"Basic Product Overview and Analysis of Time Study Considering Electrical Equipment"

Major Project Report

Submitted in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL ENGINEERING

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May 2022

CERTIFICATE

This is to certify that the Major Project Report entitled "Basic Product Overview and Analysis of Time Study Considering Electrical Equipment" submitted by Mr. Patel Parth Nileshkumar (18BEE081) and Mr. Sharvil Tabhani (18BEE116) towards the partial fulfillment of the requirements for the award of degree in Bachelor of Technology in the field of Electrical Engineering of Nirma University is the record of work carried out by him under our supervision and guidance. The work submitted has in our opinion reached a level required for being accepted for examination. The results embodied in this major project work to the best of our knowledge have not been submitted to any other University or Institution for award of any degree or diploma.

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ACKNOWLEDGEMENT

I must acknowledge the strength, energy and patience that almighty **GOD** bestowed upon me to start & accomplish this work with the support of all concerned, a few of them I am trying to name hereunder.

I would like to express my deep sense of gratitude to *all faculties of Electrical Engineering Department* for their valuable guidance and motivation.

I would like to express my sincere respect and profound gratitude to **Prof. (Dr.) S. C. Vora**, *Professor & Head of Electrical Engineering Department* for supporting and providing the opportunity for training.

I would also like to thank all my friends who have helped me directly or indirectly for the completion of my training.

No words are adequate to express my indebtedness to my parents and for their blessings and good wishes. To them I bow in the deepest reverence.

- Parth N. Patel (18BEE081) & Sharvil N. Tabhani (18BEE116)

ABSTRACT

The manufacturing and production industry deals with unwanted problems and errors everyday which hampers the smooth production activity and does not add any value to the industry. Most of the times the errors caused are due to human errors unless the industry is fully automated. To reduce these small errors and to move towards lean manufacturing, manpower traceability or Time study Monitoring of individual components is initialized. Various techniques to suppress the human errors is discussed in align with root cause analysis considering a real time fault. As manpower is the ultimate liability of any manufacturing industry, time required to make a product comes into picture which is a function of many components. To monitor each and every individual activity, product manufacturing stages are discussed in order to gain brief knowledge about the components used in the product. Besides this, for simulation purposes, a grid connected system considering Solar Inverter, as a focus, with technical specifications is also considered followed by design of Switched Mode Power Supply Card.

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

IT	: Information Technology
ISO	: International Organization for Standardization
UPS	: Uninterruptible Power Supply
RBC	: Railway Battery Charger
PCS	: Power Conditioning System
AC	: Alternating Current
DC	: Direct Current
SLD	: Single Line Diagram
LV	: Low Voltage
MV	: Medium Voltage
GTI	: Grid tide inverter
MPPT	: Maximum Power Point Tracking
SCM	: Supply Chain Management
EPC	: Engineering, Procurement and Construction
BOM	: Bill of Material
GRN	: Goods Received Note
ERP	: Enterprise Resource Planning
PMD	: Production Management Department
IQC	: Initial Quality Check
SQDC	: Safety, Quality, Delivery, Cost
PV	: Photo Voltaic
PLL	: Phase Locked Loop
DCDB	: DC Distribution Box
PCC	: Point of Common Coupling
ACDB	: AC Distribution Box
IGBT	: Insulated Gate Bipolar Transistor
ST	: Standard Time
IEC	: International Electrotechnical Commission
CB	: Circuit Breaker
SPD	: Surge Protection Device
PWM	: Pulse Width Modulation
NPC	: Neutral Point Clamped
SMPS	: Switched Mode Power Supply
PCB	: Printed Circuit Board
ACB	: Air Circuit Breaker
SA	: Stand Alone
CR	: Cascaded Redundancy
PR	: Parallel Redundancy
SMFB	: Sealed Maintenance Free Battery

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TO WHOMSOEVER IT MAY CONCERN

This is to certify that Patel Parth Nileshkumar (18BEE081) and Sharvil Tabhani (18BEE116), a student of B.Tech. in Electrical Engineering from Institute of Technology, Nirma University worked in Hitachi Hi-Rel Power Electronics Ltd. As a project trainee during 12^{th} Jan to 12^{th} May 2022 of dissertation. During this period he was found regular and had done his project on “Basic Product Overview and Analysis of Time Study Considering Electrical Equipment”, under my supervision.

He has worked with utmost dedication and high level of engineering and analytical competence.

We wish him all the best for his future endeavors.

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Undertaking for Originality of the Work

I, Patel Parth Nileshkumar, Roll No. 18BEE081 and Sharvil Tabhani, Roll No. 18BEE116, give undertaking that the Major Project entitled "Basic Product Overview and Analysis of Time Study Considering Electrical Equipment" submitted by me, towards the partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering of Nirma University, Ahmedabad, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any other published work or any project report elsewhere; it will result in severe disciplinary action.

Signature of Students

Date: 21/05/2022

Place: Ahmedabad

Endorsed by:

Mr. Harsh Bhavsar
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CHAPTER 1: INTRODUCTION

- Manufacturing and Production Industry

The manufacturing industry is expanding in several sectors as the need for goods develops on a commercial, industrial, and individual basis. With its forward and backward linkages and great employment potential, the industrial sector is critical to a country's economic development. India has achieved a reasonable level of self-sufficiency in the manufacturing of a number of basic and capital products since independence. By diverting the majority of the workforce away from low-wage agriculture, manufacturing growth has the potential to lift a large portion of the Indian population out of poverty. This would result in a more stable and affluent India, which would attract more investment. It's no secret that India is an emerging manufacturing power to be reckoned with.

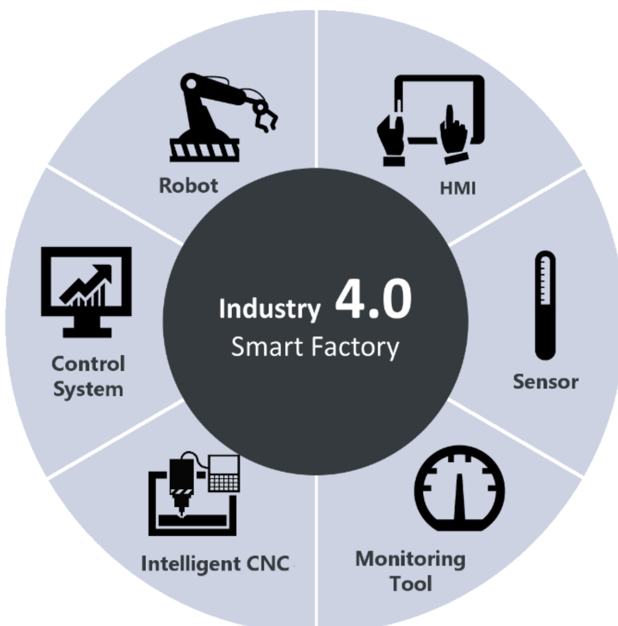

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Fig1. Evolution of Manufacturing Industry.

The Manufacturing sector which was focused here was Power Electronics in regard with Electrical Equipment and the Industry concerned with it was Hitachi Hi-Rel Power Electronics Pvt Ltd. It deals with a varied range of products, such as industrial UPS, Information Technology (IT) UPS, medium & Low Voltage Drives, Grid Tied solar inverters and Railway products. This Industry is a global leader due to;

- Pioneer in power electronics.
- Leading manufacturer of UPS, Drives, Solar Inverters and Air Compressors.
- Manufacturing facility at Sanand and Gandhinagar near Ahmedabad in Gujarat, India.
- ISO 9001:2015, ISO 14001:2015 & BS OHSAS 18001:2007 certified company with export house status.
- Approved by leading consultants and Engineering Procurement and Construction (EPC) vendors.
- Global and pan India presence.
- Dedicated & decentralized 24x7 after-sales-service.

As Manufacturing and Assembly are the two most important factors of any product development, manpower traceability becomes an important factor as they drive the overall process. By managing labor at different processes or at an individual level overall productivity can be increased hence assuring a reliable and smooth manufacturing process. Through this manpower traceability, efficiency and output of human involvement can be measured and analyzed.

CHAPTER 2: PRODUCT OVERVIEW

Wide variety of Electrical Equipment are manufactured by this Industry. Products ranging from few Kilowatts (KW) to Megawatts (MW) are manufactured. The Whole factory is designed in such a way which ensures a smooth process beginning from Storage and Warehouse Area till Dispatch. Products manufactured by this industry are as follows;

1. Uninterruptible Power Supply (UPS)
2. Drives (Low Voltage and Medium Voltage Drives)
3. Railway Battery Chargers (RBC)
4. Grid Tied Inverters (Solar Power Conditioning System (PCS))

Fig2. Products Manufactured by the Industry.

Tab.1 Ratings of Products.

Products		Type	Ratings	Remarks
Uninterruptible Power Supply	I4 series (KVA)	I4	5, 10, 15, 20, 30, 40	Single Phase Equipment
		I4ET	5, 10, 15, 20, 30, 40	
		I4ETI	10, 20, 60, 80, 100, 120, 160	
	I6 series (KVA)	I6S	10, 20, 30, 40, 60, 80, 120, 150	Three Phase Equipment
		I6M	60, 120, 160	
		I6E	60, 80, 100, 120, 160, 200, 250, 300	
		I6ET	30, 40, 60, 80, 100, 120, 160, 200, 250, 300, 400, 500	
Industrial Drives		LV (KW)	2.2, 15, 22, 30	
		MV (KV)	3.3, 6.6, 11	
Railway Battery Chargers		(KW)	6.5	
Grid Tied Inverters/ Solar Power Conditioning System		(KW)	250, 500, 630, 670, 715	Central Inverter
		(MW)	1, 1.25, 1.34, 1.43, 2.5	

2.1 Uninterruptible Power Supply (UPS)

When a regular power source fails or voltage drops to an unacceptable level, Uninterruptible Power Supply (UPS) offers alternate power supply to sensitive and critical electronic loads such as computer centers, telephone exchanges, and numerous industrial-process control and monitoring systems. Basically, it comprises of a Rectifier and Inverter and Works as an AC-AC Converter. Fig.3 Shows a basic block diagram of UPS.

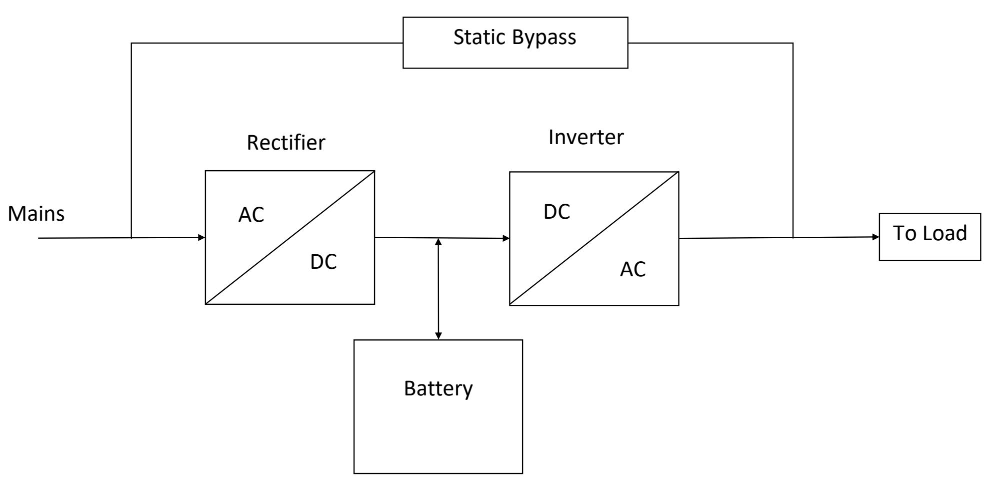

Fig3. Basic Block Diagram of UPS.

Need of UPS :-

1. It provides isolation from noise which can be generated by winding of the motor.
2. It acts as a power conditioning device hereby negating harmonics, surges, spikes, sag, swell and many other unwanted noises, providing a smooth waveform.

Application :-

1. Commercial: Bank Server, Security, Data Center, Fire Alarm, ATM etc.
2. Industrial: Transmitter, Control System.
3. House: Personal Computer (PC)

Hitachi Manufactures mainly two types of UPS:

1. i4 Series – This are Single Phase UPS and are totally customizable as per user requirements.

Fig4. Typical i4 Series UPS.

Tab.2 Typical Specifications of i4 Series UPS.

MAINS INPUT	
Voltage	415 V + 15% -25% Three phase Three wire
Frequency	50 Hz ± 10%
DC BUS	
Voltage	304 to 434 V
OUTPUT	
Normal Voltage	220/2330/240 V
(1 Phase)	110/115/120 V
Load Power Factor - Rated	0.8
Load Power Factor - Range	0.6 to unity
Voltage Regulation	
Steady State	± 1%
100% Step Load	± 5% typical
Frequency	50 Hz
Total Harmonic Distortion	
Linear Load	<2.5%
Non-linear Load (CF 3:1)	<5%

2. i6 Series – This are Three Phase UPS and are standardized products.

Fig5. Typical i6 Series UPS.

Tab. 3 Typical Specifications of i6 Series UPS.

Parameter		**Specifications**
MAINS INPUT	Voltage	415 V + 10%, -15%
	Frequency	50 Hz ± 10%
DC BUS	Voltage	357 VDC to 476 VDC
	Maximum DC Bus Ripple	<1%
OUTPUT	Nominal Voltage	380-400-415 VAC, Three Phase + Neutral
	Load Power Factor Rated[#1]	0.8
	Efficiency	Up to 94%
	Frequency	50 Hz
	Total Harmonic Distortion	
	Linear Load	<2.5%
	Nonlinear load	<5%

2.2 Drives

The electrical drive for a motor draws electrical energy from the mains and supplies it to the motor at whatever voltage, current, and frequency required in order to generate the intended mechanical output. Fig.6 Shows a basic block diagram of Electrical Moor Drive.

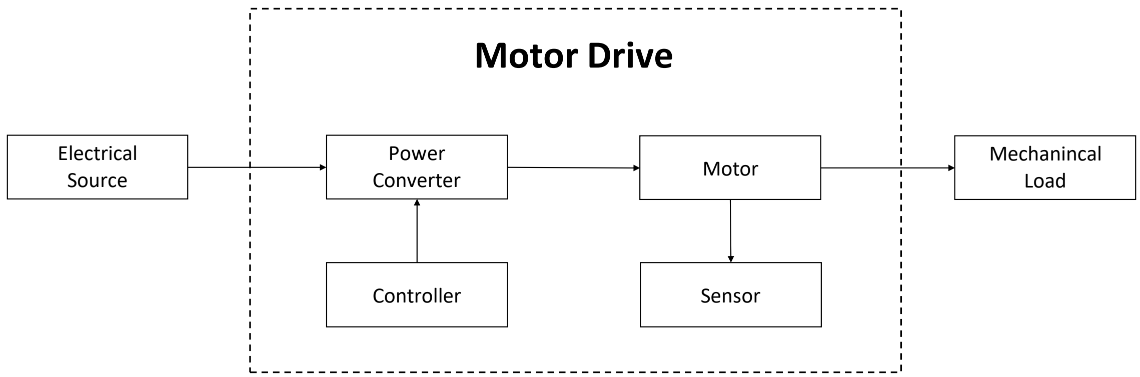

Fig6. Basic Block Diagram of Electrical drives.

Need of Drives :-

1. Ease of Controlling equipments.
2. Load equalisation.
3. Variable supply as per need.

Application :-

1. Lifts
2. Escalators
3. Gate Drives

Hitachi Manufactures two types of drives Low Voltage Drives (LV) as well as Medium Voltage Drives (MV) as per requirements.

1. Low voltage Drives – The LV drive comes under various series for example SJ700, HH10 etc.

Fig7. Typical SJ700 series LV drive.

2. Medium Voltage Drives – MV drives as known as Variable Frequency Drive (VFD) are manufactured upto 14,700 KVA. MV drives comes under 3 rating 3.3 KV, 6.6 KV, 11 KV.

Fig8. Typical HVI-E series MV Drive.

Tab.4 Typical Specifications of a MV drive.

Item		Specifications
Power Supply	Input Voltage	AC, 3,000 V / 3,300 V / 4,160 V / 6,000 V / 10,000 V / 11,000 V
	Input Frequency	50 / 60 [Hz]
	Input PF	Better than 0.95
	Voltage Fluctuation	Within ± 10 %
	Frequency Fluctuation	Within ± 5 %
	Ambient Temperature	50 °C
Control	Driving Method	2 quadrant operation
	Carrier Frequency	3.3 kHz
	Overload	110%
	Efficiency	Typical 97% (Including transformer)

2.3 Railway Battery Chargers (RBC)

Railway battery charger (RBC) is used to charge the battery of the rail cabin with the help of pantograph. It also acts as a backup power supply. Fig.9 shows a basic block diagram of RBC.

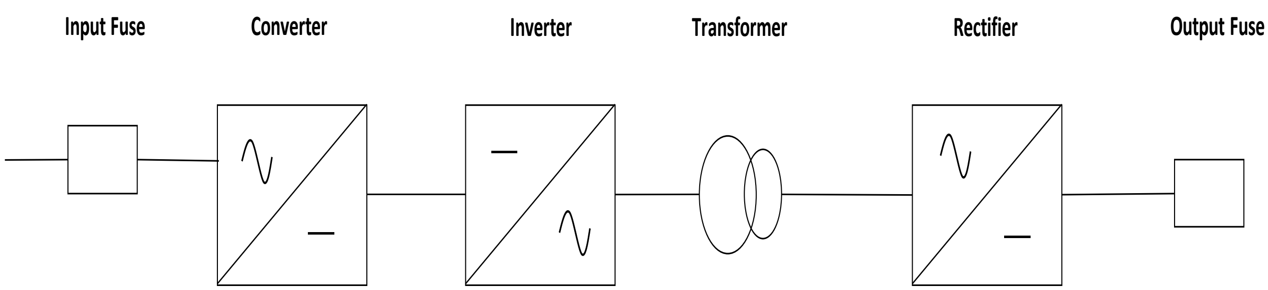

Fig9. Basic Block Diagram of RBC.

Hitachi Manufactures a standard RBC of rating 4.5 KW shown in Fig.10.

Fig10. Typical RBC manufactured by Hitachi.

Tab. 5 Typical Specifications of RBC.

Input Data	**Output Data**		
Nominal Input Voltage: 3ϕ, 415 V ± 5%	Rated Output Voltage	:	<135 V
Maximum Input current: 20 Amps	Battery Charging current	:	20 Amps
	Max. Output current	:	50 Amps
	Max. load current battery	:	50 Amps. Minus charging current
	Max. o/p Power	:	V < 3 V, I < 2 Amp

2.4 Solar Inverter/Power Conditioning System (PCS)

A Solar Inverter or Solar Power Conditioning System (PCS) can be defined as an electrical converter that changes the uneven DC (direct current) output of a solar panel into an AC (alternating current). This current can be used for different applications like in a viable electrical grid otherwise off-grid electrical network. Fig.11 Shows a basic block diagram of Solar PCS.

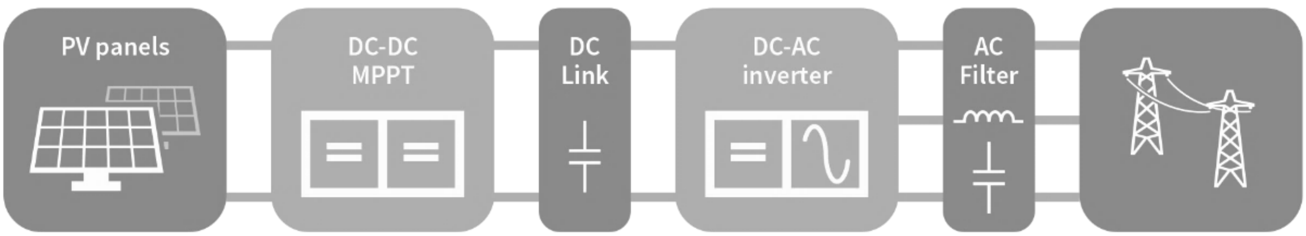

Fig. 11 Block Diagram of Solar Power Conditioning System.

Need of PCS:

1. Conversion of DC to AC power.
2. Maximization of energy production.
3. Ensuring safe system operations.
4. Efficient tracking of power output.

Fig 12. Typical Central Inverter (MW Scale).

Tab. 6 Typical Specifications of Solar PCS.

