DESIGN OPTIMIZATION OF RESIDENTIAL AIR CONDITIONER FOR QUALITY ENHANCEMENT AND FAILURE REDUCTION

A Dissertation submitted in fulfilment of the requirements for the Degree
of

MASTER OF ENGINEERING
in
Power Systems

Submitted by

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DECLARATION

I hereby certify that the work which is presented in dissertation entitled, "Design optimization of residential air conditioner for quality enhancement and failure reduction ", in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Power Systems, submitted to Electrical & Instrumentation Engineering Department of Thapar Institute of Engineering & Technology (Deemed to be University) is as authentic record of my own work carried under the supervision of Mr. Raghav Sharan and Dr. Manbir Kaur. It refers others researcher's work which are duly listed in the reference section. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

Place: Patiala
Date: 28 July, 2022

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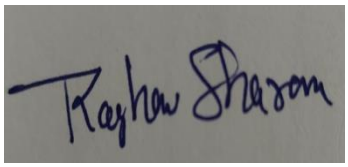
It is certified that the above statement made by the student is correct to the best of my knowledge and belief.



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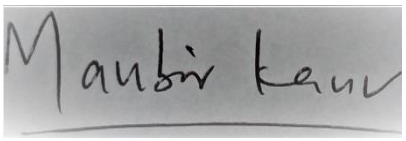

Dr. Manbir Kaur
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ACKNOWLEDGEMENT

"Theory without practice is a bird that never lands.

Practice without theory is a bird that never flies."

"To people, who make it possible to disseminate knowledge to enlighten the young and curious minds"

As the quote suggests, the internship opportunity which I got from **L.G. Electronics India Pvt. Ltd.** was a great fortune for acquiring skills and professional advancement. I am filled with gratitude for having a chance to meet up with so many magnificent people and professionals who led me through this internship period.

First of all, I would like to pay my gratitude of thanks to **Mr. Kamal Rana** (D.G.M. - FQM , QA) for all his wisdom and lessons he shared with me, for instance, how it is also important to learn to manage apart from technical knowledge.

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ACRONYMS AND ABBREVIATIONS

FQM	Field Quality Management
QA	Quality Assurance
RAC	Residential Air Conditioner
SRAC	Split Residential Air Conditioner
AC	Air Conditioner
b/w	Between
BEE	Bureau of Energy Efficiency
ISEER	Indian Seasonal Energy Efficiency Ratio
EER	Energy Efficiency Ratio
COP	Coefficient of Performance
PCB	Printed Circuit Board
PCBA	Printed Circuit Board Assembly
BLDC	Brushless DC
IDU	Indoor Unit
ODU	Outdoor Unit
MWO	Microwave Oven
IQC	Incoming Quality Control
LQC	Line Quality Control
MOV	Metal Oxide Varistor
SMPS	Switch Mode Power Supply
NTC	Negative Terminal Coefficient
NDF	No Damage Failure

NG	Not Good
IQC	Incoming Quality Control
OQC	Outgoing Quality Control
IC	Integrated Circuit
IPM	Intelligent Power Module
LED	Light Emitting Diode
AVS	Automatic Voltage Switcher
EMI	Electromagnetic Interference
PSU	Power Supply Unit
PFC	Power Factor Correction
FFR	Field Failure Rate
RBH	Run By Hand
FCT	Functional Circuit Test

ABTRACT

LG Electronics India Pvt. Ltd. has provided a great platform to gain some extremely valuable experiences, knowledge and skills that too in a very helpful, caring and professional environment.

The project is titled as “Design optimization of residential air conditioner for quality enhancement and failure reduction”. At the QA (RAC,FQM) LGEIL, the work mainly consisted of concept development and its feasibility for various other aspects, plus testing of the different components of the product. The new development modelled along-with some modifications in existing machine. The main focus is how to reduce field failure rate by applying improvements in design so as to reduce field failures. It also consisted of study of various electronic, electrical and mechanical components being used in white goods and exploring new possibilities for improvement in quality or reduction in cost. Major components of air conditioner along with their functioning and their build inside out is analyzed to determine about the circuit behaviour and mechanism of different parts and the complete functioning of split air conditioner.

The objective of the project is to identify the issues and defects found from the customer end and based on that improvement in design and specification is suggested and validated in various parts of residential air conditioner .In this project, not only electrical and electronic components but also the mechanical components of air conditioners are dealt. The reasons and causes of field failure of various components of air conditioners along with some product liability cases are analyzed and the different AC components that have failed in field and are brought up for the purpose of analysis are tested with proper structural procedures to find common errors and troubleshot accordingly . These field failures are analyzed and discussed among different respective departments like R & D and Quality and actions taken accordingly to improve the quality and reducing the cost to company.

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CHAPTER 1

INTRODUCTION

1.1 Residential Air Conditioner Overview

Air conditioning is the process in which the properties of air (mainly temperature and humidity) are changed to more comfortable conditions, naturally with the focus of distributing the air which is conditioned to an occupied space to enhance thermal comfort and indoor air quality. HVAC (heating, ventilating, and air conditioning) is the technology of indoor and vehicular environmental convenience. Its goal is to give thermal comfort and desired indoor air quality.

Fig 1.1: SRAC

1.2 Residential Air Conditioner System

Air conditioners work their magic by applying principle of varying state, in which a liquid turns into a gas and its temperature drops down, while a gas temperature is raised by

compressing it, also its phase turns liquid. In an air conditioner, certain chemical is used as a refrigerant which has quite a low boiling point. When it is passed through an expansion valve, its phase changes from liquid to gas and cool down the IDU evaporator coils and ten passed in the room through the fan blower. This process involves the heat absorption from indoors of the room by the coils and then vaporous refrigerant flows via the compressor and which make it in liquid phase and passed it to the condenser coils which exhausted it outside through a fan blower, in the ODU.

When humid air flows over cooled EVA coils, it easily condenses the moisture over it. This clearly shows indoor air is simply dehumidified by the air conditioning process. The model used decides the handling of the water that is condensed.

The cycle repeats continuously, cooling the indoor air then passing the heat outdoors, to the point when desired indoor room temperature is attained. From the smallest window AC units to the most embellished central air conditioning systems, the working principle is same with the advancements in some of components which make the process easier.

1.3 Refrigeration Cycle

Thermodynamic cycle is used by an air conditioner called the refrigeration cycle. By this the pressure and state refrigerant is changed due to absorption or ejection of heat.

The refrigerant (also called coolant) takes the heat from indoors and eject it to the outdoors.[1]

The aim of refrigeration cycle is to absorb heat and to reject heat.

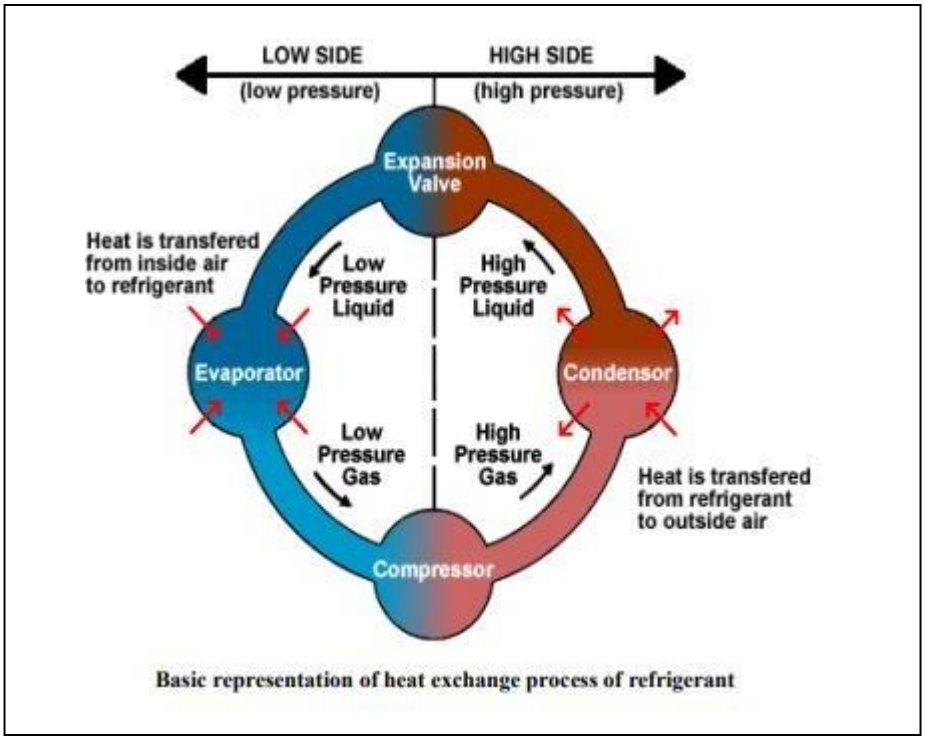


Fig 1.2: Heat Exchange Process of refrigerant

1.3.1 Fundamental elements of a basic cycle

1. Compressor
2. Condenser
3. Electronic expansion valve
4. Evaporator

The following components or elements make the air conditioner work. Their functionality is discussed in the next section. [2]

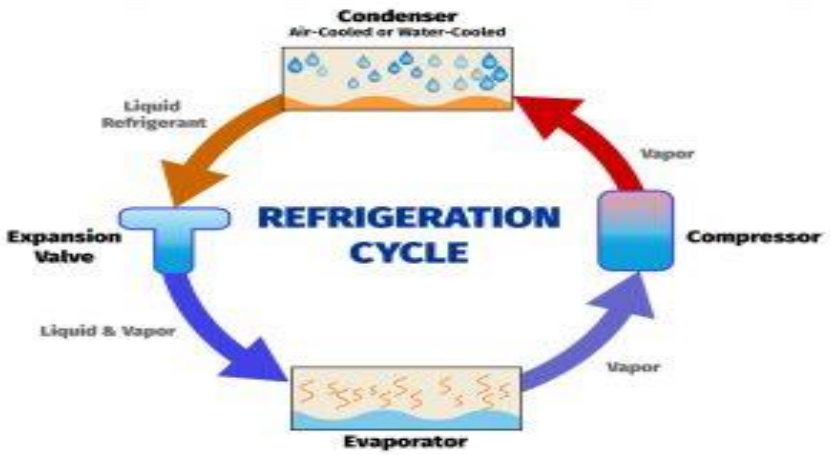


Fig 1.3: Refrigeration Cycle

1.3.2 Working of the elements:

- **Compressor**

The compressor is the kernel of the refrigeration cycle. It functions as a pump that moves the refrigerant via the system.

