جامعة الأمير محمد بن فهد

PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Electrical Engineering

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Senior Design Project Report

Microgrid Power Management System

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical Engineering

Team Members

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Abstract

Industrial cities, large factories, and companies who work in any field such as oil extraction, metal melting furnace, and more areas where the demand of the power is high and should be consistent cannot start their job until they got control on the electrical power supplied. Moreover, these kinds of areas where the delay of a minute will be so hard on the company's economy. In addition, some accidents might take a place in the work area in the absence of the power control system.

This project aims to deliver the best control of any kind of workstations like plastic factories and metal melting furnace factories which they use big generators to supply their station. Also, to build a safe working area between the employees to make sure that there won't be any cutoff in the electricity supplied, which will make big machines to stop suddenly and cause some problems to the operators who near to the machine. Moreover, using this project will decrease the production cost. Also, it minimizes the operational costs by decreasing the number of operators because the system is automated and control through a display screen shows the whole system. Moreover, overload management is taking a place in this project.

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1. Introduction

1.1 Project Definition

Our aim is to design a simple generation and distribution scheme, with automatic load shedding, through an automated system for avoiding plant shut down.

1.2 Project Objectives

1. Avoid the electricity shutdown.
2. Reduce the production, investment, and minimize the operational costs.
3. To avoid accidents and have a safe operation for operators.

1.3 Project Specifications

1. Designing a simple generation and distribution scheme for load shedding demo.
2. All the parameters assigned as an analog I/O’s (4-20mA) & Digital I/O’s (0-1) from external source to PLC.
3. Parameters, logics, controls and conditions assigned in PLC software.
4. All the PLC communication connected to HMI for monitoring.
5. Demo will be explained as per the plant sequential of operation and load shedding functions.
6. External power supply for I/O’s, PLC & HMI (220V/10A AC).

1.4 Project Architecture and Components

The subsystems are shown in [Fig1] below states the three subsystems, including the generation and distribution, Programmable Logic Controller, and the Human Machine Interface. In addition, [Fig2] indicates a functional photo of the project.

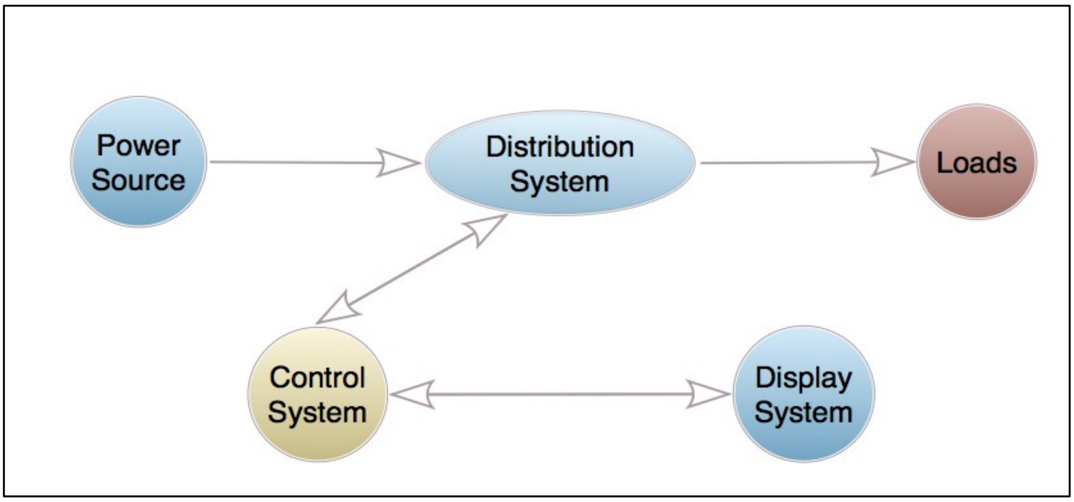


Fig.1: Project Architecture

Fig.2: Photo of the project

1.5 Applications

The proposed system can be used in:

- Captive power plant.
- Power grid.
- Radial substations.
- Process plant.

2. Literature Review

2.1 Project background

There are some issues those will be solved by this project like shut down on critical loads, money loss, production interruptions and delays, and reliable power to customers. We looked over three projects which they use the almost the same function in different ways, one is a smart power management system, the second is a device measure the quality of the power supplied, the last is an AC device that gives different characteristics like power factor, voltage, and frequency. However, our project is load scheduling based on frequency to cut down the power on the uncritical loads to keep the critical loads working properly without any issues.

2.2 Previous Work

The first proposed solution we looked at is the [Smart Power Management System. University of PMU,2016 and it established two years ago in Prince Mohammed Bin Fahad University and it's generally about to design and implement SCADA based power management system with additional quality-based source selection based on harmonics analysis.

The second solution we read about it is Power quality monitoring & power measurements, Ss. Cyril and Methodius University, 2009 and it is about a device that gives you the quality of electricity supply.

The last solution we went over is the A.C system-monitoring device, Bradley University, 2016"and it is an alternating current (AC) monitoring device is a device to monitor voltages, current, power factor, and other AC power characteristics.

2.3 Comparative Study

Table1: Projects comparison

Area of Comparison	PMCS	Power Quality monitoring and measurements	Smart Power management System	AC System
Frequency and monitoring wise	Frequency &monitoring control the power stability	Measure Harmonics and Correction	Quality power-based Harmonics analysis	Frequency measurement & power factor control
Equipment control over Scada	Yes	Yes	Yes	No
Power source	Yes	Yes	Yes	No
SCADA	HMI	DAQ	DAQ	Ethernet
Metering	YES	Yes	Yes	Yes
Protection	Yes	No	Yes	No
Automation	Yes	No	Yes	No

3. System Design

3.1 Design Constraints

3.1.1 Design Constraints: Engineering Standards

- Electrical System:
  - NFPA 79: Electrical Standard for Industrial Machinery.
  - UL 508A: Standard for Industrial Control Panels (up to 600V).

- Load Shedding system:
  Effective of Standard: PRC-006-2 — Automatic Under Frequency Load Shedding

- Power System Communication and SCADA System:
  - IEC61850: Communication Standard for Electrical Substation Automation Systems.
  - IEEE1815: Standard for Electric Power Systems Communications Distributed Network Protocol (DNP3).
  - MODBUS.

- Automation Algorithms:
  - IEC61131: Standard for Programmable Controllers.

3.1.2 Design Constraints: Safety, Reliable, and Integrate

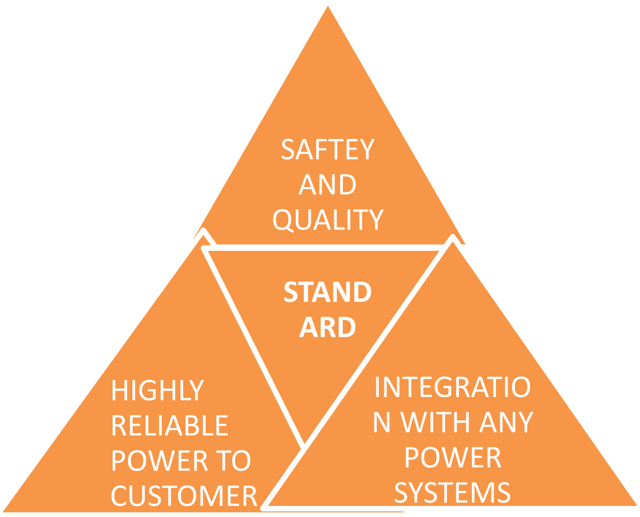


Fig.3: Design Constraints

3.2 Design Methodology

Approach:

To initiate this project and ideas were began from power and distribution sector where I am working in power and process plant operations. Our task is how to deliver reliable operation to the customer to achieve satisfactory level without interrupting their critical loads and increase the productivity.