Solar PCS Rating (AC)	1250 kW
DC-AC Conversion System	3 Level High Frequency PWM Inverter
Control System	MPPT and AC Current Control
Grid Data	
Power Rating	1250 kW @50 °C degree ambient
AC Grid Connection	Three Phase
Maximum AC Current	2214 A @50 °C degree ambient
Nominal Output Voltage (rated voltage)	350 V AC
Output Voltage Range	350 V ± 10%
Output Frequency Range	50/60 Hz ± 5%
Peak Efficiency	98.4% at Min DC Input Voltage
Power Factor	0.80 Lead to 0.80 Lag (with in Max. KVA limited at maximum Ampere rating)
PV Side	
Maximum DC Power loading (1)	1500 kW
MPPT Voltage Range (2)	DC 525 to 900 V
Maximum DC Input Voltage (OC)	1000 V
Minimum DC Input Voltage	525 V
Maximum Input Current DC	2400 A

CHAPTER 3: PROCESS AND OPERATIONS

3.1 Storage Operations

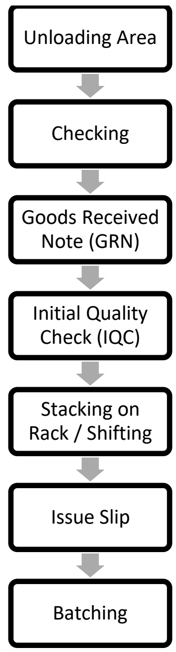

Fig.13 Storage operation Flowchart and Process.

1. Unloading Area: The Supply chain Management (SCM) department places order as per Bill of Material (BOM) and the raw material consisting of Electrical and Mechanical parts arrive in this area.

2. Checking: The material is checked as per the list and is loaded in a safe area.

3. Goods Received Note (GRN): As the material is received, with the help of BOM and the material received GRN is made in an Enterprise Resource Planning (ERP) software which can be useful for Production Management Department (PMD) as well as Financial Department.

4. Initial quality check (IQC): Based on random sampling, few materials are chosen and their functionality is checked.

5. Stacking on Rack/Shifting: After the material has passed IQC it is unloaded in to rack as per code of the material.

6. Issue slip: Whenever a Work Order is generated, PMD issues an issue slip consisting the necessary materials required to assemble a product.

7. Batching: The material is safely loaded and passed into Soft-floor (Assembly Area).

3.2 Assembly Process

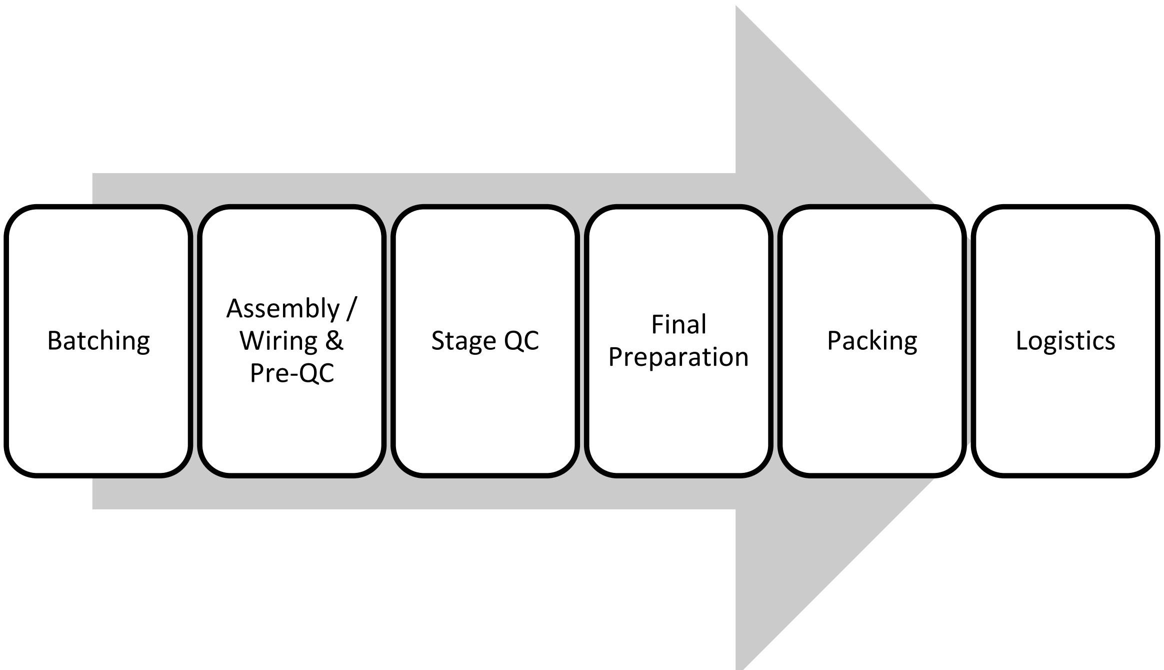

Fig.14 Overview of Operations in the Assembly area.

1. Batching: After the batching is done at storage in trolleys, the raw material is again unloaded in the soft floor considering zone of the product whose assembly is required.

2. Assembly/Wiring and Pre-Quality Check (QC): As the material is available in the zone the assembly starts followed by Wiring and Pre-Quality check of the product.

3. Stage Quality Check (QC): After Pre QC is done, Final QC or stage QC is done where whole product is thoroughly checked.

4. Final Preparation and Packing: After passing various tests the product is moved in the Dispatch area where in Proper vacuum sealing is done.

5. Logistics: With the help of third party, the product is shifted to its destination.

CHAPTER 4: TIME STUDY MONITORING

For having smooth and reliable process this monitoring is necessary. Manpower traceability and increasing Productivity is the ultimate goal of this monitoring.

There are basically 4 types of time study involved in this:

1. Cycle Time – It has to do with how often a process really completes a part or product, as measured by observation. It is basically the total time required to make a product.

Formula: $$\frac{\text{Net Production Time}}{\text{Number of Units Produced}}$$

2. Takt Time – It has to do with how quickly a business should develop or manufacture a product or service in order to meet total demand.

Formula: $$\frac{\text{Total Available Time}}{\text{Total Demand of Products}}$$

3. Standard Time – It is related with the total time in hours required for a product to make. For example, in case of Solar PCS starting from Assembly till Quality Check (QC) the total time in hours required is monitored.

4. Lead Time – It is related with the total time in days required to complete the assembly as well as dispatch of the product.

Formula: Order Delivered – Order Received

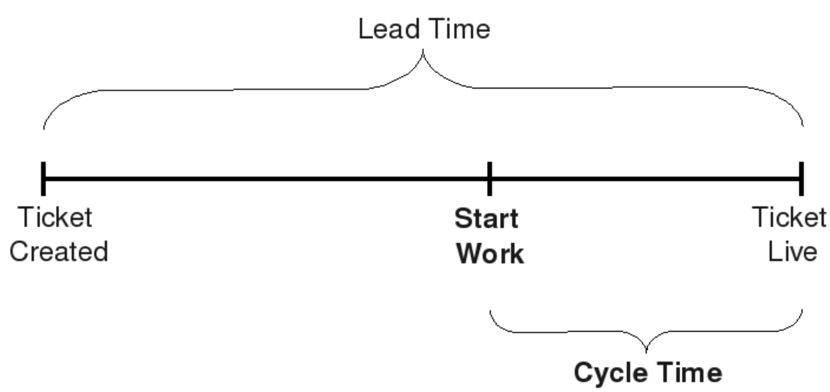

Fig.15 Topology of Different Time Study.

Need of Time Study Monitoring :-

- For easy Manpower Traceability.
- Compare planned time with actual time.
- Planning manpower requirements.
- Allocation of unused manpower for other activities.

4.1 Definition and Techniques

❖ SQDC

For a smooth and reliable operation concept of SQDC is adopted which includes;

1. Safety
2. Quality
3. Delivery
4. Cost

All the concepts of SQDC are in hierarchical orders and safety being first and foremost important. The hierarchical order is shown in Fig.16;

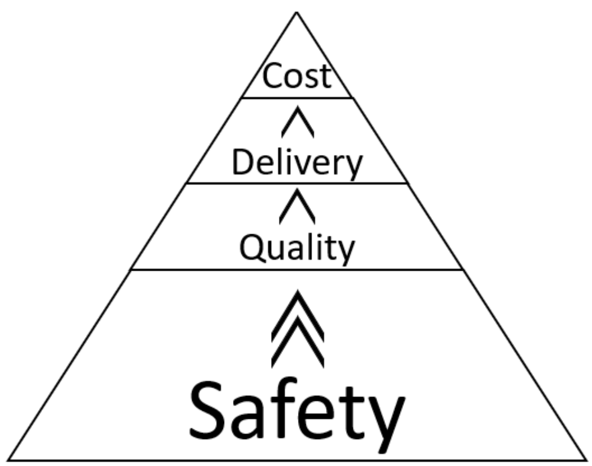

Fig.16 Concept and Hierarchy of SQDC.

❖ MUDA

The term ‘MUDA’ is a Japanese term which means waste or unnecessary task. Fig.17 shows the components involved in MUDA.

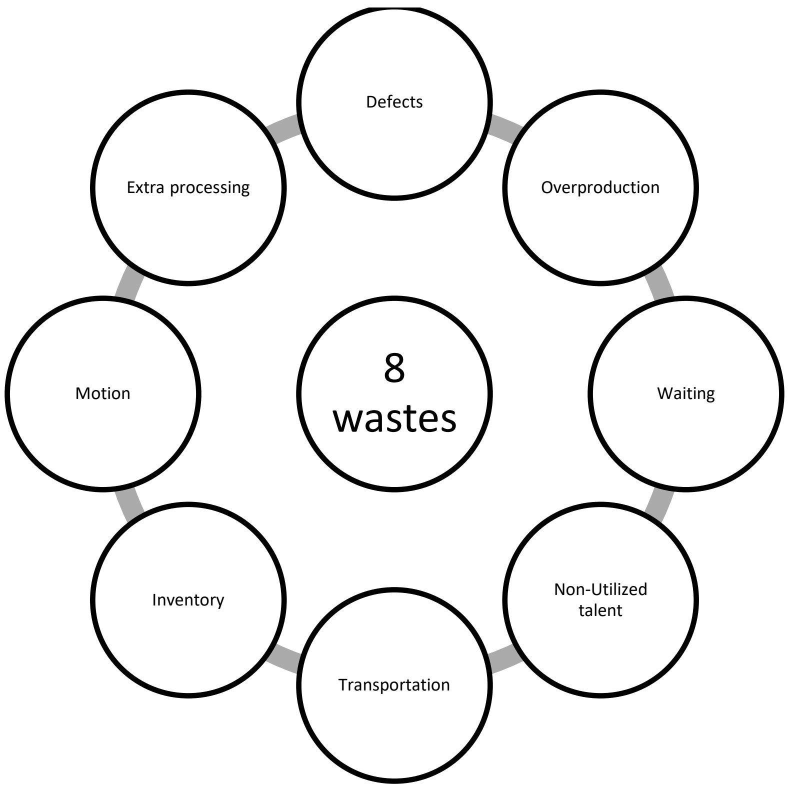

Fig.17 Topology and Types of MUDA.

Basically this ‘MUDA’ is classified into 3 activities:

1. Valid Activity – Routine tasks which adds value to the Product as per demand. For example, it includes any kind of activity which increases the production stage further.

2. Invalid Activity – Any unwanted task that hampers the productivity and does not add value to the Product. For example, rework after Quality check.

3. Invalid but necessary Activity – Same as Invalid Activity but is necessary for Routine Tasks. For example, unwrapping of Plastic.

4.2 5M-5W Analysis

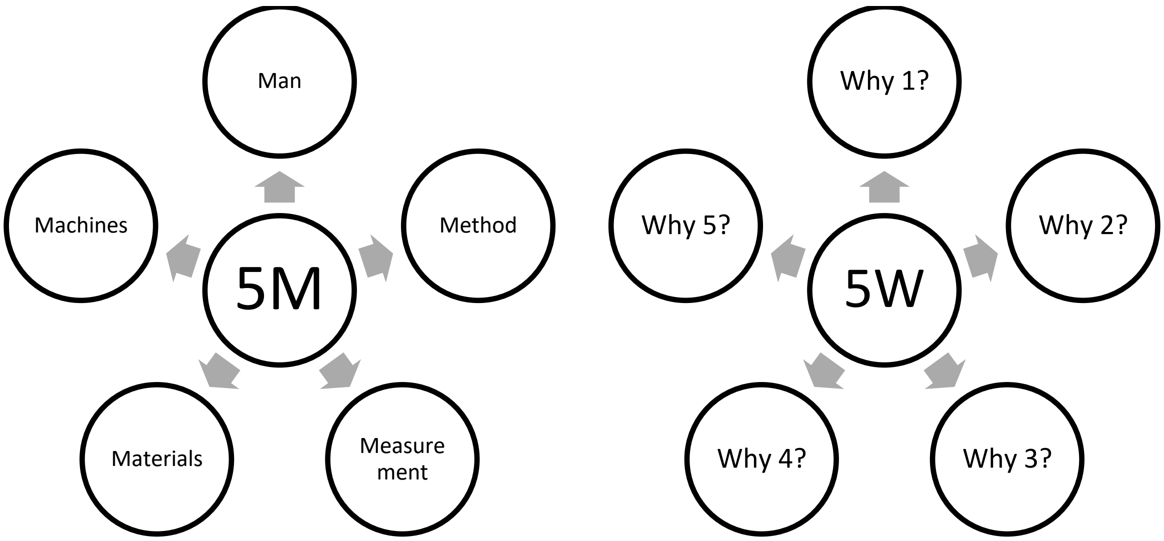

Fig.18 Elements of 5M-5W Analysis.

5M-5W Analysis is an absolute analysis done in order to find a root cause of an event that occurred disturbance in a smooth production process. It takes account the following steps;

1. First of all, an issue or problem statement is identified regarding what actually has happened.
2. The second step involves brain storming commonly called as 5M method or fishbone method wherein all possibilities of what could happen is taken into account without investigating the issue.
3. After fishbone diagram is filled, the actual investigation starts in parallel with 5W analysis in order to reach to the ultimate root cause of the problem.
4. Finally, countermeasures are taken into account so that this issue doesn't occur repetitively and doesn't hamper smooth production.

A classic example of 5M-5W Analysis considering a real time problem statement is shown in Fig.19 and Fig.20 respectively.

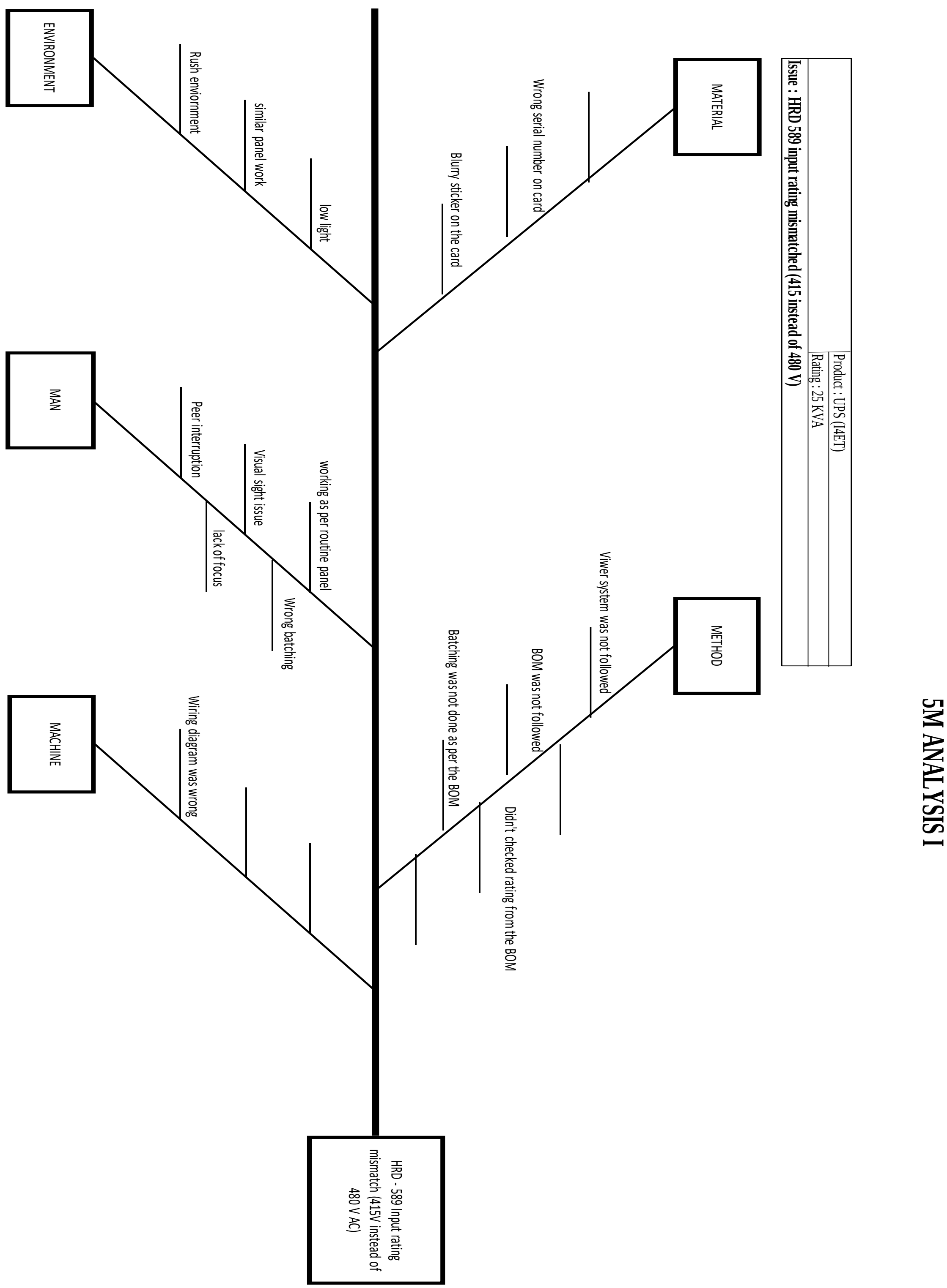

Fig.19 5M Analysis Considering real time Problem Statement.

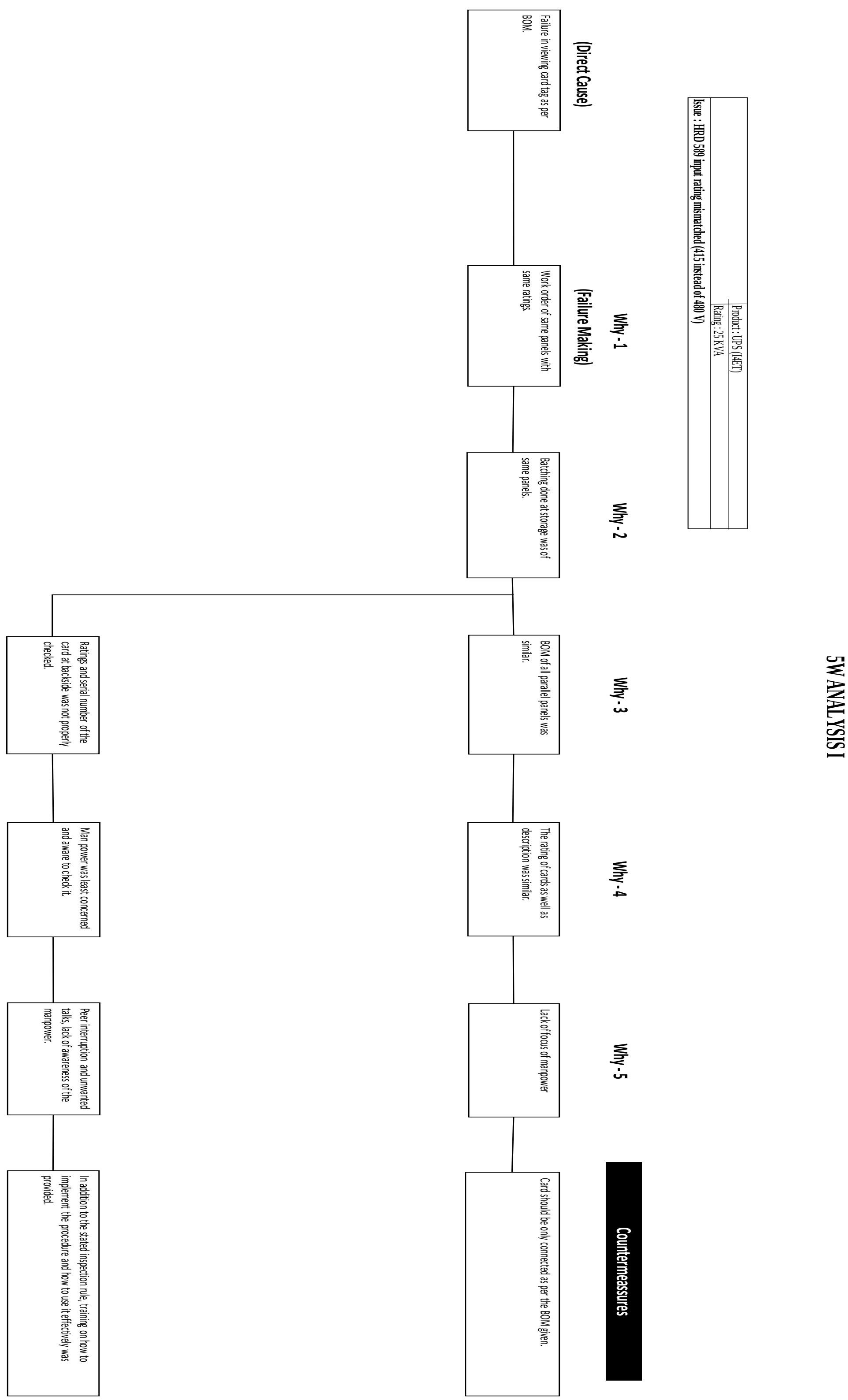

Fig.20 5W Analysis Considering real time Problem Statement.