Compression is the initial process of refrigeration cycle. In this pressure of the refrigerant gas is increased which pass into the compressor having pressure as low , also low-temperature gas, and exits it as a high-pressure, high-temperature gas.

Fig 1.4 Compressor

- **Condenser**

The condenser, or condenser coil, is a type of heat exchangers applied in a basic refrigeration circuit .This part is equipped with temperature and pressure as high, vaporized refrigerant go over off the compressor. The condenser eliminates heat from the high temperature refrigerant vapour gas vapour till it condenses into a saturated liquid state, also known as condensation.

After this, the refrigerant is a high-pressure, low-temperature liquid, which put to route to the expansion device of the loop.

Fig 1.5 Condenser

- **Expansion Device**

An expansion valve task is to create a dip in pressure following that the refrigerant exits the condenser. This pressure stop by will cause some of that refrigerant to quickly boil, creating a two-phase mixture. This rapid phase change is named as flashing, and it helps organize the next piece of equipment in the circuit, the evaporator, to perform its required operation.

Fig 1.6 Expansion Device

- **Evaporator**

Just like the condenser, evaporator is also a heat exchanger in the standard refrigeration cycle of the air conditioner, also its name serves its primary function. It absorbs heat while the refrigerant flows through it as a low temperature liquid having low pressure and the fan blows air across the EVA fins which cools the air by heat absorption from the area.

Fig 1.7 Evaporator

Then the refrigerant is directed back to the compressor, and cycle restarts. And that, concisely , this is the way how refrigeration cycle functions.

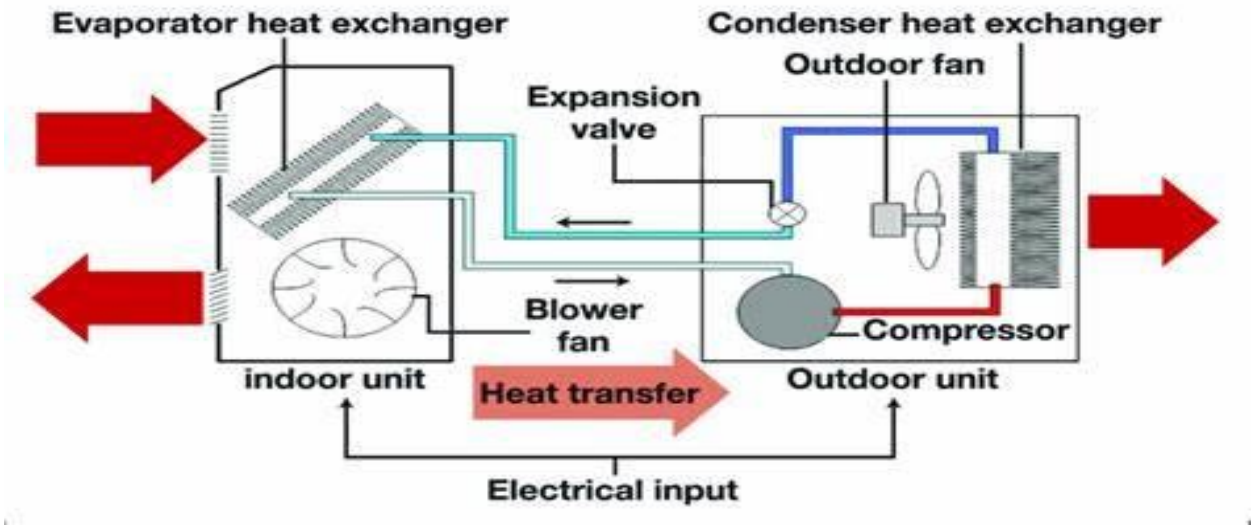


Fig 1.8 Refrigeration Process

1.4 Technologies in Split Air Conditioners

- **ON/OFF Air Conditioners**

On-Off type compressor air conditioners are most common, old and widely used air conditioning technology in the current air conditioning market. In these the air compressor works on its full capacity until the desired temperature is achieved and after that it cut to off state. While the blower keeps blowing the air in the rooms. After some times when the temperature of the room raises certain unit above the set temperature, compressor again starts to run at its full capacity till the desired temperature is achieved again and this process keeps on going.

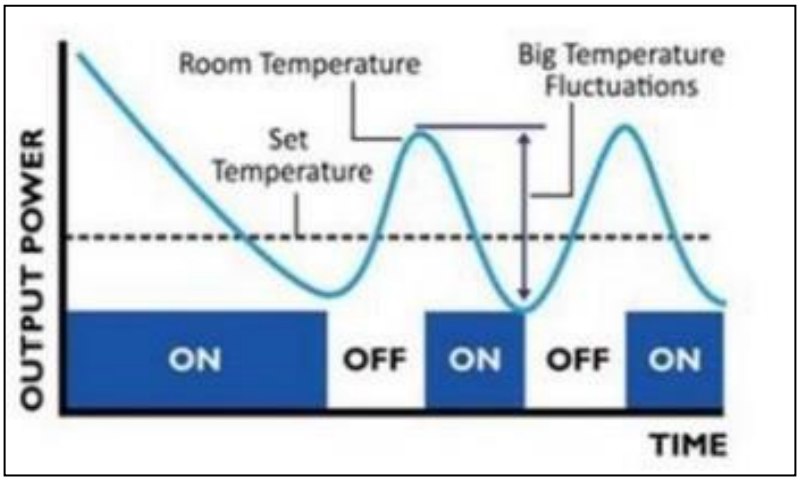


Fig 1.9 Non –Inverter graph

- **Inverter Air Conditioners**

This is the latest technology in air conditioning market and is in the market from past few years and still evolving towards betterment. These air conditioners in addition to older technology have the ability of adjusting the compressor frequency and the refrigerant flow rate as per the required conditions in accordance to the standards set and programmed by the manufacturer. Instead of cutting to off state the compressor keeps on running at lower frequencies to continuously maintain the desired temperature hence providing efficient and more comfortable cooling. These air conditioners are considered to be more energy efficient and are proven to provide more comfortable cooling because of less fluctuating temperature and quieter operation [3].

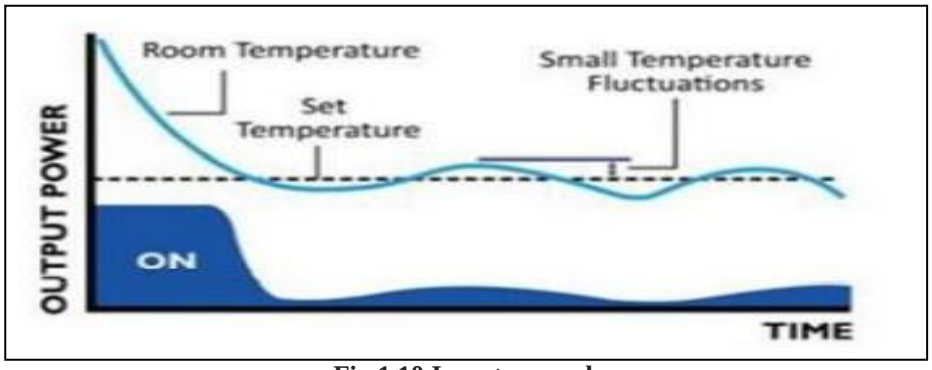


Fig 1.10 Inverter graph

1.5 Dual Cool Inverter Technology Air Conditioners

LG Inverter air conditioners has varying tonnage technology which has lower energy consumption and give faster cooling. Each LG Air Conditioner is designed to ensure finer life , whole protection , highest savings and complete reassurance.

1.5.1 Inverter Technology

It modifies the cooling capacity as needed by the user with automatic compressor speed control. It automatically increases the cooling capacity to provide faster cooling until the desired temperature is achieved and lesson the tonnage thereafter to deliver energy savings.

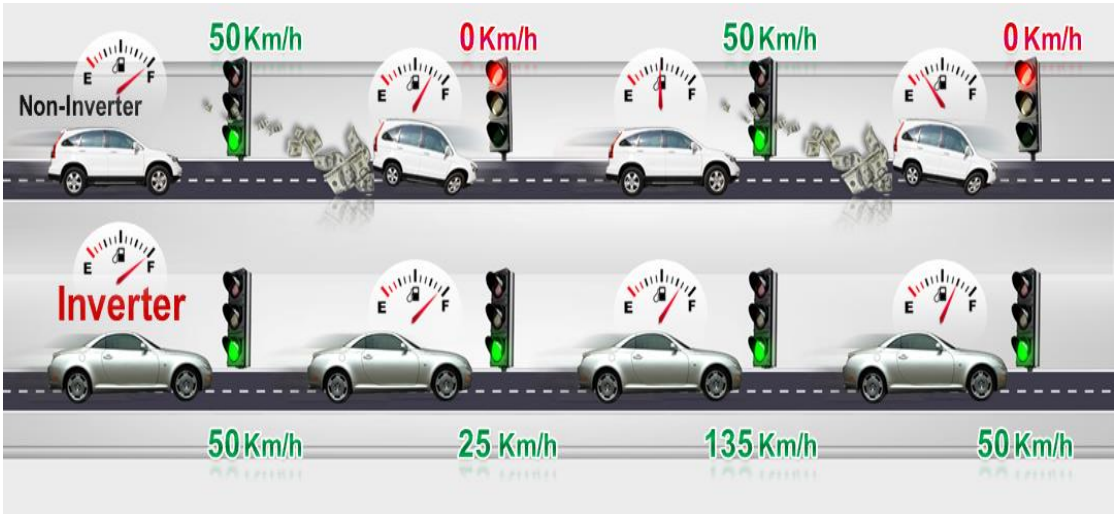


Fig 1.11 Illustration of on/off and inverter technology

1.5.2 Dual Cool Technology

LG Air Conditioner with Dual Cool technology has changing speed Dual Rotary Compressors

with broad rotational frequency extent . It has quick cooling and additional savings as well as severe cutting in noise and vibration intensity.[4]

Fig1.12 Dual Rotary Compressor

The latest LG ACs based on dual inverter compressor technology, a latest BLDC motor which has ability to perform at a broader frequency spectrum to maintain the needed temperature levels with the very less fluctuations. Dual inverter compressors utilize varying tonnage technology.

