blow Fuse	Radio Shack	2701018	1	1.5
DURA pulse GS3 AC Drives	Automation Direct	GS3-21P0	1	242
Ethernet Communication Module	Automation Direct	GS-ERDV100	1	199
8 Channel Analog Input	Automation Direct	F2-08AD-1	1	144
8 Channel Analog Output	Automation Direct	F2-08AD-2	1	186
8PT 110 VAC Input Modulel input	Automation Direct	D2-08NA-1	1	77
8 Channel Digital Output	Automation Direct	D2-08TA	1	110
High-speed counter interface module	Automation Direct	H2-CTRIO	1	321
Do-more CPU Module	Automation Direct	H2-DM1E	1	399
DL205 9-Slot Base, 120 VAC PWR	Automation Direct	D2-09B-1	1	220
ZIPLink module, 20-pole	Automation Direct	ZL-RTB20	1	4
Cable 10-term/24-pin 0.5m Ziplink for Dl205	Automation Direct	ZL-D2-CBL10	4	92
Series IEC contactor, 9A, 3 poles, 120 VAC (60Hz)	Automation Direct	GHISBN-03-01A	1	44.5
Overload Relay	Automation Direct	RTD32-180	1	62.25
C-More 8-inch Color Touch Screen Interface Panel	Automation Direct	EA7-T8C	1	675.63
HMI to Computer cable	Automation Direct	EA-2CBL	1	20
AC to DC switching power supply	Automation Direct	PSB12-030-P	1	23.5
Fuse block, GRY 1A 20-6 AWG, 250V	Automation Direct	DN-F6MN	1	20
Power Cord	All Electronics	LCAC-310	1	4.5
Lock Out Relay (Series 24)	Shallco	7601D	1	55.00
Terminal block, DIN, 2 position, 4mm, 26-10AWG, Black	Schneider	NSYTRV42BK	1	1.37
Terminal block, DIN, 2 position, 4mm, 26-10AWG, Red	Schneider	NSYTRV42RD	1	1.37
End plate, 2.2 mm	Schneider	NSYTRAC22	1	1.37
3U Filler Panel with Stability Flanges (7")	Rack Solutions	102-1824	3	48.00
4U Filler Panel with Stability Flanges (5.25")	Rack Solutions	102-1825	1	18.99
15U Filler Panel with Stability Flanges (15.25")	Rack Solutions	102-1825	1	20.99
Modular fuse holder, 3 phase, 30A	Edison	EHM1DU	3	51.00
Safety Lockout Hasp	Grainger	1U177	1	5.60
Push Button Safety Cover	Grainger	7151	1	68.49
Stranded Hook-up wire, 300V, UL1007, 18 AWG, red	BulkWire.com	Wire-ST-18-02-100	1	16.25
Stranded Hook-up wire, 300V, UL1007, 18 AWG, black	BulkWire.com	Wire-ST-18-06-100	1	16.25
Stranded Hook-up wire, 300V, UL1007, 18 AWG, blue	BulkWire.com	Wire-ST-18-00-100	1	16.25
Stranded Hook-up wire, 300V, UL1007, 18 AWG, black	BulkWire.com	Wire-ST-18-05-100	1	16.25
Stranded Hook-up wire, 300V, UL1007, 18 AWG, white	BulkWire.com	Wire-ST-18-09-100	1	16.25
Schimitte Trigger Chip	Texas Instrument	SN74ACT14N	1	0.49
Semi-conductor bipolar transistor	Mouser Electronics	2N3904	1	0.42
5.6 kilo ohm resistor	Vetco Electronics	Green/Blue/Red	1	0.29
1 Megohm resistor	Sparkfun	Brown/Black/Green	1	0.15
3.3 Kilo ohm resistor	Accidore	orange/orange/red	1	0.09
100 ohm resistor	Accidore	Brown/Black/Brown	1	0.09
100 kilo ohm power resistor	Jameco Valuepro	Brown/Black/Yellow	1	0.1
		Total Cost		**$4405.86**

3.8 Points List

PLC TYPE:

PLC Card Slot Assignments:

PLC Chassis	Slot 1/5	Slot 2/5	Slot 3/5	Slot 4/5	Slot 5/5
1	DMPLC	110VACI	24VDCO	220VACO	2CAO-1

Card Details

Slot	Card Name	Card Mnemonic	Part Nember	Comments
1/6	Do-More PLC CPU	DMPLC	H2-DM1E	
2/6	H2 CTRIO INPUT	24VDC OUTPUT	H2-CTRIO	
3/6	110 Volt AC Input	110VACI	D2-08NA-1	
4/6	110-220 Volt AC Output	220VACO	D2-08TA	
5/6	Analog Input	ANALOG 8CH	F2-08AD-2	
6/6	2 Channel Analogue Output	2CAO-1	F2-02DAS-2	

Figure 1: PLC Card Slot

Analog Input(Slack)

F2-08AD-2

		POINT TYPE						
		Hardware Point						
Point Description	Origin Address	DO	DI	AO	AI	Virtual Point	Destination Address	Destination Description
COMMON	ZIPLINK 4 PORT C		1	0	0	0	NEUTRAL NODI	24V ground
COMMON		0	0	0	0	0		
0	ZIPLINK 4, PORT 0	0	0	0	0	0		
1	ZIPLINK 4, PORT 5	0	1	0	0	0		Over load
2	ZIPLINK4, PORT 11	0	1	0	0	0		24V hot node
3	ZIPLINK 4, PORT	0	0	0	0	0		
4								
5								
6								
7								
	Total Points	0	3	0	0	0		

Figure 2: Analog Input

Analog Out (Slack) F2-08AD-2		POINT TYPE						
		Hardware Point						
Point Description	Origin Address	DO	DI	AO	AI	Virtual Point	Destination Address	Destination Description
COMMON	IPLINK 1 PORT C		1	0	0	0		24V Ground
COMMON		0	0	0	0	0		
0	IPLINK 1, PORT	0	1	0	0	0		24V node
1	IPLINK 1, PORT	0	1	0	0	0		1120V ground
2	IPLINK1, PORT 1	0	1	0	0	0		120V hot node
3	PLINK 1, PORT 1	0	0	0	0	0		
4								
5								
6								
7								
	Total Points	0	4	0	0	0		

Figure 3: Analog Output

H2-CTRIO(Slack)		POINT TYPE							
		Hardware Point							
Point Description	Origin Address	DO	DI	AO	AI	Virtual Point	Destination Address	Destination Description	Notes
COMMON	ZIPLINK 1, POR	0	0	0	0	0		Neutral Node	
0	ZIPLINK 1, POR	0	1	0	0	0			
1		0	0	0	0	0			
2		0	1	0	0	0		120V hot node	
3		0	0	0	0	0			
4		0	0	0	0	0			
5		0	0	0	0	0			
6		0	0	0	0	0			
7		0	0	0	0	0			
	Total Points	0	2	0	0	0			

Figure 4: H2-CTRIO

3.9 Credits(Slack)

This section of the system and report was designed, built and completed by:

- **Joshua McCarroll -**
  Overview
  Electrical Diagram
  Ladder Logic
  Researched designed and implemented PI Controller
  testing
  troubleshooting

- **Andrew Guth**
  Realized specifications
  3 Phase/Communications Wiring Diagram
  AC/DC Wiring Diagram
  Panel Layout Diagrams
  3 Phase Wiring, AC and Dc Wiring on Slack Rack troubleshooting

- **Yudong Lan**
  Bill of materials
  testing
  troubleshooting
  research

- **Sami Alhefdhy**
  Points list
  Designed, Constructed and tested Schmidt Trigger Circuit

4 Gen V

4.1 Gen V Overview

On this project the class as a whole is working together to design, build, and operate a three-phase AC micro-grid.

To achieve that goal, the tasks have been divided into seven large tasks. Our group was assigned to maintain the voltage of grid within a range of 0.95 per unit to 1.05 per unit while allowing the user to change the set point from 0.9 to 1.1 per unit. We were also assigned to synchronize the PV bus to Slack bus to make sure the frequency set point is stably maintain within the micro grid. To achieve that, we will have built, tested, and validated a PI voltage controller using DL205 AD PLC and have met relevant NFPA 70 standards.

The final product consists of a working PI voltage controller that automatically set the point within range as well as display it on a screen for the operator to observe. It also allows for user input to manipulate that set point within the PI controller.

This final product documentation consists of realized specifications, NFPA 70 standards requirements, bill of materials, point lists, and wiring diagrams.

4.2 Realized Specifications

1. *A DL205 AD PLC shall be used as the controller for the PV Generator.*
   We met this requirement by using the DL205 AD PLC as a controller for the Slack and PV generator.

2. *The PLC shall communicate with Central Control via a local TCP/IP network*
   We have successfully communicated with the central control unit to allow read/write capabilities using TCP/IP network.

3. *The Gen V group shall coordinate with the Gen P Group to implement the voltage controller specifications within the PV generator PLC.*
   We have communicated and coordinated with PV group to implement our design into their rack.

4. *The Gen V group shall coordinate with the Slack Group to implement the voltage controller specifications within the slack generator PLC.*
   We have communicated and coordinated with Slack group to implement, test and validate our design into their rack.

5. *The controller shall use PI compensation.*
   Do-More PI controller and tuning has been utilized to achieve the desired outcome. This was done through PI Struct and tuning functions. The tuning was done visually at first. Then, it was permanently store in the PI structure.

6. *The allowed voltage set-point shall be within the range of 0.95 pu to 1.05 pu.*
   The range of voltage set-point is within the the range of 0.95 pu to 1.05 pu which corresponds to 114 VAC to 126 VAC.

7. *The controller shall provide voltage control only when voltage is outside of the 0.95 pu to 1.05 pu band.*
   The voltage controller is set to tune as voltage goes out of range.

8. *Steady-state error at 0.95 and 1.05 pu should be zero within 3 seconds.*
   Within less than 3 seconds, the steady-state error is most nearly zero at the specified range.

9. *Overshoot should not exceed 0.02 pu.*
   The overshoot never exceeded 0.02 pu. This was set using a fast response time to quickly adjust the voltage.

10. *The PV Generator shall be able to synchronize with the slack Generator,adhering to the relevant specifications noted in the EE 348 term project.*
    Design, implementation, and verification was completed as per EE 384 specification. However, the final product was not delivered due to issues with the PV group rack.

4.3 NFPA 70

- Lockout/Tagout Procedure
  We followed the sequence of the lockout/tagout system procedure using the Annex G in the NEC 2017.

- Control Circuit Conductor Sizing
  According to the NEC 2017 table 310.15(B)(16), we are allowed to use any guage conductor because we are drawing less then 1 amp of current. So we decided to use 18 AWG copper wire.

- Control Circuit Conductors
  All conductors are sized, insulated, and marked according to the requirements listed in the NEC 2017 Article 310.

- Grounding Conductor Marking
  Grounding conductors have a continuous outer finish of green following the NEC 2017 Article 250.119.

- Grounded Conductor Marking
  Grounded conductors have a continuous outer finish of white following the NEC 2017 Article 200.6

- Control Circuit Hot Conductor Marking
  Ungrounded 120VAC single phase hot conductors have a continuous outer finish of red following the NEC 2017 Article 210.5(C)(1)(a).

- Control Circuit DC Conductor Marking
  For 240VDC conductors, the positive ungrounded conductors have a continuous outer red finish, while the negative ungrounded conductors have a continuous outer black finish. This follows the NEC 2017 Article 210.5(C)(2).

- Power Circuit Overcurrent Protection
  Power circuit overcurrent protection was sized using the NEC 2017

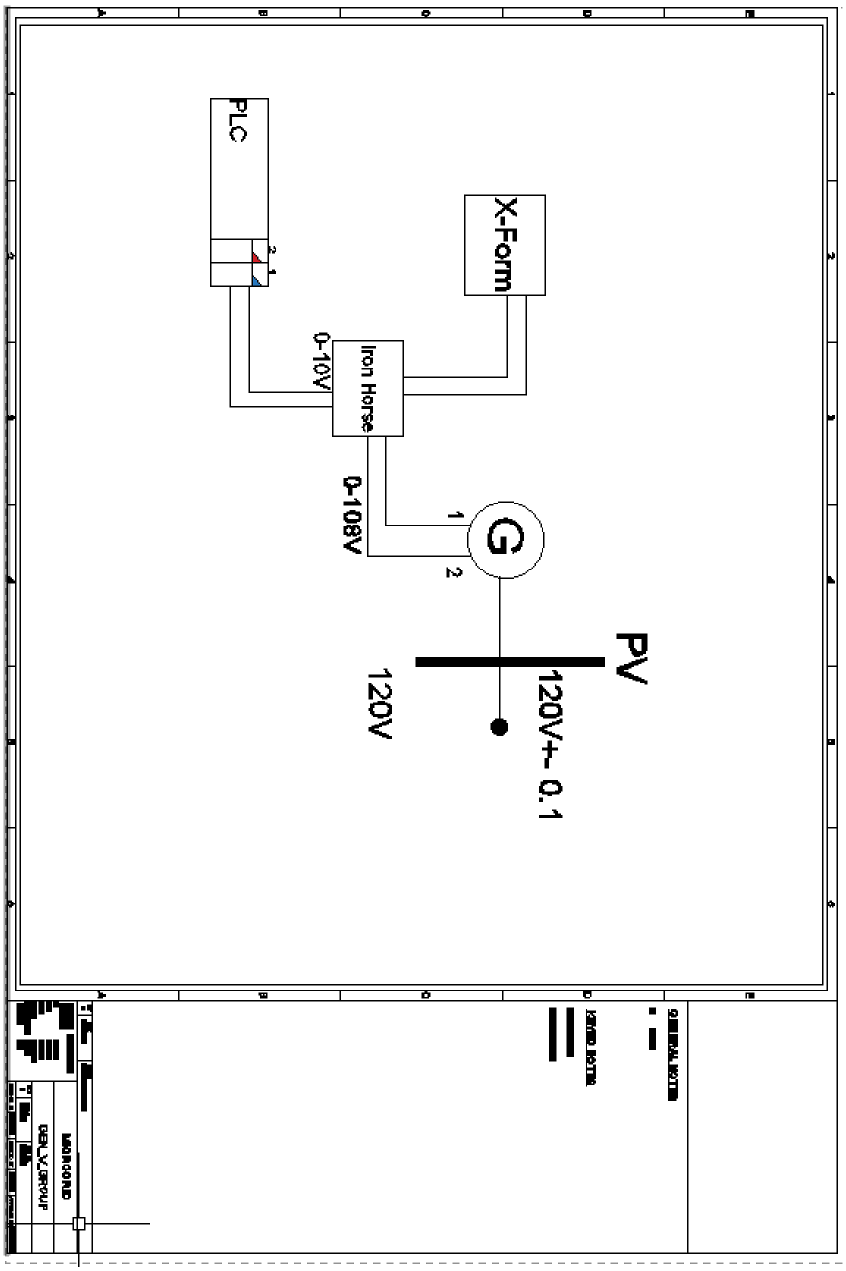
Article 430.52(A), 430.52(B), 430.52(C) with a reference to table 430.52. We calculated a Full Load Current of the motor to be 2.1 amps. The next largest fuse to use would be a 3 amp fuse per phase, but we have 8 amp fuses installed for this project.

- Power Circuit Conductor Sizing
  According to article 430.22(G)(1)(2) in the NEC 2017, we sized our conductors as TFFN stranded 18 AWG copper wires.

- Power Circuit Hot Conductor Marking
  Ungrounded 208VAC 3-phase hot conductors have a continuous outer finish of red, black and blue for phase a, b and c respectively in accordance with the NEC 2017 Article 210.5(C)(1)(a).