CHAPTER 5: SOLAR INVERTER (PCS)

Solar inverter can be broadly classified into 3 categories:

1. Grid Tied Inverter
2. Off Grid Inverter
3. Hybrid Inverter

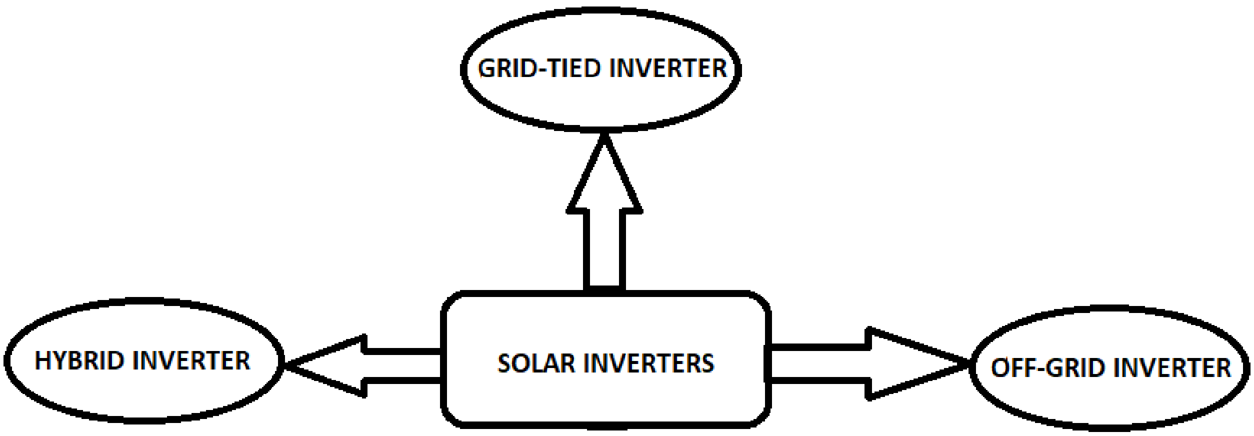

Fig.21 Types of solar inverter.

Hitachi Manufactures Grid Tied Inverters consisting of different ratings.

- Grid Tied Inverters (GTI)

Grid-tied photovoltaic systems are power-generating systems that are connected with grids. Solar PV energy that is generated must be processed with the help of a grid-connected inverter before putting it to use. This inverter is present between the solar PV arrangement and the utility grid.

The grid-tied inverter converts Direct Current (DC) electricity from the panels into alternating current (AC) electricity.

The main function of a Grid tied solar inverter is to smooth the operation of power flow in between the utility grid and PV plant. Block diagram of a PV plant consisting Grid tied Inverter is shown in Fig.22.

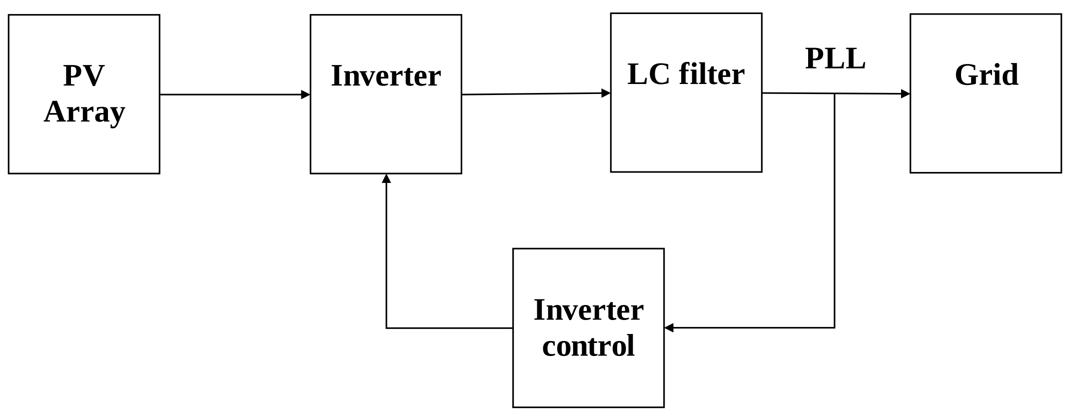

Fig.22 Block diagram of Grid connected Inverter.

Here as shown in the Fig.22, Output from all PV cells/PV Arrays which is DC in nature is carried out at each terminal. Then with the help of DC-DC Boost converter the voltage is stepped up at desired level along with filtering of ripples (Boost Control). Then the output of DC-DC Boost converter is fed into Inverter of suitable rating which converts the PV panel output which is DC in nature to AC Power which is usable by the utility Grid. Typically, after the conversion stage an Inductor-Capacitor (L-C) filter is also used to remove the unwanted noise, distortion and have a clean sinusoidal form which is then fed to the utility grid. Apart from DC-AC Conversion the role of Grid Tied Inverter includes Reactive power control, Maximum Power Point Tracker (MPPT), Active Power Filtration and many more which comprises under Inverter Control. The synchronization between Grid and Inverter considering parameters like Voltage, Frequency and Phase sequence are taken care by Phase Locked Loop (PLL).

Grid Connected Solar Inverter can be further classified as shown in Fig.23,

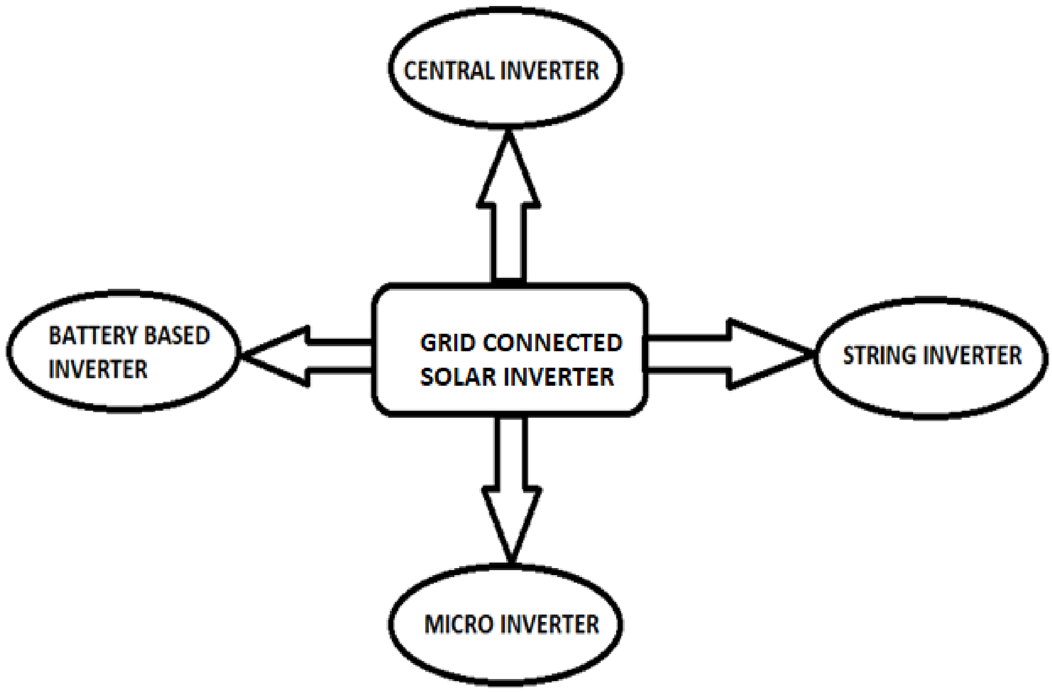

Fig.23 Topologies of Grid Connected Solar Inverter.

Hitachi manufactures GTI based on topology of Central Inverters.

- Central Inverter

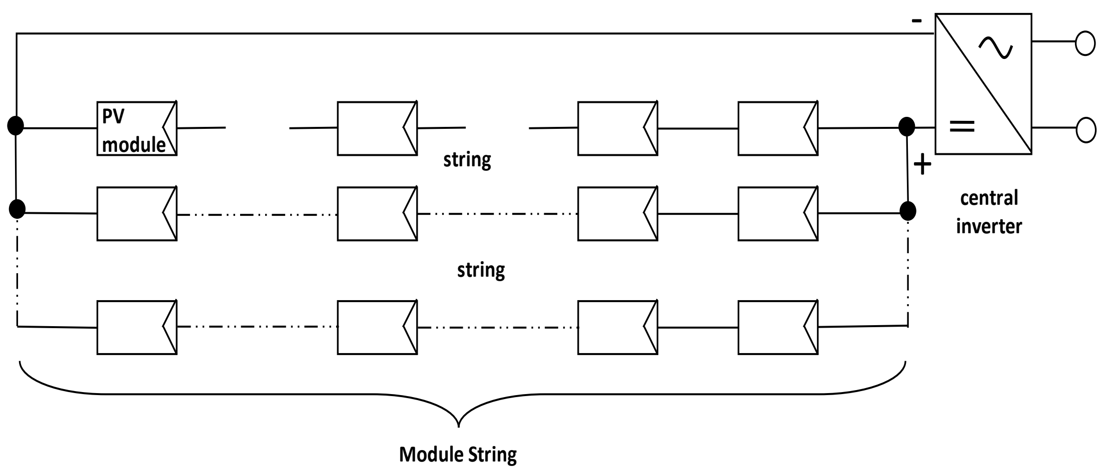

Fig.24 Central Inverter Topology.

Central inverters are similar to string inverters with a high-capacity range, needing only one large inverter for the entire plant / section of plant. Instead of string running together the output of each is fed into DC combiner Box and a large inverter then converts into power which is AC in nature. Central inverters are generally used for large commercial installations, industrial facilities or utility-scale solar farms as central inverters support uniform and consistent production throughout.

As shown in Fig.24, all PV modules are connected in strings and are carried out at one common point known as Point of Common Coupling (PCC). Moreover, a DC string Combiner Box is also placed which collects the DC power from all the string at one place. This DC combiner box output is then fed into DC input terminals at the DC Distribution Box (DCDB) side and then gradually to the Inverter. The main advantage of this topology is lower cost and is generally preferred for large scale solar farms.

5.1 Assembly Process

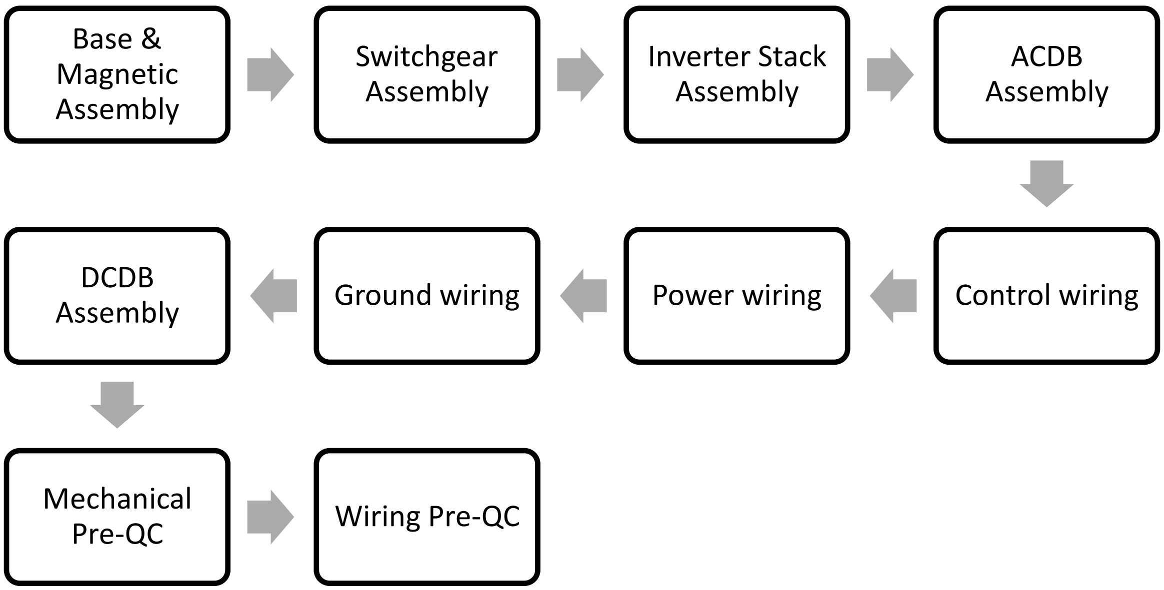

Fig.25 Detailed Process and Flowchart of Solar PCS Assembly.

As shown in the Fig.25, in case of Solar PCS, base/plate assembly along with magnetic components is done. After that switch gear assembly which includes Relay, Current sensors, Circuit Breakers etc. is mounted. Then comes the Inverter stack consisting of suitable IGBT stacks as per mentioned in Bill of Material (BOM) followed by Air circuit breaker in the AC Distribution Box (ACDB) section and various other components in the DC Distribution Box (DCDB). With the help of busbar, wiring is done and at last Pre quality check of the assembled product is done.

5.2 Time Study Monitoring and Results

For a smooth and reliable operation time study is necessary and here solar PCS is analyzed. For this manpower traceability chart is provided consisting of different columns. And parallel with that an activity list is also provided which covers all activity involved for the assembly of PCS. Through both this documents, charts and graphs can be generated which can be used for analyzing actual standard time (ST) to make a product versus its targeted standard time (ST).

SOLAR PCS/UPS ACTIVITY LIST

Activity no.	Activity Name	
1		Material Batching
2	Wire & Harness	Control wire Harness
3		Power wiring (HM)
4		Transformer mounting
5		High place work
6		Stack assembly
34		Soldering (Stack)
7	Main work	Loose parts sub-assembly
8		Loose parts fitting or panel assembly
9		Labeling
10		Control wiring
11		Power wiring
70		Ground wiring
12		Pre-QC
13		Process QC
14		Side door cover shroud fitting
15		Panel Movement
36		Half day leave

Activity no.	Activity Name	
16	Rework	After QA/QC/Testing/MOM
17		due to prod. Problem
18		due to Engg. Mistake
19		due to SCM
20		ECN time
21	Idle	due to Engg.
22		due to low work volume
23		due to SCM
24		due to IQA
25		due to prod.
26		Manpower used for 5S
27		Kaizen time
28		CSD work
30	Training	For Product Knowledge
31		For HR
32		For skill level Upgradation
33		For HIS & work refreshment
35		Working in another line

Fig.26 Solar PCS Activity List.

NO.	Date	Name	Activity No.	W.O.	Rating	Start time	Finish time	Other (min)	Reason	Result(hrs)
1	5/3/2022	Piyush	9	X-1221-0064	250 KW	15:15	15:35			0.33
2	5/3/2022	Rajendra	70	X-1221-0064	250 KW	15:37	16:18			0.68
3										
4										
5										
6										
7										
8										
9										
10										
11										
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Fig.27 Manpower Traceability Chart for Solar PCS.

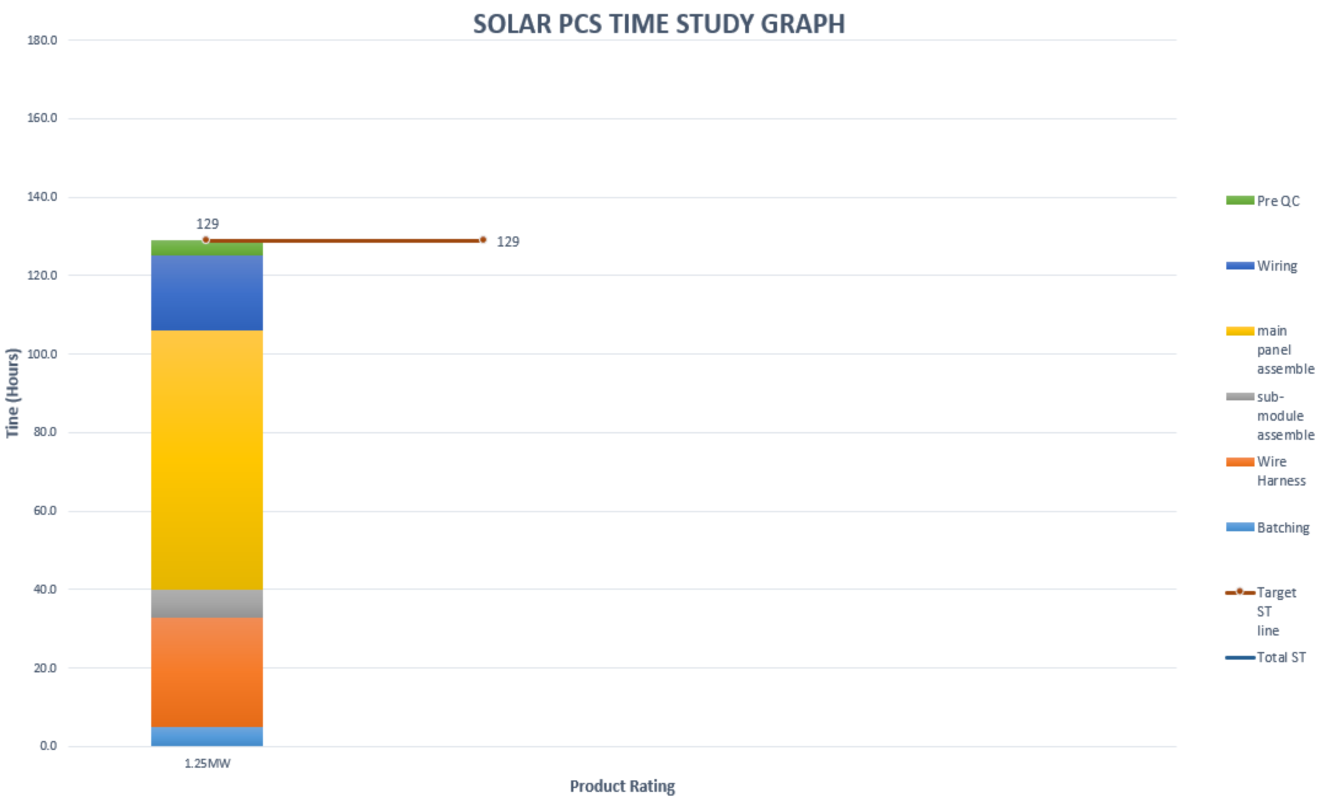

Fig.28 Time study Graph considering Solar PCS.