For example, a 1.5-ton AC which works on varying tonnage technology can change the tonnage from as low as 0.26-tons to as high as 1.71-tons, subjected to cooling needs.

Thus, it works far off the usual operating frequency levels than the standard inverter compressor. These ACs can run at frequencies of even 10Hz to save power.

At the same time, they can run at higher frequencies up to 120Hz to give quicker cooling.

1.6 Few Common Terms related to Air Conditioner

1.6.1 Tonnage

The Tonnage is calculated on the following concept:-

In general, the size and cooling capacity of an air conditioner is rated in the unit of 'Tonnage'.

- 144 Btu is used to melt one pound of ice at 32°F
- 2,000 pounds of ice (1 ton) will need 288,000 Btu to melt (144 Btu x 2,000 pounds)
- If the melting of 1 ton of ice takes place in one day (24 hours), 12,000 Btu must be used by the ice every hour (288,000 Btu / 24 hours)
- 12,000 Btu/hr = 200 Btu/min = 1 ton of refrigeration

1.6.2 About BEE and Star Rating

The Government of India set up Bureau of Energy Efficiency (BEE). on 1st March 2002 under the provisions of the Energy Conservation Act, 2001. The purpose of the Bureau of Energy Efficiency is to help in developing policies and strategies with force on self-regulation and market principles, inside the overall framework of the Energy Conservation Act, 2001 with the basic objective of reducing energy intensity of the Indian economy.

1.6.3 ISEER (Indian Seasonal Energy Efficiency Ratio)

Calculation of ISEER for air conditioners:

Energy Efficiency Ratio (EER) = Cooling Capacity/Power Consumption

Coefficient of Performance (COP) = EER/3.4

BEE labels provide a lot of information about the energy efficiency of the appliance and more stars implies more energy savings. The below table values are stipulated by BEE in 2017, followed by all its amendments. It is for split air conditioning system valid from 1 January, 2022 to 31 December, 2024.

ISEER		
Star Level	**Minimum**	**Maximum**
1-Star	3.3	3.49
2-Star	3.5	3.79
3-Star	3.8	4.39
4-Star	4.4	4.99
5-Star	5.0	

Table 1: Star rating according to EER value [5]

1.7 Inverter Air Conditioner Technology

The Inverter technology is the newest advancement of technology relating to the electro motors of the compressors. Inverter technology means to manage the speed of the motor used for

compressor, so as to constantly adjust the temperature. ACs which possess Inverter Technology have a changing-frequency drive that consists of a controllable electrical inverter to adjust the speed of the electromotor, which implies the compressor and the blower's fan heating/ cooling output. This changing frequency drive is used to transform the incoming alternating current to direct current and then through a pulse width modulation produces current of required frequency. Temperature sensors i.e. thermistor used through a microcontroller can senses each ambient air temperature and speed of the compressor is controlled accordingly. [6]

1.7.1 Advantages of Inverter-AC

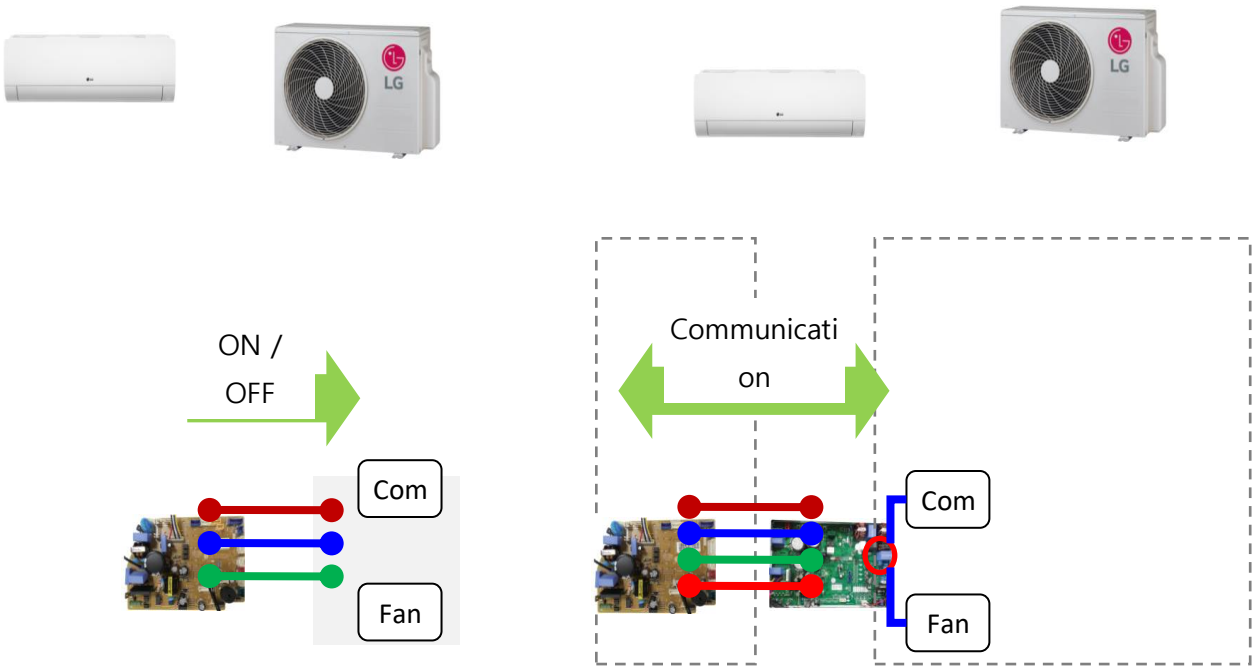
- Quickly achieve the needed room temperature.
- Energy efficient and economical as 30% lesser usage than regular AC.
- Able to prevent excessive load when air conditioner is in running condition.
- No temperature variation.

1.7.2 Disadvantages of inverter-AC

- More expensive than on/off air conditioner.
- Wattage consumption is based on room condition.
- Thicker pipe is must have.

1.8 Comparison between Inverter and Non- Inverter AC

The comparison between inverter and non inverter AC has been shown in the figure 1.13 and table below [6]



Non- Inverter system **Inverter system**

Fig 1.13 Comparison

Table 2: Comparison between inverter and non- inverter / on-off air conditioners

Parameter of Comparison	Inverter air conditioner	On-off air conditioner
Cost	Very expensive	comparably less expensive air conditioner.
Life span	prolonged lifespan	Comparably lesser lifespan
Noise	Noiseless while running.	Sound while running.

Parameter of Comparison	Inverter air conditioner	On-off air conditioner
Energy efficiency	Energy efficient due to its advanced mode of operation.	Consume energy to a greater extent.
Technology	Its compressor runs at full speed to adjust the temperature needed	It functions either at full power or no power when it is switched off.

CHAPTER 2

SPLIT AIR CONDITIONER- ELECTRICAL ASPECTS

2.1 Split Air Conditioner

The split air conditioner is distinctive in that it set apart the temperature from the humidity during its functioning. It contains two different units i.e. indoor called IDU and outdoor called ODU . The IDU contains a blower with evaporation and the ODU has compressors and desired cooling. The split air conditioning system consists of a compressor, condenser coils, an expansion joint, and a ventilation fan. The IDU contains the evaporator coil, the blower, and the filter whereas the ODU has compressor and condenser coil with a fan. Furthermore, the whole unit has variable individual unit boxes that operate with the thermostat which controls the full system.

2.2 Representation of a Split AC unit

Indoor Unit **Outdoor Unit**

Fig 2.1 IDU&ODU

2.2.1 Major electrical and electronic parts :

- IDU PCBA
- IDU Motor
- Stepper Motor
- Remote
- Display
- ODU PCBA
- ODU Motor

2.2.2 Mechanical parts

<u>Outdoor Air Conditioning Unit</u>: It is home to essential parts needed for the system to run as efficiently as it should.