The below digarm [**Fig.4**] explain the construction of our project:

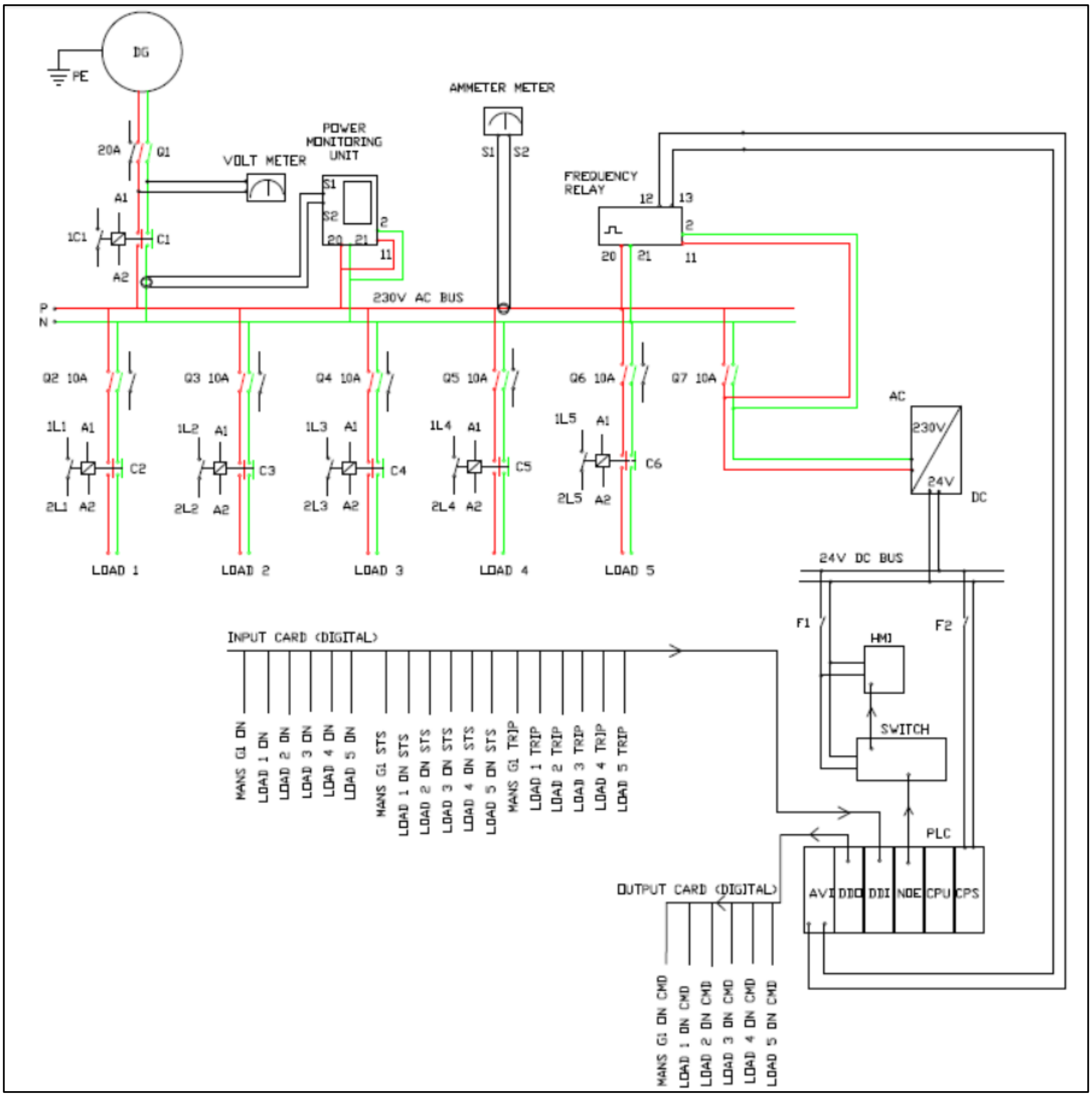


Fig.4: The project architecture

Strategy:

1. Reliable operation.

2. Customer satisfaction.
3. High productivity.

3.3 Product Subsystems and Components

Alternatives options:

- **Subsystem1:** We have looked over several generators to choose the one which has a stable close to 60Hz frequency.

- **Subsystem2:** Communication thru PLC from Mitsubishi. However, we have chosen PLC from Schneider Electric since we can rent it because of the cost.

- **Subsystem3:** HMI from Mitsubishi. However, we choose the one from Schneider Electric since we can rent it because of the cost.

3.3.1 Product Subsystem1: power, panel distribution

1. Generation and distribution scheme [**Fig.5**]:
- Diesel generator.
- Protection MCB's.
- Isolation breakers (contactors).
- Power monitoring device.
- Common Bus.
- Frequency monitoring Relays for performing **AUFLS:** Automatic under frequency load shedding.

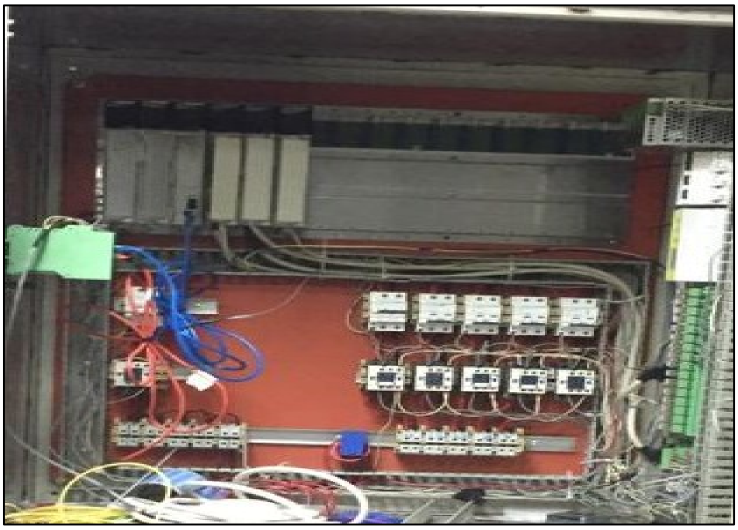


Fig.5: Power Panel

3.3.2 Product Subsystem2: control

2. Programming logic controllers [**Fig.6**]:

- I/O’s hardware and software designing.
- Assigning the logics.
- Communication between frequency relay and the system.

Fig.6: Programming logic controller

3.3.3 Product Subsystem3: communication

3. HMI (Human machine interface system) [**Fig.7**]:

- Designing of animated scheme.
- Communication between PLC & HMI.

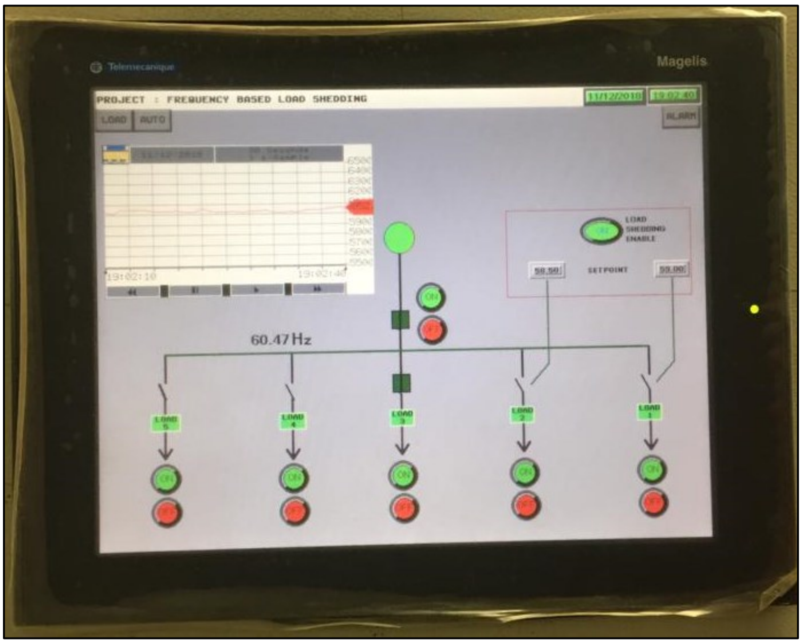


Fig.7: HMI

3.4 Implementation

1. We are purchasing the componants from direct OEMs for reliable operation. In case any failures and defective componants may sent to OEMs lab and get the technical clarification from their lab experties and getting replacement with free of cost (if its confirmed as manufacture defects).

2. We considered multiple alternatives by comparing its affordability regarding the price and the reliability.

3. We used AUTO CAD & VISIO software to design the panel to include all the components like the wirings, PLC, HMI, and the breakers to meet our requiemnts. Also, we looked over several generators to have a stable frequncy.

4. We implemented our design like building the panel startig from using the autocad ending by implemented it at a workhop after we take all the requierd measurements.

5. We tested the project at an industrial electrical LAB with proper protective device for man and machine safety.

4. System Testing and Analysis

4.1 Subsystem 1: Generation and distribution scheme:

The first subsystem is about the generation and distribution scheme system. We are using diesel generator as a power source, protection MCB's, isolation breakers, power monitoring device, common bus, and frequency monitoring relays. We test the generators to see what it gives, and we figure out that it gives close to 230 V 60Hz. And we tested also the breakers (protection MCB's, isolation breakers) to see it is work and to check the efficiency by generate the voltage and measure it by the DMM.