5.3 Structure Configuration and Technical Components

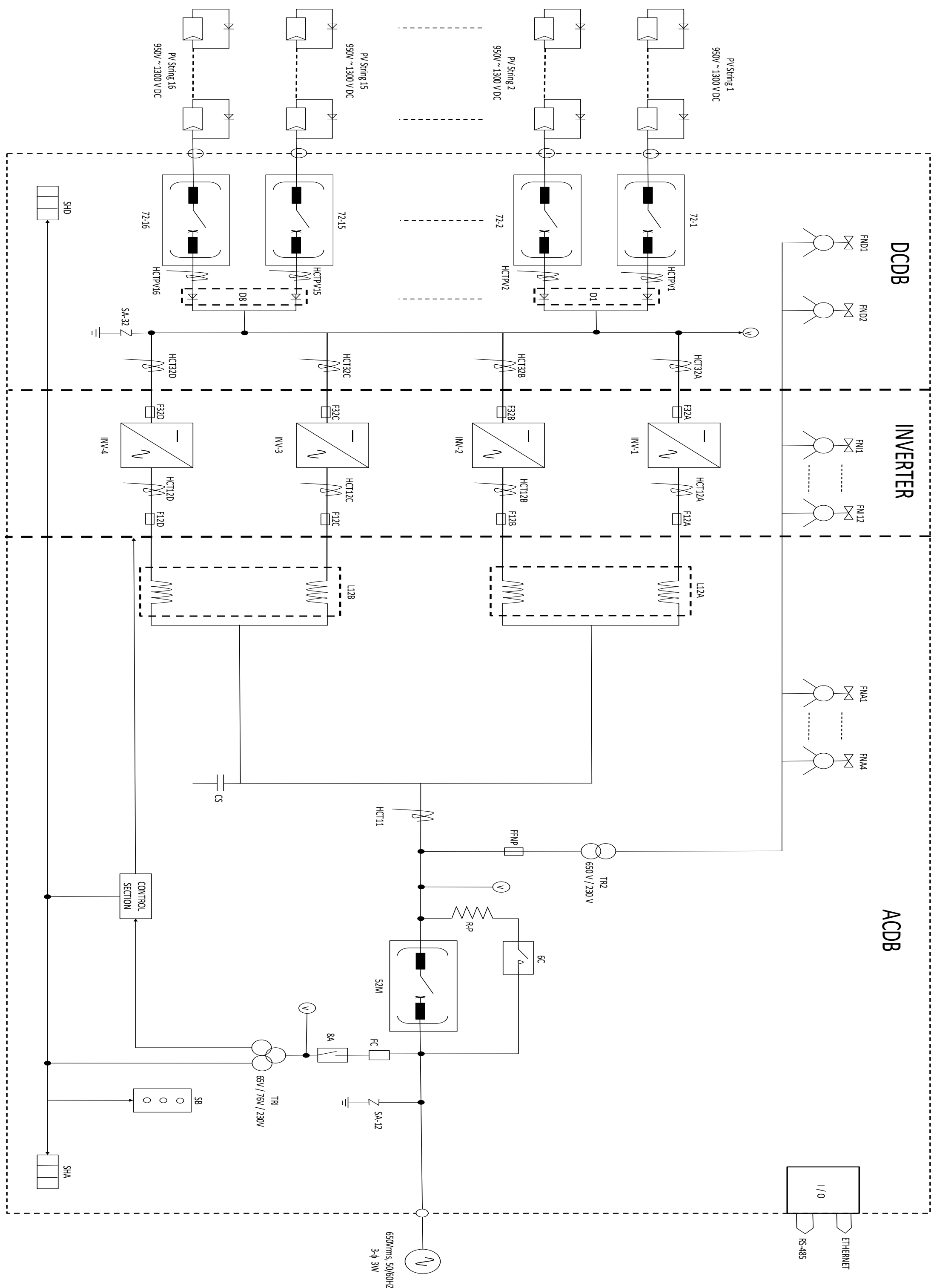

Fig.29 Typical Schematic and Single Line Diagram (SLD) of Central Inverter.

Tab. 7 Description of Components used in SLD of Solar PCS.

LEGENDS	
DESIGNATION	**DESCRIPTION**
6C	PRE-CHARGE CIRCUIT CONTACTOR
8A	CONTROL POWER DISCONNECTING DEVICE
42	RUNNNING OUTGOING CIRCUIT CONTACTOR
52M	AC CIRCUIT BREAKER
72	DC CIRCUIT BREAKER
88F	FAN CONTACTOR
SA32	DC SURGE PROTECTION DEVICE
SA12	AC SURGE PROTECTION DEVICE
L12	L12A % L12B PARRALEL DEVICE
F1S-F2S	POWER FUSE
C1A-E, C2A-E	DC CAPACITOR
HCT32, HCT11, HCT12	CURRENT SENSOR
FN	COOLING FANS
C12-UA, C12-UB	AC CAPACITOR
T-302	FAN TRANSFORMER

International Electrotechnical Commission (IEC) specify standards which helps in understanding values of Innovation undergone by the organization and helps in constant quality and performance. The legends shown in Tab.7 have standards as per C37.2.

Tab. 8 IEC standards of Grid Connected Solar PCS.

Standard	**Title**
IEC:62109	Safety of power converts for use in photovoltaic power systems. 1.General Requirements. 2. Particular Requirements for inverters
IEC 62116	Test procedure of islanding prevention measures for utility-interconnected photovoltaic inverters.
IEC61000	Electromagnetic compatibility
IEC61672-1	Electroacoustics – Sound Level Meters
IEC61683	Performance
IEC60068	Environmental
IEEE1547.1	Harmonics control

As shown in the Fig.29, the Grid Tied Central Inverter is bifurcated into three sections categorized as :-

1. DC Distribution Box (DCDB)
2. Inverter Section
3. AC Distribution Box (ACDB)

1. DC Distribution Box (DCDB)

Here in this section various components are mounted. Major Components used in this section are;

a. DC terminal – These terminals are provided where input from PV Panels and Arrays are connected in series and parallel connections as per user requirements. The Input side DC voltage should be as per ratings mentioned in datasheet of Inverter so as to ensure smooth operation. Nominally 12 input terminals are provided.

b. DC Fuse – Suitable Calculations are made to select the DC Fuse so as to make or break the circuit during Normal as well as Faulty Condition respectively at DC side.

c. Current Sensor – Detection of Current and its conversion to voltage is done by this device. Basically, it is used to sense the actual current, convert to suitable range of voltage and provide it to closed loop Feedback system.

d. DC Circuit Breaker (CB) – A circuit breaker is also chosen as per suitable rating and is made to operate during faulty conditions. Nominally 2 Circuit Breakers are used.

e. Surge Protection Device (SPD) – This are kept to limit the transients occurring in the system for some time. They provide least resistance path for current to travel to the ground hence isolating the whole system. This device rating is chosen by analytical calculation.

2. Inverter Section

a. Inverter – As we know in case of Solar PCS, Inverter is considered as the heart of the system and basically converts DC waveform to Sinusoidal AC waveform by generating Pulse Width Modulation (PWM). Here 3 phase IGBT based Neutral Point Clamped (NPC) Inverter with 3 level High Frequency PWM switching is used. The control strategy used here comprised of Neutral Point Clamped (NPC) Technology. In case of 2.5 MW Inverter/Solar PCS, 6 stacks of IGBT are there and each stack comprises of 6 modules of IGBT and each module has 4 IGBT devices incorporated in it.

❖ Neutral Point Clamped (NPC) Technology

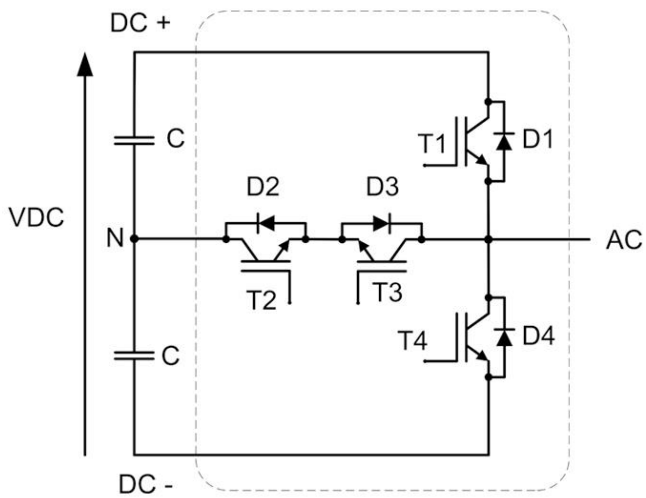

Fig.30 Typical Schematic of 3 Level Neutral Point Clamped Inverter (T type) used in 1.25MW Solar PCS.

Industry standard three-level inverter topologies could be used to increase the performance of solar installations. One possibility is to use the 3Level T-NPC transistor clamped topology. Inserting two switches in common emitter configuration between the AC terminal and the midpoint of the DC connection referred to as N, Fig.30, gives this topology. Only 8 semiconductors make up a 3Level T-NPC phase leg, 4 IGBTs (T1 - T4) and 4 antiparallel Free-Wheeling Diodes (D1 - D4). The T-NPC is connected to the split DC-link at DC+, N, and DC- as a 3Level NPC. The AC output is provided by the fourth power terminal.

In 3Level T-NPC topology the conduction paths are either through one higher blocking semiconductors (outer switch) or two lower blocking devices in series (inner switches).

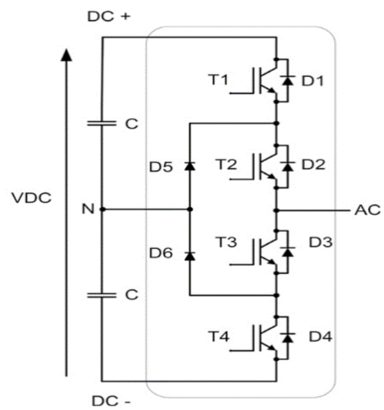

Fig.31 Typical Schematic of 3 Level Neutral Point Clamped Inverter (I type) used in 2.5MW Solar PCS.

Another alternative is to use a three-level neutral point converter, such as the 3Level–NPC shown in Fig.31. Two more clamping diodes are used in this setup to impress half of the DC link voltage over all switches. Instead of four semiconductors, the 3Level NPC module has four IGBTs (T1-T4), four antiparallel Free-Wheeling Diodes (D1-D4), and two clamping diodes (D5 and D6).

As shown in the Fig.31, Four power terminals connect the module to AC and to the DC-link: DC+, DC- and N (neutral). The DC-link is split in two symmetric halves connected in series; the upper half connecting DC+ and N and the lower half connecting N and DC-.

This section along with Inverter comprises of other switchgear and protection devices. Major Component of this section are;

b. Power Fuse – Suitable Power Fuses as per IGBT Stack rating are chosen. For example, in case of 2.5 MW Solar PCS, 12 Power fuses are used. This devices like Circuit breaker make or break the circuit during operational as well as abnormal conditions respectively.

c. DC Capacitor – This Capacitor are connected as an input to Inverter for smoothening purposes. As the DC power coming from the DCDB section may not be pure DC in nature and may consists of some ripples. So, in case to negate it, suitable capacitive filtering is used.

d. Fan Contactor and Fan – As specified in the rating of Solar PCS; Forced Air cooling is used which helps in proper maintenance of ambient temperature inside the Inverter. Fans are placed at the top of the Inverter section ensuring proper air flow.

e. Control Circuitry – A control circuitry mainly incorporates 3 Printed Circuit Boards (PCB)/cards viz.

i. Control Card – Responsible for controlling the closed loop system of Inverter consisting of NPC technology.

ii. Gate Driver Card – Responsible for controlling and generating gate pulses (PWM) for switching IGBT.

iii. Switched Mode Power Supply (SMPS) – Used to provide neat and constant DC voltage to other cards which are used in system. For example, Reverse Polarity card, Gate Driver Card.

3. AC Distribution Box (ACDB)

Similar to DCDB Section, various components are mounted. Major Components used in this section are;

1. AC Capacitor and Choke – These devices are exclusively used for filtering. As the waveform may not be pure sinusoidal and in order to connect it to the grid, with the help of this filtering devices, it is made. Analytical calculations are made as per output voltage and current obtained.

2. Surge Protection Device (SPD) – Similar to DC SPD an AC SPD is also used to protect the device from spike of voltage, high inrush current and transients during switching.

3. Air-Break Circuit Breaker (ACB) – In case of AC side ABCB are used as a topology to quench the arc produced during faulty conditions. Here air is used to breakdown the arc voltage.

5.4 MATLAB Simulation of 2500 KW Grid Connected System

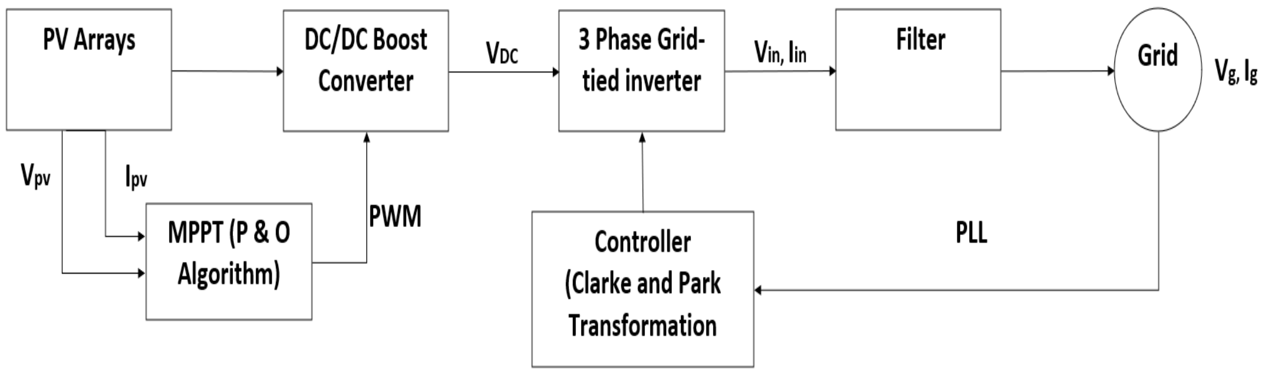

Fig.32 Developed Block Diagram for Simulation of 2.5 MW Grid Connected Solar PCS.

Tab. 9 Electrical Specification data for simulation of 2500 KW Grid Connected Solar PCS.

Item	**Specification**	**Remark**
Rated capacity	2500 KW (AC)	
AC – DC conversion system	2 Level High-Frequency PWM Inverter	
AC/DC isolation system	No isolation (Transformer Less Type)	
Inverter control	Clarke and Park Transformation	
Rated AC voltage, Tolerance	AC 650 V, ± 10% (Continuous)	
Maximum AC Current	AC 2474 A	
Rated frequency, Tolerance	50Hz, ± 2%	
Output power factor	0.8 lead to 0.8 lag	Within Max. KVA Limit
Current Harmonics	<3 %	At Rated AC Power
Maximum DC Voltage	DC 1500 V	
DC Voltage Range (MPPT Range)	DC 950 ~ 1300 V	
Maximum DC Current	DC 2668 A	
Efficiency (estimated)	Maximum η =99	DC 950 V, AC 650 V, PF=1.0
Switching frequency	4kHz	

Components and Calculations

1. **Solar PV Array**

As specified in the Tab. 9, for a voltage input of 750 V to the DC-DC Boost converter and as per the panel specification the panel configurations can be calculated as;

Panel Power Rating (W_p): 330 W

Voltage Input to Boost Converter (V_{in}): 750 V

Voltage at Maximum Point (V_{mp}): 37.58 V

Series Configuration (N_s): $\frac{750}{37.58}$ = 20 Panels

Total PV Power (P_{Pv}): 2500 KW

Current Input to Boost Converter (I_{in}): $\frac{2500\ KW}{750\ V}$ = 3300 A

Current at Maximum Point (I_{mp}): 8.78 A

Parallel Configuration (N_p): $\frac{3300}{8.78}$ = 375 Panels

2. **DC-DC Boost Converter**

The calculations pertaining to DC-DC Boost converter considering Inductor (L) & Capacitor (C) are specified in Appendix. Matlab code is implemented and suitable values for L & C are obtained. Apart from that, this boost converter also incorporates Maximum Power Point Tracking (MPPT) Algorithm which is also mentioned in Appendix. The necessary values calculated for this section are as follows;

Output Voltage of DC-DC Boost Converter (V_{out}): 1000 V

Switching Frequency (F_s): 4000 Hz

Input Capacitor (C_{in}): 0.0159 F

Output Capacitor (C_{out}): 0.0159 F

Input Inductor (L_{in}): 0.0014 H

3. **Inverter and Control Strategy**

A classic Universal Bridge is considered as a 3 phase Inverter and for the control strategy, Clarke and Park Transformation is taken into account. Apart from that a classic Phase Locked Loop (PLL) Block is considered for the smooth Grid Integration. Overall, a closed loop followed by Proportional and Integral (PI) control is implemented.

4. **Grid**

For a Grid, a conventional three phase source is considered. The Grid values are selected as per Tab. 9 and are as follows;

Grid Voltage (V_g): 650 V

Grid Current (I_g): 2400 A

Grid Frequency (F_o): 50 Hz

5. **Filter and Other components**

a. Inductor Design

$$L = \frac{\varDelta V \;\; x \;\; (5{-}8\% \, Voltage \; Drop)}{2 \, \pi \;\; Fo \;\; Io}$$

Where,

Phase Voltage of Grid ($\varDelta V$): $\frac{650}{\sqrt{3}}$ = 376 V

Grid Frequency (F_o): 50 Hz

Output Current (I_o): 2400 A

$$= \frac{376 \text{ x } 0.08}{2 \text{ x } 3.14 \text{ x } 50 \text{ x } 2400}$$

= 40 uH ~ **50 uH**

b. Capacitor Design

$$C = \frac{1}{4\,\pi^2\,F_r^2\,L}$$

Where,

Resonant Frequency (Fr): 40% x Fs = 1.6 KHz

Inductor Value (L): 50 uH

$$= \frac{1}{4 \text{ x } (3.14)2 \text{ x } (1.6 \text{ x } 103)2 \text{ x } 50 \text{ x } 10{-}6}$$

= 198 uF ~ **200 uF**

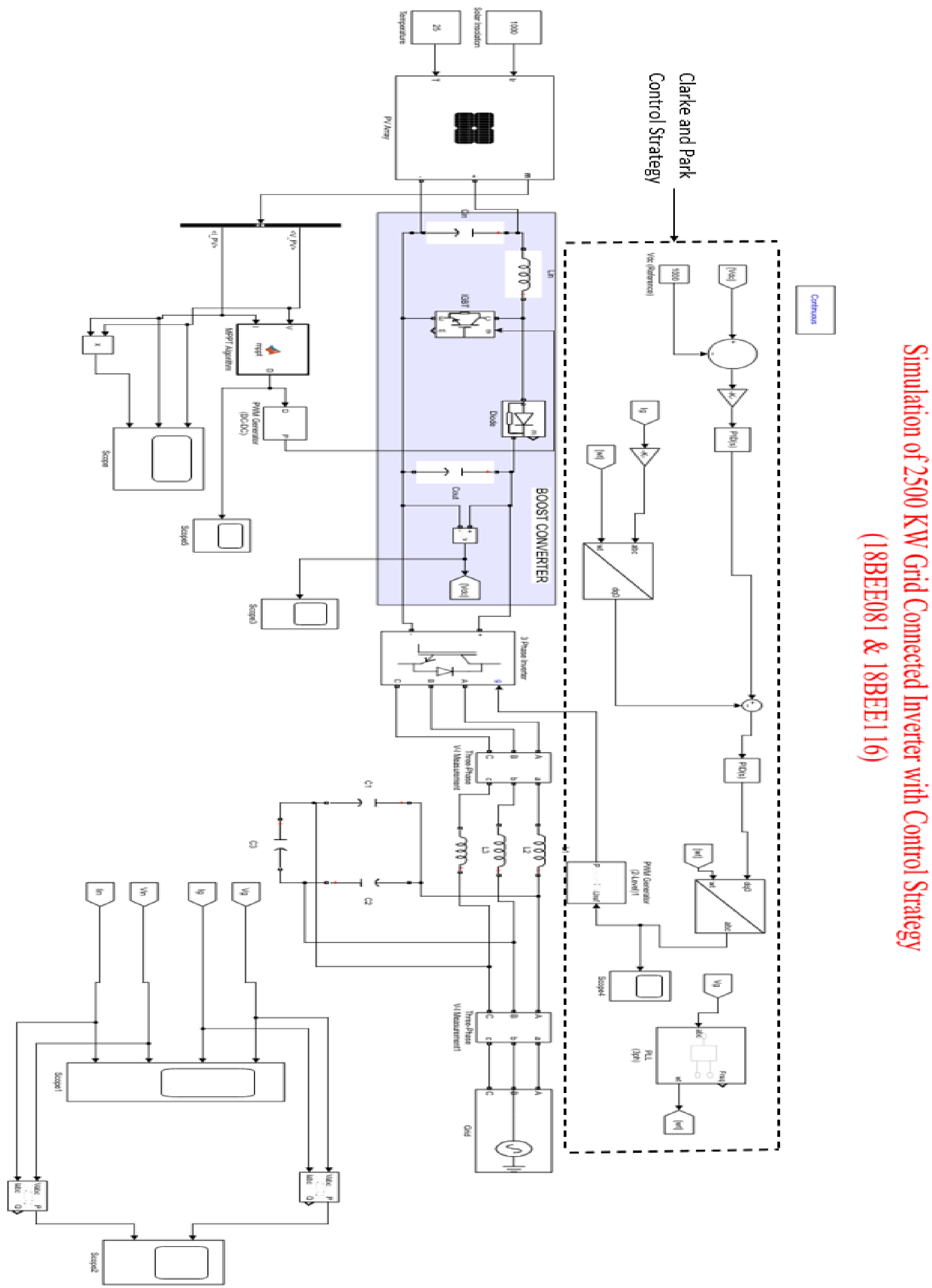

Fig.33 Matlab-Simulink Model of Grid Connected Solar PCS.