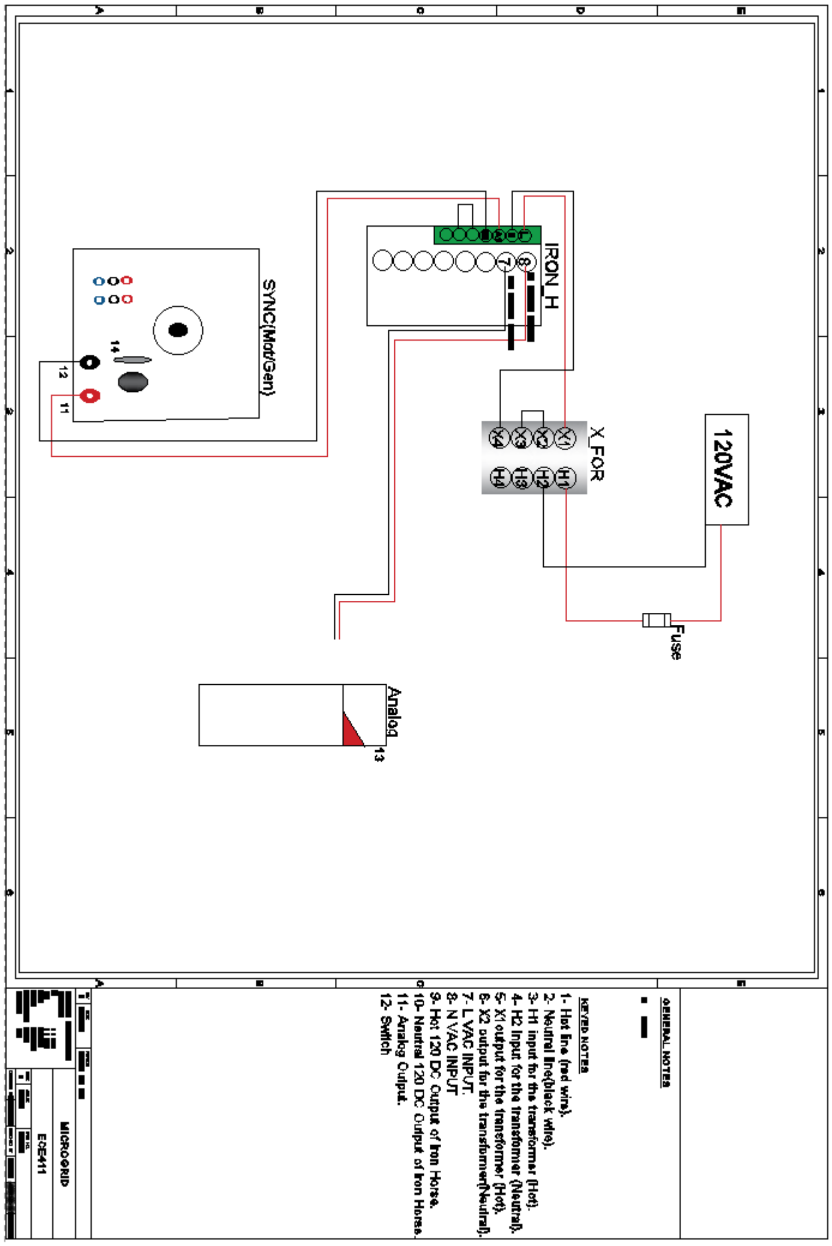
4.4 Electrical Diagram

Figure 5: Electrical Diagram

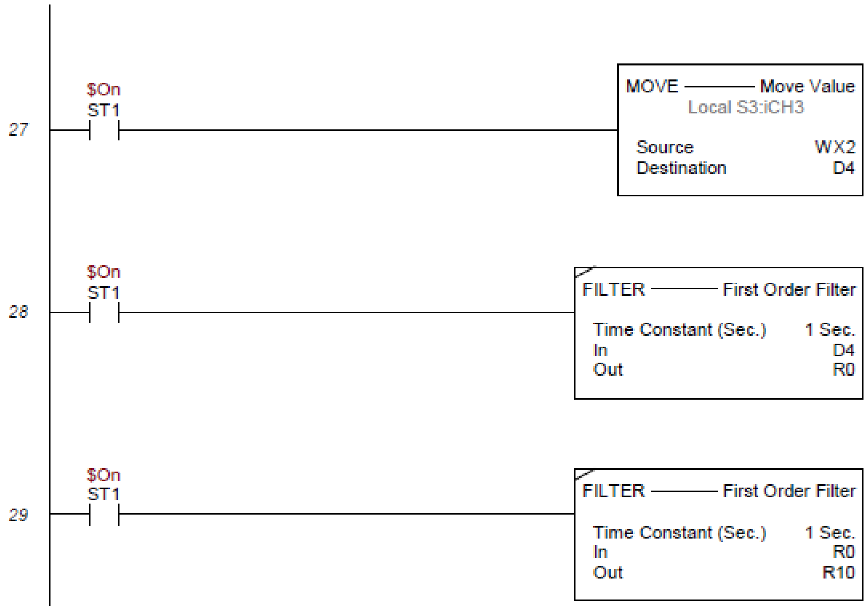


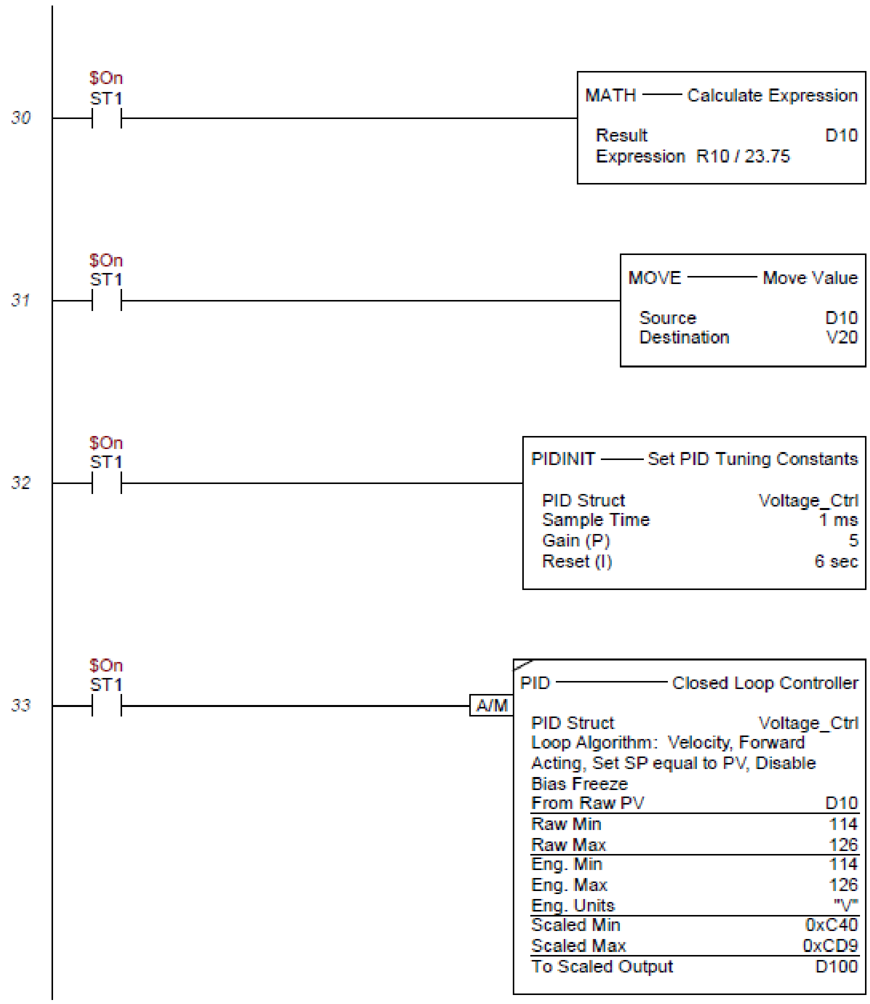
4.5 Wiring Diagram

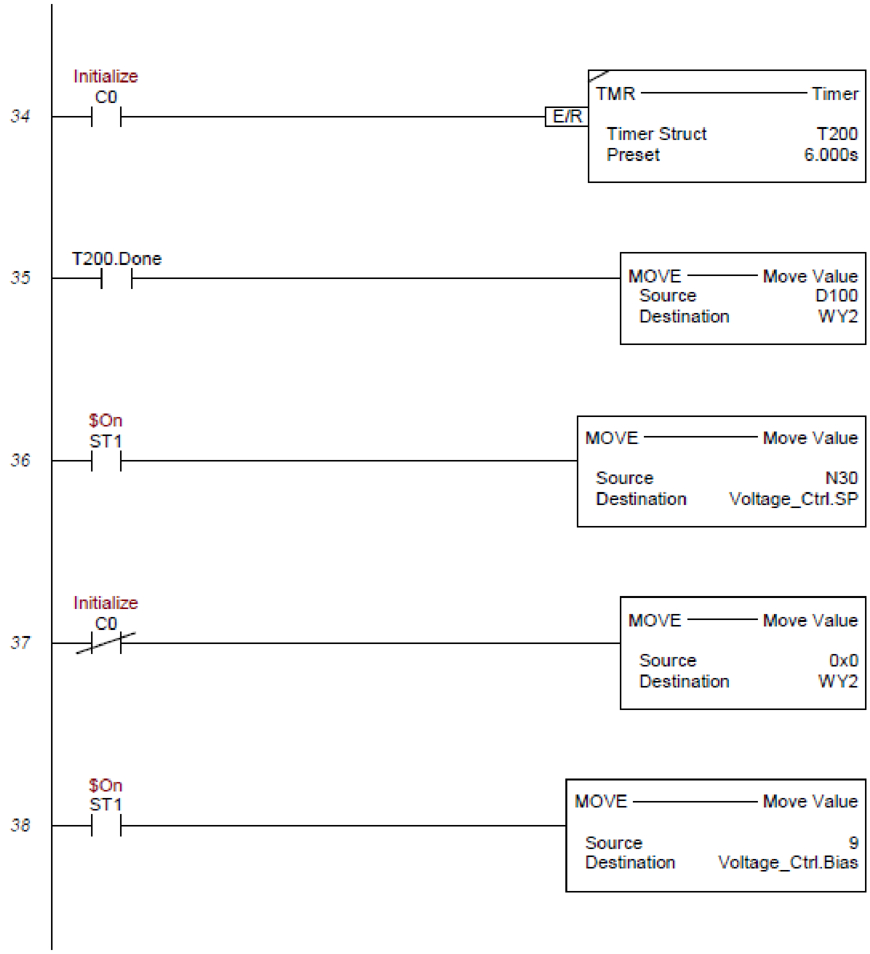
Figure 6: Wiring Diagram



4.6 Ladder Logic




30
$On
ST1
MATH — Calculate Expression
Result D10
Expression R10 / 23.75
31
$On
ST1
MOVE — Move Value
Source D10
Destination V20
32
$On
ST1
PIDINIT — Set PID Tuning Constants
PID Struct Voltage_Ctrl
Sample Time 1 ms
Gain (P) 5
Reset (I) 6 sec
33
$On
ST1
A/M
PID — Closed Loop Controller
PID Struct Voltage_Ctrl
Loop Algorithm: Velocity, Forward Acting, Set SP equal to PV, Disable Bias Freeze
From Raw PV D10
Raw Min 114
Raw Max 126
Eng. Min 114
Eng. Max 126
Eng. Units "V"
Scaled Min 0xC40
Scaled Max 0xCD9
To Scaled Output D100


34
Initialize
C0
E/R
TMR
Timer
Timer Struct
T200
Preset
6.000s
35
T200.Done
MOVE
Move Value
Source
D100
Destination
WY2
36
$On
ST1
MOVE
Move Value
Source
N30
Destination
Voltage_Ctrl.SP
37
Initialize
C0
MOVE
Move Value
Source
0x0
Destination
WY2
38
$On
ST1
MOVE
Move Value
Source
9
Destination
Voltage_Ctrl.Bias

4.7 Panel CAD Drawing

Since our group doesn't have a rack of our own, both Slack and PV groups have drawings that include the limited number of components that we have used.Those components include: Iron-Horse, Transformer, Analog In Module, Analog Out Module, Fuse Box and Input/Output Ports. Please refer to Slack and PV group drawings.

4.8 Bill of Materials

#	Item	Vendor	Part Number	Per Station Quantity	Per Item List price	Per Station Net price
1	ZipLink 20-pole feed through module	Automation Direct	ZL-RTB20	2	$20	$40
2	USB type A-B Connector cable 6ft	Automation Direct	USB-CBL-AB6	2	$9.50	$19
3	DL205 analog output module	Automation Direct	F2-02DAS-2	2	$ 255	$ 510
4	IronHorse GSD7 series DC reversing drive	Automation Direct	GSD7-240-5CR3	2	$ 172	$344
5	Transformer Encap 500VA	Automation Direct	C1FC50WE	2	$ 122.25	$ 244.50
6	Cable 10-term/24-pin 0.5m Ziplink for Dl205	Automation Direct	ZL-D2-CBL10	2	$37.5	$75
7	Fuse Block,GRY 30A 20-6 AWG,300V	Automation Direct	DN-F6MN	2	$20	$40
8	DL205 BASE 9-SLOT REQ 110/220VAC PWR W/300mA 24VDC AUX P/S	Automation Direct	D2-09B-1	2	$220	$440
9	Stranded Hook-up wire, Black	Home Depot	Wire	1	$ 10	$10
10	Stranded Hook-up wire, Red	Home Depot	Wire	1	$ 10	$ 10
11	Stranded Hook-up wire, Green	Home Depot	Wire	1	$10	$10
12	Stranded Hook-up wire, White	Home Depot	Wire	1	$10	$10
13	PCB Printed Circuit Board Prototype Breadboard	Walmart	PCB	1	$9.50	$9.50
14	Resistors of different type	PSU makerspace	Resistors		$5	$5
15					$	$
16					$	$
	Total cost				**$** 863.25	**$** 1777.0

-Total Engineering hours : **180**

-Total cost of Engineering hours **$4725**

-Total per station item [net price] : **$6501.0**

4.9 Points List

Figure 7: Slack

PLC TYPE:	EA9-T8CL	
PLC Card Slot Assignments:		Slack
Card Details		

Slot	Card Name	Card Mnemonic	Part Nember	Comments
1/6	Do more CPU	H2DM1E	H2DM1E	
5/6	24 VDC Outputs CTR IN	H2-CTRIO2	H2-CTRIO2	
3/6	110VAC input	D2-08NA-1	D2-08NA-1	
4/6	110-220 VAC output	D2-08TA	D2-08TA	
5/6	8 Channel Analogue In	F2-08AD-2	F2-08AD-2	
6/6	8 Channel Analogue Output	F2-08DA-2	F2-02DAS-2	

		POINT TYPE							
		Hardware Point							
Point Description	**Origin Address**	DO	DI	AO	AI	**Virtual Point**	**Destination Address**	**Destination Description**	**Notes**
Iron Horse	WX0	0	0	0	1	0	Ziplink		
Voltage +	CC	0	0	0	1	0	Ziplink		
Voltage -	CC	0	0	0	1	0	Ziplink		
	Total Points	0	0	0	3	0			

Figure 8: Gen p

PLC TYPE:	EA9-T8CL
PLC Card Slot Assignments:	
Gen P	
Card Details	

Slot	Card Name	Card Mnemonic	Part Nember	Comments
1/6	Do more CPU	H2DM1E	H2DM1E	
2/6	110-220 VAC output	D2-08TA	D2-08TA	
3/6	110VAC input	D2-08NA-1	D2-08NA-1	
4/6	2 Channel Analogue Output	F2-02DAS-2	F2-02DAS-2	
5/6	8 Channel Analogue In	F2-08AD-2	F2-08AD-2	
5/6				

		POINT TYPE							
		Hardware Point				Virtual			
Point Description	**Origin Address**	DO	DI	AO	AI	**Point**	**Destination Address**	**Destination Description**	**Notes**
Iron Horse	WX0	0	0	0	1	0	Ziplink		
Voltage +	CC	0	0	0	1	0	Ziplink		
Voltage -	CC	0	0	0	1	0	Ziplink		
	Total Points	0	0	0	3	0			

4.10 Credits(Gen V)

- **Neal Alnajran**
  Overview
  Team Management
  Ladder Logic
  HMI Logic PID Control
  PCB Design
  Testing Validating Procedures
  NFPA 70
  Report

- **Mohammed Albabtain**
  Report.
  Wiring Diagram.
  Wiring Ironhorse.
  Electrical Diagram.
  Wiring Transformer.
  Testing and Validating Procedures.
  Communicating with other groups.

- **Tewodros Terefe**
  Bill of materials
  Points list
  Realized Specifications
  AC/DC design

5 Gen P

5.1 Gen P Overview

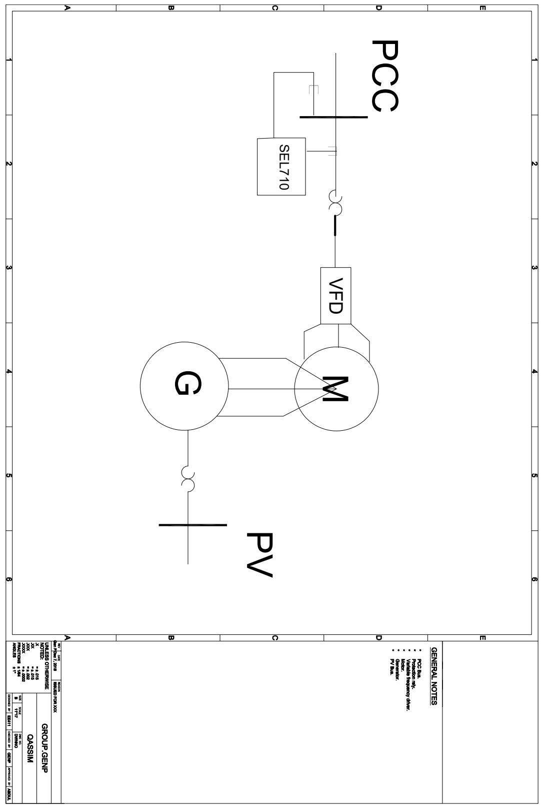
In this part of the project, our group's task is to develop a PI controller that maintain real power on a PV bus. Setpoints in the range of 0.1 - 1.1 p.u will be used as they span the full range of the generator's real power capability. We will use a synchronous generator that is driven with a squirrel cage induction motor as a prime mover which is controlled by a Variable Frequency Drive (VFD).

5.2 Realized Specifications

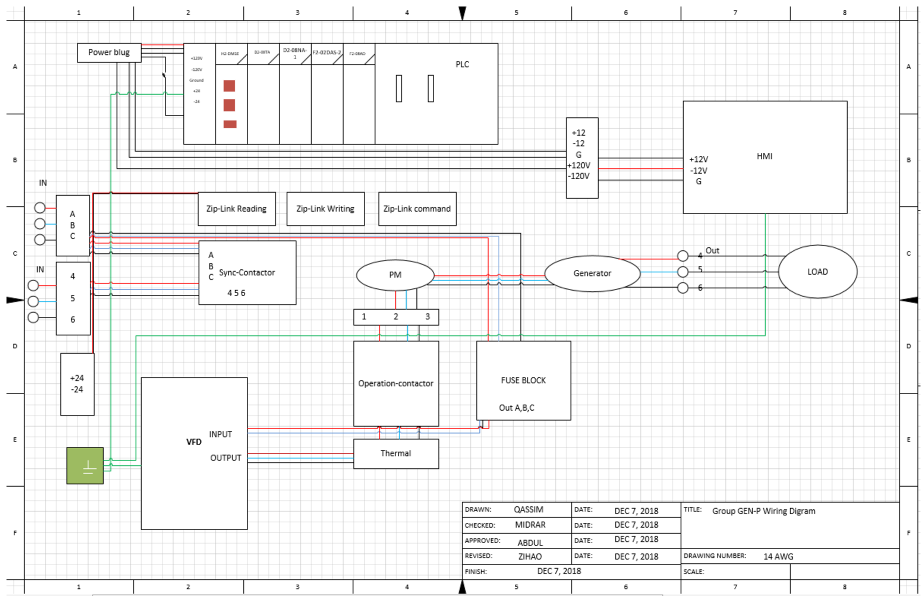
1. A DL205 AD PLC shall be used as the controller for the PV Generator.
   - Direct logic 205 cotntrols the AC and DC voltages of the generator by using multiple modules connected to ZIPLINK in order to
2. The controller should use an HMI to recieve inputs and show outputs.
   - The HMI is installed in the panel and simulated using C-More in order to simulate buttons, lights, etc.
3. The PLC shall communicate with Central Control via a local TCP/IP network.
   - Our group communicated with TCP/IP group so they can control our panel.
4. The Gen P group shall coordinate with the Gen V group to implement the power controller specifications within the PV generator PLC using HMI.
   - Our group communicated with Gen V group to plan and work on the required designs.
5. The Gen P group shall work with the MPR group to provide the applicable IEEE Std C37.2-2008 protective relays at the PQ bus.
6. The controller shall use PI compensation.
   - PI is designed using Do-More software.
7. The allowed power setpoint shall be within the range of 0.1 pu to 1.10 pu of the nameplate apparent power.
   - The per unit value is converted by using the rated power on the machines' nameplates.
8. Steady-state error should be zero.
   - Steady state error is minimized to a value that is closed to zero.

9. Error should decay to 5 tau within 3 seconds.
    - the steady state error reaches the steady state after 3 seconds.
10. Overshoot should not exceed 0.10 pu.
11. The prime mover (PM) for the PV generator should be an induction motor.
    - A squirrel cage induction motor is used as a prime mover that provides a mechanical input to the synchronous generator.
12. The PM induction motor should be controlled using a VFD.
    - The variable frequency drive is used to control the primemover by setting the voltage which decrease or increase the rotor speed of the synchronous machine.