4.2 Subsystem 2: Programming logic controllers

The controller that we will use is the PLC. This subsystem is taking the action of considering the two stages under frequency load shedding. It reads the frequency at the common bus to indicate what it should be done, whether disconnecting the non-critical loads or not. As the frequency drop regarding the overload, PLC reads it from the frequency relay and then it starts to disconnect the non-critical loads on two stages. The first stage when the frequency at 59 Hz and the second stage is at 58 Hz. [**Fig.8**]: explains how PLC is taking the order and implement it.

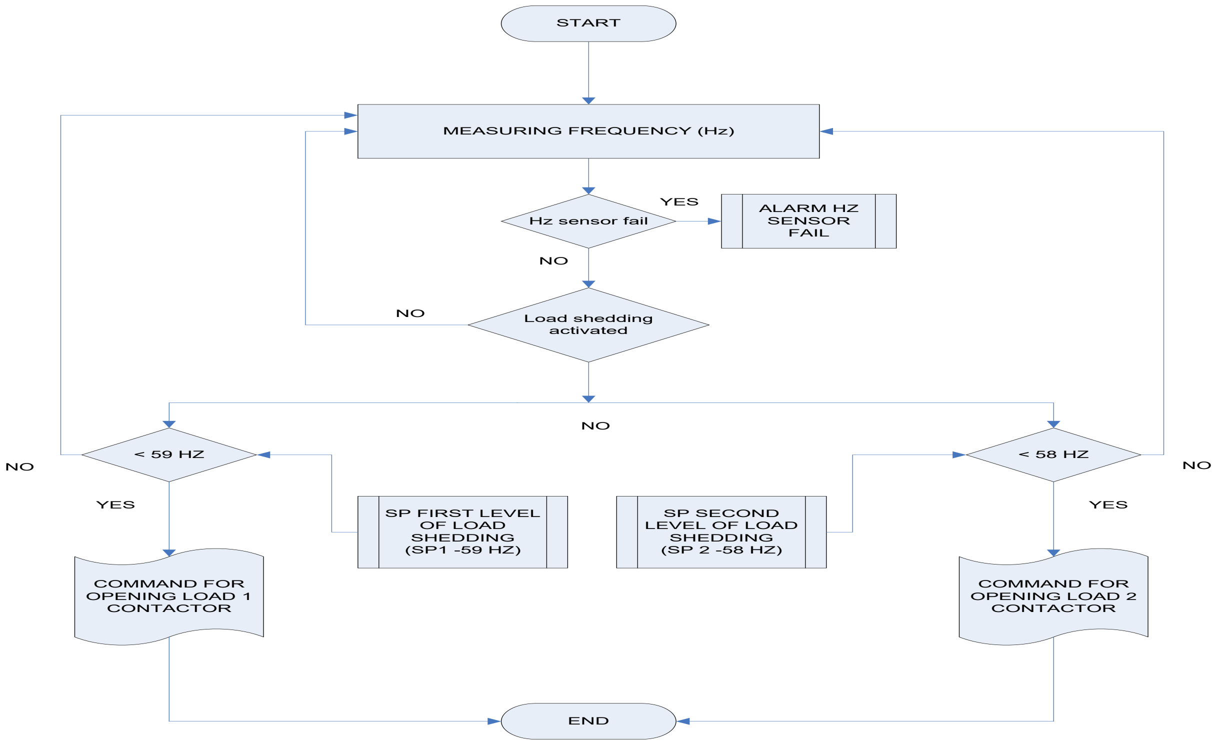


Fig.8: Project Flow Chart

4.3 Subsystem 3: HMI (Human machine interface system)

This part is responsible of displaying the whole system on screen and control the system through it. It is connected to PLC through a matching protocol, and both of them from

Schneider Electric. From HMI we have a control over the loads and activating automatic under frequency load shedding (AUFLS). Also, it displaying the frequency curve, bus, and loads.

4.4 Overall Results, Analysis and Discussion

In [Fig.9]: Testing the frequency of the generator in very important because one of our project objectives is to make the frequency always at 60 Hz and if the generators cannot give 60Hz it will be useful. Also, this is the testing of voltage for the generator and it gives approximation 220V and that what we need in our project.

In [Fig.10]: This is testing the efficiency of the breakers, which give very good reading. The results: By testing the components of the generation and distribution scheme subsystem, we find out that the subsystem is ready and all results of this system are like what we need.

Fig.9: Testing the voltage & frequency of the generators.

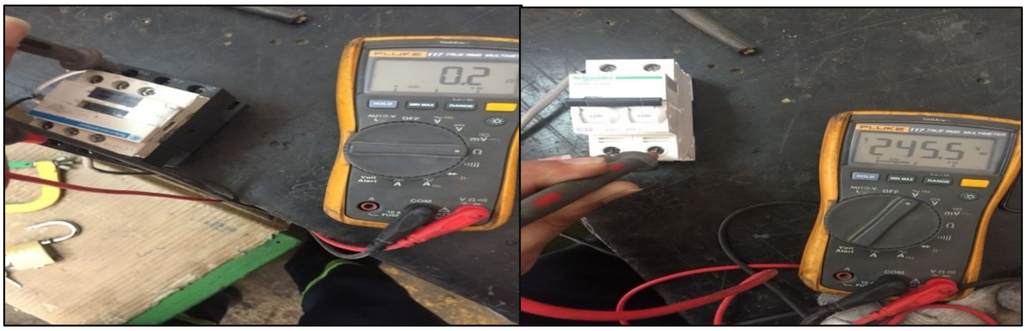


Fig.10: Testing the efficiency of both breakers and the contactors

5. Project Management

5.1&5.2 Project Plan and Contribution of Team Members

Next table shows what each member have contributed in the team along with the project for the two semesters in building the project:

Table2: Project plan

Task	Mohammed	Moyed	Abdullah	Amer
Search & acquire components	25%	25%	25%	25%
Design & build Panel	15%	45%	25%	25%
Design & build Circuit diagram	25%	20%	20%	35%
Test component	45%	15%	25%	15%
Write Report &Presentation	15%	15%	40%	30%

5.3 Project Execution Monitoring

Every week we were meeting to discuss about the project and see what we can do more to improve the project. In addition, we were meeting the advisor Dr. Jawad Al-Asad every two weeks and showed them what we added new to our project in order to take some advises. Also, we showed our project to Mr. Adel Khan and Mr. Ahmed AbulHussain to give us more advises.

5.4 Challenges and Decision Making

Many challenges we faced during this semester some of it was easy and we solve it but some of it was difficult.

The difficult challenges were:

1- using one power source in state of using two: the problem was what we need to make both generator 60Hz and 220V and make it stable, one of the generators was giving

60Hz and 220V and another generator was giving less than that. We solved this problem by searching in the internet and we find the solution which is by increasing the speed of the generator (the one who gave less than 60Hz and 220V) until it be stable with the first generator.

2- Most of the components was 3 phase: most of the components was 3 phase but what we need in our project only single phase

3- Cost: the components was very expensive if you want to buy it for example the PLC cost 20 000 SAR and HMI cost 10 000 SAR. Therefore, we rent it and we saved a lot of money.

5.4 Project Bill of Materials and Budget

Table 3 shows the project budget and what we paid for this project:

Table 3: Budget

No.	Description	Quantity	Unit Cost (SAR)	Total Cost (SAR)
1	Human Machine Interface system (HMI) and software.	1 set	10,000	Rent
2	PLC – CPU, PS, AI, DI, DO, TCP/IP cable and software.	1 set	20,000	Rent
3	Rental generators.	1 set	1000	1000
4	Frequency monitoring relay.	1 set	4000	Rent
5	MCB's and Power contactors	20	300	Rent
6	Wires 1.5 to 2 sqmm + Synchronoscope	10m + 1PC	50 + 2500	2550
7	Connectors + 1000X600X200 Electra panel board	50 pc + 1000	50 + 1000	1050
Total			**4600 SAR**	

6. Project Analysis

6.1 Life-long Learning

1. Project selection:

   We form the team for select the valuable project and discussed how it will help to lead our future carrier in engineering field. Finally concluded to select the power scheme related project is the suitable and it can perform easily in live test with limited and lower range source in power distribution scheme with load shedding options.

2. Project feasibility study thru tools:

   Our obstacle is that we can't control the source voltage and frequency in the scheme due to such kind of controller costing more than our budget cost at the same time we can't synch with other source dg's, that's the reason we fixed our project design as single source load shedding scheme. Our aim to understand the AUFLS curve in practical way of knowledge. Single or Dual source operation, our AUFLS cure and response will be the same, that's the reason we fixed single source scheme due to all the components are available at local market and accessible with rent basis.

3. Project scheduling, designing & BOM availability:

   Scheduled properly and according to that we accessed the material in various location. While dealing with material purchase, we learnt about component specification, design, control setting range is within that or not? Warranty class, material factory test certificates, product standards, operation ratings and protection grading from source to load thru MCB installation (It will prevent the components as well as failsafe result).