Waveform and Results

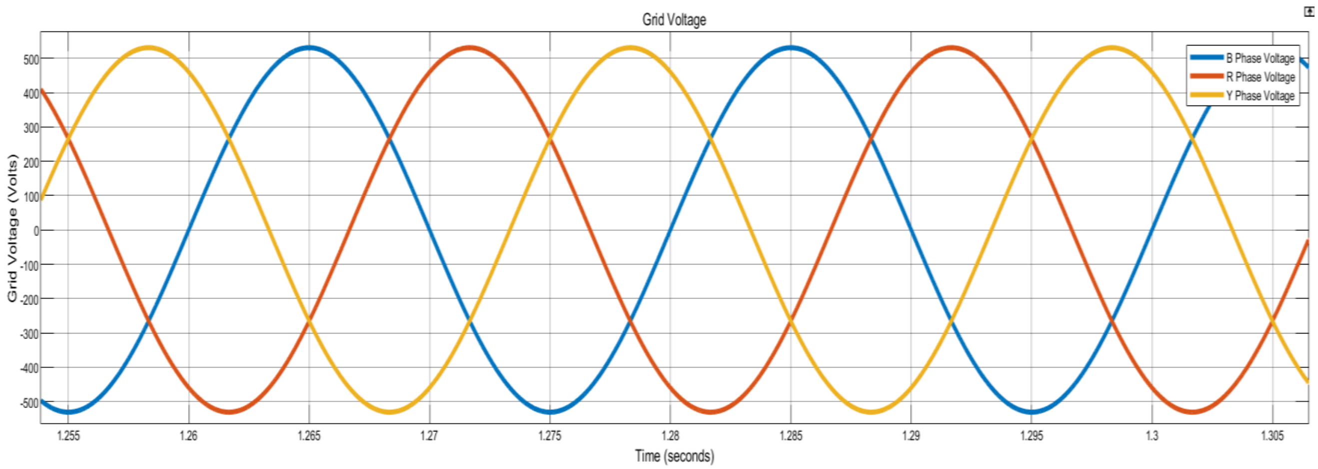

Fig.34 Waveform of Three Phase Grid Voltage.

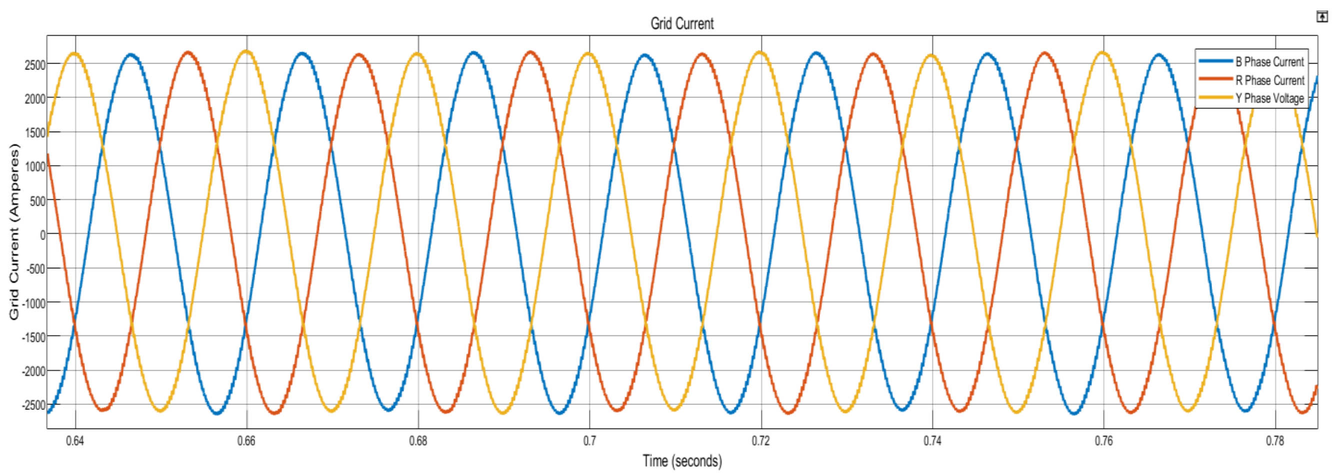

Fig.35 Waveform of Three Phase Grid Current.

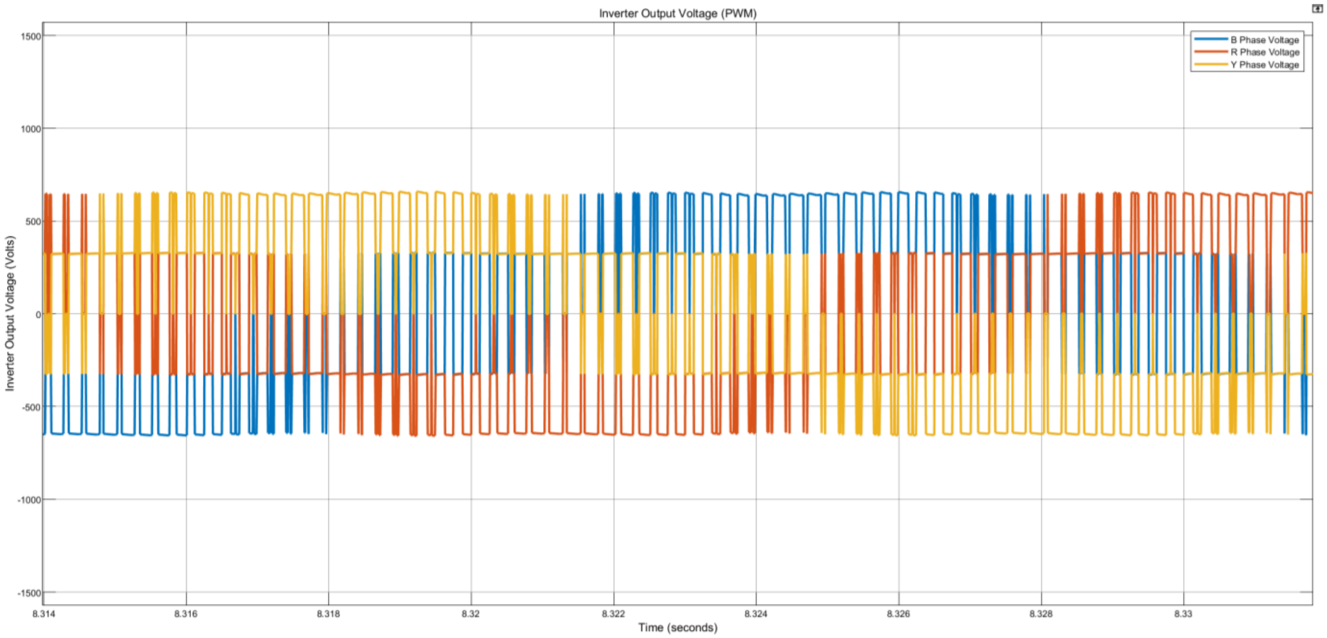

Fig.36 Waveform of Generated Pulse Width Modulation (PWM).

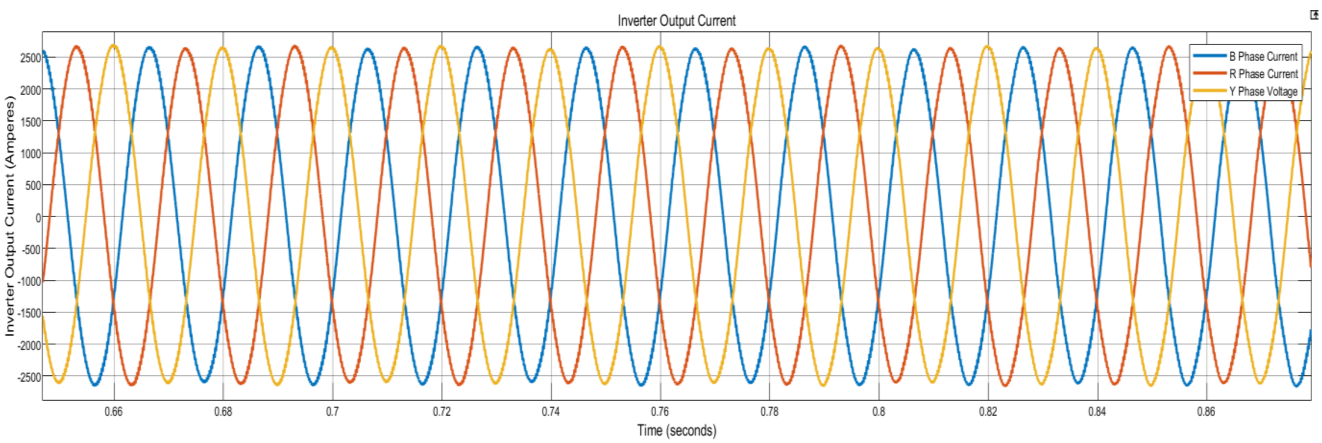

Fig.37 Waveform of Three Phase Inverter Output Current.

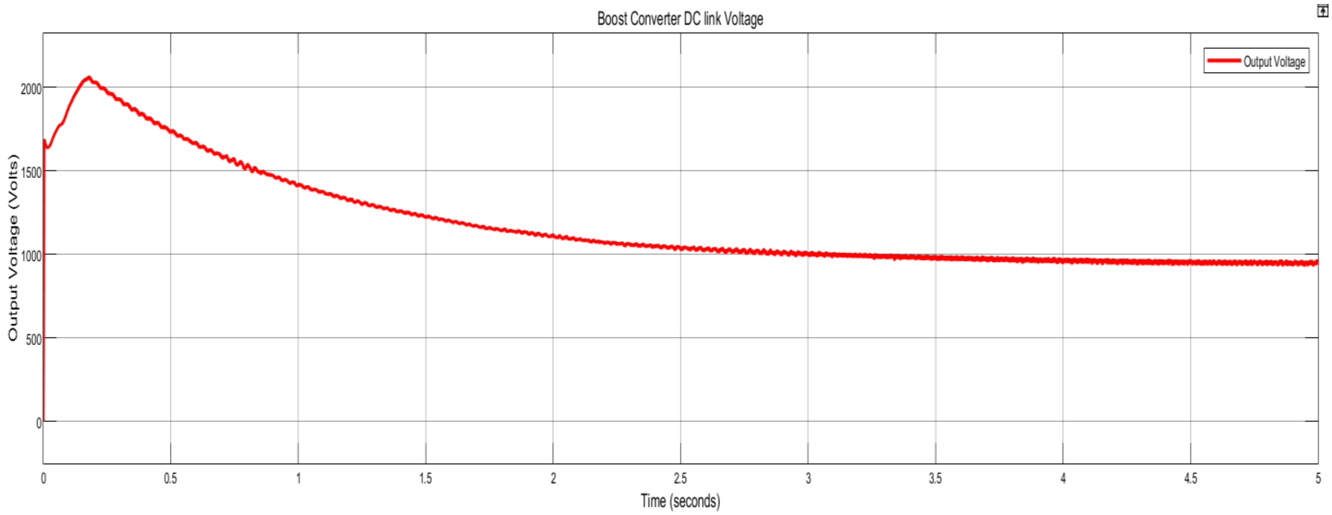

Fig.38 Waveform of Boost Converter Output Voltage.

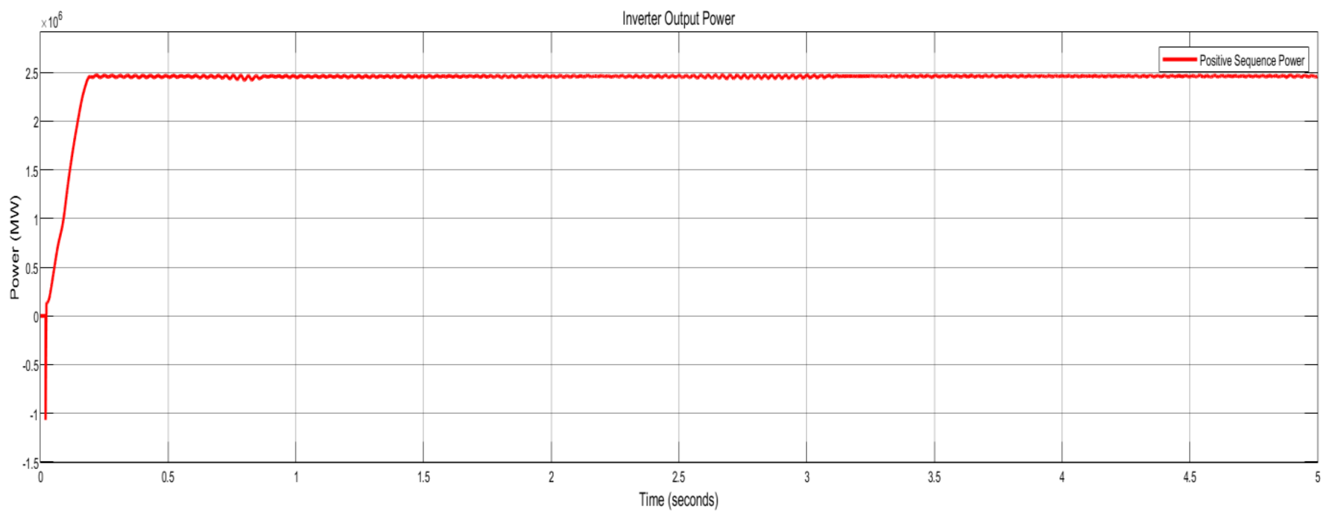

Fig.39 Waveform of Inverter Output Power.

5.5 Design and Simulation of Switched Mode Power Supply (SMPS) Card

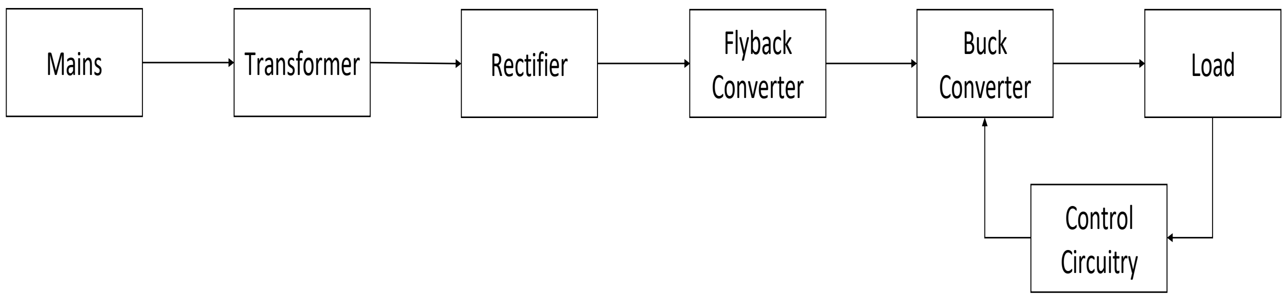

Fig.40 Block Diagram for Design of SMPS.

This SMPS is designed for different applications but having common supply input. Here, various power electronic converters are used having different ratings and different applications. As shown in the Fig.40, a delta connected three phase source is taken as an input to the Star-Delta (Y-D) Transformer to step down the voltage at suitable level. After that, converters are designed as per required applications. As the applications are crucial and sensitive, Flyback converter, which incorporates an isolation transformer, is used. A detailed table containing components and ratings of SMPS is provided below;

Tab.10 Components and their ratings in SMPS Card.

<table>
<tr><th>Sr. No</th><th>Component</th><th>Rating</th><th>Application (Used By)</th></tr>
<tr><td>1</td><td>Three Phase Delta Connected Source</td><td>230V AC</td><td>-</td></tr>
<tr><td>2</td><td>Star-Delta Transformer</td><td>230V/85V</td><td>-</td></tr>
<tr><td>3</td><td>6 Pulse Rectifier</td><td>110V DC</td><td>Gate Driver Card</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Flyback Converter</td><td rowspan="2">24V DC</td><td>Relay I/O Card</td></tr>
<tr><td>DC Reverse Polarity Card</td></tr>
<tr><td>5</td><td>Buck Converter</td><td>5V DC</td><td>Control Card</td></tr>
<tr><td>6</td><td>Load</td><td>5 Ohm</td><td>-</td></tr>
</table>

Components and Calculations

1. Input Calculations

Supply Voltage (V_{in}): 230 V

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$\therefore V_{peak} = 325\,V$$

Transformer Rating = 230 V / 85 V

2. Rectifier Design

$$C_{out} = \frac{I_L}{2\, f\, \Delta\, Vr}$$

Voltage Ripple (ΔV_r) = 1V (Assumption)

Load Current (I_L) = 1A

$$\therefore \quad C_{out} = \frac{1}{2 \text{ x } 50 \text{ x } 1}$$

$$C_{out} = 1000\,\mu F$$

3. Flyback Converter Design

Switching Frequency (F_S) = 140 K

Output Voltage (Vo) = 24 V

Suppose $\frac{N_S}{N_P} = \frac{1}{3}$ (Ideal condition)

$$\frac{N_S}{N_P} = \frac{V_0}{V_S}\left(1 - \frac{D}{D}\right)$$

Duty Cycle (D) = 40%

→ In case of PWM switching would be 0,145°

Transformer : $\frac{N_S}{N_P} = \frac{1}{3}$

→ Suppose, $\Delta iL = 500mA$

Magnetizing Inductance [L_m]

$$= \frac{V_S \text{ x } D}{\Delta \text{ iL x } F_S}$$

$$= \frac{110 \text{ x } 0.4}{140 \text{ x } 500 \text{ x } 10^{-3} \text{ x } 10^{3}} = 628\ \mu H$$

$$\text{Capacitor} = \frac{\Delta V_0}{V_0} = \frac{D}{RCF_s}$$

$R = 10\,\Omega$

$F_s = 140 \times 10^3$

$\Delta V_0 = 10\% \text{ of } V_0$

$= 2.4\ V$

$$\frac{2.4}{24} = \frac{0.4}{10 \times C \times 140 \times 103}$$

$$= 285\ \mu F \sim 300\ \mu F$$

4. Snubber Circuit Design

Calculating Maximum Current & Voltage MOSFET can withstand,

Desired efficiency = 80%

$V_O = 24\ V$

Ripple Factor = 1

$V_{in\ min} = 104$

$V_{in\ max} = 121$

$D_{max} = 0.5$

$L_m = 628\ \mu H$

$$V_{DS\ Max} = V_{in\ max} + \frac{D_{max} \times V_{in\ min}}{1 - Dmax}$$

$$= 121 + \frac{0.5 \times 104}{1 - 0.5}$$

$$= 225 + 20\% \text{ safety margin}$$

$$V_{DS\ Max} = 270V$$

$$I_p = \frac{P_{IN}}{D_{max} \, x \, V_{in\,min}} + \frac{D_{max} \, x \, V_{in\,min}}{2 \, x \, F_s \, x \, L_m}$$

$$\frac{{}^{24}/_{0.8}}{0.5 \ x \ 104} + \frac{0.5 \ x \ 104}{2 \ x \ 140 \ x \ 10^3 \ x \, 628 \ x \ 10^{-6}}$$

$$I_P = 0.86 \text{ A}$$

Max Capacitor Voltage,

$$V_{C\,max} = V_{DS\,max} \ x \ 0.1 + \frac{D_{max} \ x \ Vin_{min}}{1 - Dmax}$$

$$= (270 \ x \ 0.1) + \frac{0.5 \ x \ 104}{1 - 0.5}$$

$$= 131 \text{ V}$$

Power in Snubber resistor

$$P_R = \frac{I_P{}^2{}_{Peak} \ x \ L_{Leak} \ x \ F_s}{2}$$

$$= \frac{0.86 \text{ x } 0.86 \text{ x } 0.2 \, x \, 10^{-6} \text{ x } 140 \text{ x } 10^3}{2}$$

$$L_{Leak} = 2 \text{ \% of } L_{Primary}$$

$$L_{Primary} = \frac{\eta \ x \ (D_{max})^2 \ x \ (V_{in\,min})^2}{2 \ x \ F_s \ x \ KFR \ x \ VO}$$

$$= \frac{0.8 \ x \ 0.5 \ x \ 0.5 \ x \ 104 \ x \ 104}{2 \ x \, 140 \ x \ 10^3 \ x \ 1 \ x \ 24}$$

$$L_{Primary} = 315 \ \mu H$$

$$L_{Peak} = 2\%\ of\ 315\ \mu H = 6.3\mu H$$

$$\therefore P_R = \frac{0.86 \text{ x } 0.86 \text{ x } 6.3 \text{ x } 10^{-6} \text{ x } 140 \text{ x } 10^{3}}{2}$$