5.3 Electrical Diagram



5.4 Wiring Diagram

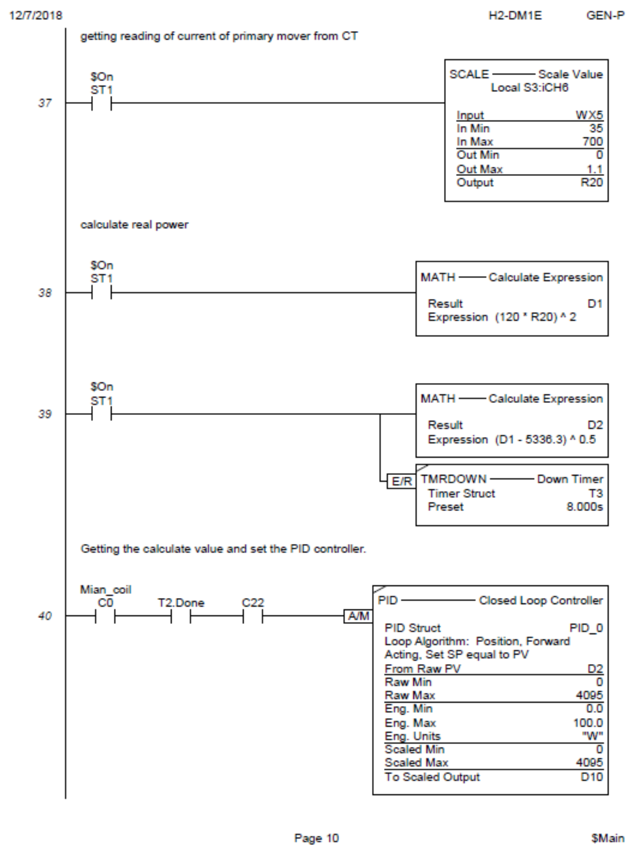


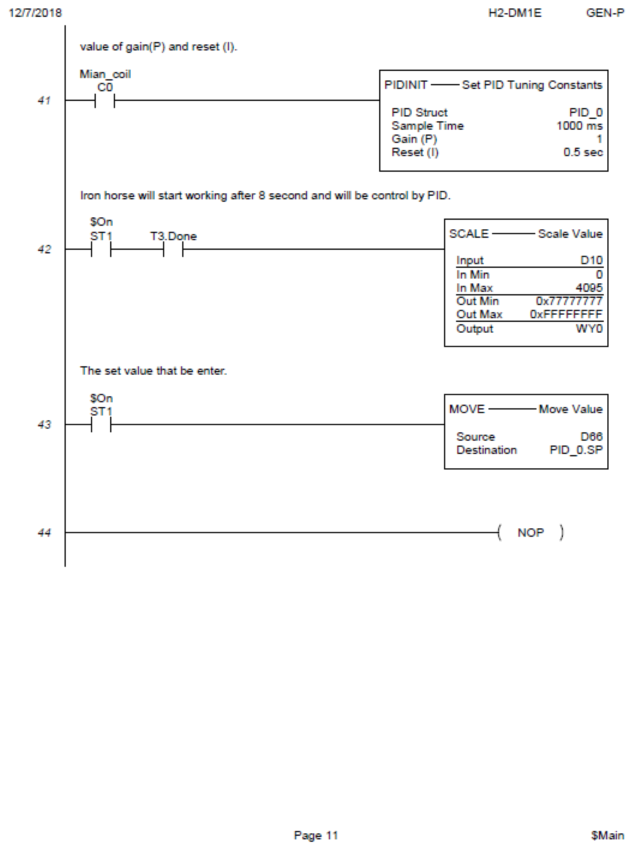
5.5 Ladder Logic

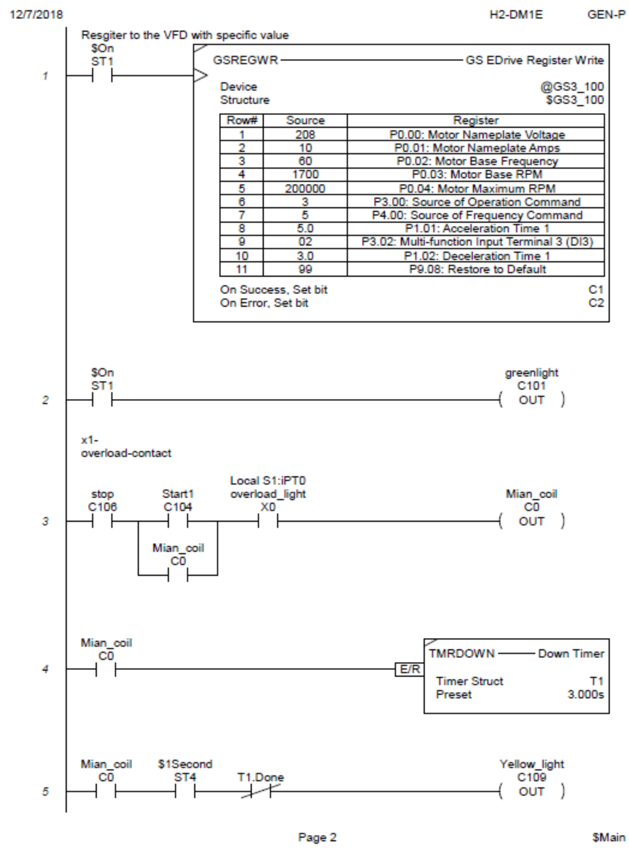
12/7/2018 H2-DM1E GEN-P

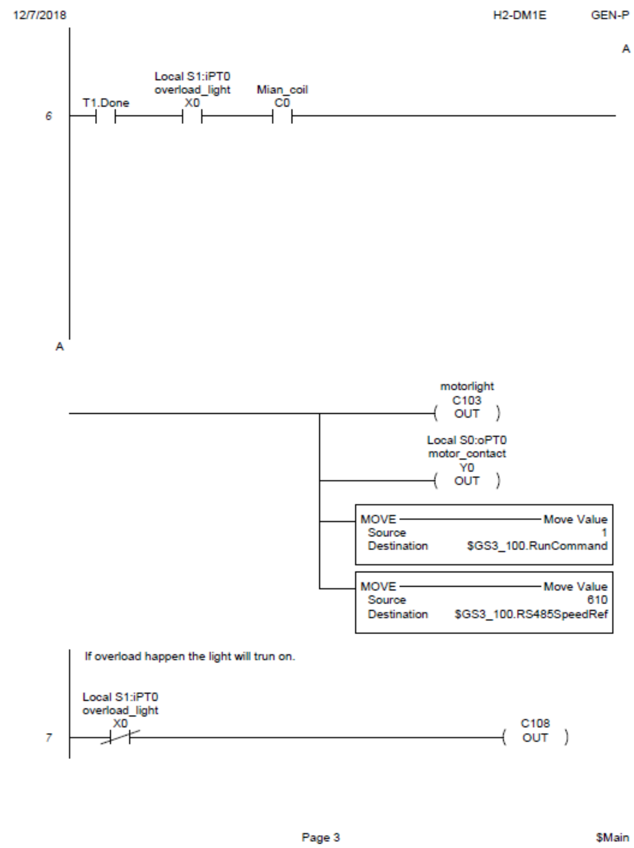
Project Path: C:\Users\abdulhai\Desktop\GEN-P.dmd
Save Date: 12/07/18 13:19:42
Creation Date: 11/30/18 00:39:19
PLC Type: H2-DM1E
Class ID: Do-more H2 Series
Link Name: lll
Do-more Technology Version: 2.3
Description: Almost Complete circuit
Version:
Company:
Department:
Programmer:

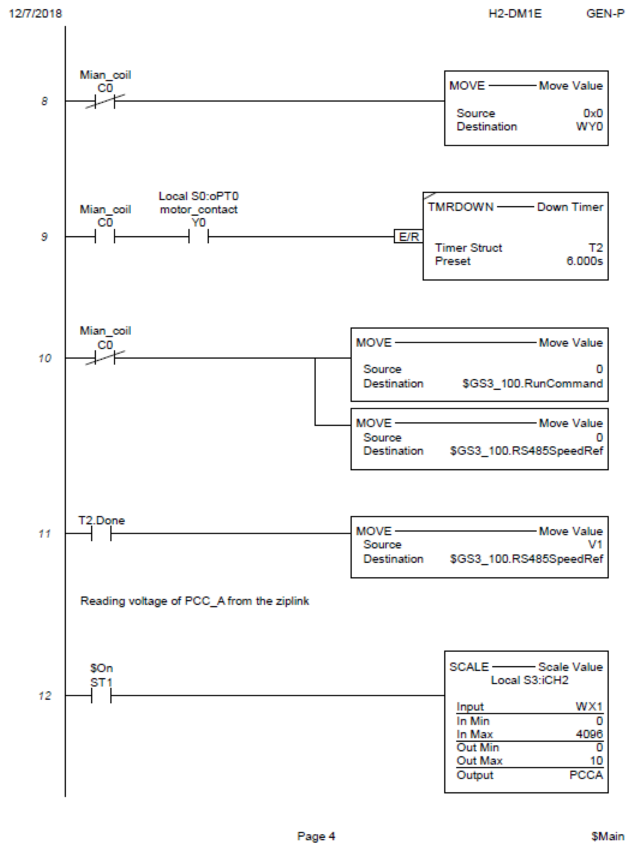
Page 1

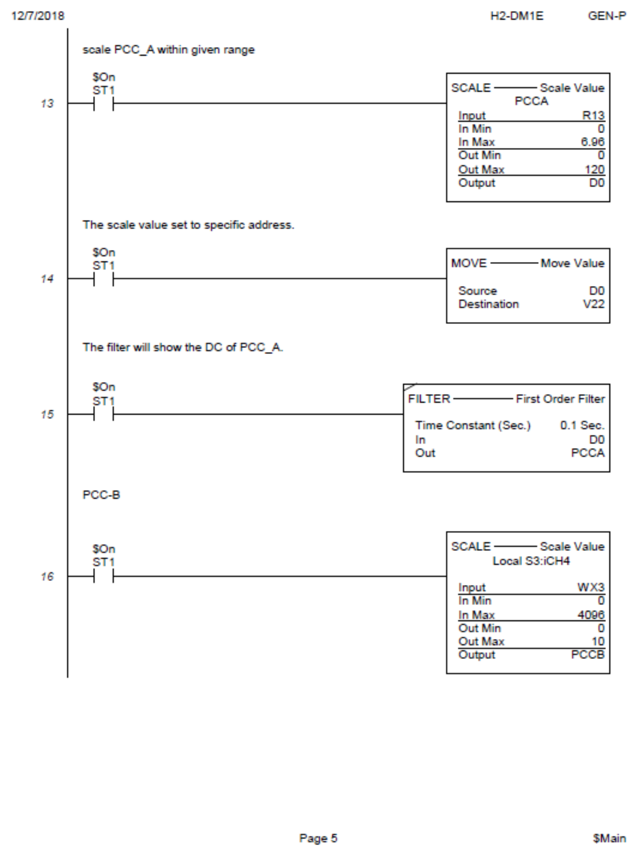

12/7/2018
H2-DM1E
GEN-P
getting reading of current of primary mover from CT
$On
ST1
37
SCALE Scale Value
Local S3:iCH6
Input WX5
In Min 35
In Max 700
Out Min 0
Out Max 1.1
Output R20
calculate real power
$On
ST1
38
MATH Calculate Expression
Result D1
Expression (120 * R20) ^ 2
$On
ST1
39
MATH Calculate Expression
Result D2
Expression (D1 - 5336.3) ^ 0.5
E/R
TMRDOWN Down Timer
Timer Struct T3
Preset 8.000s
Getting the calculate value and set the PID controller.
Mian_coil
C0
T2.Done
C22
40
A/M
PID Closed Loop Controller
PID Struct PID_0
Loop Algorithm: Position, Forward
Acting, Set SP equal to PV
From Raw PV D2
Raw Min 0
Raw Max 4095
Eng. Min 0.0
Eng. Max 100.0
Eng. Units "W"
Scaled Min 0
Scaled Max 4095
To Scaled Output D10
Page 10
$Main

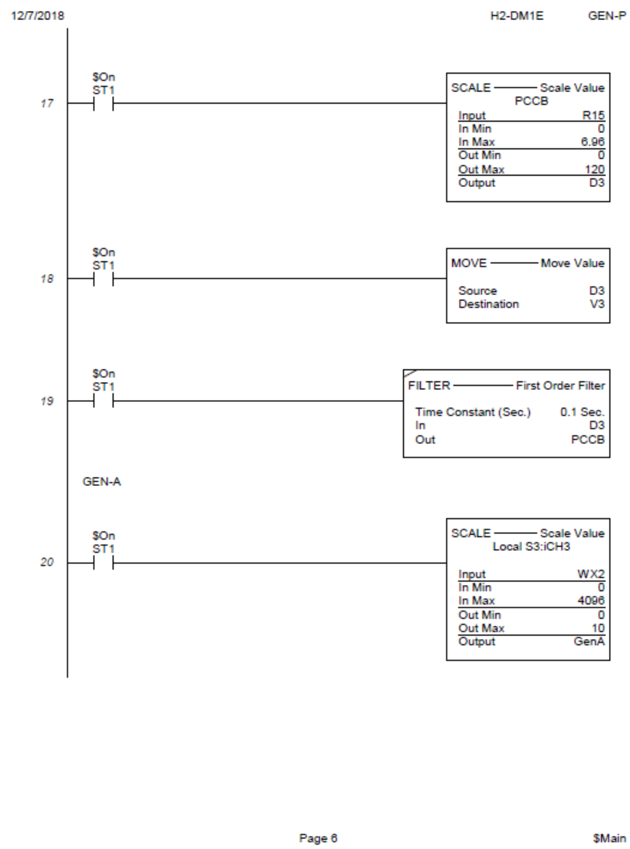

12/7/2018
H2-DM1E
GEN-P
value of gain(P) and reset (I).
Mian_coil
C0
41
PIDINIT — Set PID Tuning Constants
PID Struct PID_0
Sample Time 1000 ms
Gain (P) 1
Reset (I) 0.5 sec
Iron horse will start working after 8 second and will be control by PID.
$On
ST1
T3.Done
42
SCALE — Scale Value
Input D10
In Min 0
In Max 4095
Out Min 0x77777777
Out Max 0xFFFFFFFF
Output WY0
The set value that be enter.
$On
ST1
43
MOVE — Move Value
Source D66
Destination PID_0.SP
44
NOP
Page 11
$Main

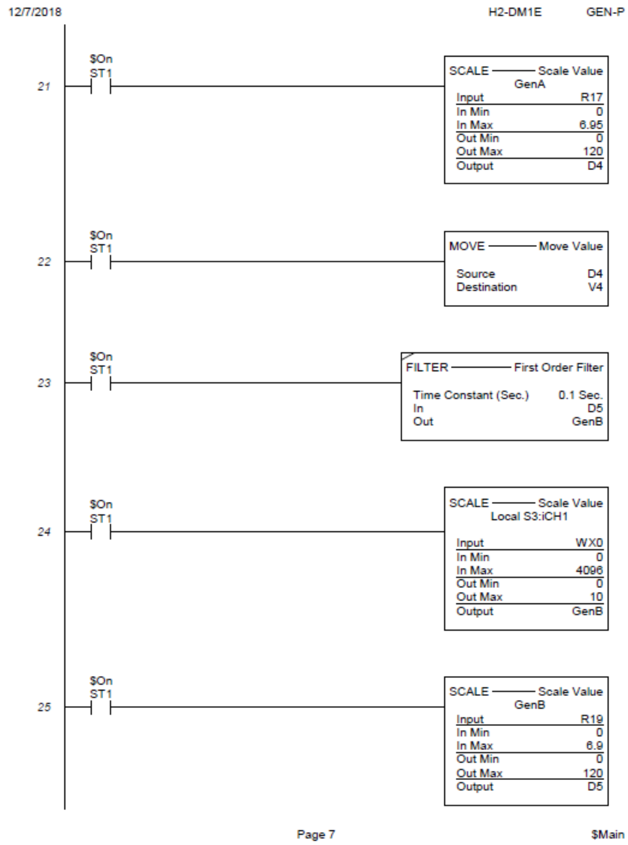

12/7/2018
H2-DM1E
GEN-P
Resgiter to the VFD with specific value
$On
ST1
1
GSREGWR
GS EDrive Register Write
Device
@GS3_100
Structure
$GS3_100
Row# Source Register
1 208 P0.00: Motor Nameplate Voltage
2 10 P0.01: Motor Nameplate Amps
3 60 P0.02: Motor Base Frequency
4 1700 P0.03: Motor Base RPM
5 200000 P0.04: Motor Maximum RPM
6 3 P3.00: Source of Operation Command
7 5 P4.00: Source of Frequency Command
8 5.0 P1.01: Acceleration Time 1
9 02 P3.02: Multi-function Input Terminal 3 (DI3)
10 3.0 P1.02: Deceleration Time 1
11 99 P9.08: Restore to Default
On Success, Set bit C1
On Error, Set bit C2
2
$On
ST1
greenlight
C101
OUT
x1-
overload-contact
3
stop
C106
Start1
C104
Local S1:iPT0
overload_light
X0
Mian_coil
C0
OUT
Mian_coil
C0
4
Mian_coil
C0
E/R
TMRDOWN
Down Timer
Timer Struct T1
Preset 3.000s
5
Mian_coil
C0
$1Second
ST4
T1.Done
Yellow_light
C109
OUT
Page 2
$Main

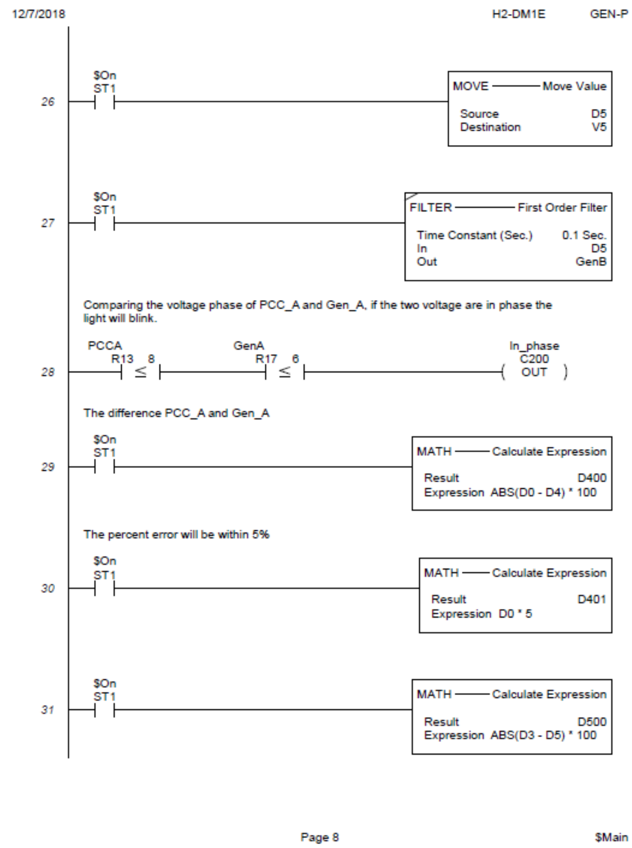

12/7/2018
H2-DM1E
GEN-P
A
Local S1:iPT0
overload_light
X0
Mian_coil
C0
T1.Done
6
A
motorlight
C103
OUT
Local S0:oPT0
motor_contact
Y0
OUT
MOVE Move Value
Source 1
Destination $GS3_100.RunCommand
MOVE Move Value
Source 610
Destination $GS3_100.RS485SpeedRef
If overload happen the light will trun on.
Local S1:iPT0
overload_light
X0
7
C108
OUT
Page 3
$Main

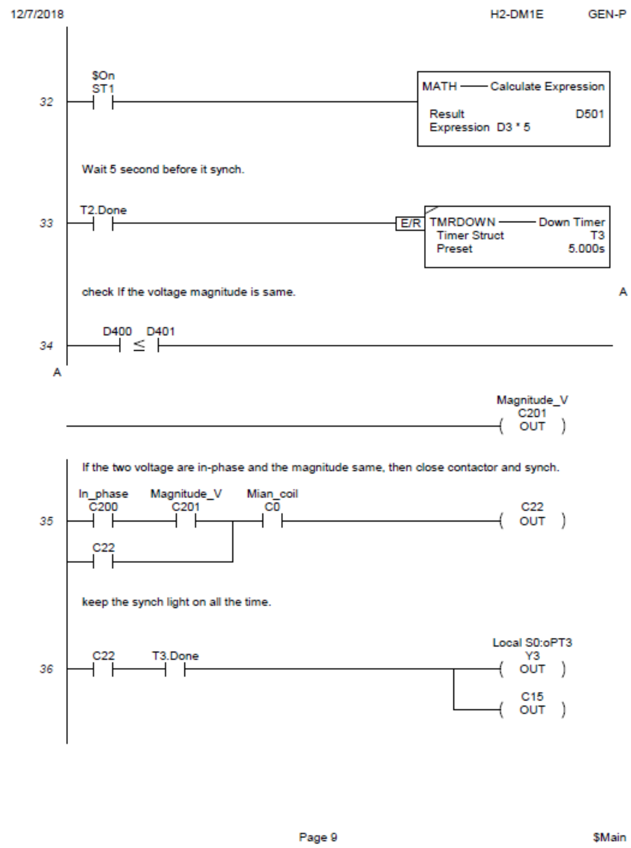

12/7/2018
H2-DM1E
GEN-P
Mian_coil
C0
8
MOVE Move Value
Source 0x0
Destination WY0
Local S0:oPT0
Mian_coil
motor_contact
C0
Y0
9
E/R
TMRDOWN Down Timer
Timer Struct T2
Preset 6.000s
Mian_coil
C0
10
MOVE Move Value
Source 0
Destination $GS3_100.RunCommand
MOVE Move Value
Source 0
Destination $GS3_100.RS485SpeedRef
T2.Done
11
MOVE Move Value
Source V1
Destination $GS3_100.RS485SpeedRef
Reading voltage of PCC_A from the ziplink
$On
ST1
12
SCALE Scale Value
Local S3:iCH2
Input WX1
In Min 0
In Max 4096
Out Min 0
Out Max 10
Output PCCA
Page 4
$Main


12/7/2018
H2-DM1E
GEN-P
scale PCC_A within given range
$On
ST1
13
SCALE Scale Value
PCCA
Input R13
In Min 0
In Max 6.96
Out Min 0
Out Max 120
Output D0
The scale value set to specific address.
$On
ST1
14
MOVE Move Value
Source D0
Destination V22
The filter will show the DC of PCC_A.
$On
ST1
15
FILTER First Order Filter
Time Constant (Sec.) 0.1 Sec.
In D0
Out PCCA
PCC-B
$On
ST1
16
SCALE Scale Value
Local S3:iCH4
Input WX3
In Min 0
In Max 4096
Out Min 0
Out Max 10
Output PCCB
Page 5
$Main