4. Each components comparative study & Programming:
   Prize, Control set, accuracy, size, PLC/HMI software installation, mapping the communication protocol thru Ethernet (TCP/IP) and overall simulation test for logical confirmation.

5. Panel fabrication and installation:
   Auto cad, design the angle and panel boards.

6. Drawing and wiring design:
   Auto cad, panel wiring design and mounting standards.

7. Test the parts:
   While testing individual parts, we understand that how to set the control system, programming in PLC, Communication protocol, sequence of control flow, in measuring system direction of current flow (CT), Protection grading from source to load (MCB), importance of earthing (Man & Machine) and accuracy in timing parts.
   AUFLS Set:
   Level # 1: 59 Hz
   Level # 2: 58.5 Hz.

8. Final testing and commissioning:

Prepared the standard operating procedure (SOP) to perform the overall test in safe method. Sources were started manually and power distribution thru HMI selection. Slightly we increase the load more than rated current as stated in name plate and observed the frequency curve, when it reaches level 1 # first feeder non-critical cut off and level 2 # second feeder non-critical cut off and frequency reached in normal and critical feeders are in safe.

Note: We faced the problem in source due to carbonator failure it was served variation frequency from without loading the scheme. It was replaced with calibrated and new generator.

9. Result:

We were simulated in loading part thru variable heater which is the capacity of 10 Amps as a critical feeder. Non-critical feeders were selected as 400watts lamp X 2 No's which can draw the 4Amps max. Total connected load is 10+4+4 = 18 Amps. Generator rating is 13 Amps max.

Normal generator operating voltage and frequency is = 230VAC 60 Hz.

With load of two non-critical lamp is = 8 amps (No changes in frequency curve).

With load of critical load step # 1 = 13 Amps (Generator at 100% loading 59.98Hz).

When increase the critical load step # 2 = 13 Amps to 18 Amps, step # 1 59Hz Non-critical first light will cut off and further into that 58 Hz non-critical load second light will cut off. Result of existing heater load 10Amps will be remains same and critical feeder will be saved.

The entire processes have been followed as stated below AUFLS curve [**Fig.11**] that has been proved in practical way thru this project.

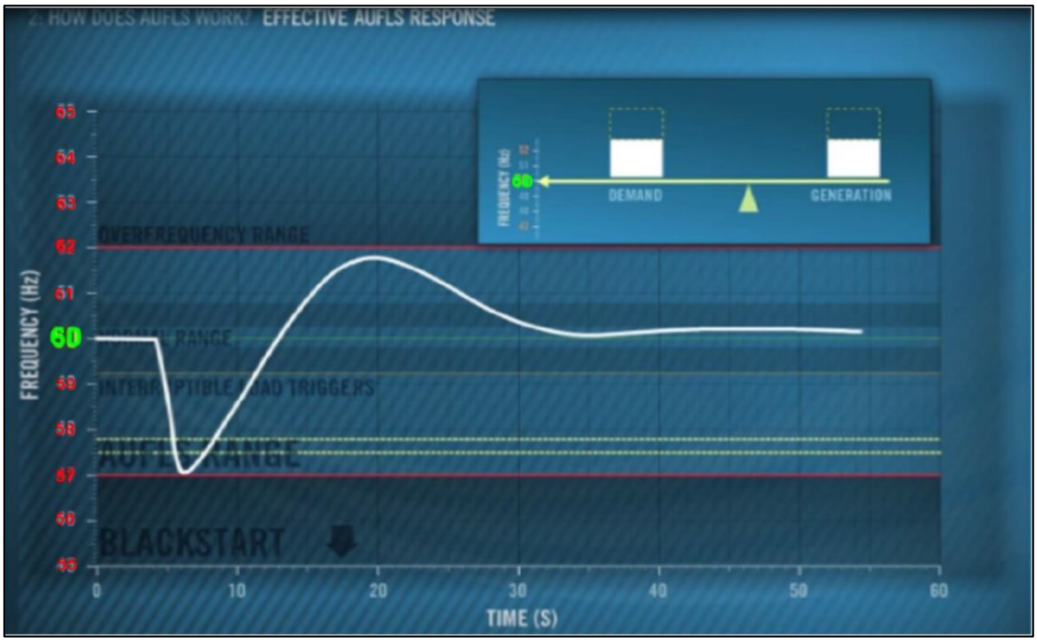


Fig.11: AUFLS curve

6.2 Impact of Engineering Solutions

This project can be applicable in hospitals, airports, social security buildings, power grid level, normal distribution level. It will prevent the critical loads which can't affect the total blackout. A part of reliable power source this scheme must be implemented in power distribution level (Substations).

6.3 Contemporary Issues Addressed

Power transmission grids have a connection with lots of power generation and load distribution thru large and small range of substations. This project will be suitable for all type of distribution with various range of voltage level thus cutting the noncritical load and will save the generation plant from overloading.

As a captive power plant and substation level will be the most suitable for this project. It will drive the part of reliability and customer satisfaction.

7. Conclusions and Future Recommendations

7.1 Conclusions

In conclusion, we have completely done our task of constructing this senior project as a team over two semesters, starting on 1st of January 2018, finished on 12 December 2018. We have done constructing and designing the power panel and put all the components inside. Moreover, we have programmed PLC through (Concept Program) to control the whole system. Likewise, we have stimulated the system on HMI screen to control and activate AUFLS and look after the frequency and loads.

Compared to the previous projects, our project was more functional and easier to have the control over the system through HMI.

This project has helped us to build a strong background on how real industrial systems work. Also, we had the chance to learn about two very important subsystems, HMI and PLC in terms of how they connect together to control the loads. Moreover, we had some challenges like programming PLC and looking for the best stable generator to match the system.

7.2 Future Recommendations

We had a future recommendation in terms of integrate the system with UPS system and put all together. Also, as Mr. Saifullah Shafiq states that we may increase the safety and add new feature like automatic load connecting to the system after it shut down.

8. References

1. http://electrical-engineering-portal.com/download-center/books-and-guides/electrical-engineering/automation-guide
2. https://w3.siemens.com.br/home/br/automacao-energia/aplicacoes/Documents/Descarte%20de%20cargas%20ingeligente%20(Load%20Shedding).pdf
3. https://store.gedigitalenergy.com/FAQ/Documents/489/GET-6449.pdf
4. http://electronics.etfbl.net/journal/Vol13No1/xPaper_12.pdf

Appendix A: Progress Reports

Table 4: Progress Report

Tasks		Description (brief but clear)	% Completion
Completed Weeks 1 to 6	**1**	Background research and reading about Power Management System	**100%**
	2	Search for components and resources within PMU and local market like generators, HMI, PLC, and circuit breakers.	
	3	Prepared project proposal and project plan	
	4	Started design for subsystem (1) **Generation and distribution**	
	5	Search for circuits and components to implement the subsystem (1) **Generation and distribution**	
In Progress Weeks 7 & 8	**7**	Design of subsystem2	**100%**
	8	Installation of all the subsystems	**100%**
	9	Wiring individual subsystem	**100%**
	10	Testing of individual subsystems.	**100%**
Comments	Comment on any reason for delays or challenges met and mention any decision taken.		
Deadlines	**ProgRpt1 (Wks 1- 6) Due March 4**	**ProgRpt3 (Wks 7, 10) Due April 1st**	
	ProgRpt2 (Wks 7, 8) Due March 18	**ProgRpt4 (Wks 11, 12) Due April 15**	

Table 5: Progress Report

SN	Tasks & Responsibilities		Semester Weeks													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Planning; Feasibility and Reading	All			100%											
2	Idea generation and selection	All			100%											
3	Project Proposal	All					100%									
4	Project management Plan	All					100%									
4	Searching for Components for subsystem xxxx	MA, KM	100%													
6	Design subsystem SS1 (Monitoring)	MA, MH	100%													
7	Select & acquire components for SS1	KM	100%													
8	Implement Design for SS1	MH	100%													
9	Test and refine design for SS1	MH, HA	100%													
10	Design subsystem SS2 (Lighting)	All	100%													
11	Select & acquire components for SS2	All	100%													
12	Implement Design for SS2	All	100%													
13	Test and refine design for SS2	All	100%													
14	Integrate subsystems SS1 & SS2	All	100%													
17	Order components for SS3,4…	All	100%													
18	write progress reports (weekly)	All	100%													
19	Prepare midterm presentations	All	100%													
20	Prepare Demo. (prototype)	?														
21	Prepare Final presentation	?														
22	Prepare final report															