$$= 0.3 \text{ W}$$

Using power as limiting parameter,

$$\therefore R_{snubber} = \frac{(V_{Cmax})^2}{P_R}$$

$$= \frac{131 \text{ x } 131}{1.10} = 15{,}600\Omega \sim 16 \text{ k}\Omega$$

$$C_{snubber} = \frac{1}{\Delta V_C \text{ x Rsnubber x } F_s}$$

$$= \frac{1}{10\% \text{ x } 16\text{k x } 140 \text{ x } 10^3}$$

$$= 4.4 \text{ nF}$$

5. Buck Converter

Output Voltage (V_o) = 5 V

Output Current (I_o) = 1 A

Swicthing Frequency (F_s) = 4000 Hz

$$L = \frac{V_O\,[1 - Dmin]}{\Delta i_L \text{ x } F_S}$$

$$D_{min} = \frac{V_O}{V_{in\ max}}$$

$$= \frac{5}{26}$$

$$= 19\%$$
$$\sim 20\%$$

$$\Delta iL = 1\% \text{ of } 1A = 0.01 \text{ A}$$

$$L = \frac{5\ [1 - 0.2]}{0.01 \text{ x } 40 \text{ x } 103}$$
$$= 10\text{mH}$$

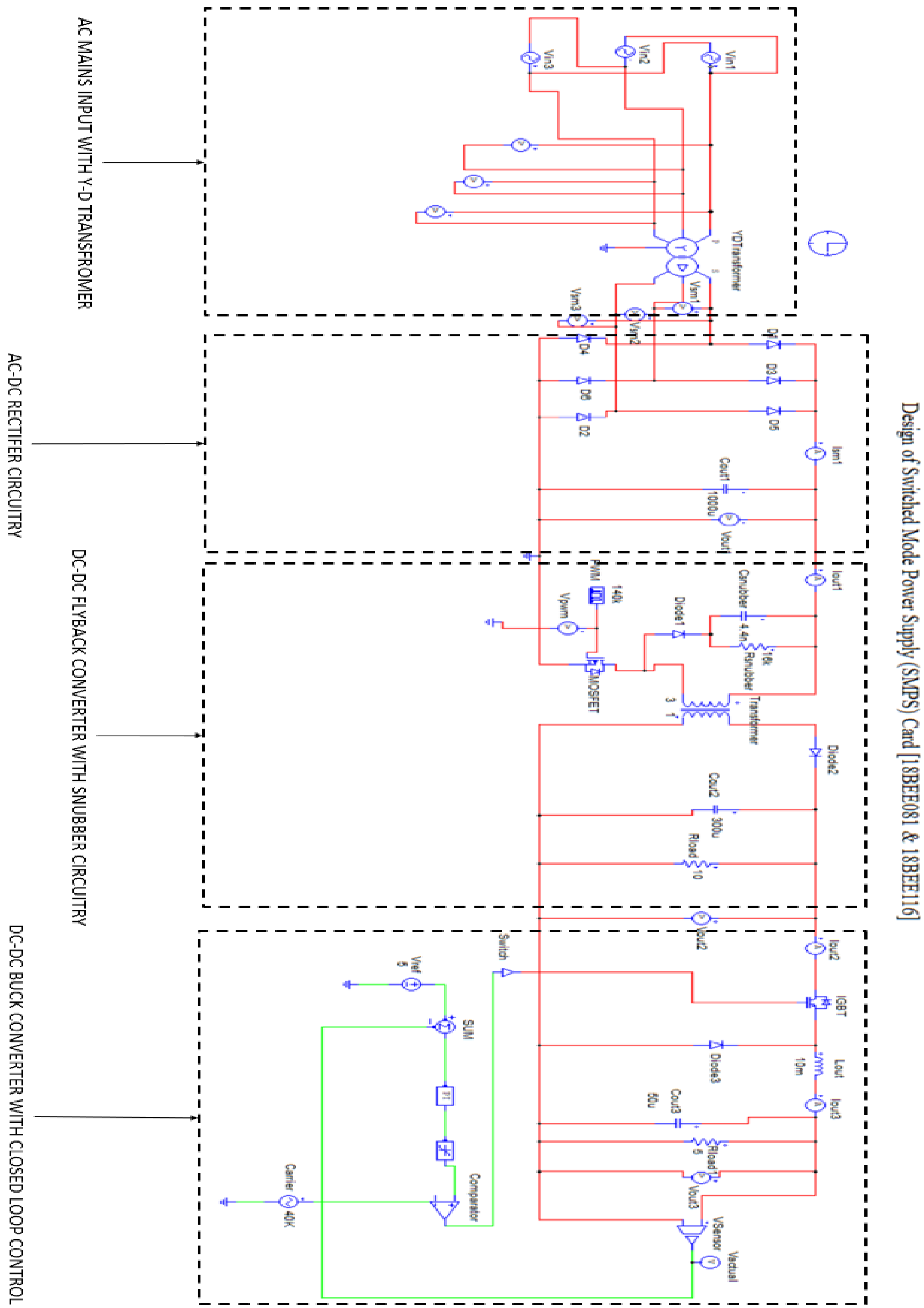

Fig.41 PSIM Model of Developed Switched Mode Power Supply (SMPS).

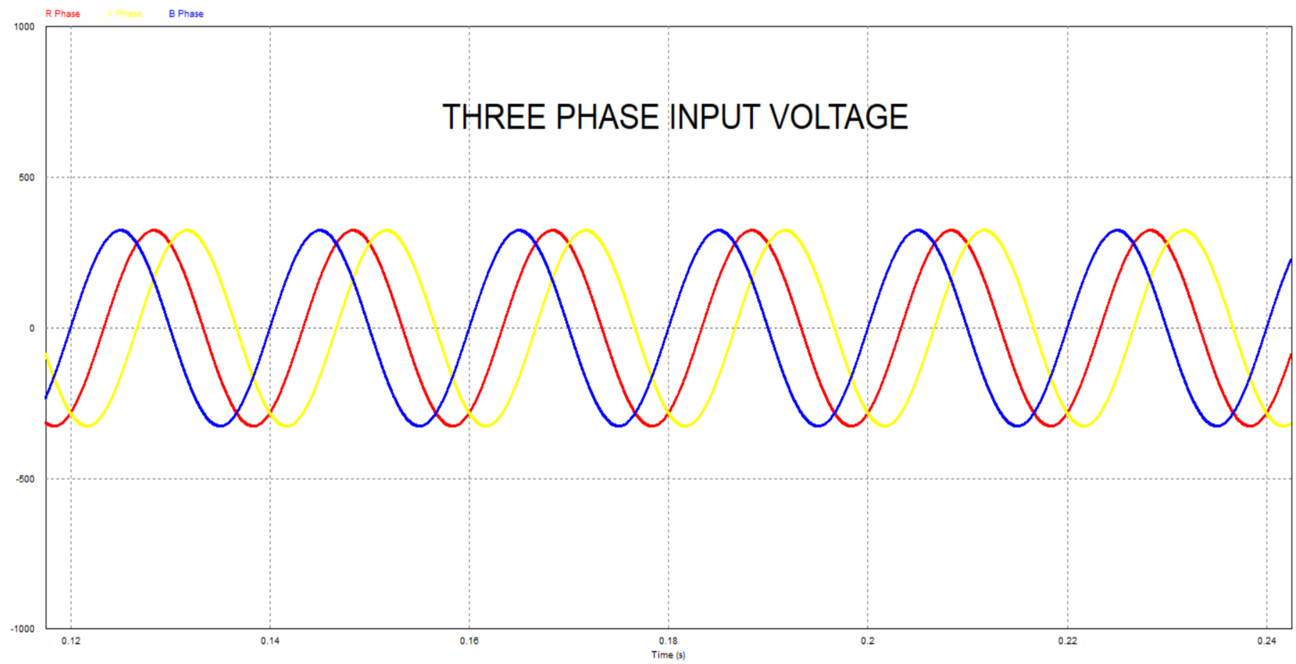

Fig.42 Waveform of Three Phase Input Voltage.

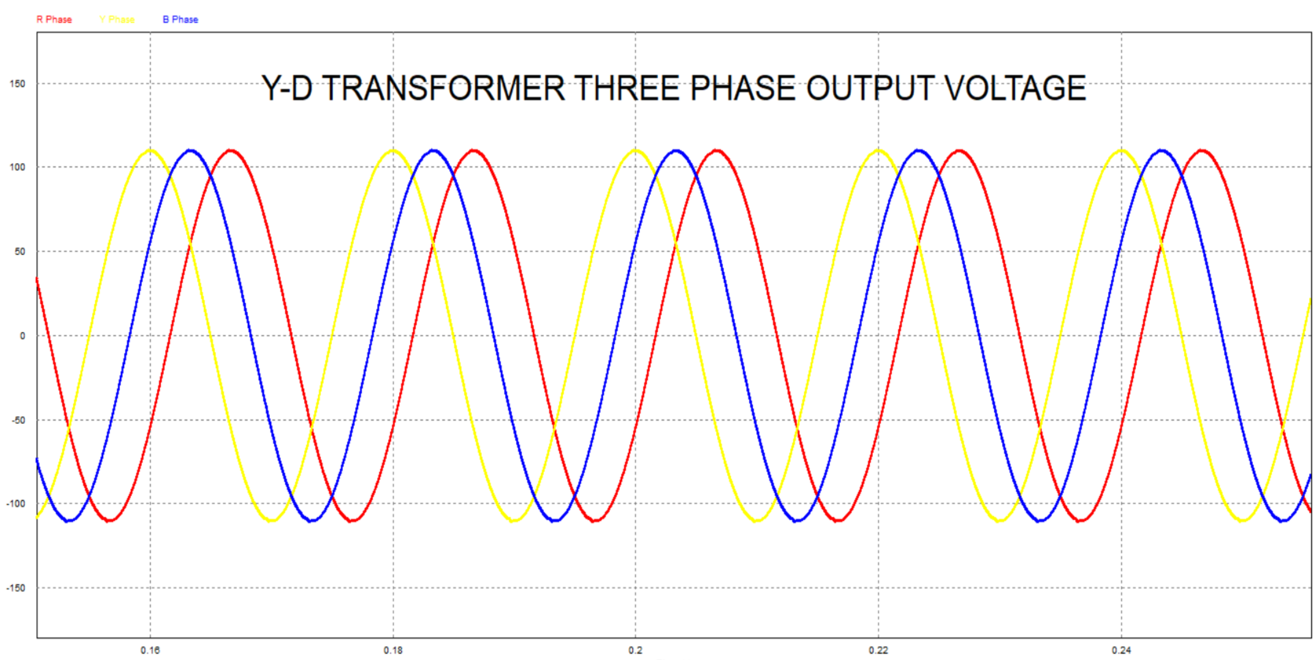

Figure.43 Waveform of Three Phase Y-D Transformer Output Voltage.

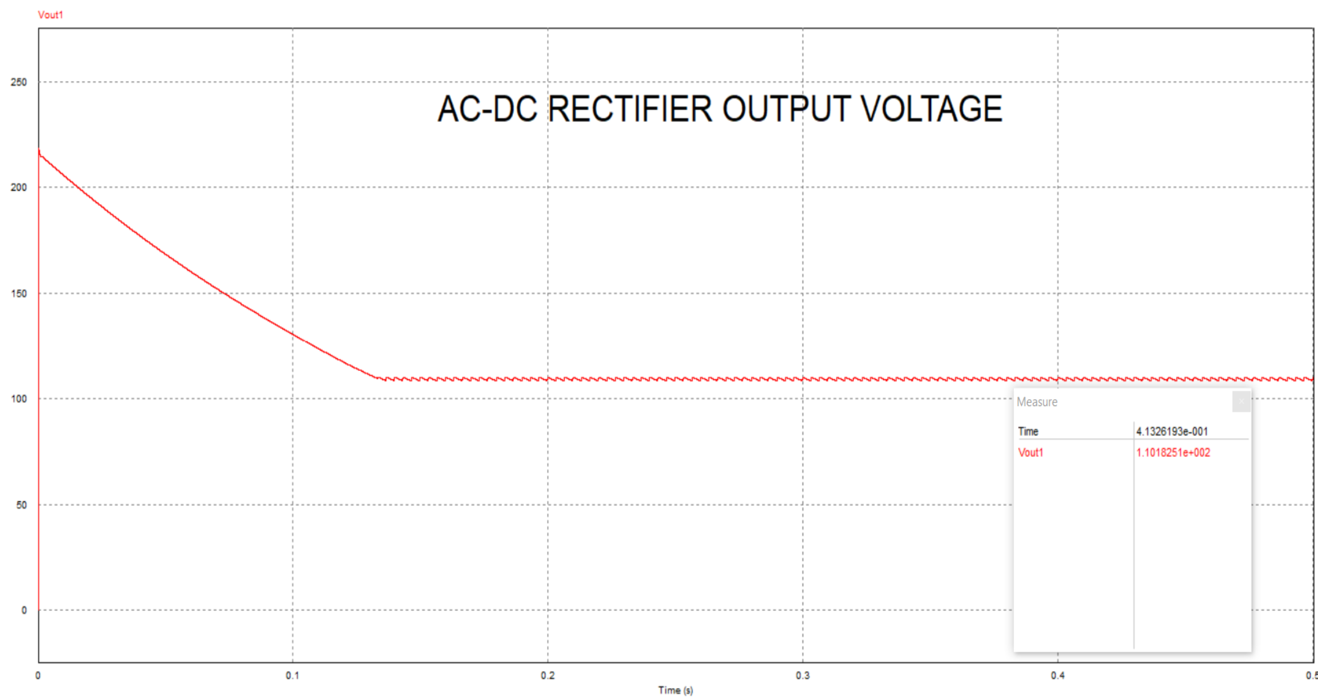

Fig.44 Waveform of Rectifier Output Voltage.

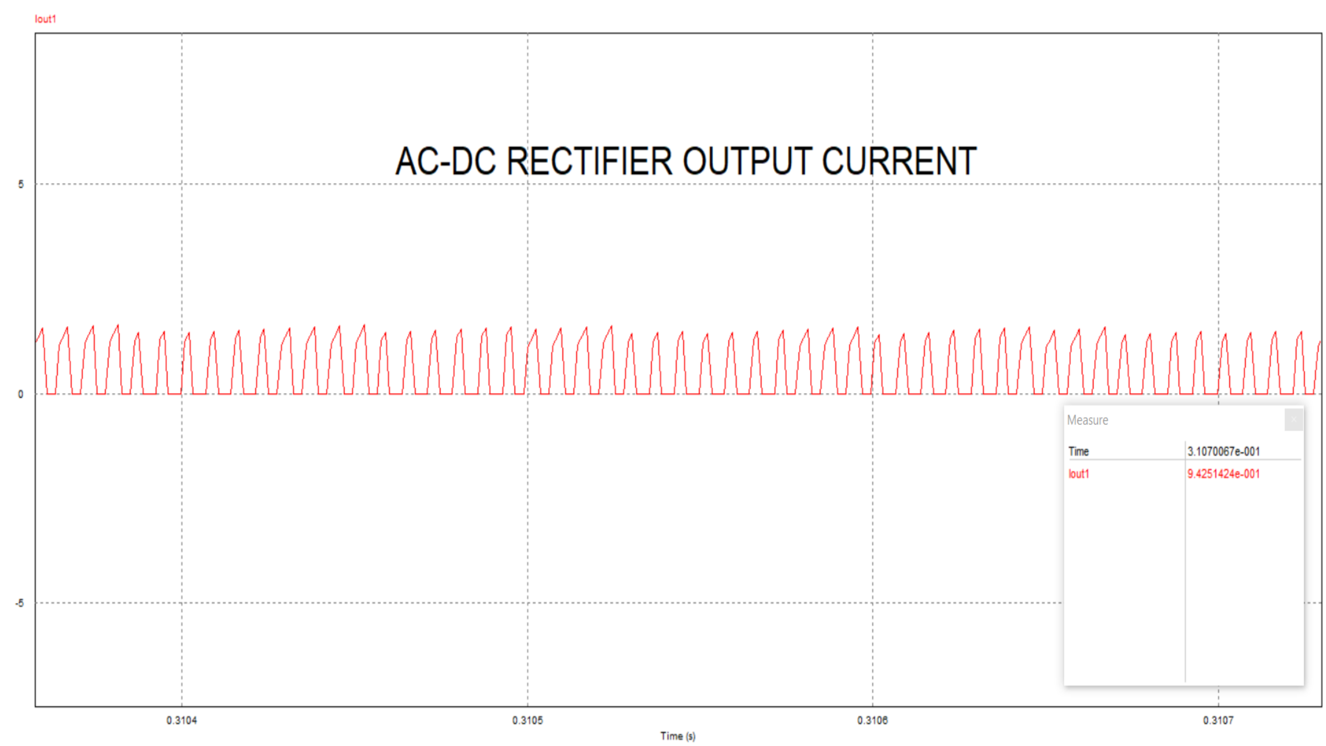

Fig.45 Waveform of Rectifier Output Current.

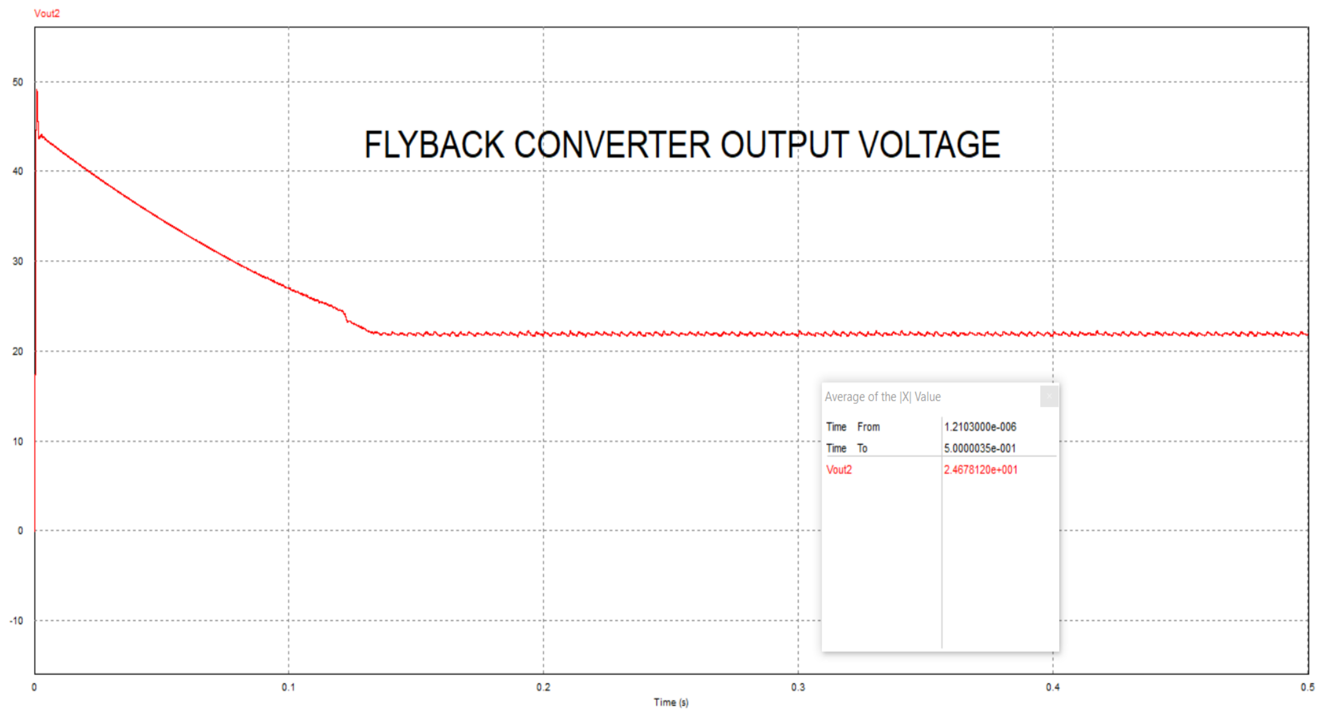

Fig.46 Waveform of Flyback Converter Output Voltage.

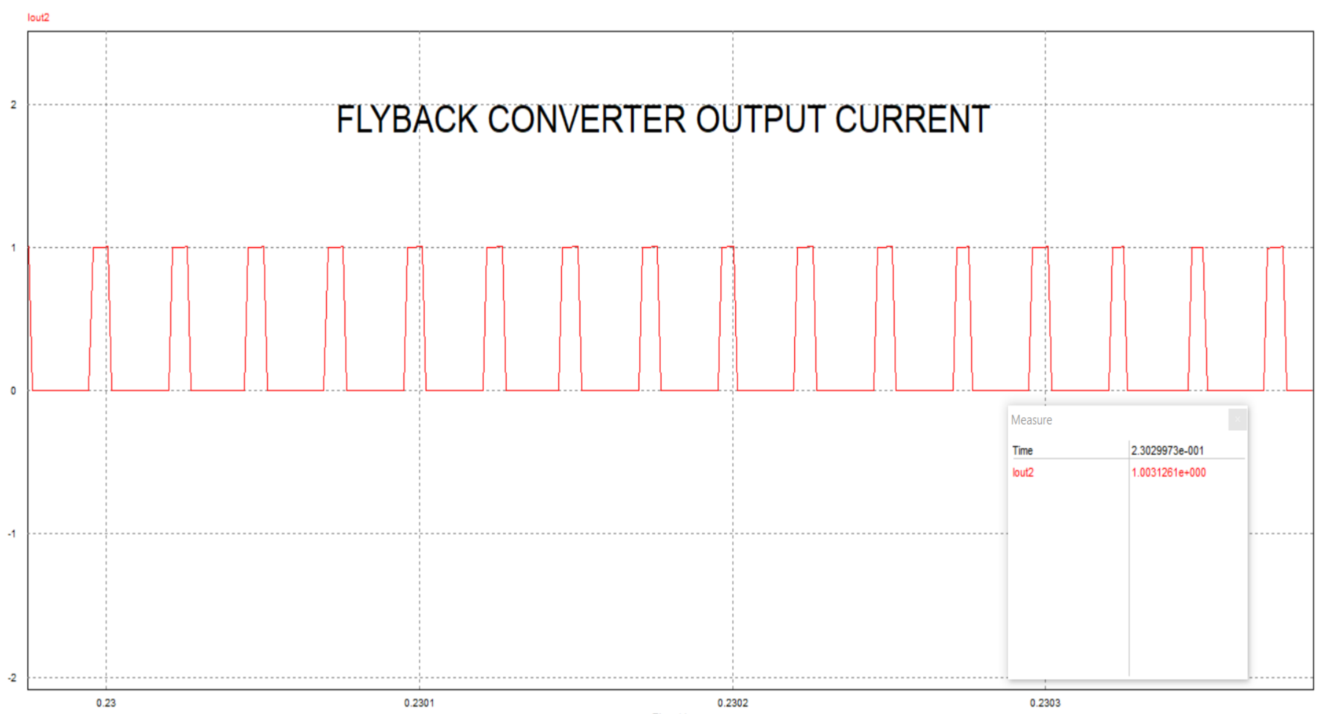

Fig.47 Waveform of Flyback Converter Output Current.