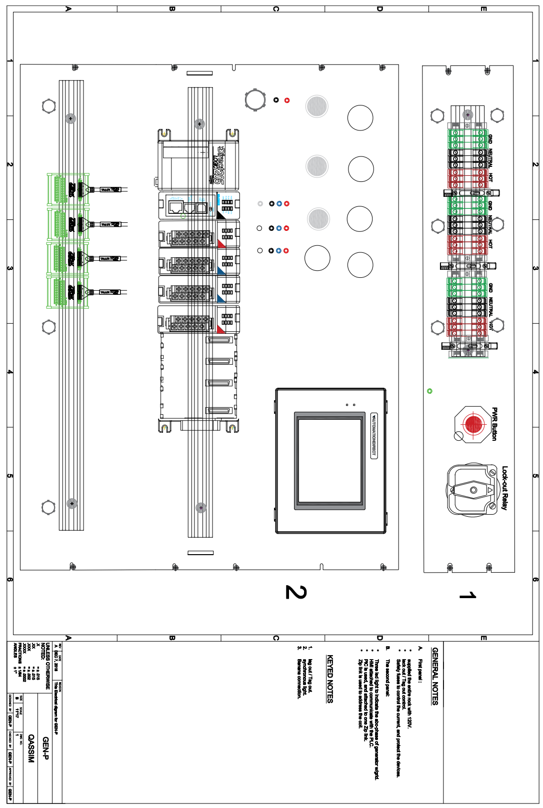

12/7/2018
H2-DM1E
GEN-P
17
$On
ST1
SCALE Scale Value
PCCB
Input R15
In Min 0
In Max 6.96
Out Min 0
Out Max 120
Output D3
18
$On
ST1
MOVE Move Value
Source D3
Destination V3
19
$On
ST1
FILTER First Order Filter
Time Constant (Sec.) 0.1 Sec.
In D3
Out PCCB
GEN-A
20
$On
ST1
SCALE Scale Value
Local S3:iCH3
Input WX2
In Min 0
In Max 4096
Out Min 0
Out Max 10
Output GenA
Page 6
$Main

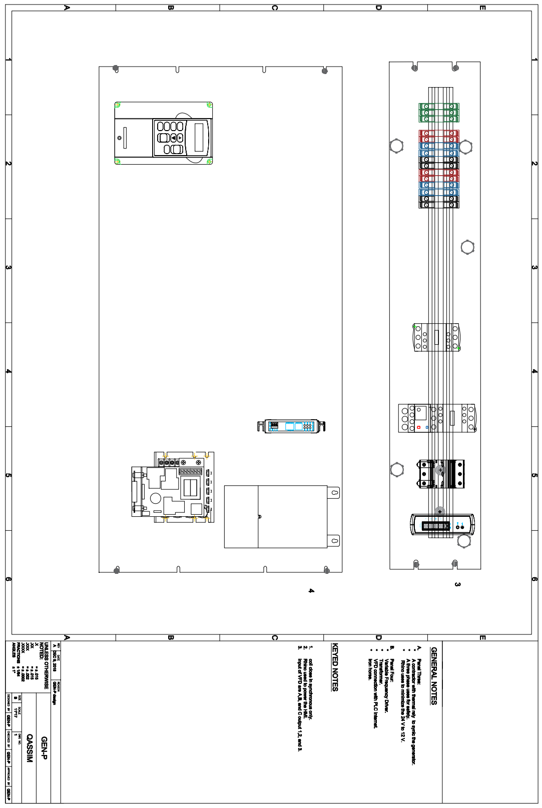

12/7/2018
H2-DM1E
GEN-P
21
$On
ST1
SCALE Scale Value
GenA
Input R17
In Min 0
In Max 6.95
Out Min 0
Out Max 120
Output D4
22
$On
ST1
MOVE Move Value
Source D4
Destination V4
23
$On
ST1
FILTER First Order Filter
Time Constant (Sec.) 0.1 Sec.
In D5
Out GenB
24
$On
ST1
SCALE Scale Value
Local S3:iCH1
Input WX0
In Min 0
In Max 4096
Out Min 0
Out Max 10
Output GenB
25
$On
ST1
SCALE Scale Value
GenB
Input R19
In Min 0
In Max 6.9
Out Min 0
Out Max 120
Output D5
Page 7
$Main


12/7/2018
H2-DM1E
GEN-P
26
$On
ST1
MOVE Move Value
Source D5
Destination V5
27
$On
ST1
FILTER First Order Filter
Time Constant (Sec.) 0.1 Sec.
In D5
Out GenB
Comparing the voltage phase of PCC_A and Gen_A, if the two voltage are in phase the light will blink.
28
PCCA
R13 ≤ 8
GenA
R17 ≤ 6
In_phase
C200
OUT
The difference PCC_A and Gen_A
29
$On
ST1
MATH Calculate Expression
Result D400
Expression ABS(D0 - D4) * 100
The percent error will be within 5%
30
$On
ST1
MATH Calculate Expression
Result D401
Expression D0 * 5
31
$On
ST1
MATH Calculate Expression
Result D500
Expression ABS(D3 - D5) * 100
Page 8
$Main


12/7/2018
H2-DM1E
GEN-P
$On
ST1
32
MATH — Calculate Expression
Result D501
Expression D3 * 5
Wait 5 second before it synch.
T2.Done
33
E/R
TMRDOWN — Down Timer
Timer Struct T3
Preset 5.000s
check If the voltage magnitude is same.
A
D400 D401
34
≤
A
Magnitude_V
C201
OUT
If the two voltage are in-phase and the magnitude same, then close contactor and synch.
In_phase
C200
Magnitude_V
C201
Mian_coil
C0
35
C22
OUT
C22
keep the synch light on all the time.
Local S0:oPT3
Y3
C22
T3.Done
36
OUT
C15
OUT
Page 9
$Main

5.6 Panel CAD Drawing





5.7 Bill of Materials

	Item	Vendor	Part Number	Quantity	Price	Net Price
1	Contact Block, 1 NO, Green	Schneider	XB4BA31	1	$56.00	$56.00
2	Contact Block, 1 NC, Red	Schneider	XB4BA42	1	$38.50	$38.50
6	Fuse block	Auto.	DN-F6MN	1	$20.00	$20.00
7	Do-more CPU Module	Auto.	H2-DM1E	1	$399.00	$399.00
8	VAC Output Module	Auto.	D2-08TA	1	$110.00	$110.00
9	VAC Input Module	Auto.	D2-08NA-1	1	$77.00	$77.00
10	DL205 X-Slot Base, 120 VAC PWR	Auto.	D2-XXXX	1	$176.00	$176.00
11	ZipLink	Auto.	ZL-RTB20	2	$20.00	$40.00
12	Ziplink for Dl205	Auto.	ZL-D2-CBL10	2	$10.00	$20.00
13	Filler Panel	Rack Solutions	102-2142	2	$44.99	$89.98
14	3U Filler Panel	Rack Solutions	102-1824	1	$15.99	$15.99
15	4U Filler Panel	Rack Solutions	102-1825	1	$18.99	$18.99
16	Rack 77" x 19"	A-I Consolidated	RR-1369-MG	1	$388.93	$388.93
17	Safety Lockout Hasp	Grainger	1U177	1	$5.60	$5.60
19	Lock Out Relay	Shallco	7601D	1	$245.00	$245.00
20	Power Cord	All Electronics	LCAC-310	1	$4.50	$4.50
21	Terminal block, DIN, 2 Red	Schneider	NSY42RD	11	$1.50	$16.50
22	Terminal block, DIN, 2 White	Schneider	NSY42WH	11	$1.50	$16.50
23	Terminal block, DIN, 2 Bule	Schneider	NSY42GN	8	$1.50	$12.00
24	Terminal Mounting Track	Schneider	90MH217	5	$10.20	$51.00
25	Lamp; Incandescent, BA 9S Base, 24 V, 2 Watt	Schneider	DL1CE24	2	$8.02	$16.04
26	Stranded Hook-up wire, Green	BulkWire	Wire-ST-14-05-100	1 Spool/100 ft	$30.62	$30.62
27	Stranded Hook-up wire, White	BulkWire	Wire-ST-14-09-100	1 Spool/100 ft	$30.62	$30.62
28	Stranded Hook-up wire, Black	BulkWire	Wire-ST-14-00-100	1 Spool/100 ft	$30.62	$30.62
29	Stranded Hook-up wire, Red	BulkWire	Wire-ST-16-09-100	1 Spool/100 ft	$22.28	$22.28
30	Contactor coil	Schneider	LC1D9G7	3	$104.60	$313.80
31	DIN mount	Schneider	8501NR51	2	$94.00	$188.00
32	Thermal Overload relay	Schneider	LRD06	1	$57.00	$57.00
33	Thermal Overload Relay	Schneider	LADB106	1	$60.00	$60.00
34	20 mm fuses	Jameco	various	1	$3.86	$3.86
35	Contact Block, 1 NO, White	Schneider	XB4BA31	1	$56.00	$56.00
36	C-More Programming Software	Automation Direct	EA9-PGMSW	1	$99.00	$99.00
37	C-More to H2-DM1 connection cable	Automation Direct	EA-2CBL	1	$20.00	$20.00
38	C-More X inch Color Touch Screen Interface Panel	Automation Direct	EA9-TXXX	1	$356.00	$356.00
39	**Total Price**					**$3367.18**

5.8 Points List

PLC Card Slot Assignments:

PLC Chassis	Slot 1/6	Slot 2/6	Slot 3/6	Slot 4/6	Slot 5/6	Slot 6/6
1	H2-DM1E	D2-08TA	D2-08NA-1	F2-02DAS	F2-08AD-2	

Card Details

Slot	Card Name	Card Mnemonic	Part Nember	Comments
1/6	PLC			
2/6	1DIGITAL OUTPUT	2CAO-1	F2-02DAS-2	
3/6	1DIGITAL INPUT		D2-08NA-1	
	1DIGITAL OUTPUT		D2-08TA	
	1DIGITAL INTPUT		F2=08AD-2	

		POINT TYPE							
		Hardware Point							
Point Description	Origin Address	DO	DI	AO	AI	Virtual Point	Destination Address	Destination Description	Notes
Common	ziplink 2 port c	1	1	0	0	0	V22	Output of PCC_A	
common	ziplink 2 port c	0	0	0	0	0			
	ziplink 1 port c	0	0	0	0	0			
	ziplink 2 port c	0	0	0	0	0			
	Total Points	1	1	0	0	0			

5.9 Credits (Gen P)

1. Wiring, Electrical Diagrams and Ladder Logic:
   - Qassim Alhay
2. BoM and Points Lists:
   - Abdulhai Mohammednur
3. Overview, Realized Specs, Report

6 Load P

6.1 Load P Overview

6.2 Realized Specifications

- **A DL205 AD PLC shall be used as the controller for the P load**

- **The controller Should use as an HMI to receive input and shows output** HMI is used to receive input and shows output.

- **The PLC shall communicate with Central via a local TCP/IP network**
  PLC is communicating with Central via local TCP/IP network.

- **The Load P group shall coordinate with the Load Q Group to implement the P controller specifications within the PQ PLC using one HMI.**
  Load P shall group shall work with the MPR group to provide the applicable IEEE Std C37.2-2008 protective relays at the PQ bus.We used induction motor to maintain real power with the use of HMI and PLC.

- **The P load controller shall use PI compensation**
  PI compensation is used to control the load.

- **The allowable real power load set point shall be within 0.2 pu to 1.10 pu of the total system nameplate apparent power.**

- **. Steady-state error should be zero, error should decay to 5 tau within 3 seconds, overshoot should not exceed 0.10 pu.**

6.3 Electrical Diagram

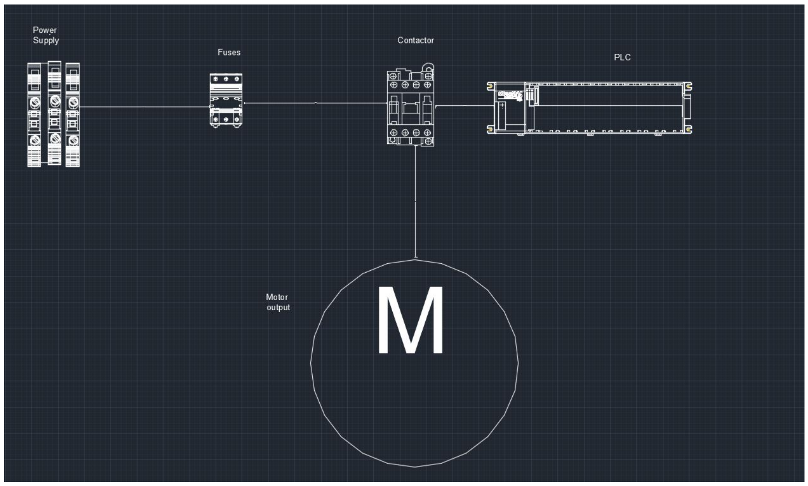


Figure 9: Electrical Diagram

6.4 Wiring Diagram

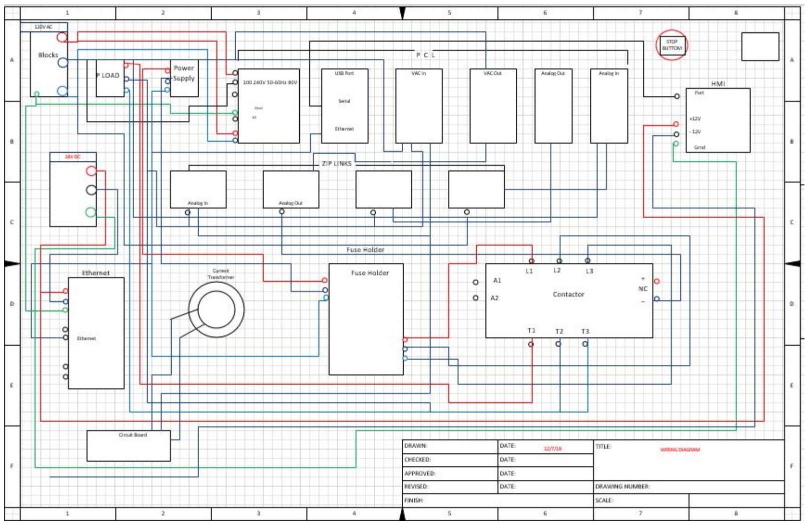
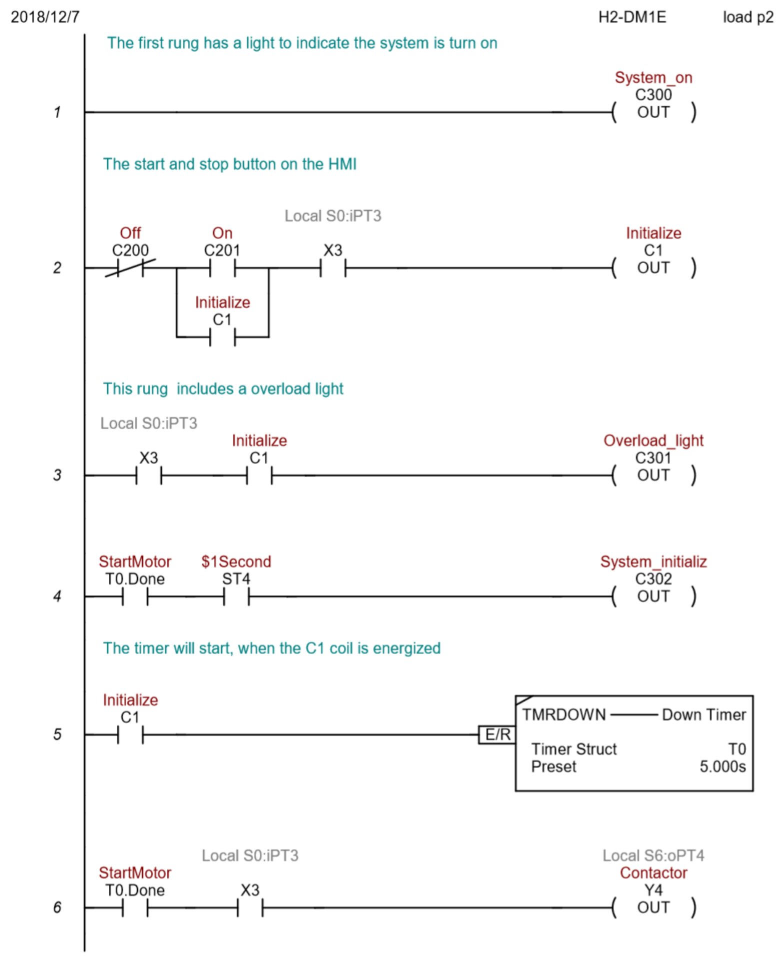


Figure 10: Electrical Diagram

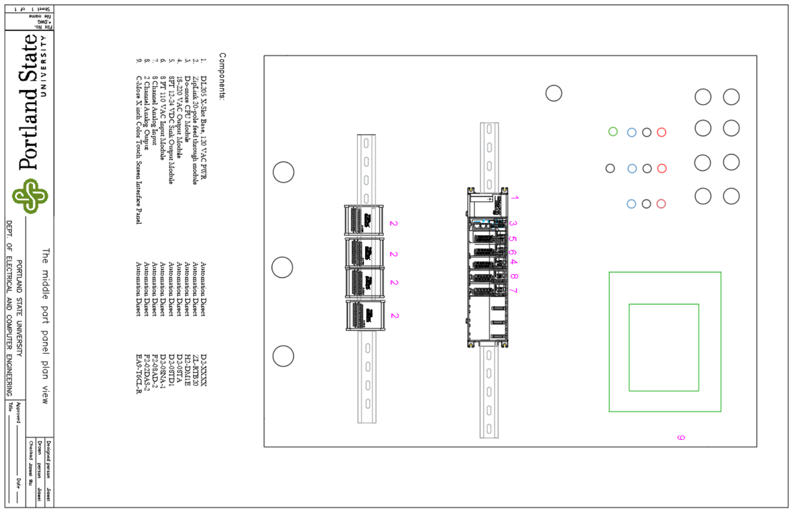
6.5 Ladder Logic

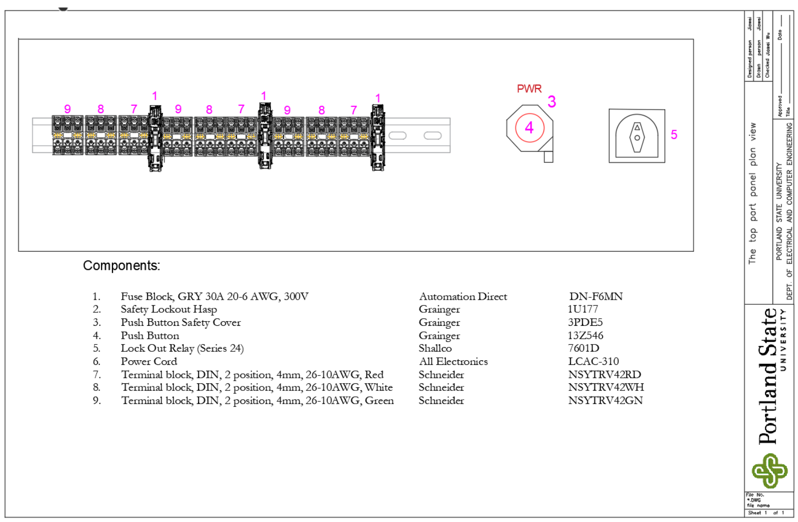


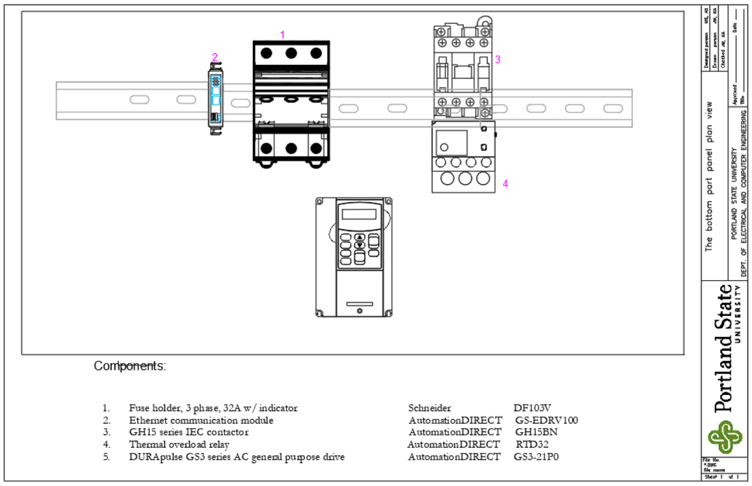
loadp_15.png

loadp_16.png

6.6 Panel CAD Drawing






1
2
3
4
Components:
1. Fuse holder, 3 phase, 32A w/ indicator Schneider DF103V
2. Ethernet communication module AutomationDIRECT GS-EDRV100
3. GH15 series IEC contactor AutomationDIRECT GH15BN
4. Thermal overload relay AutomationDIRECT RTD32
5. DURApulse GS3 series AC general purpose drive AutomationDIRECT GS3-21P0
The bottom port panel plan view
PORTLAND STATE UNIVERSITY
DEPT. OF ELECTRICAL AND COMPUTER ENGINEERING
Portland State
UNIVERSITY