Appendix B: Bill of Materials

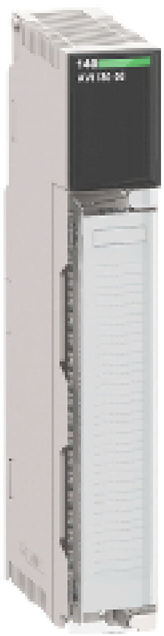
Table 6: Progress Report

No.	Description	Quantity	Unit Cost (SAR)	Total Cost (SAR)
1	Human Machine Interface system (HMI) and software.	1 set	10,000	Rent
2	PLC – CPU, PS, AI, DI, DO, TCP/IP cable and software.	1 set	20,000	Rent
3	Rental generators.	1 set	1000	1000
4	Frequency monitoring relay.	1 set	4000	Rent
5	MCB's and Power contactors	20	300	Rent
6	Wires 1.5 to 2 sqmm + Synchronoscope	10m + 1PC	50 + 2500	2550
7	Connectors + 1000X600X200 Electra panel board	50 pc + 1000	50 + 1000	1050
	Total		**4600 SAR**	

Appendix C: Datasheets

Complementary	
Group of channels	4 groups of 8
Discrete output logic	Negative logic (sink)
Addressing requirement	2 output words
Discrete output voltage	24 V DC
Output voltage limits	19.2...30 V
Absolute maximum output	56 V for 1.3 s decaying pulse
Voltage drop	0.4 V 0.5 A
Maximum load current	4 A per group 16 A per module
Surge current	<= 5 A for 0.0005 s
Response time	<= 1 ms at state 1 to state 0 <= 1 ms at state 0 to state 1
Leakage current	0.4 mA 30 V
Load inductance	Inductance(H) = 0.5/((current(A))^2 x (switching frequency(Hz))) 50 Hz
Fault indication	Blown fuse Loss of field power
Associated fuse rating	5 A per group 3 A each point
Isolation between channels and bus	1780 Vrms DC for 1 minute
Isolation between group	500 Vrms DC for 1 minute
Protection type	Internal output protection by 5 A fuse per group
Power dissipation	1.75 W + (0.4 V x total module load current)
Marking	CE
Local signalling	32 LEDs green input status 1 LED red external fault detected (F) 1 LED green bus communication is present (Active)
Bus current requirement	330 mA
Module format	Standard
Product weight	0.45 kg

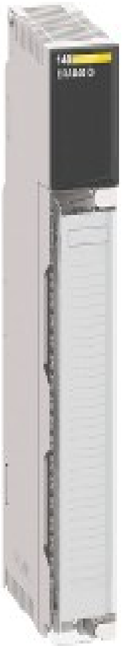
Fig.12: DIGITAL OUTPUT



Main	
Range of product	Modicon Quantum automation platform
Product or component type	Processor
Software name	ProWORX 32 Concept
Processor name	80486
Mathematical coprocessor	With

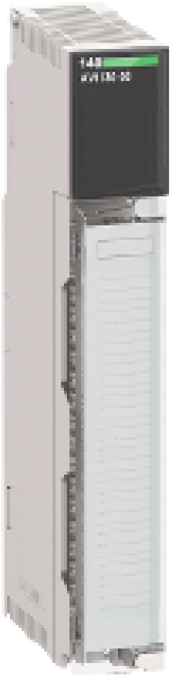
Complementary	
Clock frequency	66 MHz
Memory description	Internal RAM 896 kB
Exact time for 1 Kinstruction	0.1...0.5 ms LL984
Watchdog timer	250 ms
Clock drift	+/-8 s/day at 32...140 °F (0...60 °C)
I/O words	30 I/32 O distributed 64 I/64 O max local 64 I/64 O remote
I/O words/network	500 I/500 O distributed
Drops/Network	63 distributed
Number of drops	31 remote
Number of network	2 remote 3 distributed
Battery type	Lithium 7 µA 210 µA
Battery capacity	1.2 Ah
Battery life	10 yr
Number of port	1 Modbus Plus 2 Modbus RS232
Communication module processor capacity	6 NOM, NOE, CR, NMS

Fig.13: CPU



Main	
Range of product	Modicon Quantum automation platform
Product or component type	Power supply module
Power supply type	Redundant
Complementary	
Input voltage	125 V DC 100...150 V
Input current	500 mA 125 V
Inrush current	28 A 125 V
Input power interruption	<= 1 ms
Associated fuse rating	2 A slow-blow
Output voltage	5.1 V DC
Power supply output current	8 A redundant
Output overvoltage protection	Internal
Output overload protection	Internal
Power dissipation	6 + (1.5 x Iout) where Iout is in A
Local signalling	1 LED green power (PWR OK)
Marking	CE
Module format	Standard
Product weight	0.65 kg
Environment	
Standards	CSA C22.2 No 142 UL 508
Product certifications	CUL FM Class 1 Division 2
Resistance to electrostatic discharge	4 kV contact conforming to IEC 801-2 8 kV on air conforming to IEC 801-2
Resistance to electromagnetic fields	10 V/m 80...2000 MHz conforming to IEC 801-3

Fig.14: Power Supply



Main	
Range of product	Modicon Quantum automation platform
Product or component type	Analogue input module
Type of filter	Single pole low pass - 3 dB at 847 Hz +/- 20 %
Complementary	
Analogue input number	8
Input type	Differential
Addressing requirement	9 input words
Analogue input type	Bipolar current 20 mA Bipolar voltage +/- 10 V Bipolar voltage +/- 5 V Unipolar current 0...20 mA Unipolar voltage 0...10 V Unipolar voltage 0...5 V
Analogue input resolution	16 bits +/- 10 V 16 bits +/- 5 V 16 bits 0...10 V 16 bits 0...20 mA 16 bits 0...5 V 16 bits 20 mA
Linear measuring range	(Input range) x 1.024 mA (Input range) x 1.024 V
Absolute maximum input	25 mA 50 V DC
Input impedance	> 20 Ohm voltage 250 MOhm +/- 0.03 %
Absolute accuracy error	+/- 0.03 % +/- 0.05 % of full scale maximum
Linearity error	+/- 0.008 %
Accuracy drift according to temperature	+/- 0.0015 % of full scale/°C <= 0.004 % of full scale /°C
Common mode rejection	> - 80 dB 60 Hz

Fig.15: Analog input module

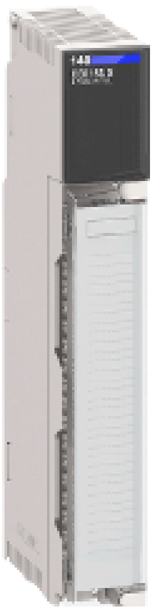
Main

Range of product	Modicon Quantum automation platform
Product or component type	Ethernet network TCP/IP module
Concept	Transparent Ready
Web server	Class B30
Web services	Data Editor (via PC terminal) Diagnostics via predefined web pages Rack viewer
Communication service	Bandwidth management FDR server Global Data I/O scanning Modbus TCP messaging SNMP network management
Communication port protocol	Ethernet Modbus TCP/IP
Physical interface	MT/RJ 100BASE-FX fiber optic RJ45 10BASE-T/100BASE-TX twisted pair
Transmission rate	10/100 Mbit/s

Complementary

Redundancy	Yes hot standby redundant architecture
Supply	Via the power supply of the rack
Marking	CE
Local signalling	1 LED 10 Mbps or 100 Mbps data rate (10 MB/100 MB) 1 LED collision detection (Coll) 1 LED download mode (Kernel) 1 LED Ethernet module fault (Fault) 1 LED Ethernet network status (RUN) 1 LED full-duplex mode (Fduplex) 1 LED module ready (Ready) 1 LED network active (Link) 1 LED rack operational (Active) 1 LED transmission/reception activity (TxAct/RxAct)

Fig.16: Ethernet network TCP/IP module



Main

Range of product	Modicon Quantum automation platform
Product or component type	Low voltage dc discrete input modules
Discrete input number	32

Complementary

Group of channels	4
Logic input	Positive (sink)
Discrete input voltage	24 V DC
Input voltage limits	19.2...30 V
Voltage state 1 guaranteed	15...30 V DC
Voltage state 0 guaranteed	-3...5 V DC
Current state 1 guaranteed	>= 2 mA at Us = 5.5 V and Uin = 0 V
Current state 0 guaranteed	<= 0.5 mA
Addressing requirement	2 input words
Input impedance	2500 Ohm
Leakage current	200 mA at Us = 5.5 V and Uin = 4 V
Absolute maximum input	30 V continuous 56 V during 1.3 ms decaying pulse
Response time	<= 1 ms from state 0 to state 1 <= 1 ms from state 1 to state 0
Protection type	Input protection by resistor limited
Power dissipation	1.7 W + (0.36 x number of points on)
Isolation between group and bus	1780 Vrms for 1 minute
Isolation between group	500 Vrms for 1 minute
Local signalling	1 LED green bus communication is present (Active) 1 LED red external fault detected (F) 32 LEDs green input status