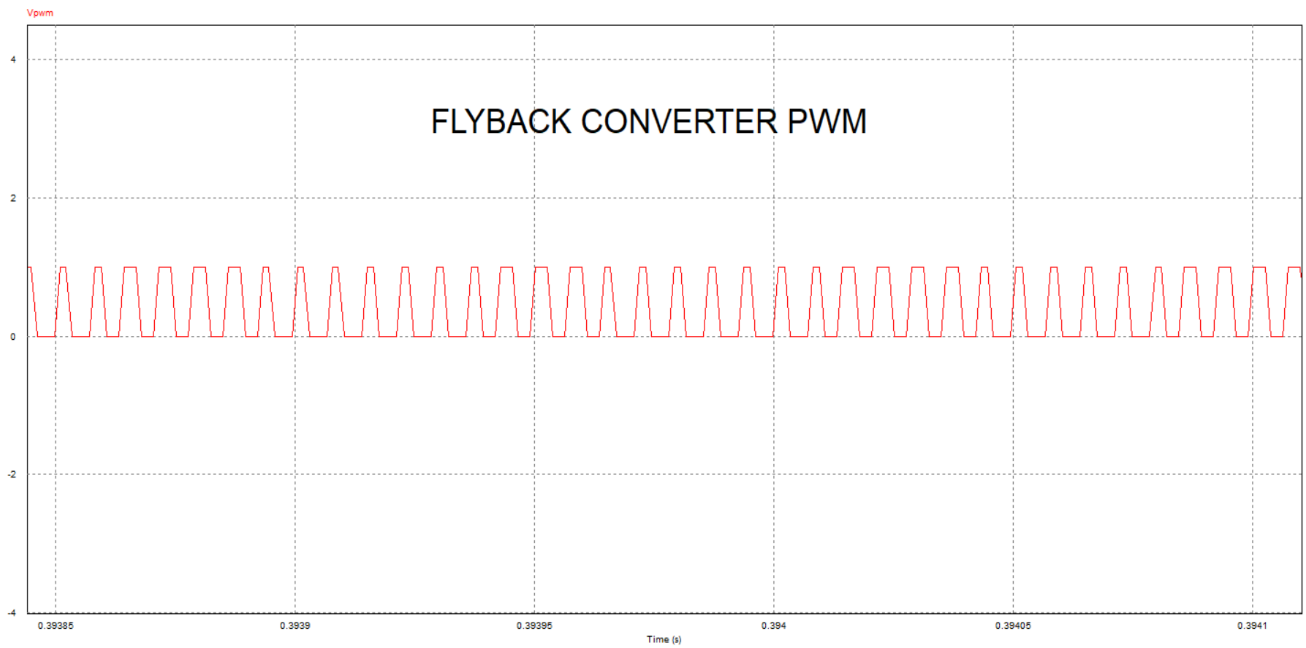

Fig.48 Waveform of PWM Generated.

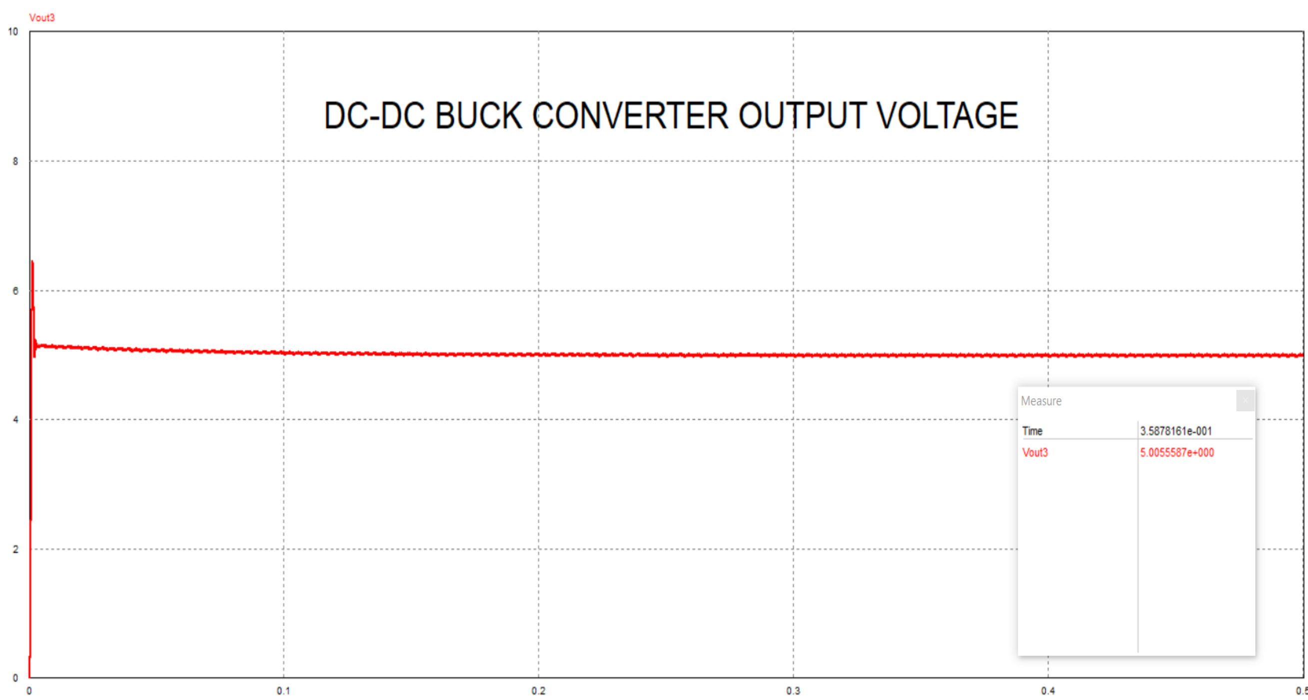

Fig.49 Waveform of DC-DC Buck Converter Output Voltage.

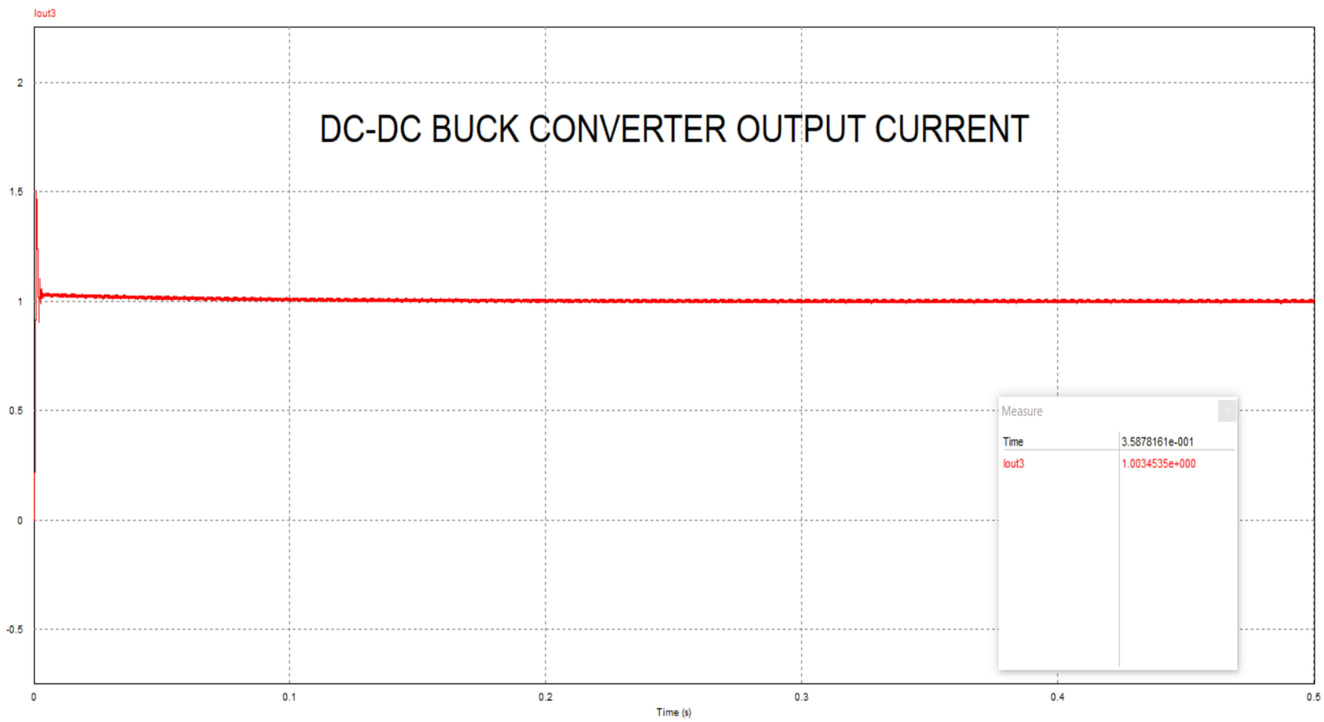

Fig.50 Waveform of DC-DC Buck Converter Output Current.

CHAPTER 6: UNINTERRUPTIBLE POWER SUPPLY (UPS)

Uninterruptible Power supply (UPS) at Industrial level considering Alternating Current (AC) network can be broadly classified into 3 categories:

1. Online UPS
2. Offline UPS
3. Line Interactive UPS

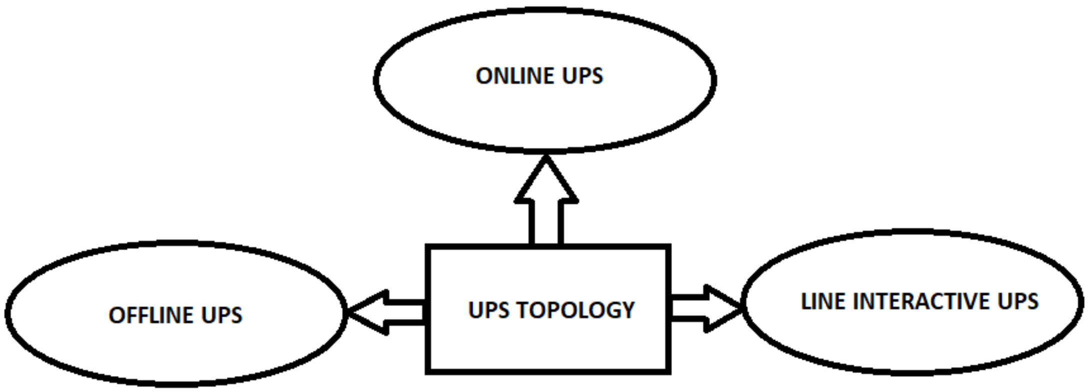

Fig.51 Topologies of AC UPS system.

❖ Online UPS

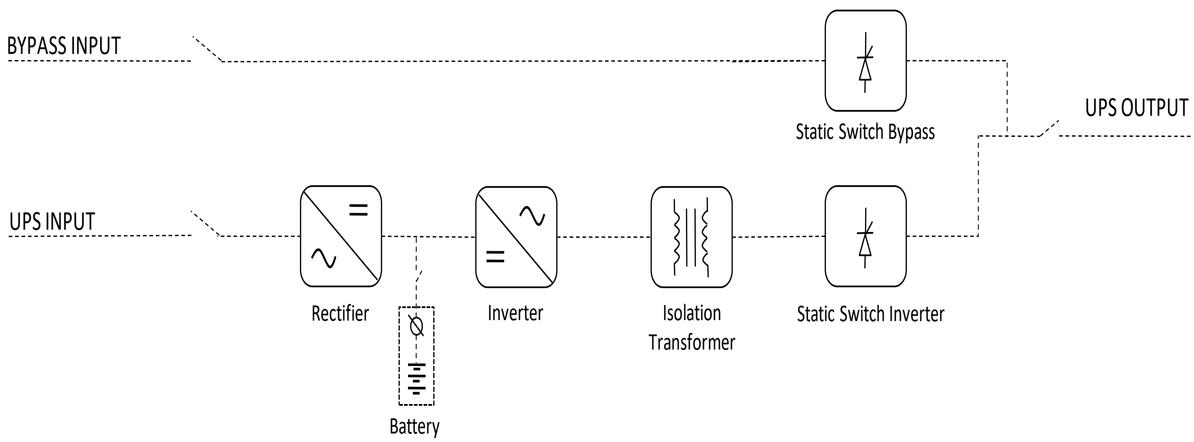

Fig.52 Single Line Diagram of Online UPS.

As shown in the Fig.52, in case of online UPS, commonly known as Double-conversion system (it utilizes both Inverter as well as Rectifier Circuit during energy conversion), UPS is considered as a primary device. Basically, there are three operations considering online UPS;

1. The AC Mains Input is directly connected to the critical load with the help of static switch of Inverter and helps to condition the power in case of normal operating conditions. This includes both Rectifier and Inverter.

2. The AC Mains Input charge the battery as well, parallelly supplying the critical load and in case of Main Input failure the battery provides power to the critical load with the help of Inverter.

3. The AC Mains Input is connected to the critical load with the help of Static Bypass switch neglecting Rectifier and Inverter.

❖ Offline UPS

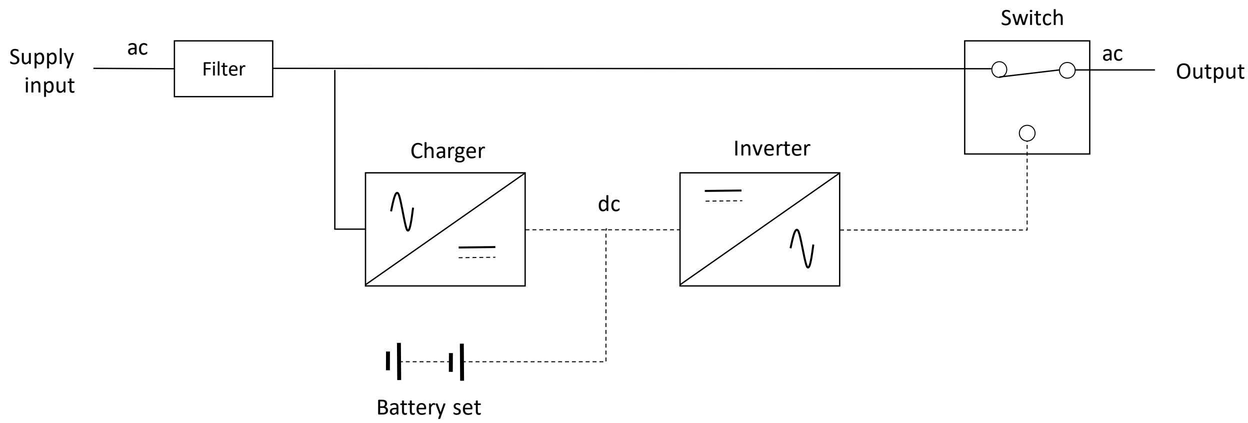

Fig.53 Single Line Diagram of Offline UPS.

As shown in the Fig.53, in case of offline UPS, commonly known as Standby system, provides a basic level of protection during abnormal conditions. When the AC Mains Input fails for a momentary level, then the battery supplies the Inverter and with the help of DC-AC conversion the load is supplied. Here UPS is considered as a secondary device as only single conversion of power happens (only DC-AC as battery supplies the Inverter during abnormal conditions).

❖ Line Interactive UPS

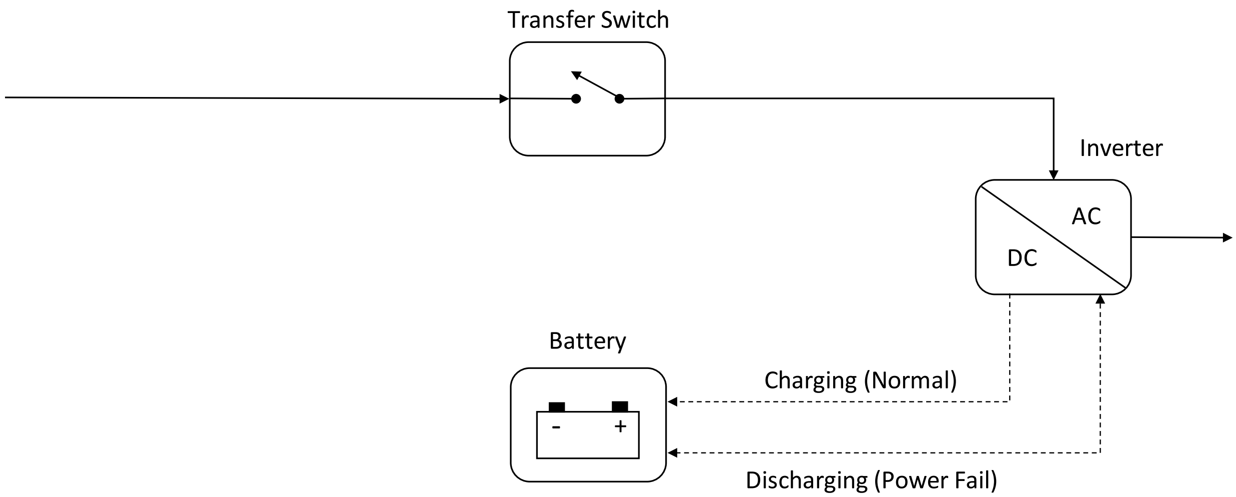

Fig.54 Single Line Diagram of Line Interactive UPS.

As shown in the Fig.54, Line interactive UPS, commonly called as Voltage Independent UPS, is a technology that comprises between online UPS and Offline UPS. In addition, it provides additional filtering as well as voltage stabilizers to smoothen the waveforms thereby reducing noise, surges and spikes.

6.1 Assembly Process

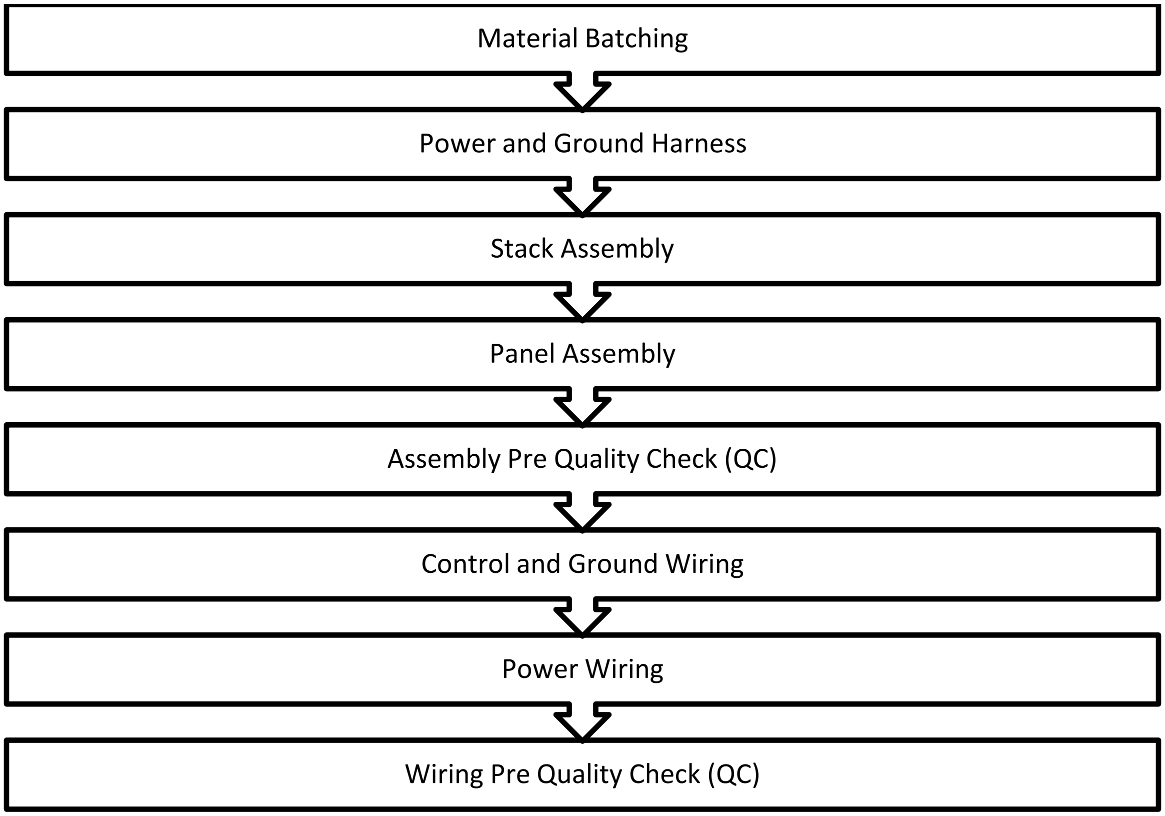

Fig.55 Overview of UPS Assembly, Flowchart and Process.