ODU Consists of

- Air Conditioning compressor
- Air Conditioning Condenser Coil
- Expansion valve
- Fan
- Refrigerant

<u>Indoor Air Conditioning Unit</u>

- Air Conditioning Evaporator coil
- Filters
- Air Conditioning ducts

2.3 Electrical circuitary of the residential air conditioner

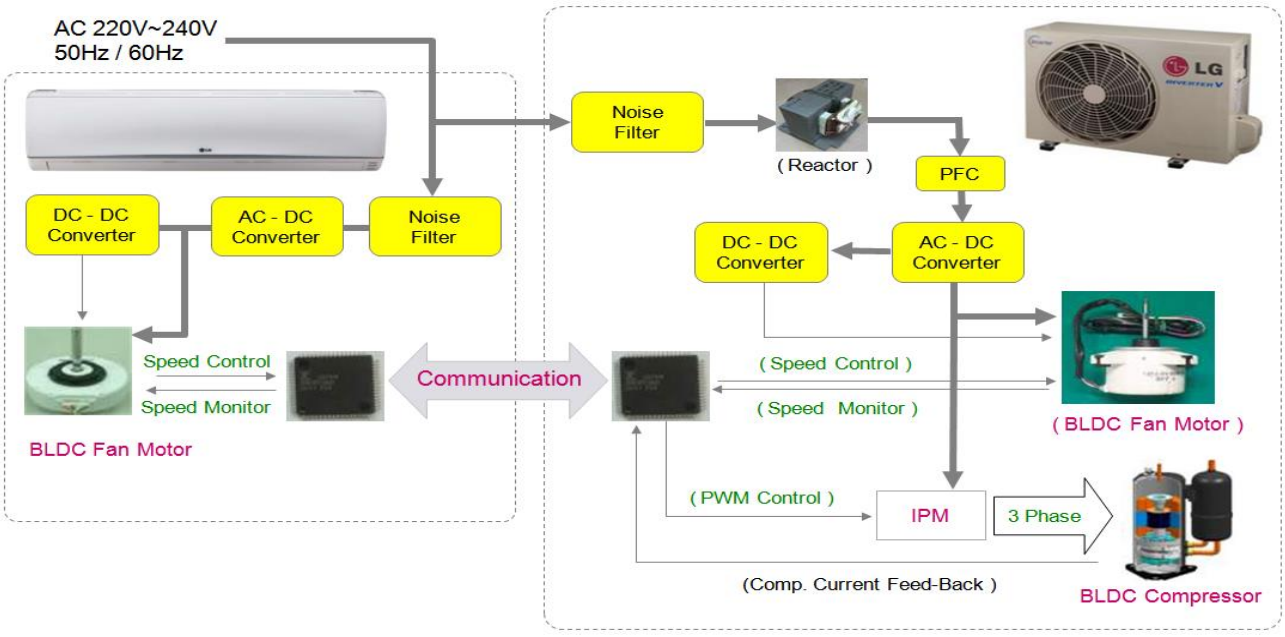


Fig 2.2 Electrical circuitry

Fig 2.1 shows the major electrical and power electronics circuitry utilized in an air conditioner .

2.4Working of split air conditioner

When a pressure is applied to a refrigerant in the ODU's compressor coil and it turns into a gas inside the unit which is being heated. The gaseous refrigerant will then flow through coil which makes it turned from gas to liquid. After that pressure is applied on the liquid and it flows through the ODU's condenser coil and then to the expansion valve joint . Once it flows through the expansion valve joint, it will decrease pressure and changed to gas which take on a low temperature by emitting heat. The gas flow back to the compressor and cycle goes on and on.

The IDU will use air absorbed from the occupied area and make it pass over IDU's EVA coils to reduce its temperature. The blower then blow back the cold air into the room and will continuously circulated on every side of the occupied space till wanted temperature is attained. The system will turned off automatically after achieving the set temperature.

2.4.1 Electrical and electronics aspects of RAC

The main electronic part of the split air conditioner is the PCB. PCB controls all the functioning in the air conditioner.

- **IDU PCB**

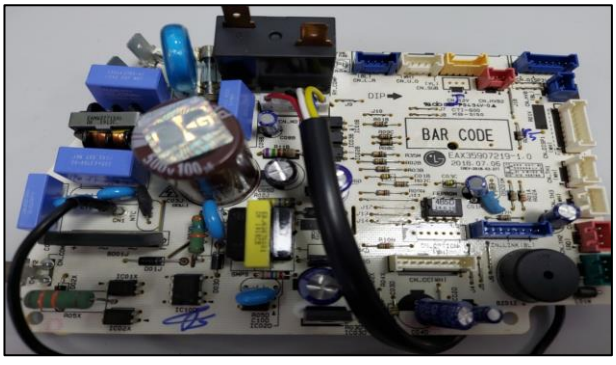


Fig 2.3 : IDU PCB

- **Switch Mode Power Supply**

Every electronic apparatus /device needs a reliable power supply unit (PSU) for its functioning or it is built within to transform the mains ac supply to a dc voltage of required level. **S**MPS (Switching Mode Power Supply) is generally utilized in many of the power supply circuits. A switched-mode power supply (SMPS) is an electronic circuit which is used to transform power using switching devices that are switched on and off at high frequencies, and storage components such as inductors or capacitors to supply power when the switching device is in its non-conduction state [7].

- **SMPS consists of different parts and sections**

❖ **Input surge and fault protection circuit.**

The fault protection circuit consists of a fuse and a Metal Oxide Varistor (MOV). Whenever the input voltage shoots up more than the limit often called as voltage surge causes extreme current flow. In this situation, MOV becomes short to the fuse and the maximum inrush current flows through the slow blow fuse.

❖ **Input filter**

A 250 V ac X-type line capacitor is connected to avoid unwanted line voltage noise generated in the circuit.

❖ **Full wave Rectifier**

The analog input voltage is digitized through a full wave rectifier. The resultant digital signal is then filtered and dc level is smoothened using a 400V capacitor with 22uF capacitance. The integrated circuit is connected to the transformer winding to get the input bias.

❖ **Switching IC**

The IC is embedded with high-power MOSFET that performs switching across the transformer. A diode changes the analog output to the dc output followed by the resistor to resist the inrush current. The output is then passed through the capacitor to smoothen the dc output ripple.

❖ **Isolation & EMI Filter**

It is important to isolate the circuit magnetically to avoid stray currents. So we are using a ferromagnetic transformer with three windings i.e. Primary, Secondary and Auxiliary C1 is a Y-class 2kV capacitor. It is kept filtering and reduce the EMI interference caused by induction in the circuit.

- **SMPS Block Diagram and its Working Principle**

1. The primary step is rectification i.e. input high voltage ac supply (230V) is transformed into high voltage dc (230V). through the bridge rectifier circuit.

2. It is passed through a filter circuit for filtration.

3. Then the filtered DC voltage of high magnitude is passed through a high-frequency switch which is controlled by the feedback and control circuit and then we get high-frequency square wave ac.

4. By using a fly back high-frequency transformer, the high-frequency ac received is step down to a low voltage (maybe 15V, 5V, etc)

5. Then again rectification is done to get low voltage ac to dc.

6. After this it filtered through filter circuit .

7. The control circuits like PWM and feedback path are required to adjust the output dc supply.

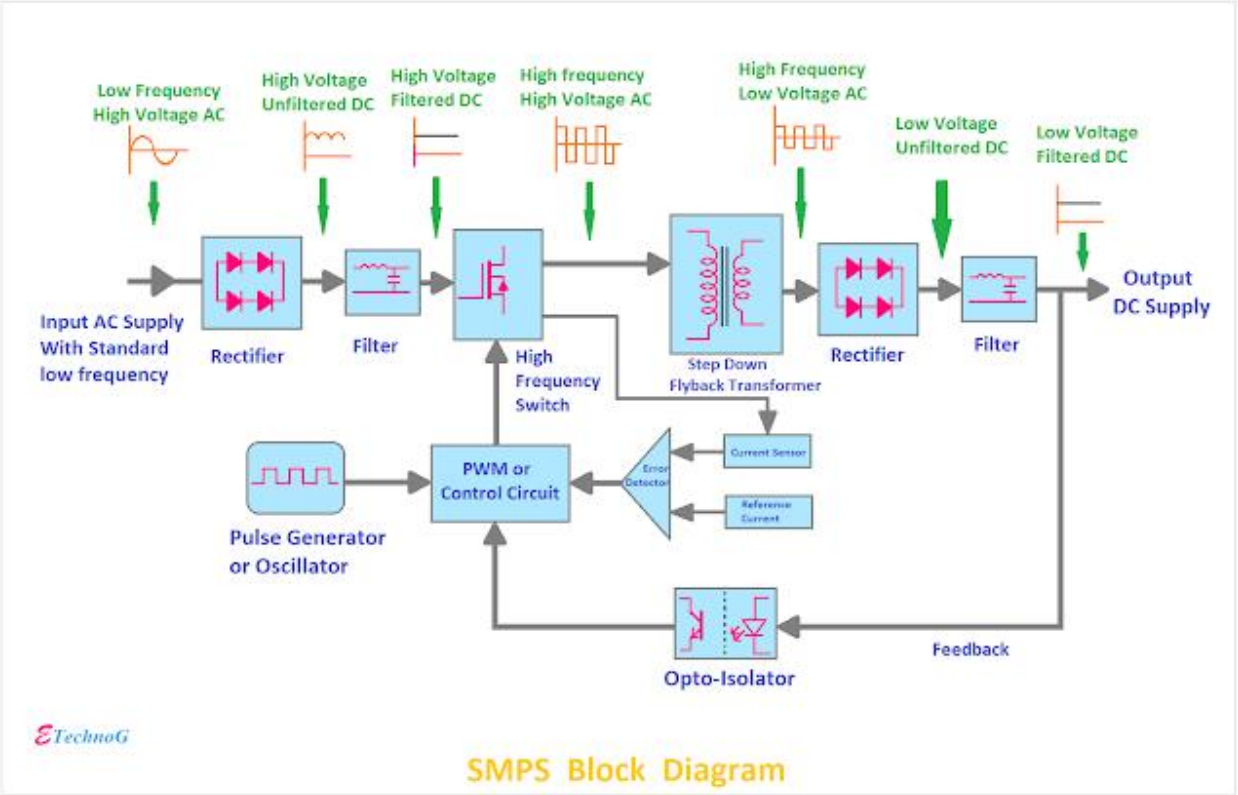


Fig 2.4: SMPS Block diagram

❖ EEPROM

EEPROM (Electrically Erasable Read Only Memory) is small storage space which possess the code for mini split to function and adjusts the operational parameters of the air conditioning system.