Fig.17: Discrete input module

Main	
Range of product	Magelis XBTGT
Product or component type	Advanced touchscreen panel
Display type	Backlit colour TFT LCD
Display colour	65536 colours
Display resolution	800 x 600 pixels SVGA
Display size	12.1 inch
Software type	Configuration software
Software designation	Vijeo Designer
Operating system	Magelis
Processor name	CPU RISC
Processor frequency	266 MHz
Memory description	512 kB SRAM back up of data with lithium battery back-up
Resistance to electrostatic discharge	6 kV conforming to IEC 61000-4-2 level 3
Cut-out dimensions	301.5 (+ 1/- 0) x 227.5 (+ 1/- 0) mm

Complementary	
Touch sensitive zone	1024 x 1024
Touch panel	Analogue
Backlight lifespan	50000 hours
Brightness	8 levels via touch panel
Character font	Korean Japanese (ANK, Kanji) Chinese (simplified Chinese) Taiwanese (traditional Chinese) ASCII (European characters)
[Us] rated supply voltage	24 V DC
Supply	External source
Supply voltage limits	19.2...28.8 V

Fig.18: HMI

Fig.19: Generator

Appendix D: Program Codes

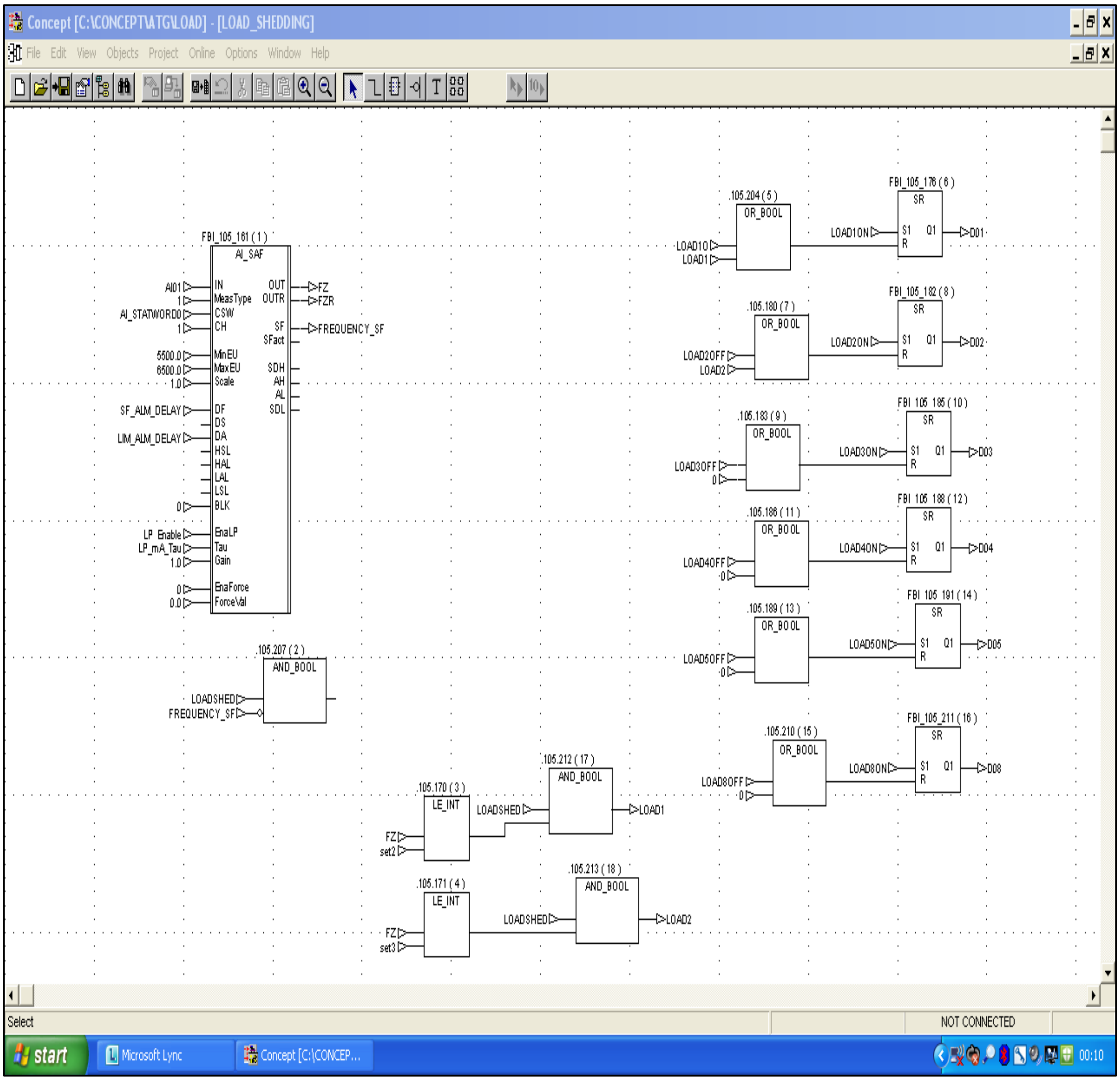


Fig.20: PLC – FUNCTIONAL LOGICS

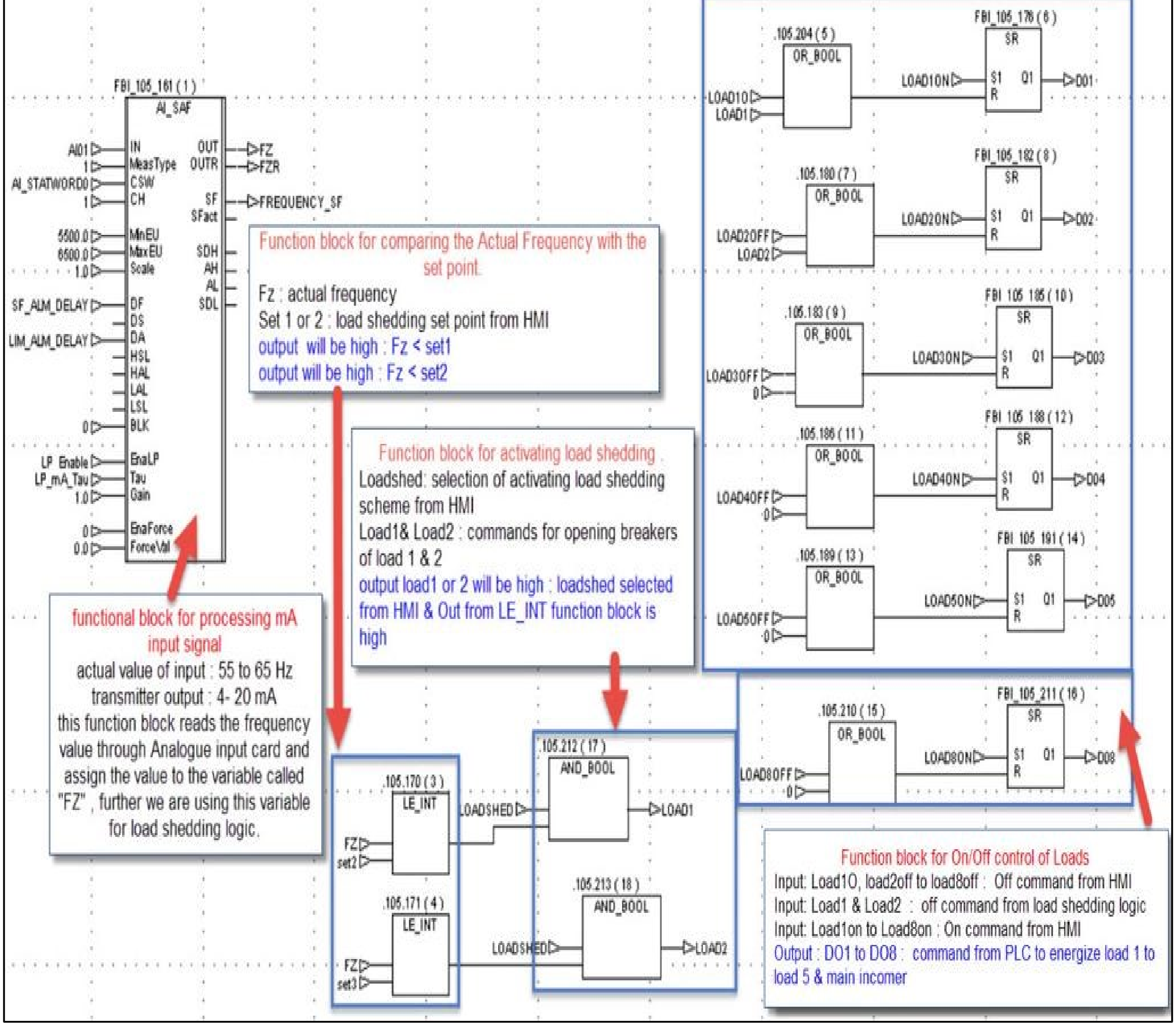


Fig.21: PLC Logic – Explanation

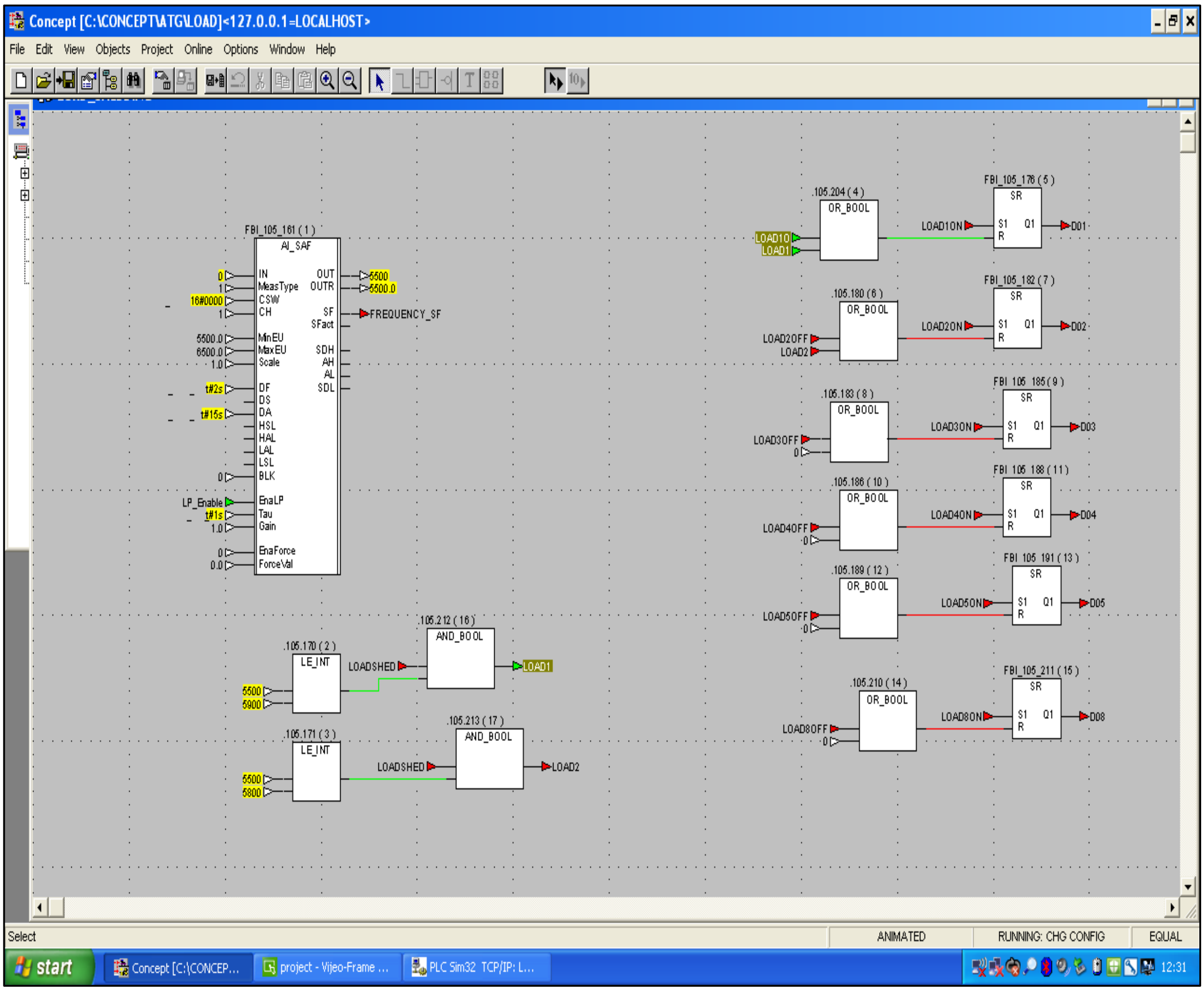