As shown in the Fig.55, and as explained in case of Solar PCS, the assembly process of UPS remains same. As the material is batched from the storage, Harness is made (A similar structure or replica of Panel in the soft floor). After this, Stack assembly which consists of Rectifier circuitry as well as Inverter circuitry is mounted followed by Wiring for the same. After all process, Pre Quality check is done so as to ensure unwanted malfunctioning of the product during testing procedure.

6.2 Time Study Monitoring and Results

As shown earlier, in case of Solar PCS, the same activity list and Manpower Traceability chart is acquired and the whole process of UPS is monitored which results in the following chart. As seen in the Fig.56, there is differ beween targeted standard time (ST) and actual standard time (ST) and this is due to diferent kinds of MUDA. As MUDA's are decreased there is overall increase in productivity and hence leads to smooth production.

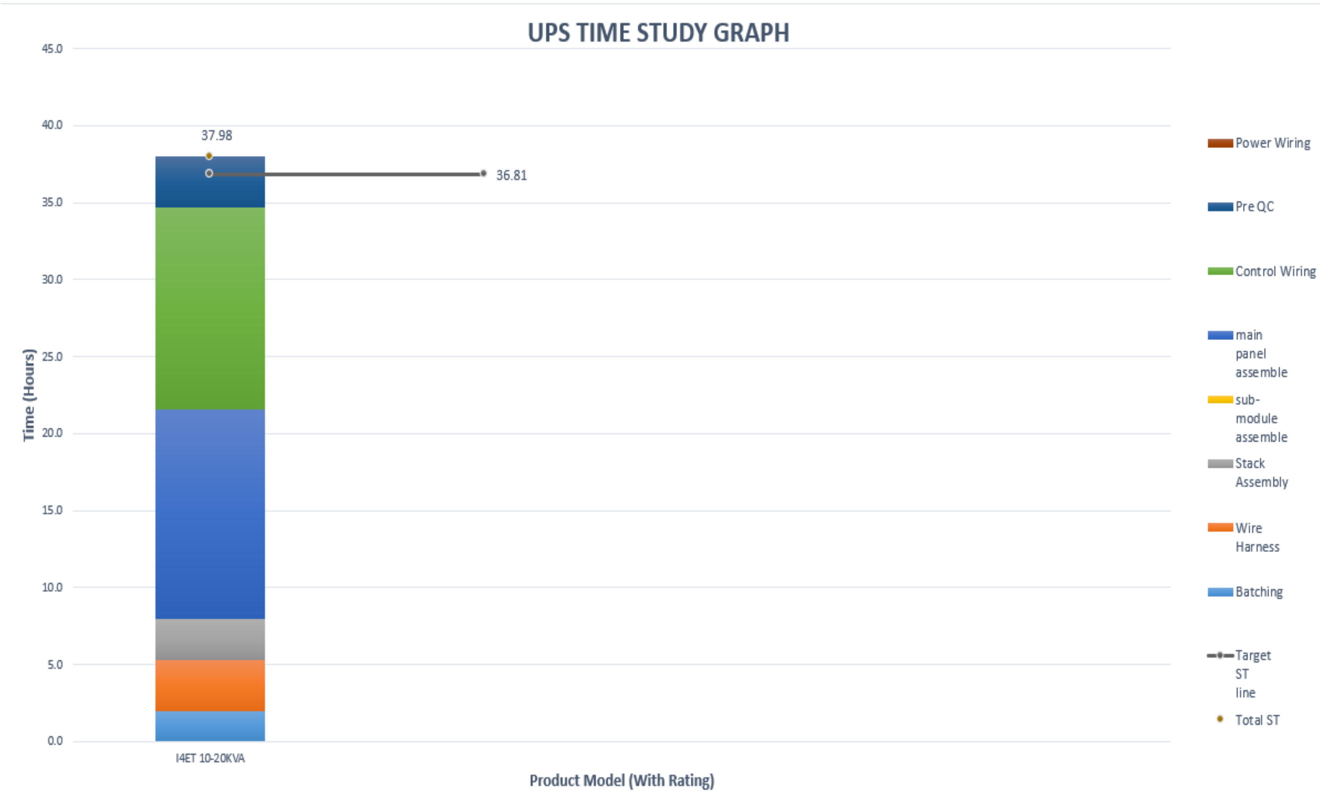

Fig.56 Time Study Graph Considering Uninterruptible Power Supply (UPS).

6.3 UPS Redundancy and Battery Calculations

Based on different configurations and type of topologies, there are broadly 4 types of UPS redundancies;

1. Stand Alone (SA)
2. Cascaded Redundancy (CR)
3. Parallel Redundancy (PR)
4. N+1 Redundancy

1. Stand Alone (SA)

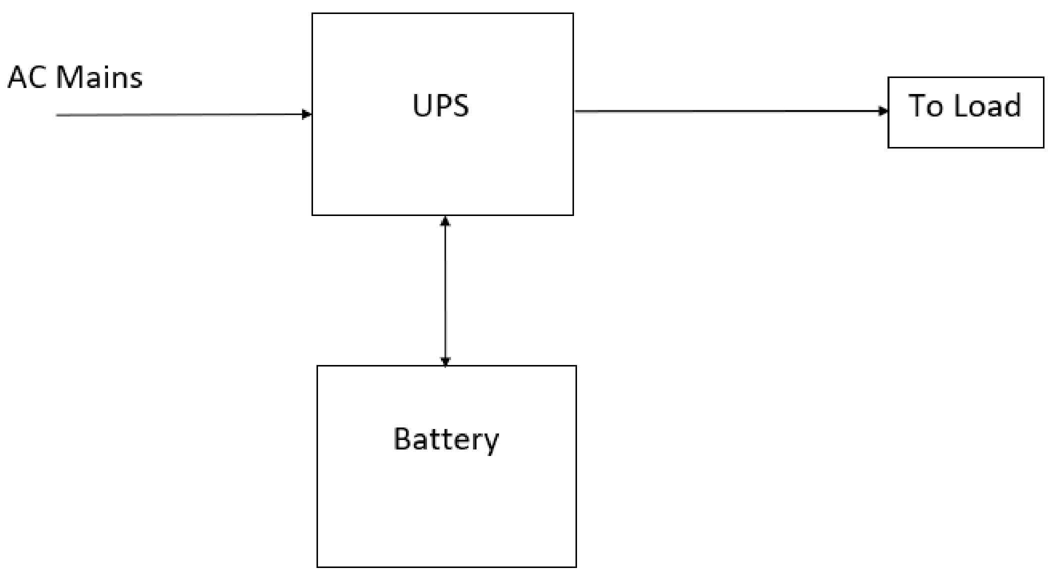

Fig.57 Typical Configuration of SA UPS.

As shown in the Fig.57, SA system is the classic system which comprises a single UPS connected to critical load. As enlisted earlier, the operation here, remains the same as a conventional UPS system under normal as well as abnormal conditions as per the configurations.

2. Cascaded Redundancy (CR)

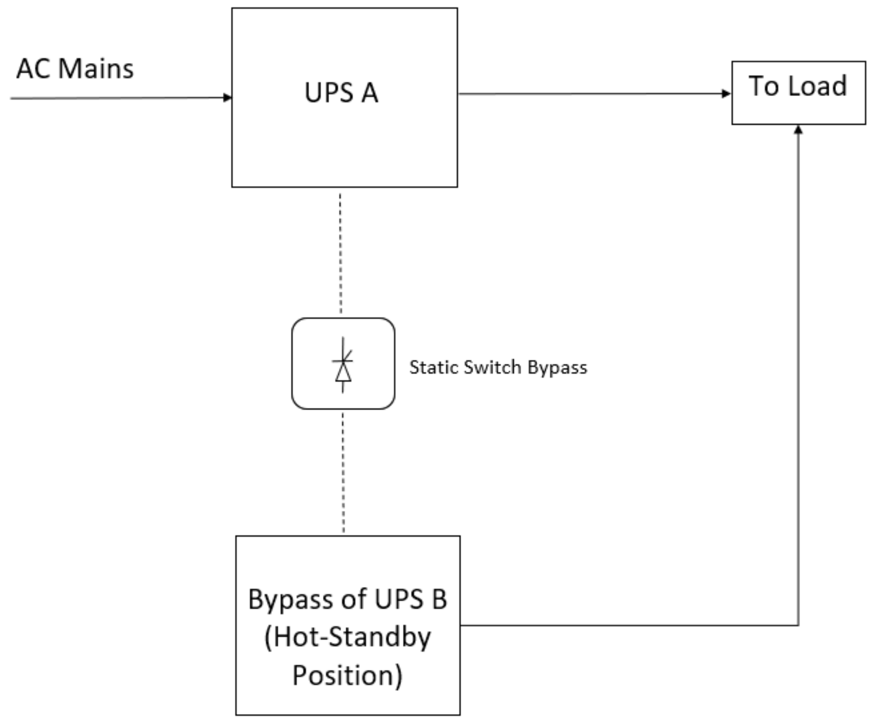

Fig.58 Typical Configuration of CR UPS.

As shown in the Fig.58, a CR system encorporates two UPS connected in parallel configuration but here the second UPS is considered as auxilary and does not operate under normal Conditions. Whenevr UPS A fails to deliever critical load, the UPS B with the help of Static Bypass switch, turns on the UPS B with the help of bypass input of UPS B and feeds the load. Here both the UPS have same raitngs.

3. Parallel Redundancy (PR)

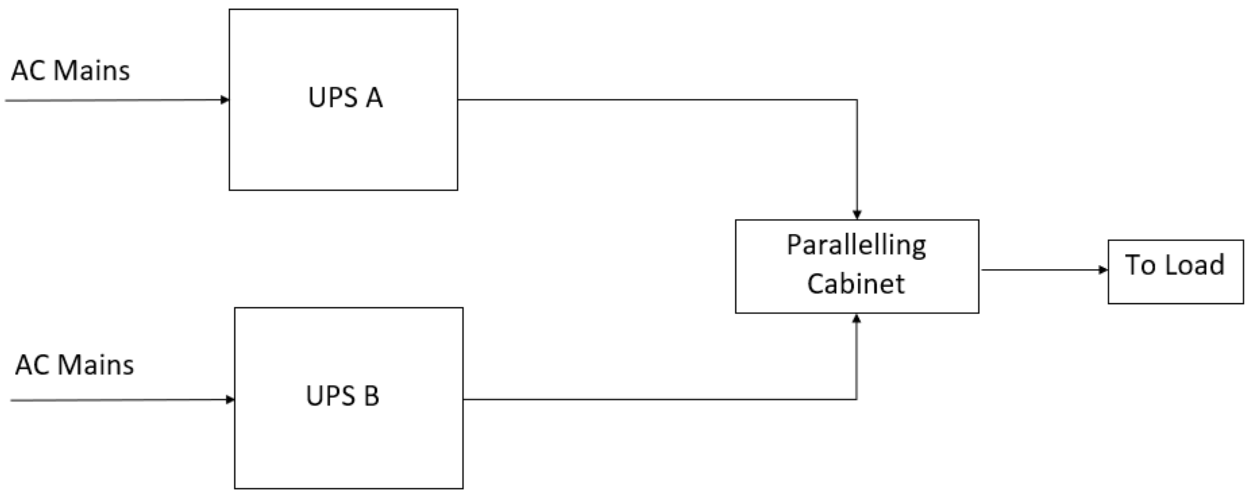

Fig.59 Typical Configuration of PR UPS.

As shown in the Fig.59, in case of PR System, UPS are connected parallelly and share the load in between them. A common bus is there between them at the critical load side called as parallel cabinet. It also consists of Inductors to share the load between them. Here the two UPS ratings are half the critical load ratings as two of them share the load.

4. N+1 Redundancy

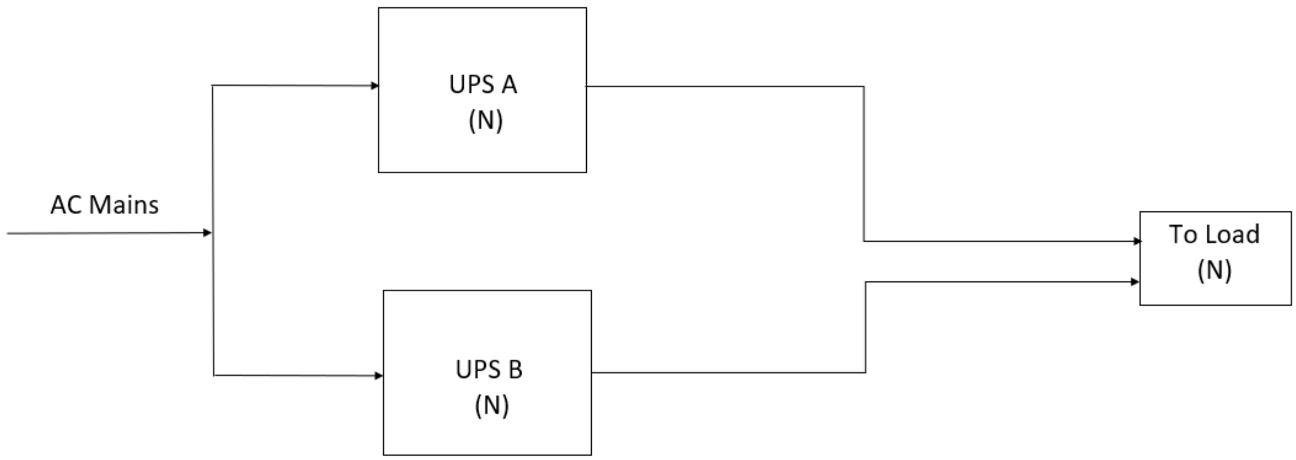

Fig.60 Typical Configuration of N+1 UPS.

As shown in the Fig.60, N+1 Redundancy also called as Modular System, is similar to PR system where UPS are connected in parallel configuration. Here the load is of N rating, so are the UPS. If the critical load remains below N, then it is considered as a redundant system.

❖ UPS Battery

Batteries are a crucial part of UPS as during power failure of AC Mains, these components drive the critical load and their sizing and raring is also a crucial part. Broadly, Battery can be classified as two types;

1. Standard battery – The one's which require maintenance comes under this category. For example, Nickel Cadmium Battery (NiCd).

2. Maintenance Free – The one's which requires minimum maintenance comes under this category. For example, Sealed Maintenance free battery (SMFB) or Valve Regulated Lead Acid Battery (VRLA).

BATTERY SIZING CALCULATION

RATING :	25 KVA
INV EFF. :	0.91
LOAD P.F. :	0.8
Back-up Time	12 Hrs
Ambient Temperature	2 degree
Battery Type	Nicd
No. of Cell :	306
End Cell Voltage	1.1

$$I_{DC}\ (\text{Max.}) = \frac{\text{UPS rating} \times 100 \times \text{Load P.F.}}{\text{No.cells} \times \text{Inv Effi.} \times \text{End Cell Voltage}}$$

$$I_{DC} = \frac{25 \times 100 \times 0.80}{306 \times 91.0\% \times 1.1}$$

$$= 65.29\ \text{A}$$

Aging Factor	1.25	=	81.62 Amp
Design Margin	1	=	81.62 Amp
TCF @ 2 degree °C	1.09	=	88.96 Amp
SOC	0.88	=	101.09 Amp
K factor	11.86	=	1190.98 AH
Achieving 2 x 50 %		=	599.49 AH
Battery Selected		=	635 AH

Tab. 11 Calculation of Transformer used in UPS.

UPS TRANSFORMER RATING CALCULATION				
UPS RATING IN KVA				**25**
Sr. No	**Parameters**	**Notations**		**Values**
1	Output Power Factor			0.8
2	Inverter Efficiency			0.91
3	Battery AH Rating			635
4	No. of Cells			306
5	Cell Nominal Voltage			1.2
6	Cell Float Voltage			1.42
7	Cell Boost Voltage			1.54
8	Inverter Input Current in Amps	A	$\frac{\text{VA Rating x Load PF x Over Load Factor (1.1)}}{\text{Inv. Eff x No of cells x cell Float Voltage}}$	55.64
9	Battery Charging Current	B	20 % of Battery AH x 2	254
10	Total Charger Rating	C	A + B	309.64
11	Charger KW Rating	D	$\frac{\text{C x No of Cells x cell float Voltage}}{\text{1000 x Rectifier efficiency}}$	141.6
12	Charger Efficiency			0.95
13	Input Power Factor			0.97
14	Input Transformer Rating	E	$\frac{\text{D}}{\text{input PF}}$	146.01
15	Input Current max./ phase			203.13
16	Input Transformer Rating considering Safety Factor 1.25%	F	E x 1.25	182.51
	SELECTED INPUT TRANSFORMER IN KVA			**200**

CHAPTER 7: CONCLUSION AND FUTURE SCOPE

As Production or Assembly is a crucial component for any manufacturing industry, a deeper focus has been put on in regard with that, followed by labor management and manpower traceability which ultimately leads to the sole conclusion of Time study Monitoring of Electrical Equipment. Apart from that, a view on the technical side considering simulation of 2.5 MW Grid connected system Solar Power Conditioning System (PCS) with analytical calculations is considered and implemented in Matlab-Simulink software with desired results. A focus on the design of Switched Mode Power Supply (SMPS) card along with component calculation and its simulation in PSIM software is also imposed with satisfactory results. In case of Uninterruptible Power Supply (UPS), battery is kept into the concentration area for the design side as well as suitable transformer considering real time data.

By removing unnecessary complications and defects in production with the help of techniques and improvements discussed, any industry can move towards lean manufacturing and can attain six sigma. This defects or any unwanted tasks that hampers production, however, can be eliminated only when continuous manpower monitoring is done keeping in mind the manpower traceability chart. After analyzing assembly process of any product starting from batching of material till its dispatch, any tasks that hampers productivity, can be removed through ideas and innovations, which further adds value to the on-time production and ultimately customer satisfaction.

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APPENDIX

MATLAB Code for Perturb and Observe Algorithm.

```
%18BEE081&18BEE116
function D = mppt(V,I)
% MPPT controller based on the Perturb & Observe algorithm.
% D output = Duty cycle of the boost converter (value between 0 and 1)
% V input = PV array terminal voltage (V)
% I input = PV array current (A)
% Param input:
Dinit = 0.42; %Initial value for D output
Dmax =0.9; %Maximum value for D
Dmin = 0.1; %Minimum value for D
deltaD = 0.00008; %Increment value used to increase/decrease the duty cycle D
% (increasing D = decreasing Vref)
%
persistent Vold Pold Dold;
dataType = 'double';
if isempty(Vold)
Vold=0;
Pold=0;
Dold=Dinit;
end
P=V*I;
dV= V - Vold;
dP= P - Pold;
if dP ~= 0
if dP < 0
if dV < 0
D = Dold - deltaD;
else
D = Dold + deltaD;
end
else
if dV < 0
D = Dold + deltaD;
else
D = Dold - deltaD;
end
end
else D=Dold;
end
if D >= Dmax | D<= Dmin
D=Dold;
end
Dold=D;
Vold=V;
Pold=P;
```

MATLAB Code for Calculation of values of Inductor & Capacitor for Boost Converter.

```
%18BEE081&18BEE16
%Script for Calculation of L and C for Boost Converter
P=2560456; %System is designed for 2.5 MW power
Vin=20*37.58; %data taken from PV Array Series Configuration
Fs=4e3; %Switching Frequency
Vout=1000; %Required as per design
Ioutmax=P/Vout;
delIL=0.01*Ioutmax*(Vout/Vin); %Inductor ripple current
delVout=0.01*Vout;
L=(Vin*(Vout-Vin))/(delIL*Fs*Vout)
C=(Ioutmax*(1-(Vin/Vout)))/(Fs*delVout)
R=Vout/Ioutmax
```

* * * * * * *