➢ ODU PCB

The PCB is connected to the indoor PCB via 4 cable that consists of a communication wire, live , neutral and earth . The PCB controls the functioning of compressor and fan motors majorly. there is a microcontroller present that receives and process the data and as per the programmed logics it sets the required conditions. The components attached are temperature sensors , compressor and fan motor.

There is the power circuit which consists of all the protection circuit i.e. overvoltage and under voltage protection and control circuit which has the communication channel and functional working through temperature sensors.

Fig2.5: ODU PCB

- **The Split Air Conditioner's electrical and electronic Parts working:**

❖ **IPM – Intelligent Power Module**

An IPM embrace a control integrated circuit which contains IGBT drive circuit and a protection circuit, therefore it is easy to create peripheral circuits and can assure high system reliability.

IPM is the most important in inverter based things such as inverter air conditioners, refrigerator, motor drives.

IPM, as its name suggests is a high performance module has 2 parts:

IGBT drive circuit – used for drawing greater performance from an IGBT Chip and bridge drive chip which is vital compact part for BLDC motor. The pins on IPM are assigned as dc input voltage , ac output voltage, input signal voltage, sensor signals etc.[8]

Custom IC : Needed for self-protection functions like short circuit, supply under voltage, and over temperature etc.

For compressor motors i.e. the ODU motor, fan motors of an air conditioner , IPM module is commonly used.

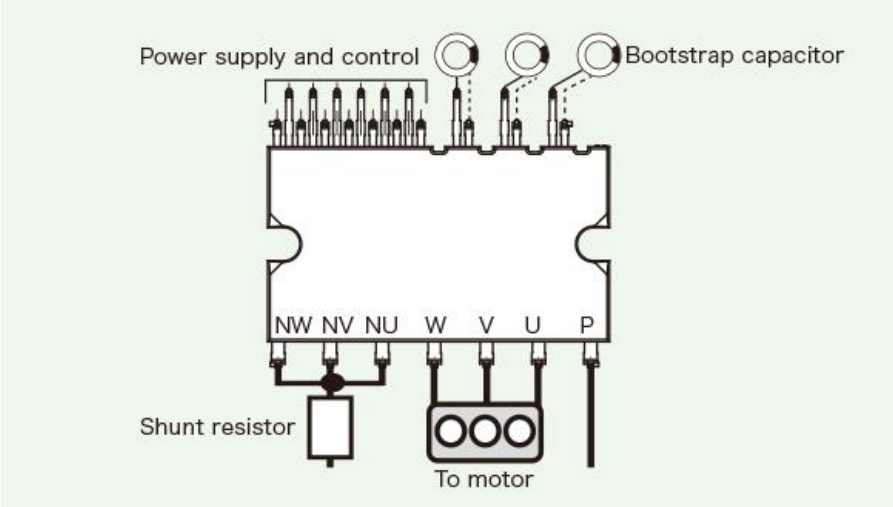


Fig 2.6: IPM Module Schematic diagram

➢ **Features of electric power modules**

- Arrangement for inverter, for PFC, built-in bootstrap diode type and rectifier diode type.
- Compact and highly efficient
- Lossless and less thermal impedance
- Qualitative and reliable

❖ **Power Factor Correction**

It is used to maintain unity power factor and lowers the harmonic distortion in the supply current and generates a current waveform close to a fundamental sine wave.

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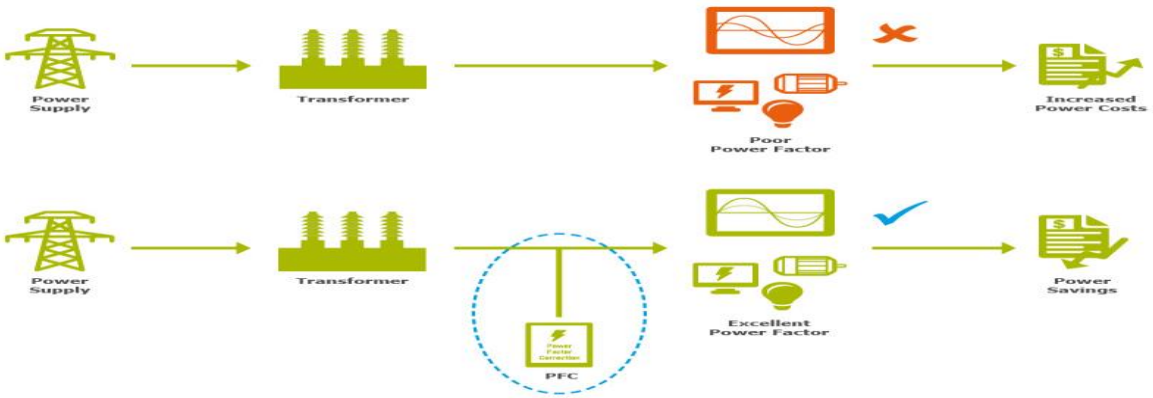


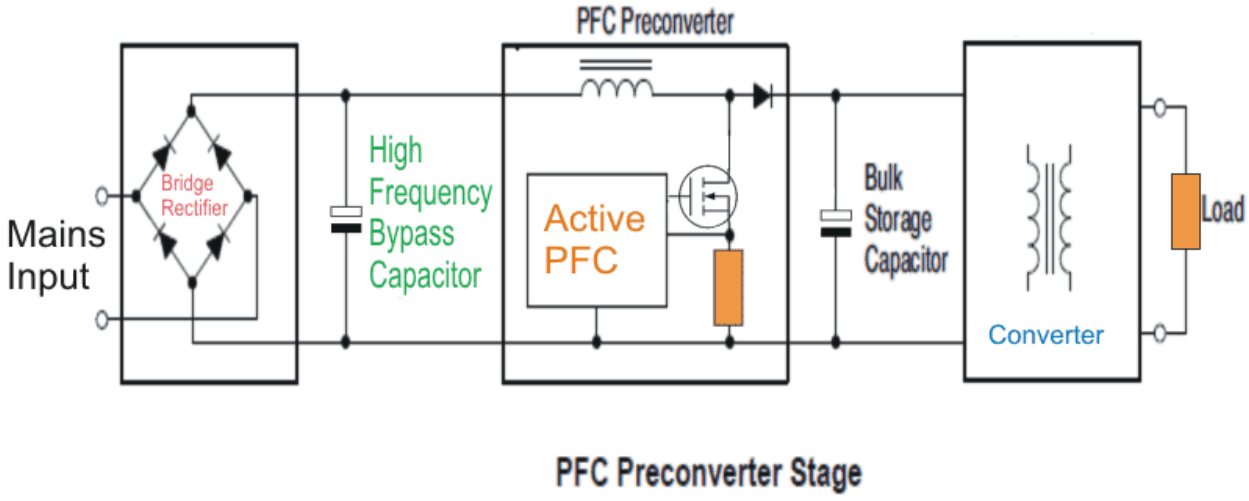


Fig 2.7 PFC Circuit

- **SYSTEM BLOCK DIAGRAM:**

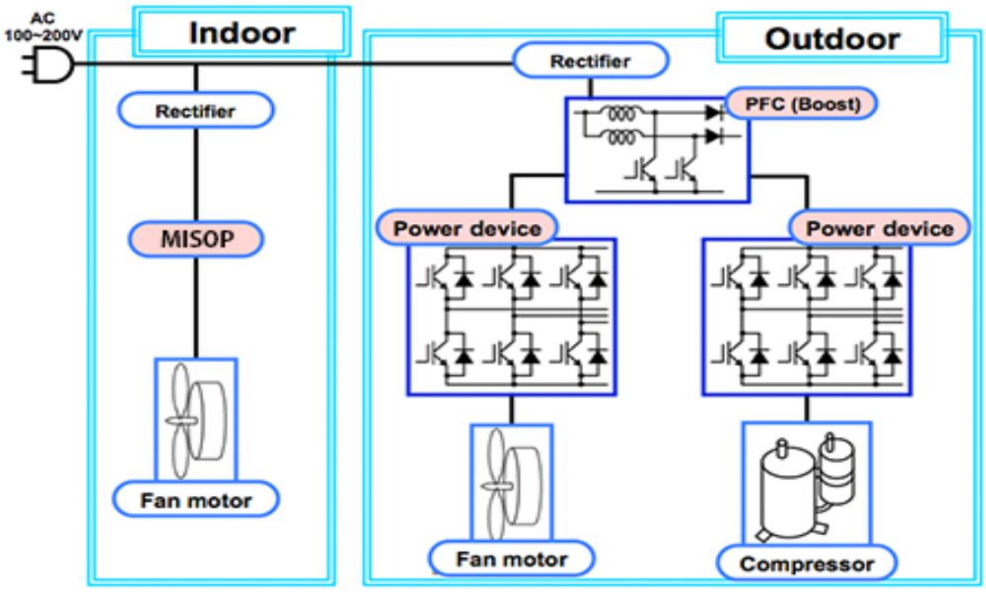


Fig 2.8: Combined IDU and ODU block diagram

- **BRUSHLESS MOTOR DRIVE CIRCUIT**

IGBT drive chip is used to energize the winding of a BLDC motor in a certain order to make it run continuously in a specified direction. IGBT switches are used to energize the 3- phase winding of the BLDC motor.