6.7 Bill of Materials

1	Part Number	Vendor	Quantity	Unit Cost $	Cost $
2	8501KPR12P14V14	Schneider	1	45	45
3	8501NR51	Schneider	1	12.3	12.3
4	LRD06	Schneider	1	60	60
5	LAD7B106	Schneider	1	8.7	8.7
6	LC1D09G7	Schneider	1	94	94
7	LAD8N11	Schneider	1	20.7	20.7
8	LADN11	Schneider	2	20.7	41.4
9	XB4BBA31	Schneider	1	38.5	38.5
10	XB4BA42	Schneider	1	38.5	38.5
11	ZB4BA5	Schneider	1	13	13
12	ZB4BZ101	Schneider	2	22	44
13	ZB4BZ102	Schneider	2	135	270
14	9070T50D23	Schneider	1	24	24
15	ZB5AD204	Schneider	1	38.79	38.79
16	DF103	Schneider	1	20	20
17	DN-F6MN	Automation Direct	1	399	399
18	H2-DM1E	Automation Direct	1	110	110
19	D2-08TA	Automation Direct	1	58	58
20	D2-08TD1	Automation Direct	1	77	77
21	D2-08NA-1	Automation Direct	1	1,290	1,290
22	EA9-TXXX	Automation Direct	1	321	321
23	H2-CTRIO	Automation Direct	1	274	274

Figure 11: Electrical Diagram

22	EA9-TXXX	Automation Direct	1	321	321
23	H2-CTRIO	Automation Direct	1	274	274
24	F2-08AD-2	Automation Direct	1	255	255
25	F2-02DAS-2	Automation Direct	1	20	20
26	EA-2CBL	Automation Direct	1	258	258
27	D2-XXX	Automation Direct	1	120	120
28	ZL-RTB20	Automation Direct	1	105	105
29	ZL-D2-CBL10	Automation Direct	1	44	44
30	ZL-D2-CBL19	Automation Direct	1	75	75
31	SE-SW5U	Automation Direct	1	204	204
32	GS-EDRV100	Automation Direct	1	99	99
33	EAS-PGMSW	Automation Direct	1	229	229
34	GSX-XXX	Automation Direct	1	172	172
35	GSD7-240-5CR3	Automation Direct	1	122.25	122.25
36	C1FC50WE	Automation Direct	1	44.99	44.99
37	102-2142	Rack Solutions	1	15.99	15.99
38	102-1824	Rack Solutions	1	18.99	18.99
39	102-1825	Rack Solutions	1	481.05	481.05
40	RR-1369-MG	A-I Consolidated	1	32.9	32.9
41	RC-7758-PR	A-I Consolidated	1	32.9	32.9
42	RC-7758-PR	A-I Consolidated	1	5.6	5.6
43	1U177	Grainger	1	69.25	69.25
44	3PDES	Grainger	1	48.4	48.4

Figure 12: Electrical Diagram

41	RC-7758-PR	A-I Consolidated	1	32.9	32.9
42	RC-7758-PR	A-I Consolidated	1	5.6	5.6
43	1U177	Grainger	1	69.25	69.25
44	3PDES	Grainger	1	48.4	48.4
45	13Z546	Grainger	1	64.75	64.75
46	7601D	Shalco	1	4.5	4.5
47	LCAC-310	All Electronics	1	42	42
48	DN-T12B-A	Automation Direct	1	42	42
49	DN-T12BLK-A	Automation Direct	1	42	42
50	DN-T12RED-A	Automation Direct	1	26	26
51	DN-T12W-A	Automation Direct	1	16	16
52	DNT12GRN-A	Automation Direct	1	26.1	26.1
53	DN-EC1210	Automation Direct	1	36.5	36.5
54	NSYTRV42SF5LD	Schneider	5	39.5	197.5
55	DN-2J2Y	Automation Direct	1	10.2	10.2
56	DN-3J2Y	Automation Direct	1	44	54
57	NDN-EB35	Automation Direct	1	54	1
58	9080MH217	Automation Direct	1	12	12
59	9080MH220	Schneider	1	22	22
60	7.82002E+11	Automation Direct	3	11	33
61	CF25-105-JTW	Automation Direct	1	15	15
62	6.53476E+11	Automation Direct	1	2	2
63			TOTAL = 98	TOTAL = $ 6,724	TOTAL = $ 7,255

Figure 13: Electrical Diagram

6.8 Points List

PAGE NO.	NO. OF SHEETS	DESCRIPTION
2	1	PLC SLOT ASSIGNMENTS
3	1	Do-more CPU module
4	1	Points Description PLC Slot 1
5	1	Points Description PLC Slot 2
6	1	Points Description PLC Slot 3
7	1	Points Description PLC Slot 4
8	1	Thermal Overloag relay
9	1	C-More Interface Panel
10	1	Ethernet communication module
11	1	Variable Frequency drive
12	1	The top GH15 series IEC contactor
13	1	Modular fuse holder

REV	DATE	ER. NO.	DESCRIPTION	BY	CH	ENG	APP	APP
1	11/07/2018	1		Jiawei Wu				

BY:	DATE:	APPROVED	
ENG:			

PLC Chassis	Slot 1/6	Slot 2/6	Slot 3/6	Slot 4/6	Slot 5/6	Slot 6/6
1	DMH2SC-1	8CAO-1	2CAO-1	18-220VOM-1	16PAIM-1	8PDOM-1

Card Details

Slot	Card Name	Card Mnemonic	Part Nember	Comments
1/6	Do-more H2 series CPU	DMH2SC-1	H2-DM1E	
2/6	8-pt. DC output module	8PDOM-1	D2-08TD1	
3/6	8-pt. Discrete input module	2PDIM-1	D2-08NA-1	
4/6	18-220 VAC Output Module	18-220VOM-1	D2-08TA	
5/6	2 Channel Analogue Output	2CAO-1	F2-02DAS-2	
6/6	8 Channel Analogue Voltage Output	8CAO-1	F2-08AD-2	

Do-More CPU Module
PN:H2-DM1E

Point Description	Origin Address	Destination Address	Destination Description	Notes
	USB PGM PORT	Computer	Personal Computer	
	RS-232 serial	C-More Panel	EA9-T7CL-R	
	10/100 Ethernet	GS-EDRV100	ETHERNET	
	Total Points	3		

8 Channel Analogue Voltage Input
PN: F2-08DA-2

		POINT TYPE							
		Hardware Point				Virtual Point			
Point Description	Origin Address	DO	DI	AO	AI		Destination Address	Destination Description	Notes
common	ziplink 1						Netural hub		
Current input	ziplink 4			WX4			Extrnal circuit		
	Total Points	0	0	2	0	0			

2 Channel Ac input module
PN: D2-08NA-1

		POINT TYPE							
		Hardware Point				Virtual Point			
Point Description	Origin Address	DO	DI	AO	AI		Destination Address	Destination Description	Notes
Common	ziplink C						Neutral Hub		
Relay 1	ziplink 4	x4					PN:RTD32 98		
	Total Points	2	0	0	0	0			

18-220 VAC Output Module
PN: D2-08TA

		POINT TYPE							
		Hardware Point				Virtual Point			
Point Description	Origin Address	DO	DI	AO	AI		Destination Address	Destination Description	Notes
Common	ziplink C						Neutral Hub		
Conactort input	ziplink 4	Y4					Actuator Coil A1		
	Total Points	2	0		0	0			

Thermal Overload relay, 1 to 1.6A
PN: RTD32

Point Description	Origin Address	Destination Address	Destination Description	Notes
Left most	97	Hot line Hub	external voltage supply	
Second from the left	98	110VAC ziplink 14	D2-08NA-1	
A Phase	T1	T1 AC Drive	Output of VFD drive	
B Phase	T2	T2 AC Drive	Output of VFD drive	
C Phase	T3	T3 AC Drive	Output of VFD drive	
		Total points:5		

C-More Interface Panel
PN: EA9-T6CL-R

Point Description	Origin Address	Destination Address	Destination Description	Notes
VDC input	+12-24 V	L	PLC Module +24V out	
VDC common	-12-24 V	N	PLC Module -24V out	
Earth ground	Ground	Ground	PLC Module ground	
Port 1	Port1	RS-232	RS-232 Serial on Do-more CPU Module	
	Total Points 4			

Ethernet communication module
PN: GS-EDRV100

Point Description	origin address	Destination Address	Destination Description	Notes
Ethernet connector to Acdrive	RS458	Serial Port	Serial port on VFD (GS3-21P0)	
Ethernet connector to Do-more	Ethernet	Do-more CPU Module	Ethernet conect to CPU module H2-DM1E	
	Total Points: 2			

Variable Frequency drive
PN: GS3-21P0

Point Description	Origin address	Destination Address	Destination Description	Notes
A phse input	L1	3 phase fuse	DF103 (Top right)	
B phse input	L2	3 phase fuse	DF103 (Top middle)	
C phse input	L3	3 phase fuse	DF103 (Top right)	
A phse out	T1	L1	GH15BN Self-lifting pressure plate (L1)	
B phse out	T2	L2	GH15BN Self-lifting pressure plate (L2)	
C phse out	T3	L3	GH15BN Self-lifting pressure plate (L3)	
Ground	Ground	Ground Hub	Node for ground (green) There are two grounds, one in the left, one in the right	
Serial port to communicate with Do-more	Serial Port	GS-EDRV100	Ethernet RS485	
	Total Points: 9			

The top GH15 series IEC contactor
PN: GH15BN

Point Description	Origin Address	Destination Address	Destination Description	Notes
Self-lifting pressure plate	L3	L3	Variable Frequency drive	
Self-lifting pressure plate	L1	L1	Variable Frequency drive	
Self-lifting pressure plate	L2	L2	Variable Frequency drive	
Actuator coils	A1	Ziplink 4	D2-08TDA	
Actuator coils	A2	Hot line hub	External voltage supply	
	Total Points: 5			

Modular fuse holder, 3 phase, 30A
PN: EHM1DU

Point Description	Origin Address	Destination Address	Destination Description	Notes
3 phase fuse	Three bottom points	L1,L2, and L3	Three phase input	
3 phase fuse	Three top point	The hole on panel	External power supply	
	total point: 6			

Solid Core Instrument Grade Current Transformer
PN: AL500

Point Description	Origin Address	Destination Address	Destination Description	Notes
One turn customer supplied	RTD32-180 (Port: T3)		The output in panel	
white& black output	X1 and X2		External circuit	
	total point: 3			

6.9 Credits (Load P)

Jiawei Wu

1. Ladder logic
2. Points List
3. Panel view
4. PI control
5. Wiring connections
6. C-More

David Eding

1. Bill of materials.
2. Wiring diagram.
3. Electrical diagram.
4. Wiring connections.
5. Documentation.

7 Load Q

7.1 Load Q Overview

Load Q group develop a PI controller which can maintains the reactive power load set point at the PQ bus. The set point range is sufficient to test the full range of Q+ anfd Q-.

7.2 Realized Specifications

- **A DL205 AD PLC shall be used as the controller for the Q load**
  Dl205 is used as the controller for the Q load.

- **The controller Should use as an HMI to receive input and shows output** HMI is used to receive input and shows output.

- **The PLC shall communicate with Central via a local TCP/IP network**
  PLC is communicating with Central via local TCP/IP network.

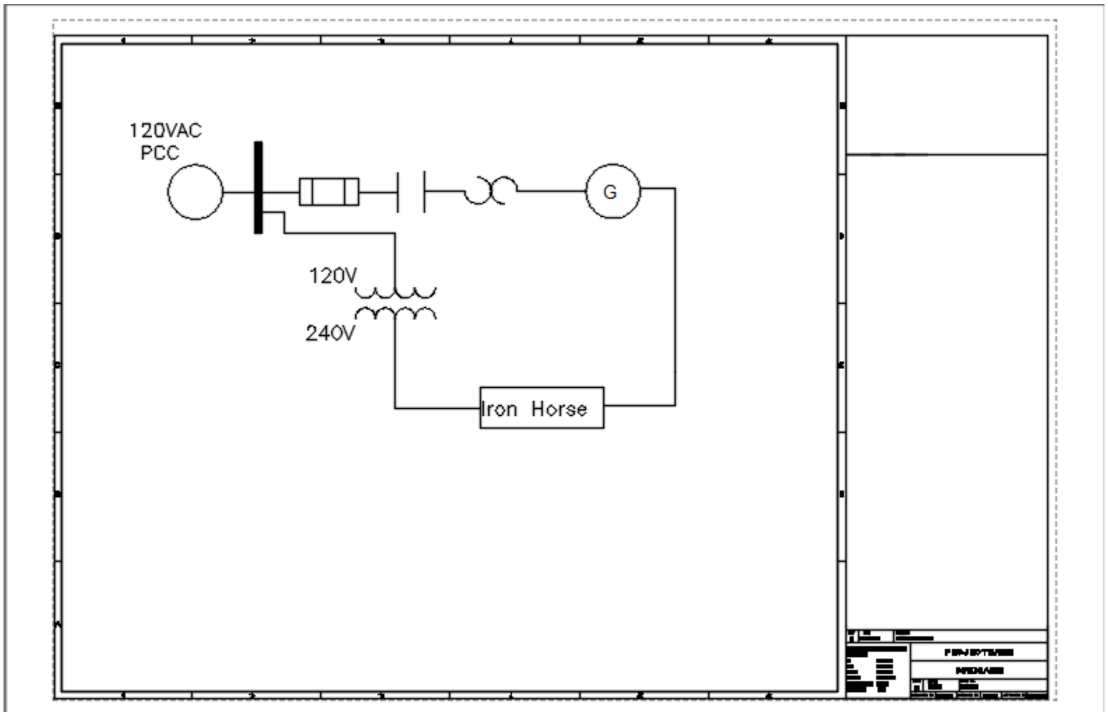
- **The Load Q group shall coordinate with the Load P Group to implement the Q controller specifications within the PQ PLC using one HMI.**
  Load P used Induction motor to maintain real power.We used synchronous machine to maintain reactive power by using different HMI and PLC.

- **The Q load controller shall use PI compensation**
  PI compensation is used to control load Q

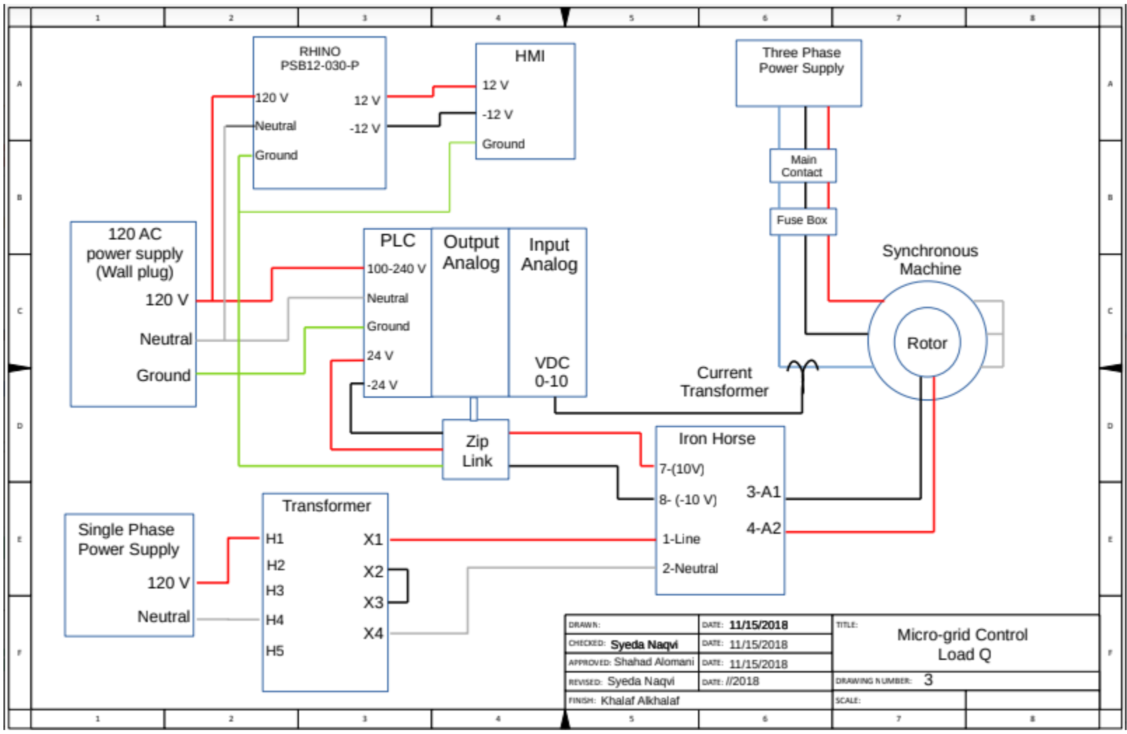
- **The allowable reactive power load setpoint shall be within 0.2 pu to 1.10 pu of the total system nameplate apparent power, both reactive and capacitive.**
  We were only able to control load set point witnin 0.3pu -1.1pu due to machine limitation.

- . **Steady-state error should be zero, error should decay to 5 tau within 3 seconds, overshoot should not exceed 0.10 pu.** Steady state error is almost close to zero, and we don't have overshoot.