Fig.22: PLC Logic – Explanation

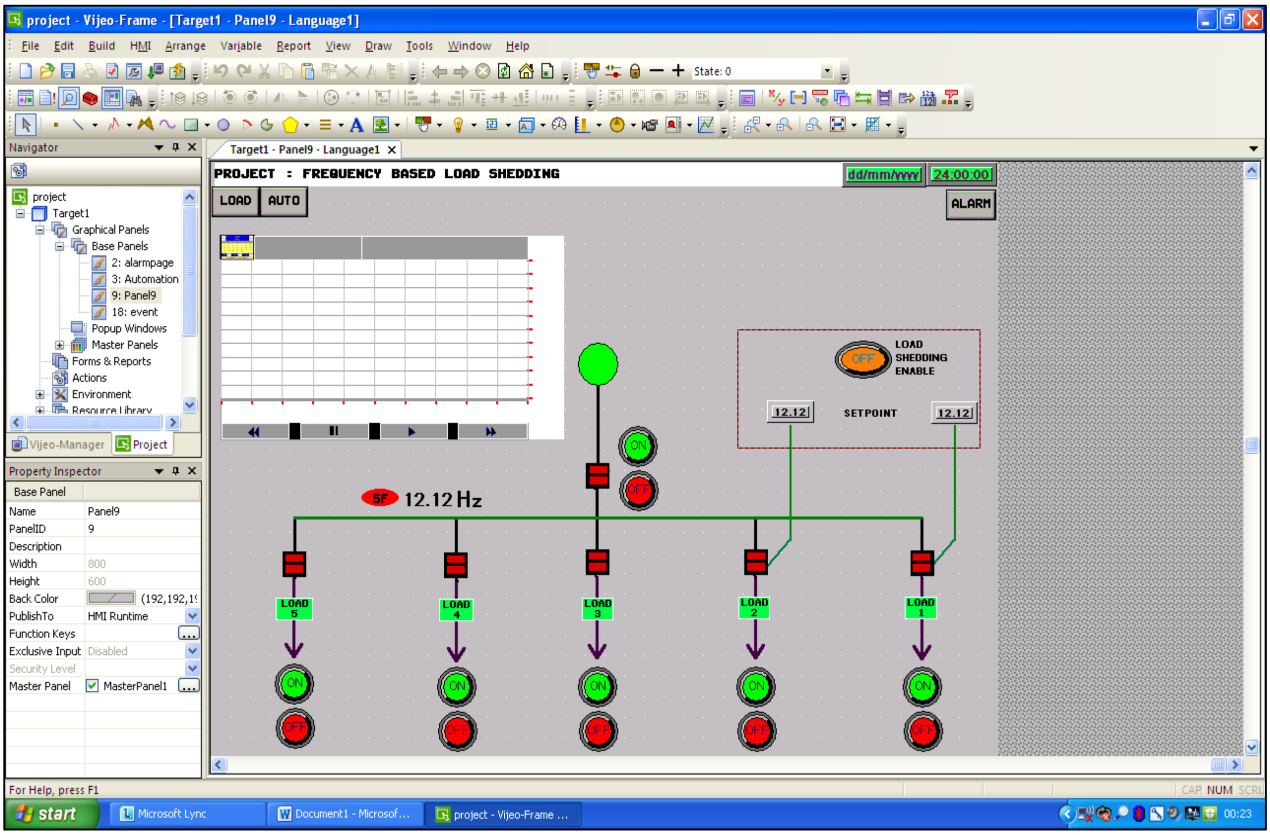


Fig.23: HMI – Front Screen

Appendix E: Operation Manual

SOP (Standard operating procedure

1. Refer the Control Drawing and Isolate all he breakers in control panel.

2. Check all the earthling system is connected or not for man and machine safety.

3. Check the generator fuel level for avoiding the voltage fluctuation during test.

4. Start the generator and check the output voltage, must be 220VAC / 60 Hz.

5. Switch "ON" the mains MCB 20Amps. (MCB – Miniature circuit breaker for protection) and give switching command thru HMI for closing the main contractor.

6. Check the measuring system, Main bus and distribution is getting the voltage/Frequency.

7. Check the HMI and measuring system parameters.

8. Switch "ON" the distribution breakers (10 Amps MCB's).

9. Loading procedure can be start thru HMI to switch the distribution contactors.

10. We were simulated in loading part thru variable heater which is the capacity of 10 Amps as a critical feeder.

11. Non-critical feeders were selected as 400watts lamp X 2 No's which can draw the 4Amps max. Total connected load is 10+4+4 = 18 Amps. Generator rating is 13 Amps max.