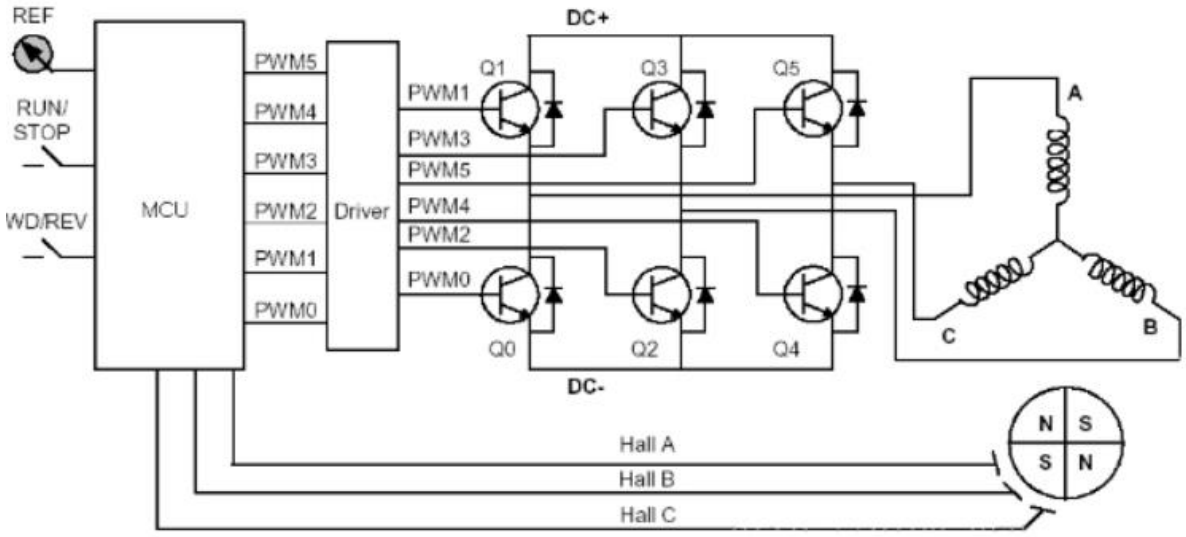


Fig 2.9: BLDC Motor Drive Circuit

2.5 Inverter Operation

SMPS i.e. Switch Mode Power Supply is utilized using various peripheral components such as IPM. It converts ac to dc using switching devices which helps to obtain an average value of the desired voltage level. DC voltage undergoes high frequency switching then used to excite the rotor coils of BLDC compressor motor at different time instants and thus motor speed is regulated accordingly resulting in energy savings.[9]

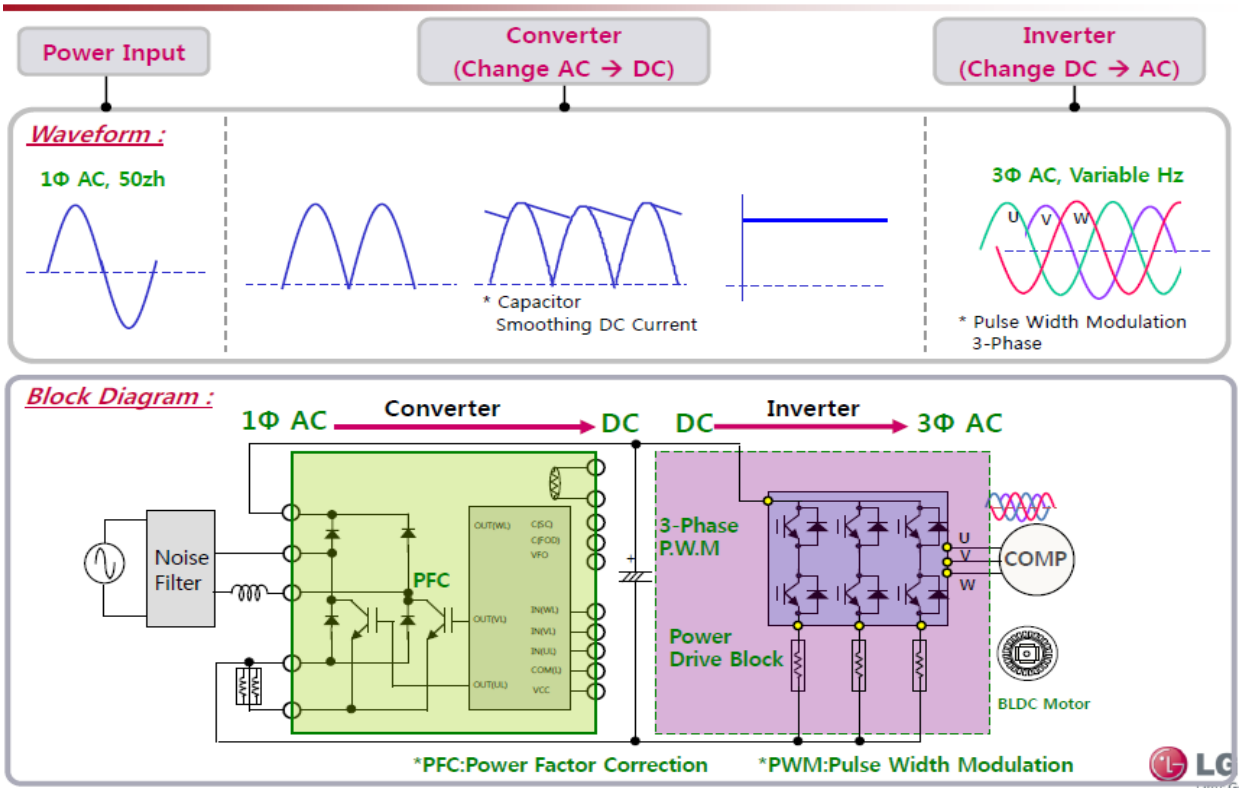


Fig 2.10: Inverter Circuit Representation

2.6 Specialty of Inverter air conditioner

2.6.1 BLDC Motor Control

In a BLDC motor, the rotor of the motor is made by using permanent magnets whereas the stator contains the winding. As the name suggests, there are no brushes and commutator.. Therefore the problems like sparks, brush life, brush residue or the brush maintenance and electrical noise are not there. There is power electronics control i.e. the IPM linked to the windings of the motor which are having control over motor speed through a micro controller.

Various monitoring as well as protection circuits are incorporated into the electronic controls to secure efficient running and reliability.

Hence, the main advantages of the BLDC motor compressor is its noiseless function, small size, lastingness, energy efficiency and better capacity adjustment. Its applicability is no longer

restricted to air conditioner equipment but also in other household appliances like, washing machines, refrigerators, fans and pumps.[10]

In many SRAC designs, IDU fan used is DC i.e. run by BLDC motor. Also the ODU fan used is DC fan instead of the traditional AC fan.

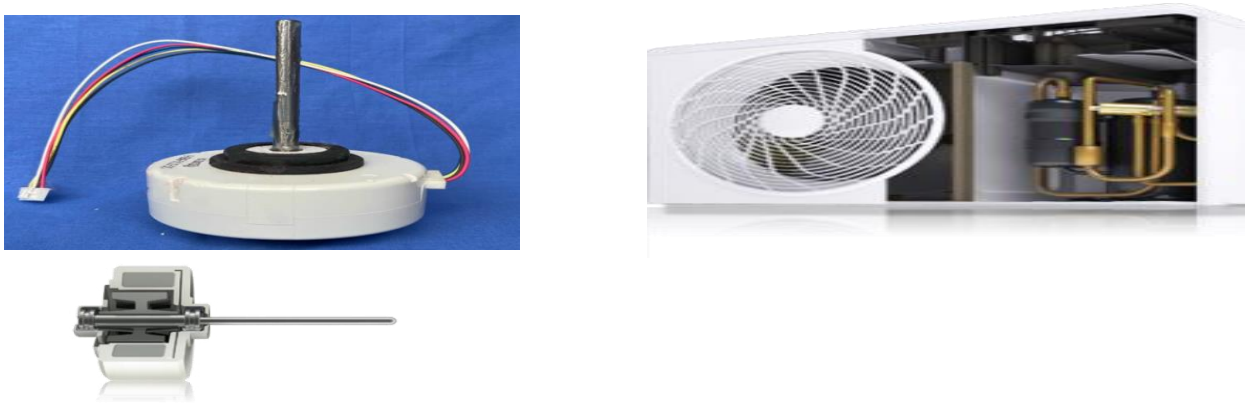


Fig2.11 BLDC motor

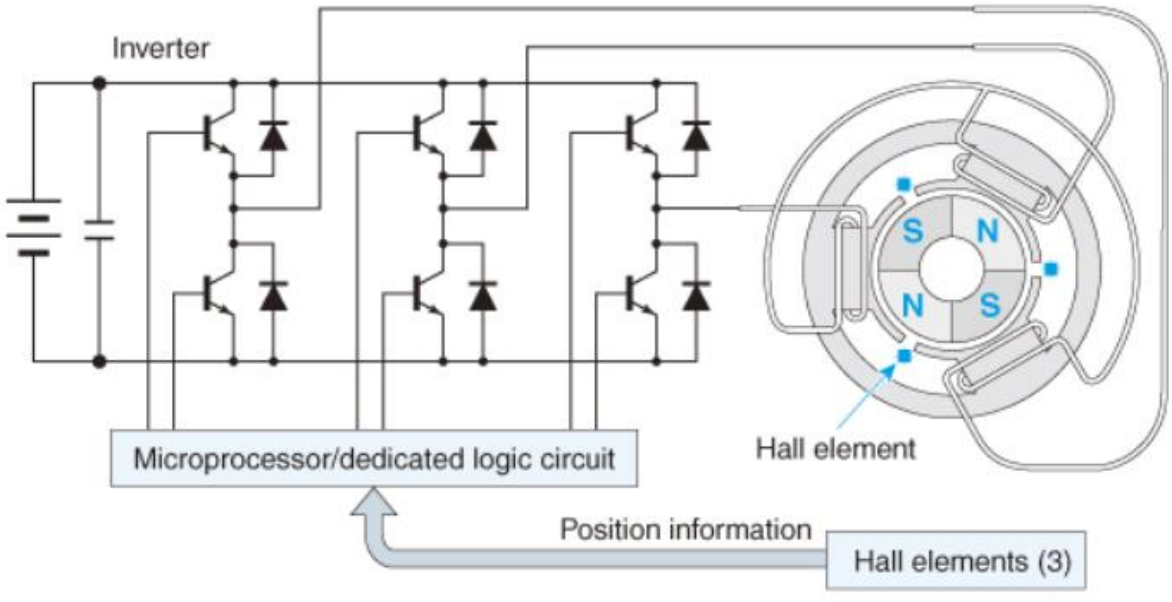


Fig 2.12: Configuration diagram of a BLDC motor using an inverter microcontroller

2.6.2 Advantages of using BLDC motors in inverter technology

- Higher Energy efficiency.
- Directly driven by renewable energy like solar power .
- BLDC motors runs on nearly at unity power factor.
- Offers higher frequency variation, and higher dynamic responses. Therefore utilized for high speed usage (10,000 rpm or above) and dynamic speed control.