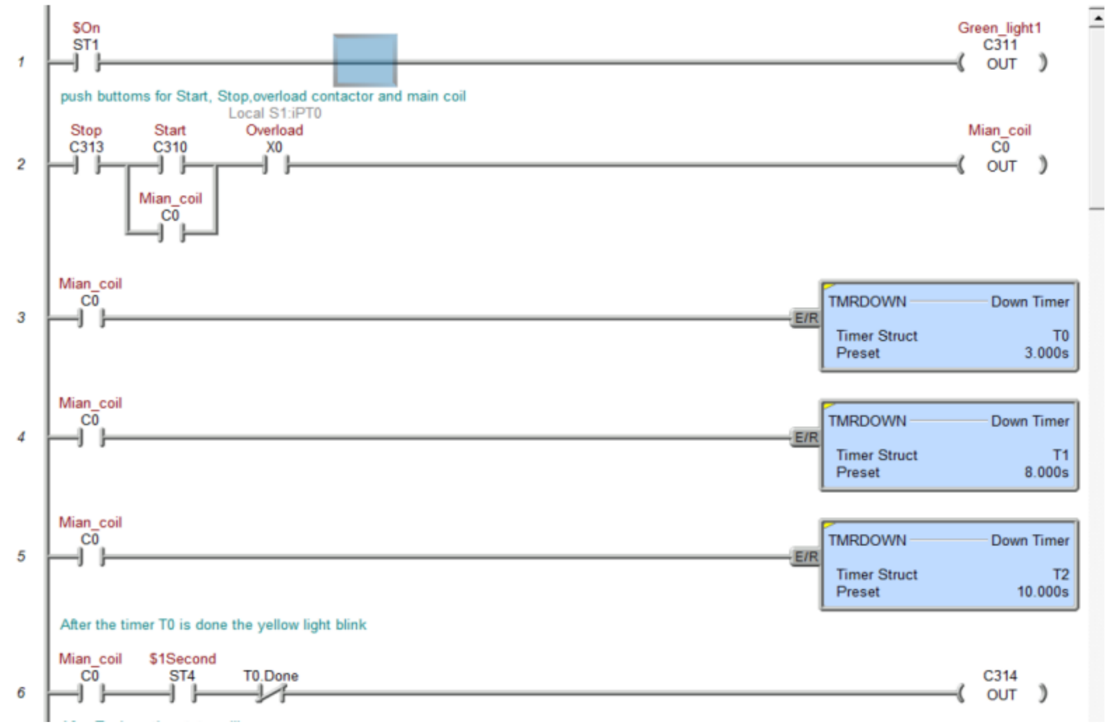
7.3 Electrical Diagram

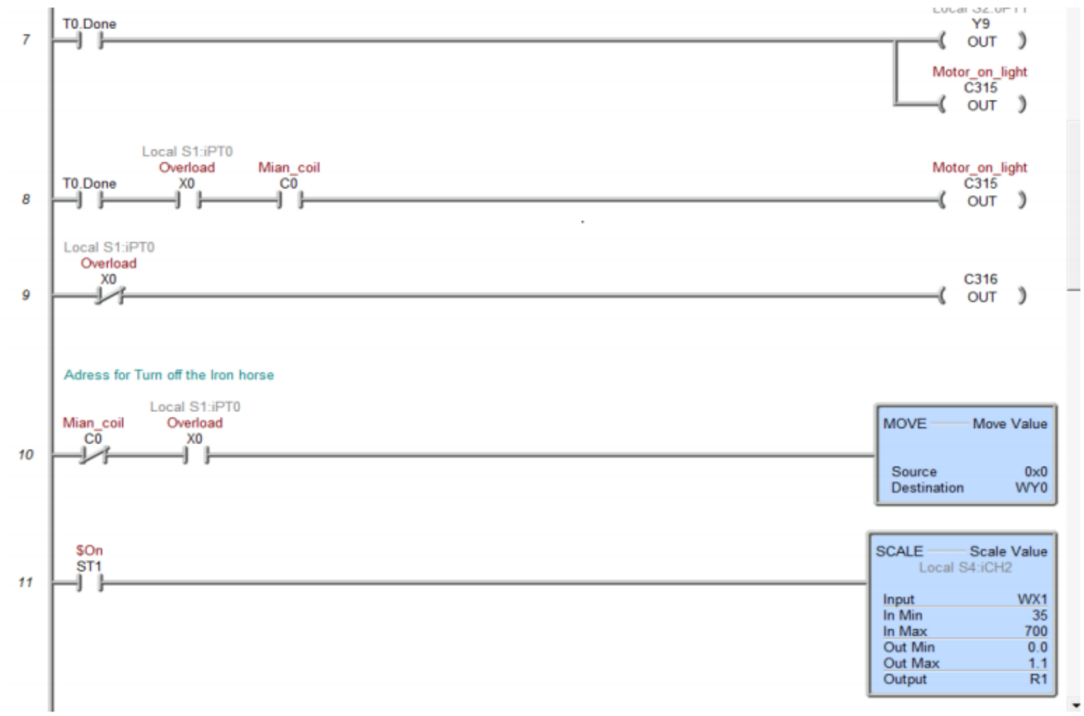


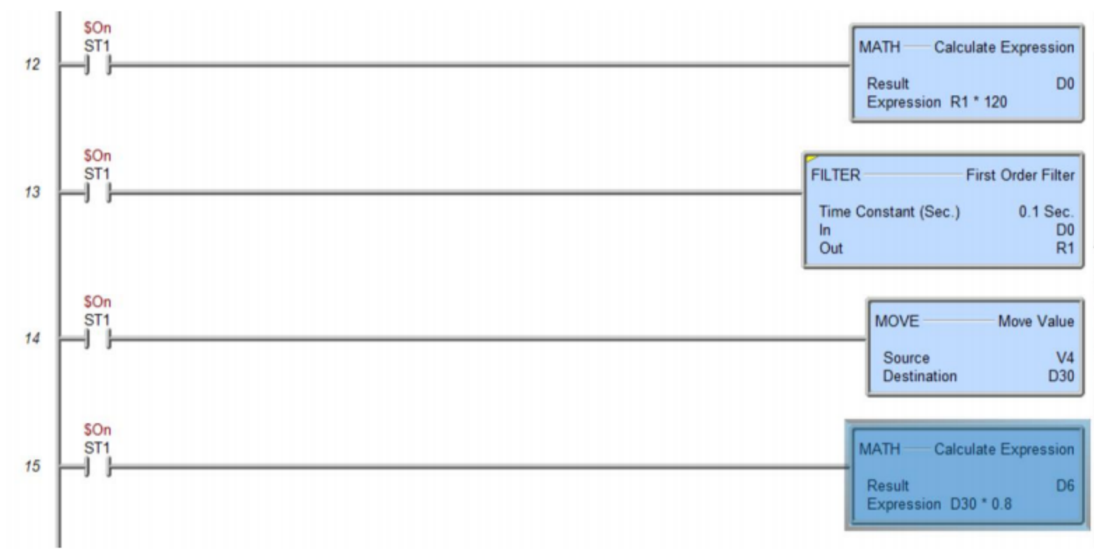
7.4 Wiring Diagram

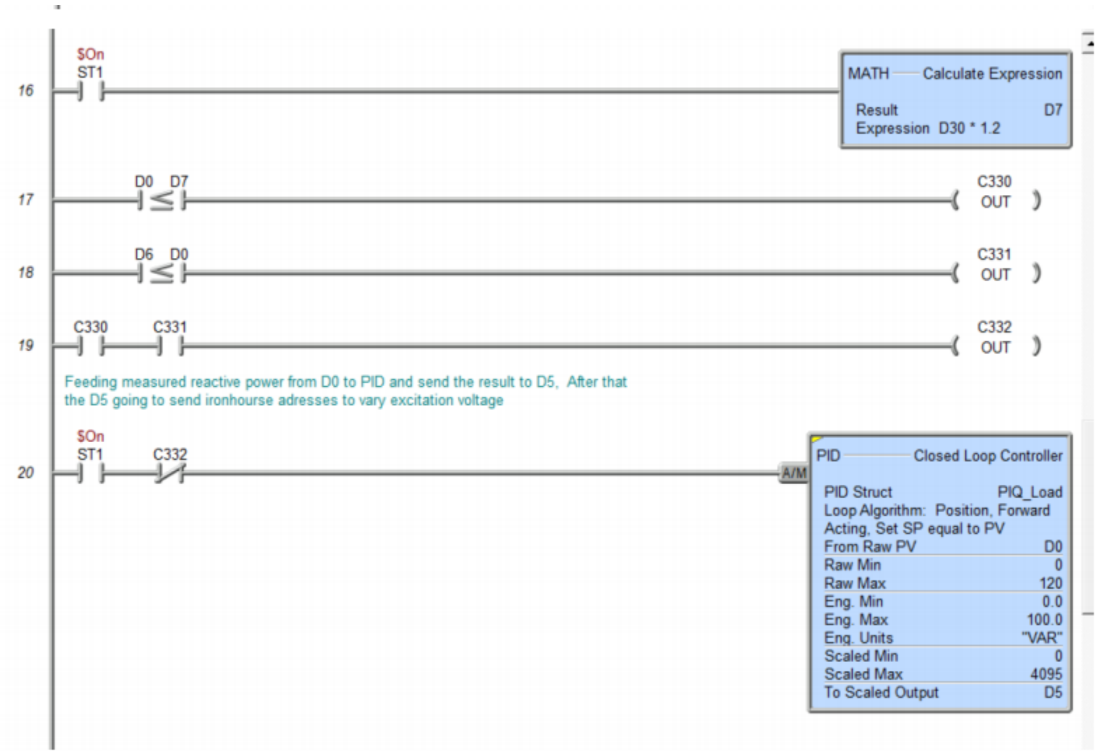


7.5 Ladder Logic

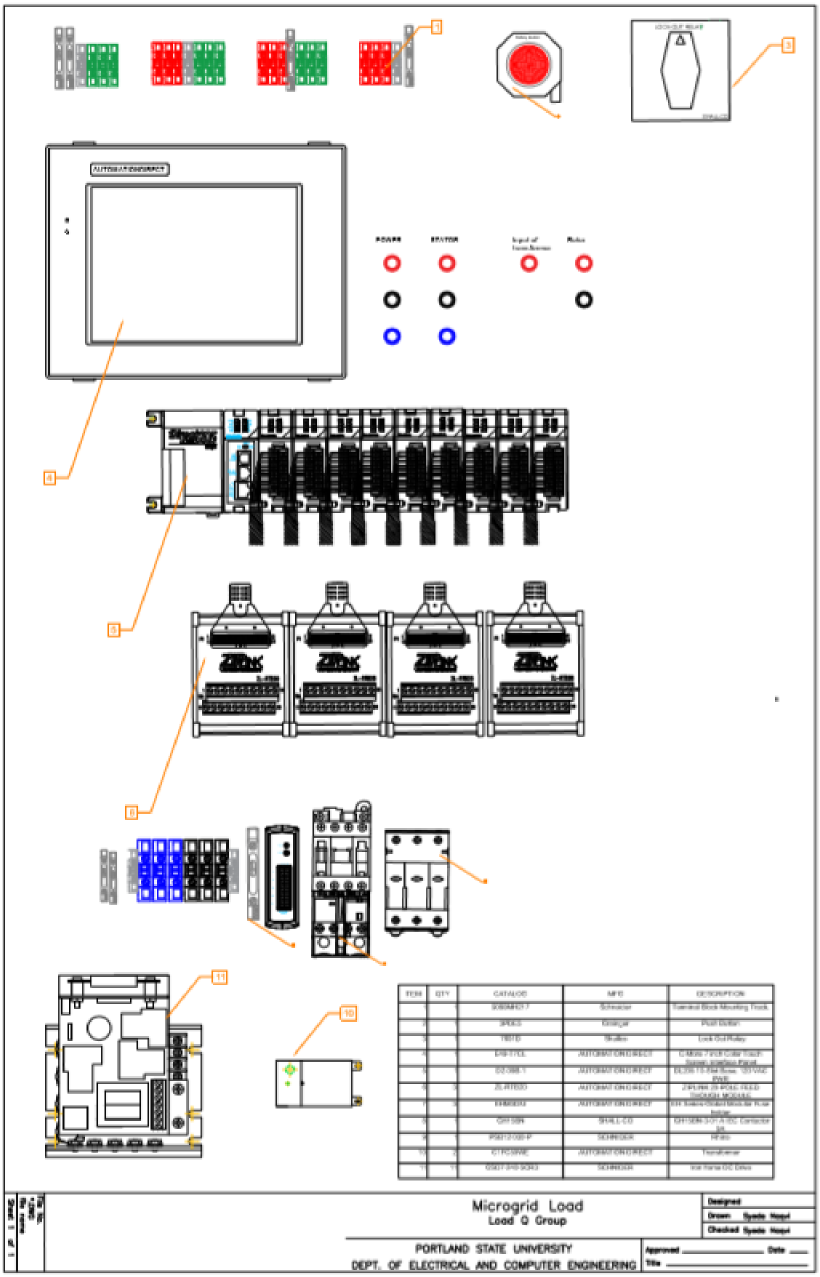



7
T0.Done
Y9
OUT
Motor_on_light
C315
OUT
8
T0.Done
Local S1:iPT0
Overload
X0
Mian_coil
C0
Motor_on_light
C315
OUT
9
Local S1:iPT0
Overload
X0
C316
OUT
Adress for Turn off the Iron horse
10
Mian_coil
C0
Local S1:iPT0
Overload
X0
MOVE Move Value
Source 0x0
Destination WY0
11
$On
ST1
SCALE Scale Value
Local S4:iCH2
Input WX1
In Min 35
In Max 700
Out Min 0.0
Out Max 1.1
Output R1


12
$On
ST1
MATH Calculate Expression
Result D0
Expression R1 * 120
13
$On
ST1
FILTER First Order Filter
Time Constant (Sec.) 0.1 Sec.
In D0
Out R1
14
$On
ST1
MOVE Move Value
Source V4
Destination D30
15
$On
ST1
MATH Calculate Expression
Result D6
Expression D30 * 0.8


$On
ST1
16
MATH Calculate Expression
Result D7
Expression D30 * 1.2
17
D0 D7
C330
OUT
18
D6 D0
C331
OUT
19
C330 C331
C332
OUT
Feeding measured reactive power from D0 to PID and send the result to D5, After that
the D5 going to send ironhourse adresses to vary excitation voltage
$On
ST1
C332
20
A/M
PID Closed Loop Controller
PID Struct PIQ_Load
Loop Algorithm: Position, Forward
Acting, Set SP equal to PV
From Raw PV D0
Raw Min 0
Raw Max 120
Eng. Min 0.0
Eng. Max 100.0
Eng. Units "VAR"
Scaled Min 0
Scaled Max 4095
To Scaled Output D5

7.6 Panel CAD Drawing



7.7 Bill of Materials

No	Item	Vendor	Part Number	Per Station Quantity	Price
1	Thermal Overload relay, 1 to 1.6A	Schneider	RTD-328	1	$62.50
2	22mm Metal PB w/ Contact Block, 1 NO, Yellow	Schneider	XB4BA31	1	$38.50
3	22mm Metal PB w/ Contact Block, 1 NO, red	Schneider	XB4BA42	1	$38.50
4	22mm Metal PB w/ Contact Block, 1 NO, green	Schneider	XB4BA39	1	$38.50
5	22mm Metal PB w/ Contact Block, 1 NO, red	Schneider	XB4BA39	1	$38.50
6	Fuse block, GRY 30A 20-6 AWG, 300V	Automation Direct	DN-F6MN	3	$ 60
7	Do-more CPU Module	Automation Direct	H2-DM1E	1	$399
8	18-220 VAC Output Module	Automation Direct	D2-08TA	1	$110
9	C-More 7 inch Color Touch Screen Interface Panel	Automation Direct	E49-T8CL	1	$999
10	C-More to H2-DM1 connection cable	Automation Direct	EA-2CBL	1	$20
11	DL205 10-Slot Base, 120 VAC PWR	Automation Direct	D2-09B-1	1	$220
12	C-More Programming software	Automation Direct	EA9-PGMSW	1	$99
13	Rack 77" x 19", Al Finish	A-I Consolidated	RR-1369-MG	1	$481.09
14	Casters, Hard Tread Composition, 2.75 in, 200 lbs, pair of 2	A-I Consolidated	RC-7758-PR	1	$32.90
15	Casters, Hard Tread Composition, 2.75 in, 200 lbs, pair of 2	A-I Consolidated	RC-7758-PR	1	$32.90
16	Safety Lockout Hasp	Grainger	1U177	1	$6.40
17	Push Button Safety Cover	Grainger	3PDE5	1	$69.25
18	Push Button	Grainger	13Z546	1	$27.50
19	Lock Out Relay (Series 24)	Shallco	7601D	1	$349.95

7.8 Bills Of Material

No	Item	Vendor	Part Number	Per Station Quantity	Price
21	Power Cord	All Electronics	LCAC-310	1	$4.50
22	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Blue	Schneider	NSYTRV42BL	3	$4
23	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Black	Schneider	NSYTRV42BK	6	$9
24	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Red	Schneider	NSYTRV42RD	15	$15
25	Terminal block, DIN, 2 position, 4mm, 26-10AWG, White	Schneider	NSYTRV42WH	9	$20
26	Terminal block, DIN, 2 position, 4mm, 26-10AWG, Green	Schneider	NSYTRV42GN	9	$15
27	Plug-in jumper, red, 2 way	Schneider	NSYTRAL42	9	$1.50
28	Plug-in jumper, red, 3 way	Schneider	NSYTRAL43	10	$1.50
29	End Stop for 35 mm DIN, clip-on	Schneider	NSYTRAAB35	11	$14.85
30	Terminal Block Mounting Track, 17”	Schneider	9080MH217	5	$58
31	Lamp; Bulb, Incandescent, BA 9S Base, 24 V, 2 Watt	Schneider	DL1CE024	3	$20.90
32	Stranded Hook-up wire, 300V, UL1007, 18 AWG, red, 16/30	BulkWire.com	50ft	1	$20
33	Stranded Hook-up wire, 300V, UL1007, 18 AWG, green, 16/30	BulkWire.com	10ft	1	$5
34	Stranded Hook-up wire, 300V, UL1007, 18 AWG, white, 16/30	BulkWire.com	50ft	1	$20
35	Stranded Hook-up wire, 300V, UL1007, 18 AWG, blue, 16/30	BulkWire.com	50ft	1	$20
36	Stranded Hook-up wire, 300V, UL1007, 18 AWG, black, 16/30	BulkWire.com	50ft	1	$20
37	Various 1 1/4” or 20 mm fuses	Jameco	various	2	$12.20
38	GH15BN-3-01 A IEC Contactor 9A	Automation Direct	GH15BN	2	$89
39	EH Series-Global Modular Fuse holder	Automation Direct	EHM3DIU	1	37.49
40	Iron horse DC Drive	Automation Direct	GSD7-240-5CR3	1	$172
41	Transformer	Automation Direct	C1FC50WE	1	$122
42	Analog input	Automation Direct	F2-08AD-2	1	$279
43	Analog output	Automation Direct	F2-08DAS-2	1	$172
44	Current transformer	Automation Direct	CR8400	1	$28

T=$3500

7.9 Points List

1									
2				**POINT ASSIGNMENT INDEX**					
3									
4									
5									
6		**PAGE NO.**	**NO. OF SHEETS**	**DESCRIPTION**					
7									
8		2	1	ADDRESS ASSIGNMENTS					
9		2	1	ANALOG POINT ASSIGNMENT					
10		2	1	Points Description ZIP LINK 1					
11		2	1	Points Description ZIP LINK 2					
12		2	1	Points Description ZIP LINK 3					
13		2	1	Points Description ZIP LINK 4					
14		2	1	Points Description ZIP LINK 5					
15		3	1	IronHorse					
16		3	1	Hammond transformer					
17		3	1	Thermal Overloag relay					
18		3	1	HMI					
19		3	1	Contactor					
20									
21									
22									
23									
24	**REV**	**DATE**	**ER. NO.**	**DESCRIPTION**	**BY**	**CH**	**ENG**	**APP**	**APP**
25	1	03/31/15		Pointlist					
26									
27									
28									
29									
30									
31									
32									
33									
34									
35	**BY:**	Load Q Group	**DATE:**	**APPROVED**					
36	**ENG:**		**12/7/2018**	**Syeda**					

PLC Card Slot Assignments:

PLC Chassis	**Slot 1/5**	**Slot 2/5**	**Slot 3/5**	**Slot 4/5**	**Slot 5/5**
1	DMH2SC-1	110-220 Vac IN	110-220 Vac Out	8CA01	8CA01

Card Details

Slot	**Card Name**	**Card Mnemonic**	**Part Nember**	**Comments**
1/5	Do more H2 Series Cpu	DMH2SC-1	H2-DM1E	
2/5	110-220 VAC Output	110-220 IN	D2-08NA	
3/5	110-220 VAC Input	110-220 OUT	D2-08TA	
4/5	8 channel Analogue Output	8CA0-1	F2-08AD-2	
5/5	8 channel Analogue Input	8CA0-1	F2-08AD-2	

16-pt. AC Input module
PN: D2-16NA

Point Description	Origin Address	POINT TYPE: Hardware Point: DO	DI	AO	AI	Virtual Point	Destination Address	Destination Description	Notes
common	ziplink 1						100v Hub	node for 100VDC	
CH1	ziplink 14		X10				RTD32 terminal 96	IP20 finger protection	
	Total Points	0	2	0	0	0			

IronHorse

Point	Origin Address	Destination Address	Destination Description	Notes
Wiper	W	-24 Hub	Node for -24VDC	
Low	Lo	+24V Hub	Node for 24VDC	
Output 1	A1	the hole on the plane	Connect to the rotor	
Output 2	A2	the hole on the plane	Connect to the rotor	
netural	N	Netural Hub	Node for the netural	
Input	L	Transformer X1	Primary side of transformer	
	Total Points	9		

Hammond transformer

Point	Origin Address	Destination Address	Destination Description	Notes
Input	X1	Fuse bottom	The protectoin fuse	
Input	X2	X3	X2 and X3 connect together	
Input	X3	X2	X2 and X3 connect together	
Input	X4	rive netural GSD7-240-	Inron House N	
output	H1	G15BN terminal 2/T1	Node for the netural	
output	H2	he output hole on pane	xtrnal AC power suply netural line	
output	H3	--	--	
output	H4	--	--	
output	H5	--	--	
	Total Points 9	9		

Thermal Overloag relay

Point	Origin Address	Destination Address	Destination Description	Notes
Left most	95	Hot line Hub	external voltage supply	
Second from tl	96	110VAC ziplink 2	Node for 24VDC	
A Phase	PS -A	phase A	Staor -phase A	
B Phase	PS-B	phaseB	Staor-phaseB	
C Phase	PS-C	phase C	Stator-phase C	
	Total points	5		

7.10 Credits(Load Q)

- **Naqvi Syeda**
  Wiring (Transform, Iron Horse, Synchronous Machine, Ziplink)
  Work on rectifier circuit.
  Autocad Drawing.
  Point list.
  Bills of Materials.

- **Alkhalaf,Khalaf**
  Electrical Diagram.
  Comment on Ladder Logic circuit
  PID Control

- **Alomani,Shahad**
  Wiring (Transform, Iron Horse, Synchronous Machine, Ziplink)
  Electrical Diagram.

- **Bariagabir, Mussie**
  Domore
  PID control

8 MPR: Motor Protection Relay

8.1 MPR Overview

The micro-grid control system consists of three buses (slack, PV and PQ) which are protected by three SEL-710 digital relays. Unlike electro-mechanical relays, digital relays (also known as microprocessor relays) are capable of performing multiple protective functions as well as metering, communication and self-testing.
Each bus is protected by an SEL-710 relay with different function settings for each relay depending on the bus needs. However, all three buses are protected with the following relay functions: phase instantaneous over-current protection (50P), phase inverse-time over-current protection (51P), phase over voltage protection (27P) and phase under voltage protection (59P). SEL-710 digital relays have the ability to read and log data from input buses. When a relay trips, it will actuate a three-phase contactor that is located between the relay and the protected equipment.