12. Normal generator operating voltage and frequency is = 230VAC 60 Hz.
    With load of two non-critical lamp is = 8 amps (No changes in frequency curve).

13. With load of critical load increased up to = 13.5 Amps (Generator at 100% loading 59.98Hz). When increase the critical load up to = 13 Amps to 18 Amps,

14. Step # 1 59Hz Non-critical first light cut off.

15. Step # 2 58 Hz non-critical load second light cut off.

16. Result of existing heater load 10Amps will be remains same and critical feeder will be saved.

Note: To avoid the initial switching inrush current, in PLC we introduced ENABLE / DISABLE scheme button in HMI. After switching of two feeders, the system can be enabled for ready to load shed condition.

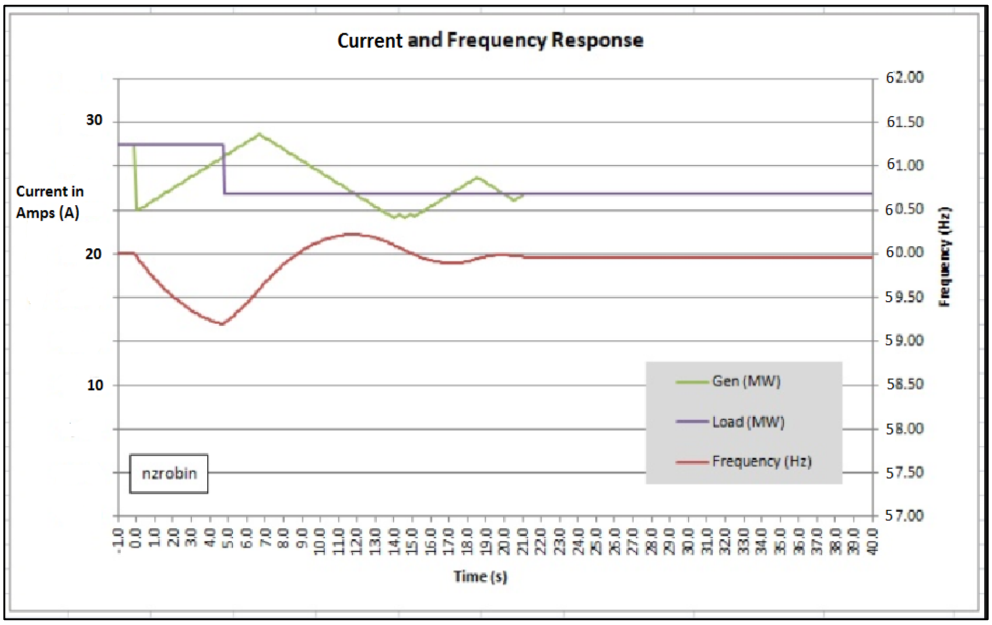


Fig.24: Frequency response

UFLS Standards

https://www.nerc.com/pa/Stand/Reliability%20Standards/PRC-006-2.pdf

AUFLS settings were tuned based on below formula

$$\frac{df}{dt} = \text{rate-of-change of frequency in Hz/sec.}$$

$$\% \text{ overload} = \frac{\text{Load} - \text{Remaining Generation}}{\text{Remaining Generation}} \times 100$$

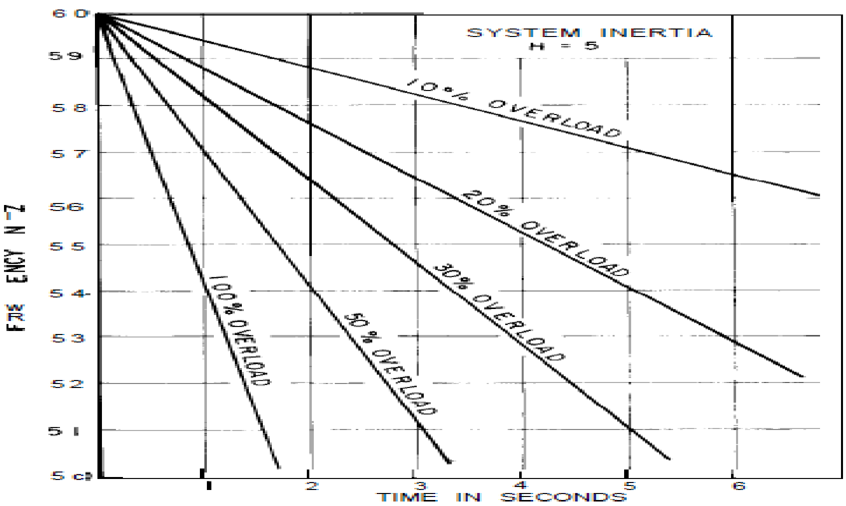
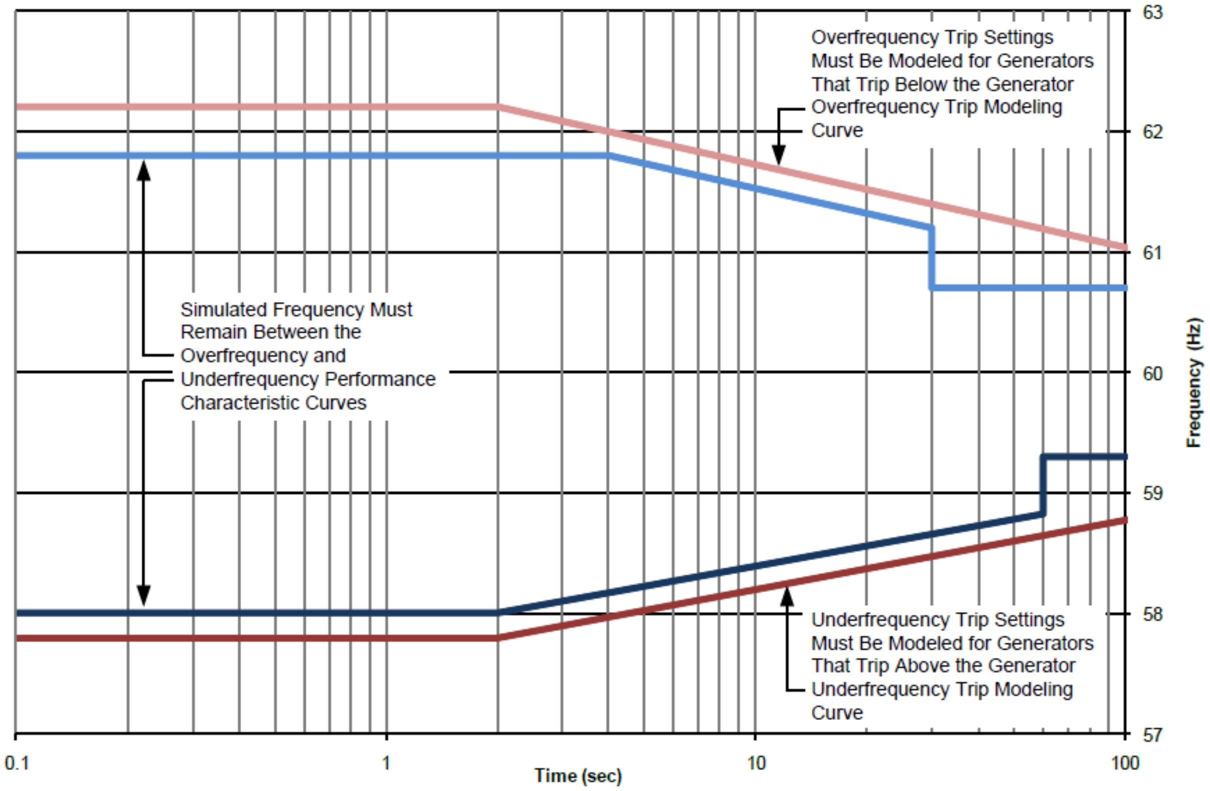


Fig. 3-3 Time-frequency Characteristic of a System for various Degrees of Overload, Generator and Load Torques Constant.

PRC-006-2 – Attachment 1

Underfrequency Load Shedding Program
Design Performance and Modeling Curves for
Requirements R3 Parts 3.1-3.2 and R4 Parts 4.1-4.6



Voltage Vs Frequency during load shedding Equation:

V – System voltage variation (Ex 216 @ 59 Hz and 214 @ 58.5 Hz).
Vp – source voltage (Phase voltage 220).
Fsys – Source frequency (60 Hz).
F1 – Change in frequency during load shedding function (ex 59 and 58.5 Hz).