2.7 RAC Circuitry

2.7.1 RAC Schematic diagram

This is the basic schematic circuitry of RAC [11]

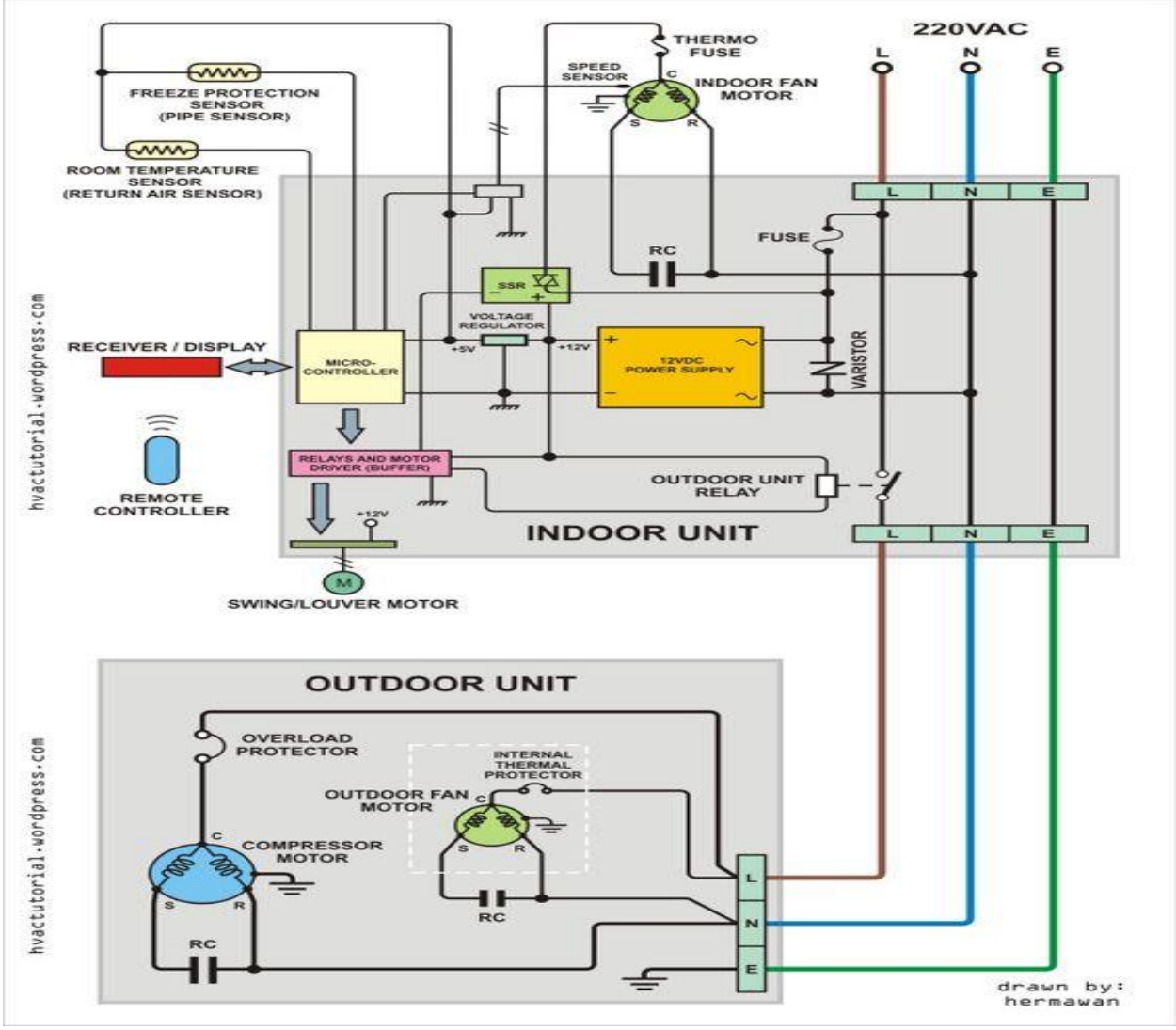


Fig2.13: Basic IDU and ODU circuit

2.7.2 Control Flow Chart

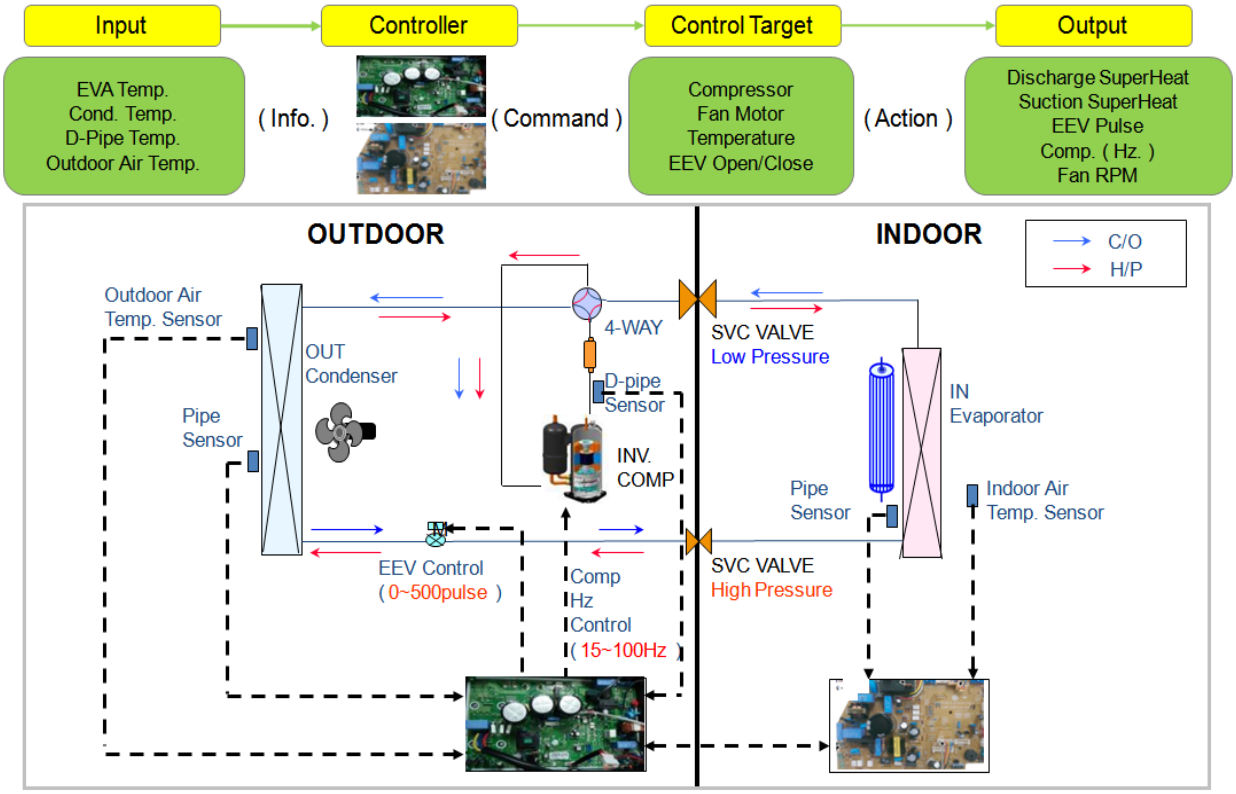


Fig2.14: Control Flow Chart

CHAPTER 3

PART FAILURE ANALYSIS

Project : PCB Defect analysis to improve the FFR in RAC

Quality analysis of products RAC and its parts is done which comes under the FFR analysis. A team consisting of QA and R&D members is made for FFR analysis. The field failure analysis of faulty products is done by testing separate parts i.e. electrical and mechanical. Electrical and electronics parts which I used to test for errors are IDU PCB , ODU PCB, IDU motor, display and remote are obtained from the field i.e. the customer end. Based on the error analysis, root cause is identified which results in making improvement plan in design and specifications in order to improve the overall product quality and reduction in failures. These parts are analyzed quarterly in a year and countermeasures were taken accordingly.

FFR analysis is done to analyze the root cause of defect of Outdoor/Indoor control box PCBs of RAC found to be faulty at field.

3.1 Need for failure analysis

- **FFR in RAC**

- On the account of customers' complaint regarding failure of electrical, electronic and mechanical part of the AC Unit, Service man replaces the defective part with a new one.

- Our team work start from calling, checking and analysis of the defective parts and their components to find the nature of defect and the frequency of its occurrence in order to find out the concern related to it.

- After analysis of the defective Part, Counter measures are taken to improve the quality of product and its effectiveness is horizontally deployed in the other models to have a smooth start up of our product manufacturing.