SEL-710 relays can be programmed to perform specific protective functions either by using a computer program, or simply by using the relays front panel to navigate and input the desired settings. In addition to the mentioned above protective functions for all buses; below is the functions used in each relay at each bus:

- Relay 1 (Slack):

  Current Unbalance Protection (46), Under-Frequency Protection (81U) and Over-Frequency Protection (81O).

- Relay 2 (PV):

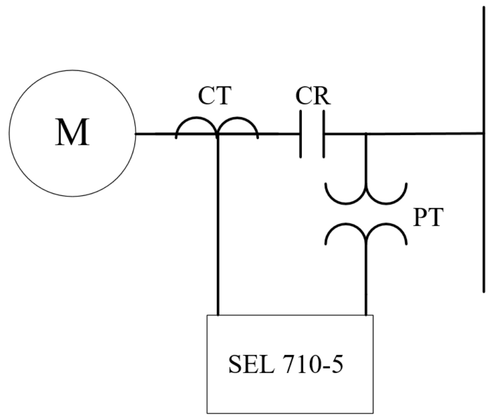
  Current Unbalance Protection (46) and Phase Reversal Protection (47).

- Relay 3 (PQ):

  Motor Differential Current Protection (87), Load Power Control Protection (90P) and Reactive Power Protection (VAR).

8.2 Realized Specifications

Figure 14: Bus One-line Diagram, applies to Relays 1,2,3. Machine may vary by bus



1. **The PR group shall install protective relays at each of the three system buses.**

   One SEL-710-5 motor protective relay is installed at each bus. All of the relays are set for basic motor protection along side specific setting functions for each bus depending on the need.

2. **An SEL 351 or SEL 710 should be used to provide relay functions.**

   Since the system essential equipment are induction motors/generators, SEL 710 relays were preferred over SEL 351 for this system.

3. **Tripped relays shall actuate three-phase contactors between the generator/load and the bus.**

   The tripping of relays cause a three-phase contactor to open contact between the bus and the equipment for protection.

4. **The PR group shall provide the following IEEE Std C37.2-2008 protective relays at all buses:**

- Instantaneous Overcurrent (50P)
- Inverse Time Overcurrent (51P)
- Overvoltage (27)
- Undervoltage (59)

  Basic motor protection functions are provided at all of the three buses.

5. **The PR group should provide the following protective relays at the Slack bus:**

   - Current unbalance (46)
   - Underfrequency (81U)
   - Overfrequency (81O)

   For the slack bus, the above additional protective functions are provided as needed.

6. **The PR group should provide the following protective relays at the PV bus:**

   - Current unbalance (46)
   - Phase Reversal relay testing (47)

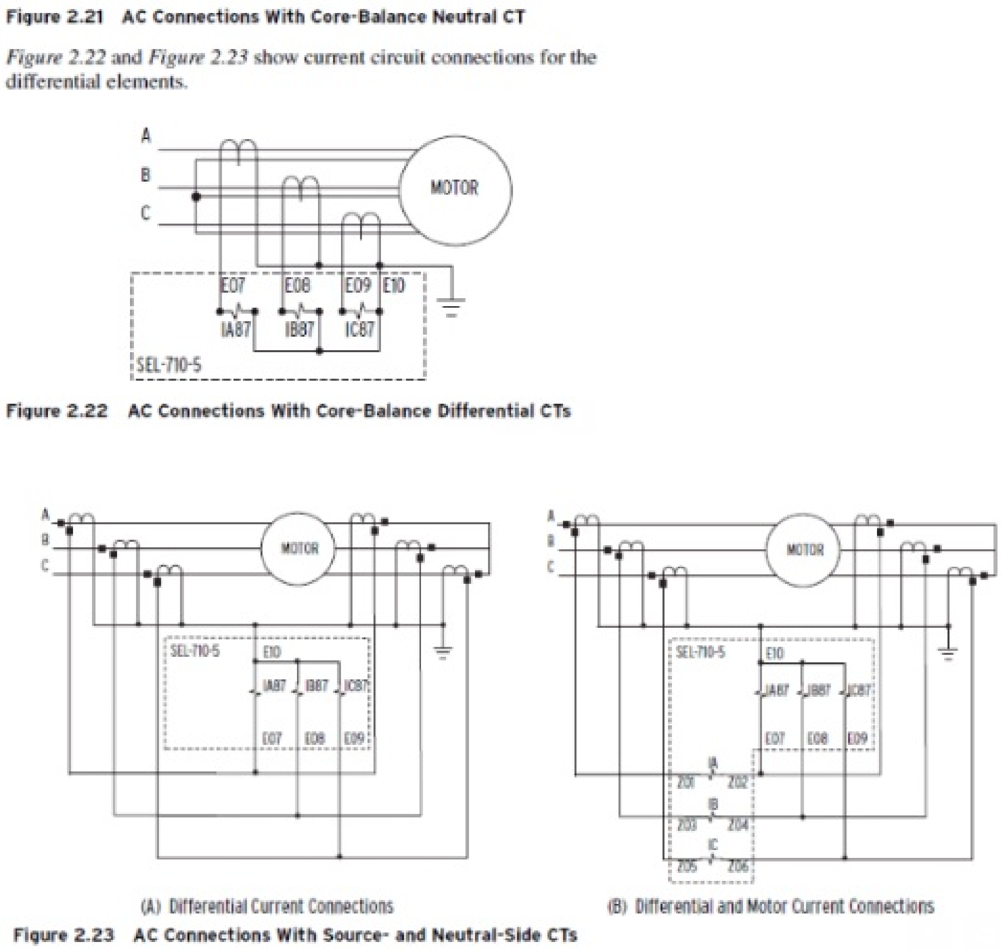
     For the PV bus, the above protective functions are provided in addition to the basic functions.

7. **The PR group should provide the following protective relays at the PQ bus:**

   - Motor differential current(87)
   - Load Control, Power (90P)
   - VAR protection (VAR)

     At the PQ bus, the above protective functions are also provided along side the basic motor protection functions. However, the motor differential current (87) function was not satisfied:

Figure 15: Differential Protection Connection



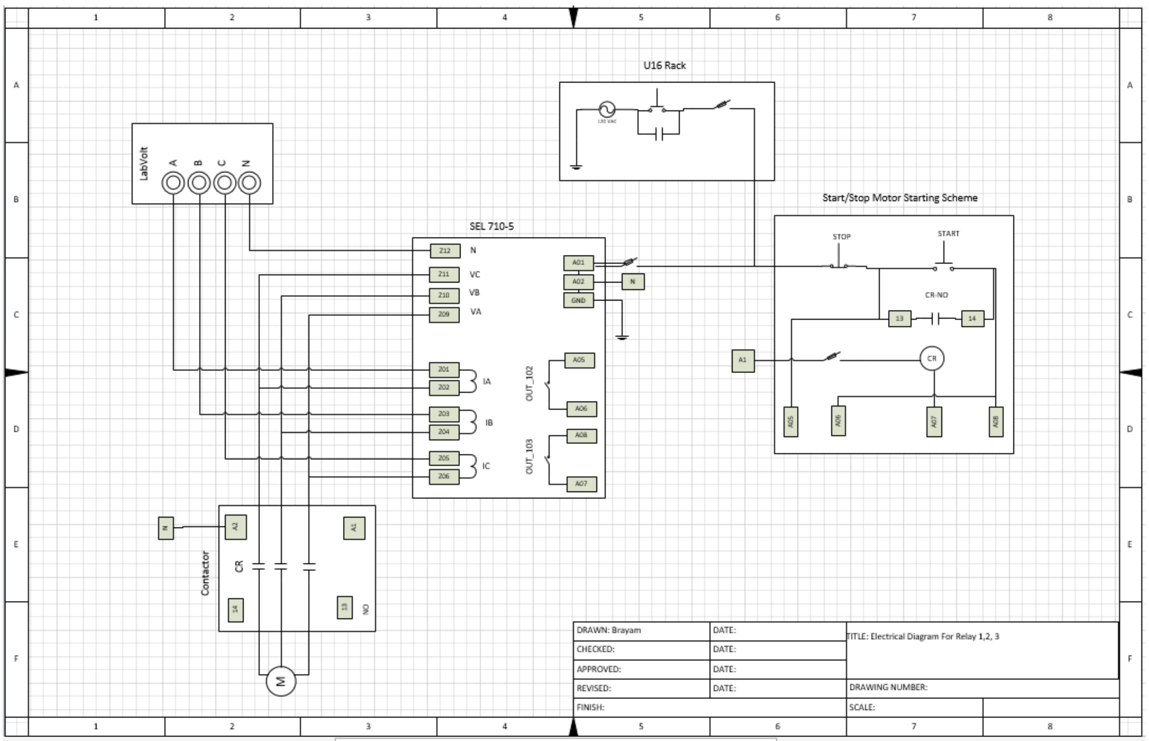
For Relay 3, which is the PQ relay we had to do a workaround in order to meet the VAR and Load protection design specifications. The workaround was increasing the current 100x in the relay, this made the relay think that 100x the current was going through it and we were able to get a higher range of real and reactive power on the secondary side.

This allowed us to be able to set high and low points for load and VAR protection. However, when we looked at implementing differential current, this caused an issue since we would need to use CTs as seen above; these

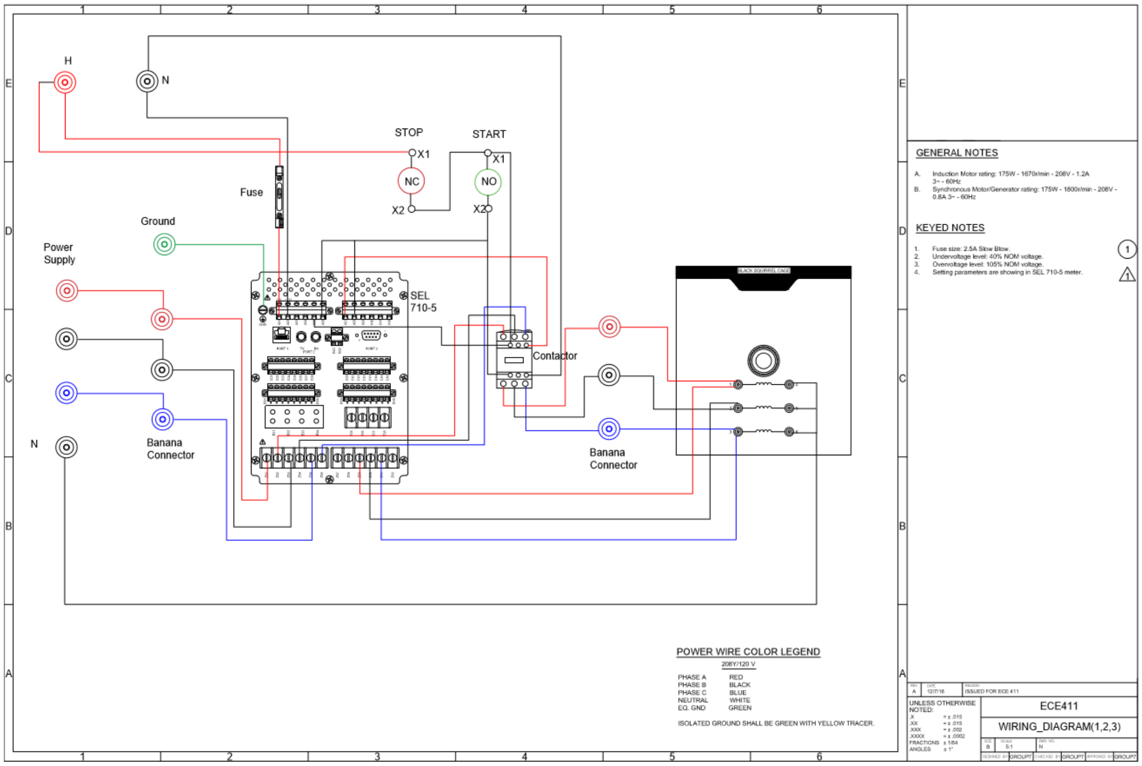
CTs would need more windings than the equipment could hold in order to get the multiple of current that we had set within the relay already. In short, the relay project specification could be met if we had the proper equipment, but at the moment we are limited by the equipment we have at our disposal.

8.3 Electrical Diagram

Figure 16: Electrical Diagram



8.4 Wiring Diagram



8.5 Panel CAD Drawing

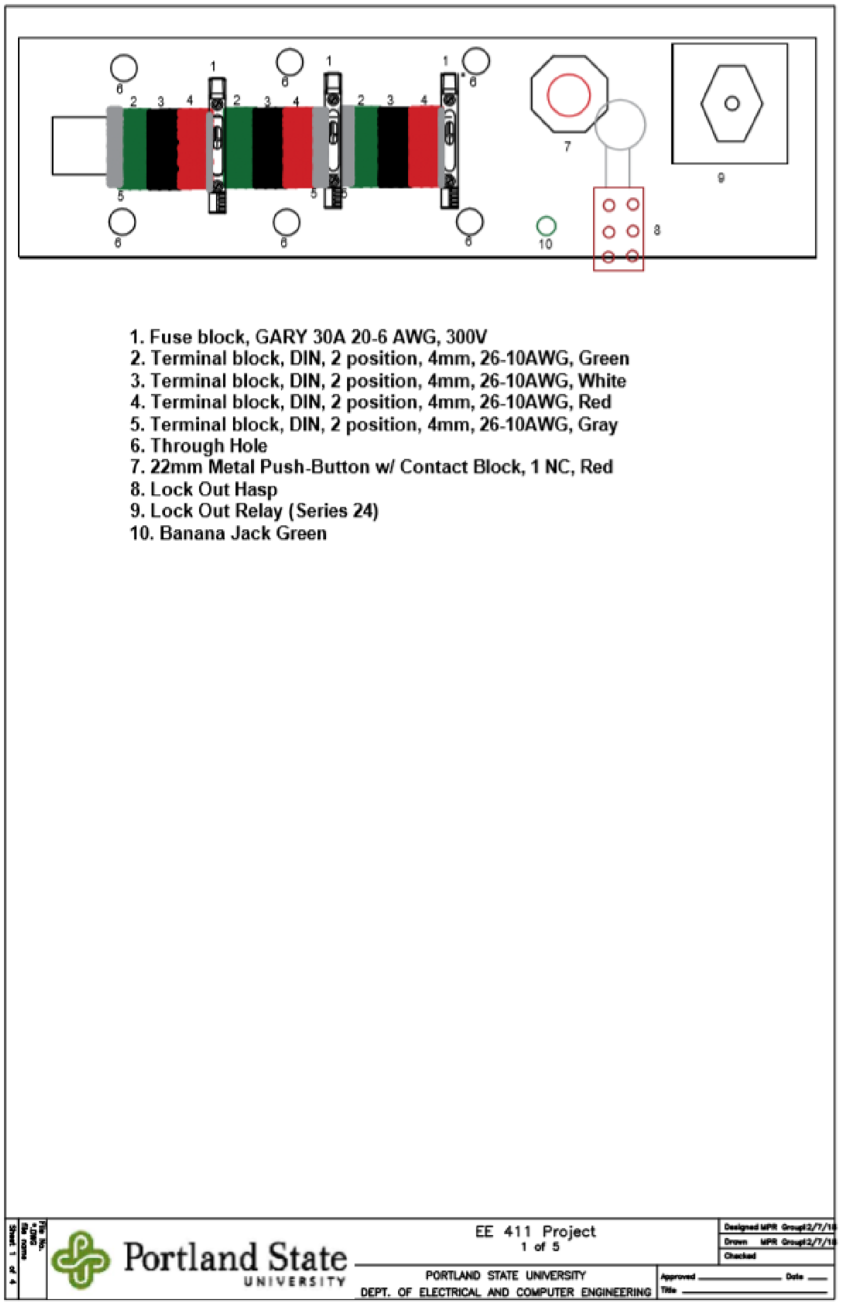


Figure 17: AutoCAD drawing 1 of 5

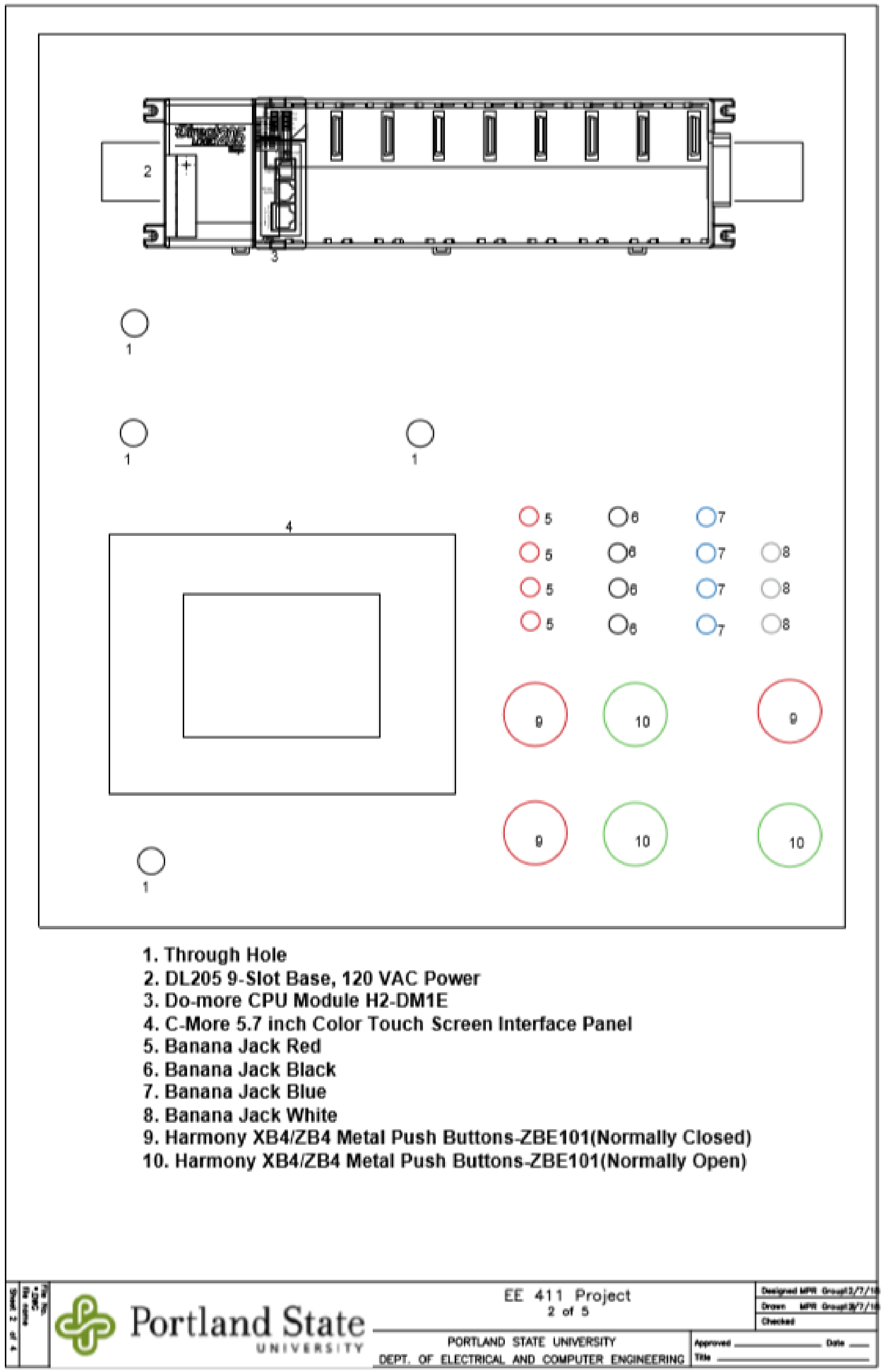


Figure 18: AutoCAD drawing 2 of 5

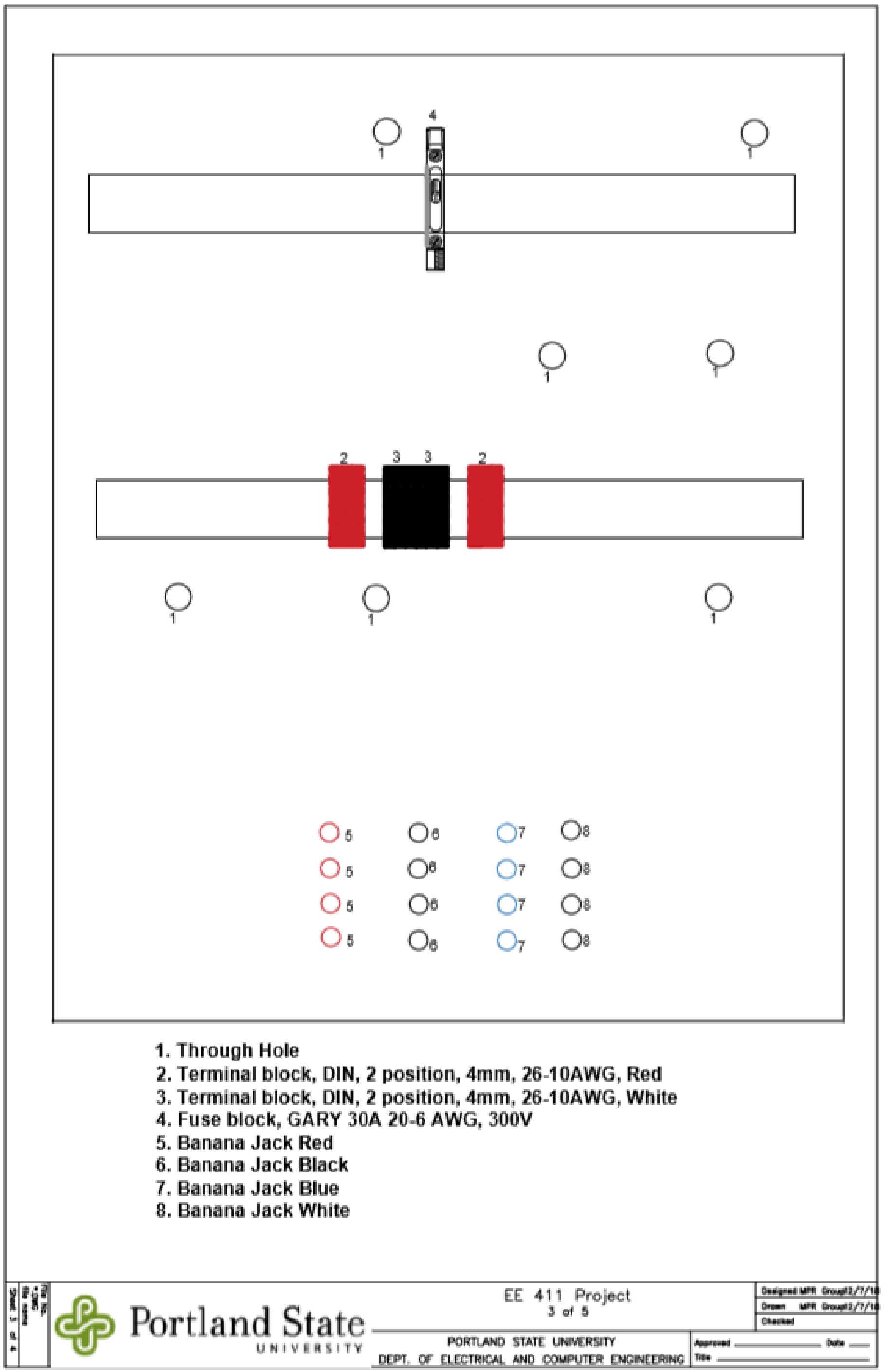


Figure 19: AutoCAD drawing 3 of 5

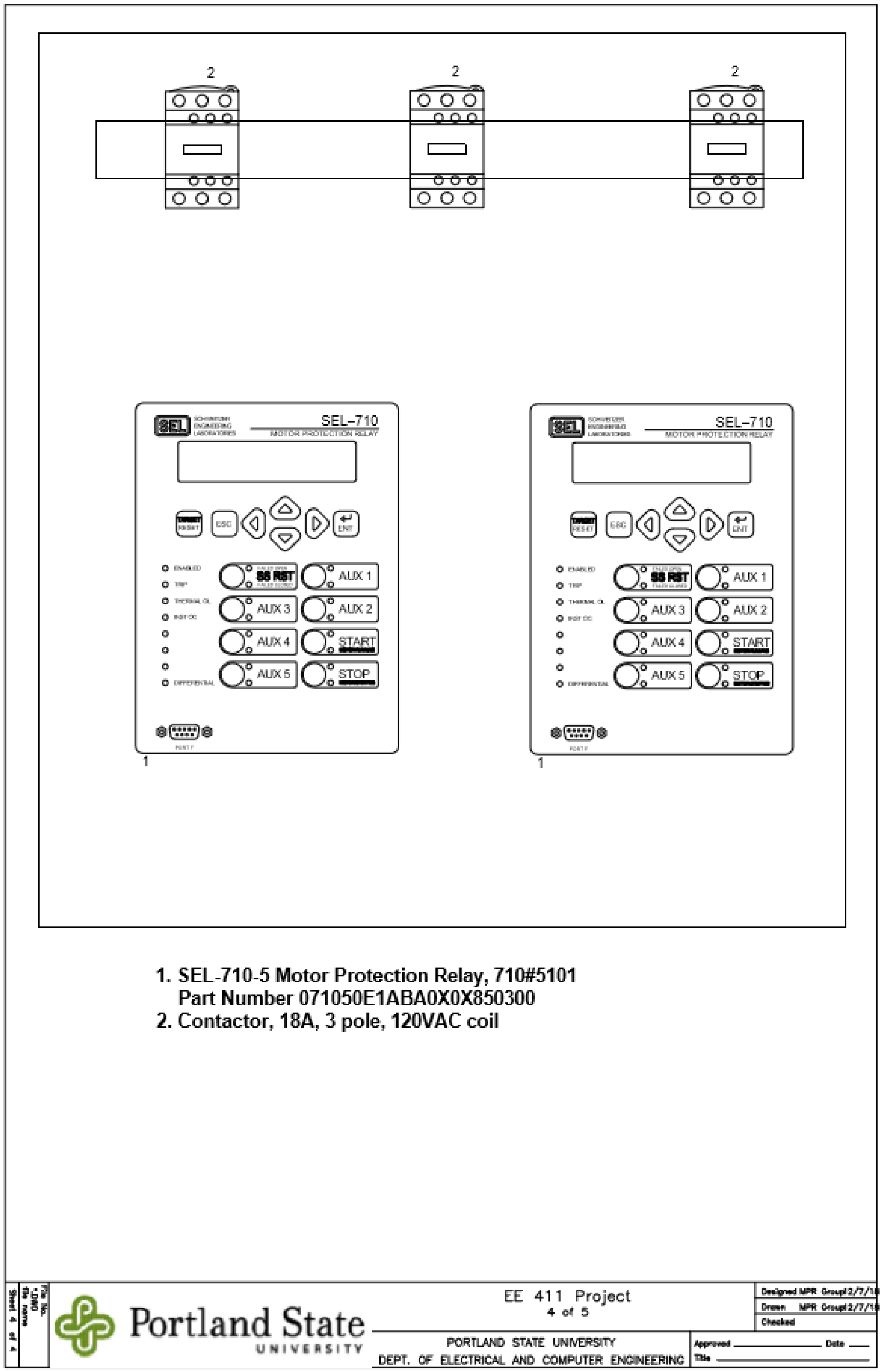


Figure 20: AutoCAD drawing 4 of 5

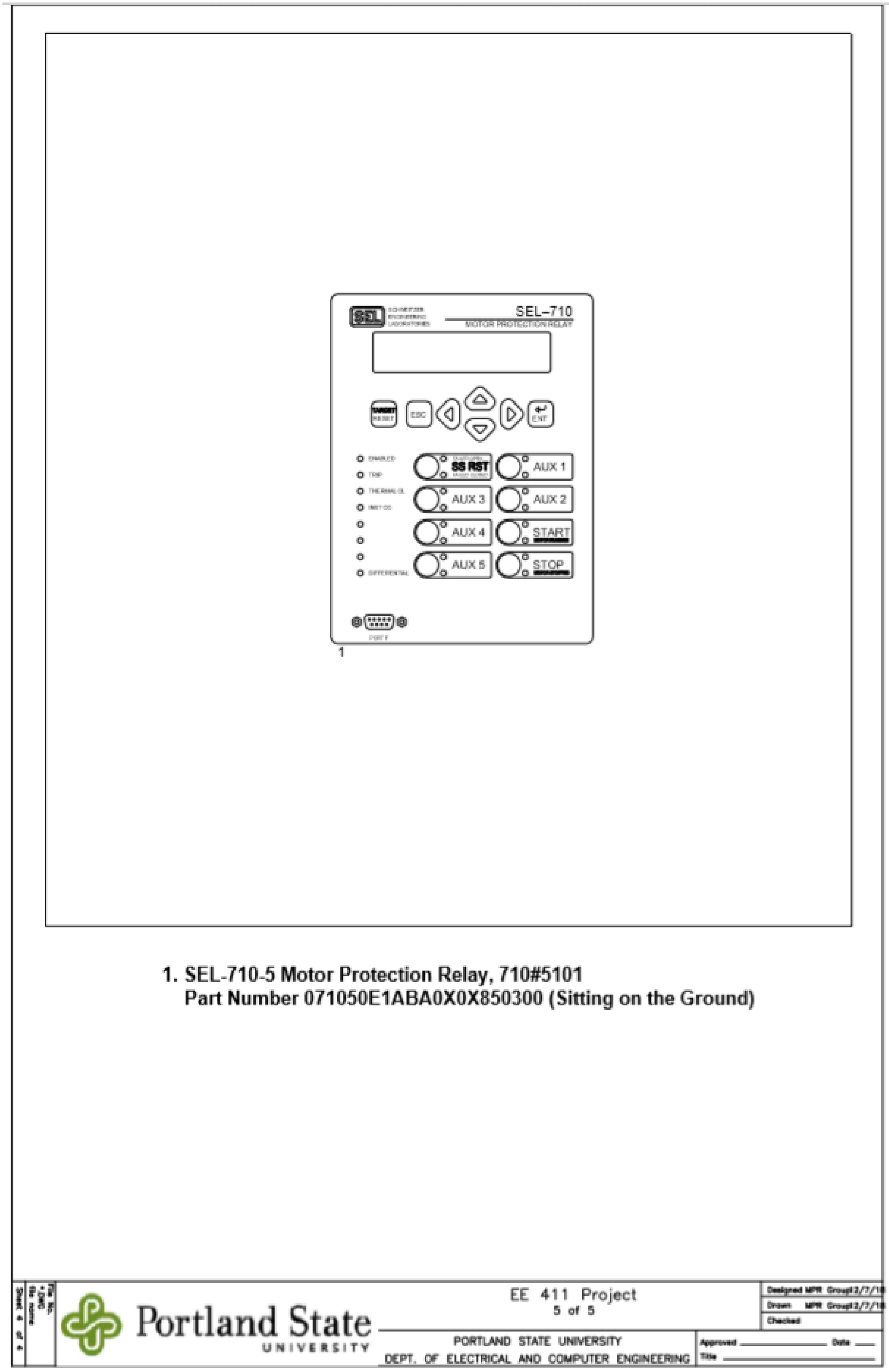


Figure 21: AutoCAD drawing 4 of 5

8.6 Bill of Materials

SEL-C662 USB Series Cables/16 Feet	Schweitzer Engineering Laboratories	C662	1	73	73
SEL-710-5 Motor Protection Relay	Schweitzer Engineering Laboratories	7105101	3	3120	9360
Lockout Hasp, Snap-On, Red, 4-1/2in. L	Master Lock	No.420	1	4.09	4.09
Rack 77”x19”, Al Finish	A-I Consolidated	ZB5AD229	1	342.98	342.98
Terminal Block, Screw Clamp, 12A, 600V	Schneider	NSYTRV42SF5LD	8	4.38	13.14
Terminal Block, DIN, 4mm, 26-10AWG, Various colors	Schneider	NSYTRV42XX	42	1.89	79.38
Contactor, 18A, 3 pole, 120VAC coil	Schneider	LC1D09G7	3	39.95	119.85
250 VAC, 3.15 Amp, Fast Acting Miniature Glass Fuse	Cooper Bussmann	GMA-3.15A	3	1.13	3.39
250 VAC, GMA Style 2 Amp, Fast Acting Glass Fuse	Cooper Bussmann	GMA-2A	1	1.29	1.29
Total Price	–	–	–	–	$9997.12

8.7 Points List

Figure 22: Points List Cover Page

POINT ASSIGNMENT INDEX

PAGE NO.	NO. OF SHEETS	DESCRIPTION
2	1	SEL 710-5 SLOT ASSIGNMENTS
3	1	SLOT Z
4	1	SLOT A
5	1	CONTACTOR

REV	DATE	ER. NO.	DESCRIPTION	BY	CH	ENG	APP	APP
1	12/05/18		RELAY POINTS LIST ECE 411					

BY: MPR GROUP	DATE: 12/5/18	APPROVED	
ENG:			

Figure 23: Points List Slot Assignment Page

SEL-710-5 Card Slot Assignments:

SEL-710	Slot 1/3	Slot 2/3
2	Z	A

Card Details

Slot	Card Name
1/2	4 ACI Current Card
2/2	SELect Power Supply With I/O

Figure 24: Points List Slot Z

Point Description	Origin Address	POINT TYPE Hardware Point Output	POINT TYPE Hardware Point Input	Destination Address	Destination Description	Notes
Current IA	From LabVolt		Z01			
		Z02		To Contactor		
Current IB	From LabVolt		Z03			
		Z04		To Contactor		
Current IC	From LabVolt		Z05			
		Z06		To Contactor		
Voltage VA	From The Motor		Z9	Relay		
Volrage VB			Z10			
Voltage VC			Z11			
Voltage N			Z12			
	Total Points	3	7			

Figure 25: Points List Slot A

Point Description	Origin Address	POINT TYPE Hardware Point Output	POINT TYPE Hardware Point Input	Destination Address	Destination Description	Notes
Power	A01			+120V	on U16 Rack	
Neutral	A02			Neutral	on U16 Rack	
Ground	GND			Ground	on U16 Rack	
Out_102	A05			13	NO contact on Contactor	
	A06			A08	Out_103	
Out_103	A08			14	NO contact on Contactor	
	A07			A1	Power of Contactor	
	Total Points	0	0			

Figure 26: Points List Contactor

Contactor
Model #: RTD32 180

		POINT TYPE				
		Hardware Point				
Point Description	Origin Address	Output	Input	Destination Addres	Destination Description	Notes
A - Phase 120 V	A - LabVolt		1L1			
		2T1		Motor 1	A - Phase 120 V	
B - Phase 120 V	B - LabVolt		3L2			
		4T2		Motor 2	B - Phase 120 V	
C - Phase 120 V	C - LabVolt		5L3			
		6T3		Motor 3	C - Phase 120 V	
+/H	A07		A1			
-/H		A2		N	Neutral	
NO	A01		13	A05		Normally Open Contact
	A01		14	A08		
	Total Points	4	6			

Slack Bus		Gen P&V		Load P	Load Q
Generator		Generator	Motor(Synchronous)	Motor(Induction)	Motor(Synchronous)
S =	120	S=120VA	P=175W	P=175W	P = 175W
V_L =	208	V_L=208V	f=60Hz	f=60Hz	f = 60Hz
V_P =	120	V_P=120V	V=208V	V=208V	V = 208V
I =	0.33	I=0.33A	I=0.8A	I=1.2A	I = 0.8A
P =	175				
Configuration Settings		Configuration Settings		Configuration Settings	
CT Ratio	1	CT Ratio	1	CT Ratio	100
PT Ratio	1	PT Ratio	1	PT Ratio	1
Full Load A	0.33	Full Load A	0.33	Full Load A	120/80
Line voltage	208	Line voltage	208	Line voltage	208
59P UnderVoltage	Settings	59P UnderVoltage	Settings	59P UnderVoltage	Settings
UV trip level	0.95	UV trip level	0.95	UV trip level	0.95
UV trip Delay(s)	2	UV trip Delay(s)	2	UV trip Delay(s)	2
UV Warn Level	OFF	UV Warn Level	OFF	UV Warn Level	OFF
27P Overvoltage		27P Overvoltage		27P Overvoltage	
Trip Pickup	1.05	Trip Pickup	1.05	Trip Pickup	1.05
Trip Delay	2	Trip Delay	2	Trip Delay	2
Alarm Pickup	OFF	Alarm Pickup	OFF	Alarm Pickup	OFF
50P1P Phase Overcurrent		50P1P Phase Overcurrent		50P1P Phase Overcurrent	
Trip Pickup(FLA)	4	Trip Pickup(FLA)	4	Trip Pickup(FLA)	4
Trip Delay (s)	0.2	Trip Delay (s)	0.0	Trip Delay (s)	0.0
51P1 Time Overcurrent		51P1 Time Overcurrent		51P1 Time Overcurrent	
Trip Pickup	1.32	Trip Pickup	1.32	Trip Pickup	1.32
Curve	U3	Curve	U3	Curve	U3
Time Dial	3	Time Dial	3	Time Dial	3
Reset Delay	0	Reset Delay	0	Reset Delay	
46 Current Imbalance		46 Current Imbalance		87 Differential Current	
Trip Pickup (%)	5	Trip Pickup (%)	5	Enable	N
Trip Delay (s)	4	Trip Delay (s)	4	90P Load Control, Power	
81U Underfrequency		47 Phase Reversal		Load Upper Power Pickup (kW)	66
Frequency Trip (Hz)	57	Enable	Y	Load Lower Power Pickup (kW)	6
Trip Delay (s)	1			VAR Protection	
81O Overfrequency				Negative Var Pickup (kVAR)	13.2
Frequency Trip (Hz)	63			Positive Var Pickup (kVAR)	N/A
Trip Delay (s)	1				

Table 1: Relay Set Points

8.8 Credits(MPR)

Brayam did: Points list, Electrical diagram, Explanation for unmet project spec, Setpoints list Dawei did: AutoCAD drawing, Wiring diagram, Bill of Materials, Setpoints list Ibrahim did: Report overview, Realized specifications,

9 Use of Relevant NFPA 70 Standards

- Lockout/Tagout Procedure
  We followed the sequence of the lockout/tagout system procedure using the Annex G in the NEC 2017.

- Control Circuit Conductor Sizing
  According to the NEC 2017 table 310.15(B)(16), we are allowed to use any guage conductor because we are drawing less then 1 amp of current. So we decided to use 18 AWG copper wire.

- Control Circuit Conductors
  All conductors are sized, insulated, and marked according to the requirements listed in the NEC 2017 Article 310.

- Grounding Conductor Marking
  Grounding conductors have a continuous outer finish of green following the NEC 2017 Article 250.119.

- Grounded Conductor Marking
  Grounded conductors have a continuous outer finish of white following the NEC 2017 Article 200.6

- Control Circuit Hot Conductor Marking
  Ungrounded 120VAC single phase hot conductors have a continuous outer finish of red following the NEC 2017 Article 210.5(C)(1)(a).

- Control Circuit DC Conductor Marking
  For 240VDC conductors, the positive ungrounded conductors have a continuous outer red finish, while the negative ungrounded conductors have a continuous outer black finish. This follows the NEC 2017 Article 210.5(C)(2).

- Power Circuit Overcurrent Protection
  Power circuit overcurrent protection was sized using the NEC 2017

Article 430.52(A), 430.52(B), 430.52(C) with a reference to table 430.52. We calculated a Full Load Current of the motor to be 2.1 amps. The next largest fuse to use would be a 3 amp fuse per phase, but we have 8 amp fuses installed for this project.

- Power Circuit Conductor Sizing
  According to article 430.22(G)(1)(2) in the NEC 2017, we sized our conductors as TFFN stranded 18 AWG copper wires.
- Power Circuit Hot Conductor Marking
  Ungrounded 208VAC 3-phase hot conductors have a continuous outer finish of red, black and blue for phase a, b and c respectively in accordance with the NEC 2017 Article 210.5(C)(1)(a).

10 Conclusion

Inter-Con group will be an essential part of the project since it will basically control the entire micro-grid. The challenges relies on connecting the different parts of the micro-grid into a single Central control center using TCP/IP protocol. secondly, it should have the communication required to allow it to control the generation, load, and the transmission between the two. Finally, it will have the data that allow him to analyze the system and adjust the system's parameters accordingly.