3.1.1 Need for Optimization:

- Failure Cost Reduction
- Quality Improvement

- Upgrade ratings of components
- Component improvement

3.1.2 Causes of Field Failure

- Faulty design
- Production department negligence.
- Quality department negligence
- Rash handling at the time of storage
- Improper transportation
- Packing failures
- Customer misuse

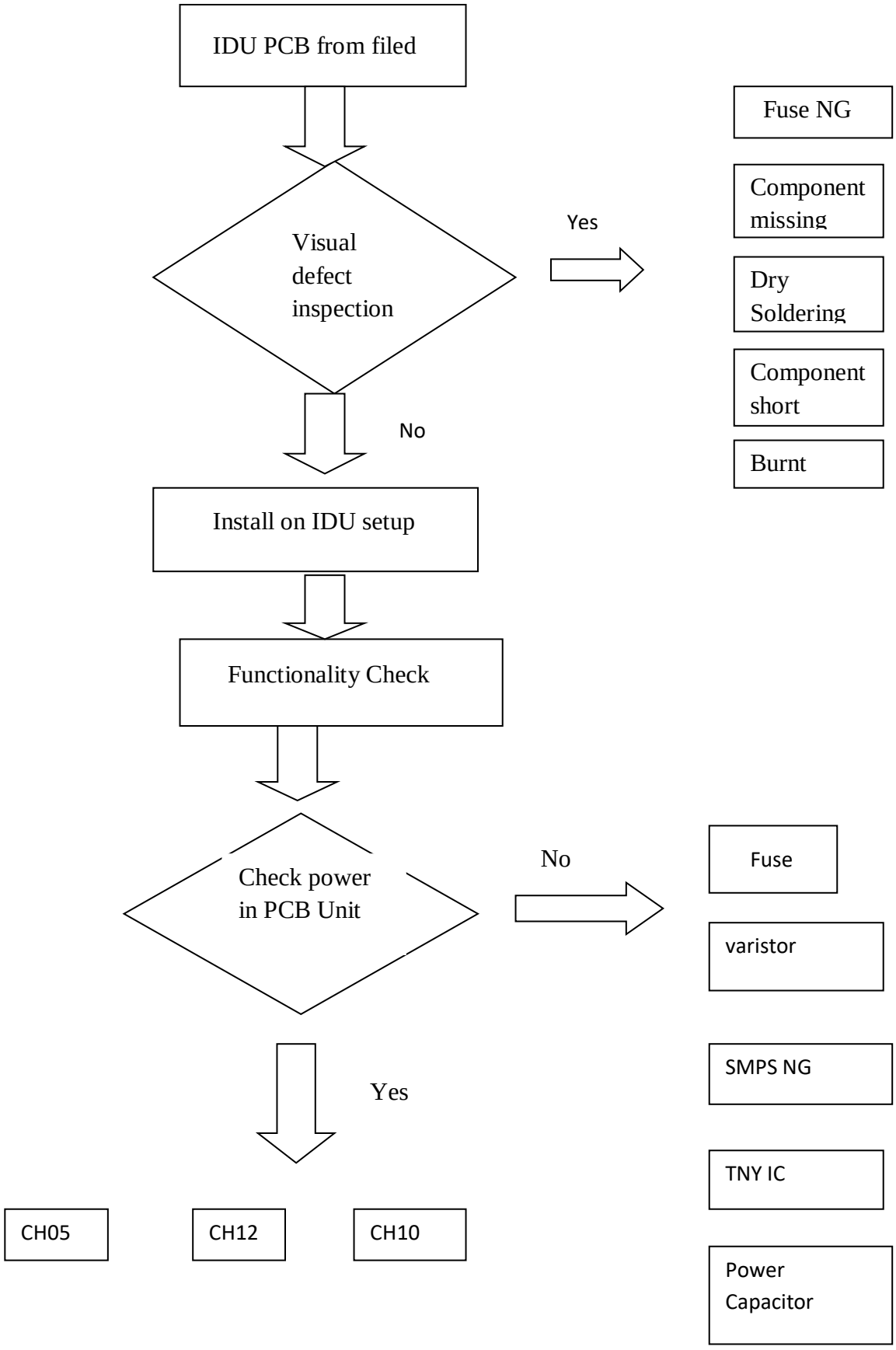
3.1.3 Majority failing parts at the field :

- PCBs- indoor and outdoor
- Evaporator coils
- Remote
- Indoor BLDC motors
- Compressors

3.2 IDU PCB ANALYSIS

3.2.1 Methodology for testing

- The first step in IDU PCB Analysis is the visual inspection of PCB like Power supply region, Fuse check, Component miss, Dry solder , components short and burnt etc.
- Once done with Visual Inspection, we check the functionality of the PCB by using following setup shown in fig 3.2


IDU PCB from filed
Visual defect inspection
Yes
Fuse NG
Component missing
Dry Soldering
Component short
Burnt
No
Install on IDU setup
Functionality Check
Check power in PCB Unit
No
Fuse
varistor
SMPS NG
Yes
TNY IC
CH05
CH12
CH10
Power Capacitor

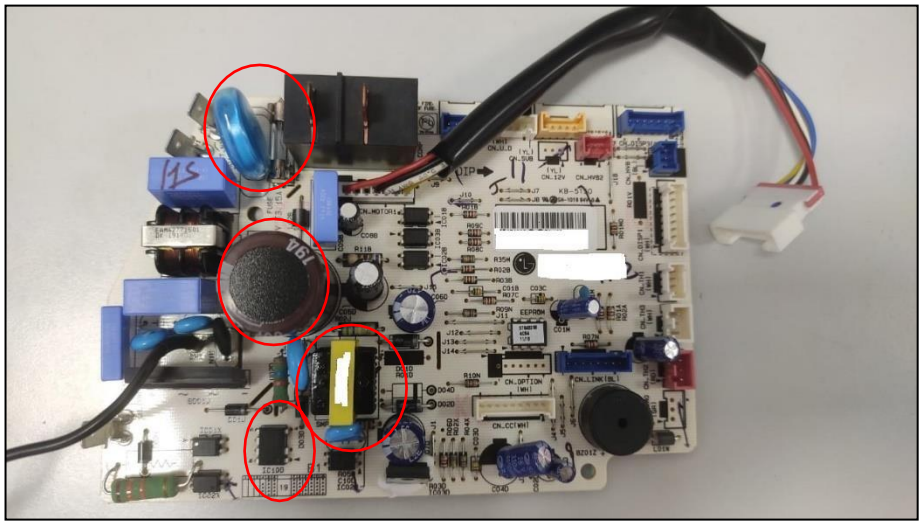


Fig 3.1: IDU PCB check points

- **Major check Points:**
  - Fuse
  - Varistor
  - SMPS
  - TNY IC
  - Power Capacitor

Dead PCB : The possible reasons are:

- Fuse NG
- SMPS NG
- TNY IC NG
- Capacitor short
- Resistors NG
- Diode NG
- Voltage regulator NG causing variable voltage.

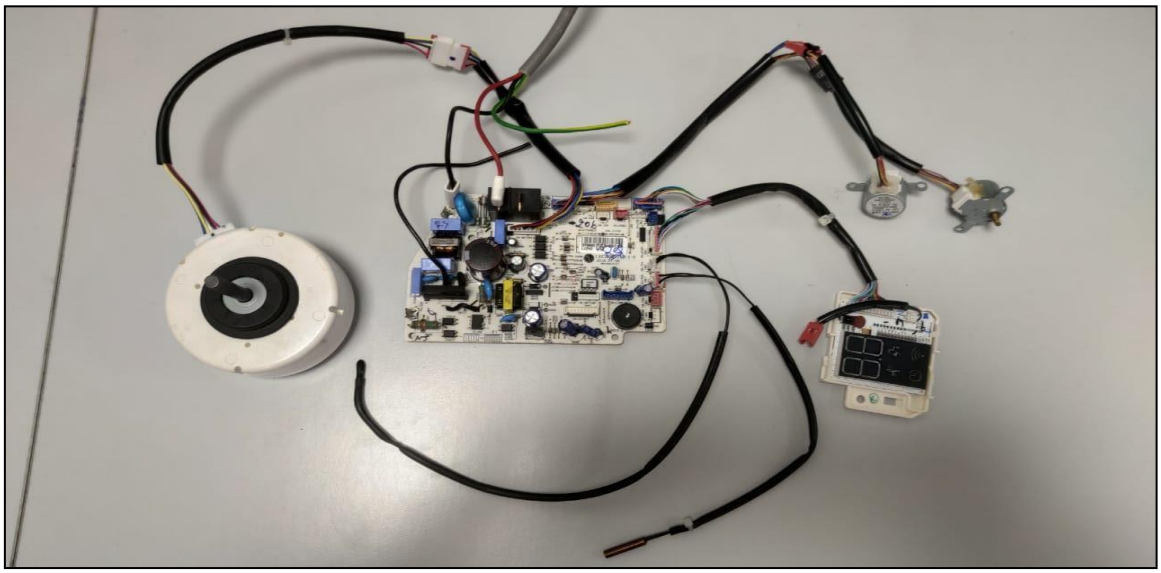


Fig3.2: IDU PCBA Checking Set Up

3.2.2 Error Code detection

On the basis of error code we analyze the issue and troubleshoot.

Table 3: Inverter AC IDU codes and faults[12]

Error Code	Description
1	Indoor unit room temperature sensor error
2	Indoor unit inlet pipe sensor error
3	Wired remote control error
4	Float switch error
5	Communication error between indoor and outdoor units
6	Indoor unit outlet pipe sensor error
9	Indoor unit EEPROM error
10	Indoor unit BLDC fan motor lock
12	Indoor unit middle pipe sensor error

- **Common Errors in IDU PCBA**
  - **CH05 Error**

It is a communication Error occurs when communication do not take place between indoor and outdoor PCB by any means indoor PCB NG, interconnecting cord NG and communication circuit of either PCB NG.

➢ **CH12 Error**

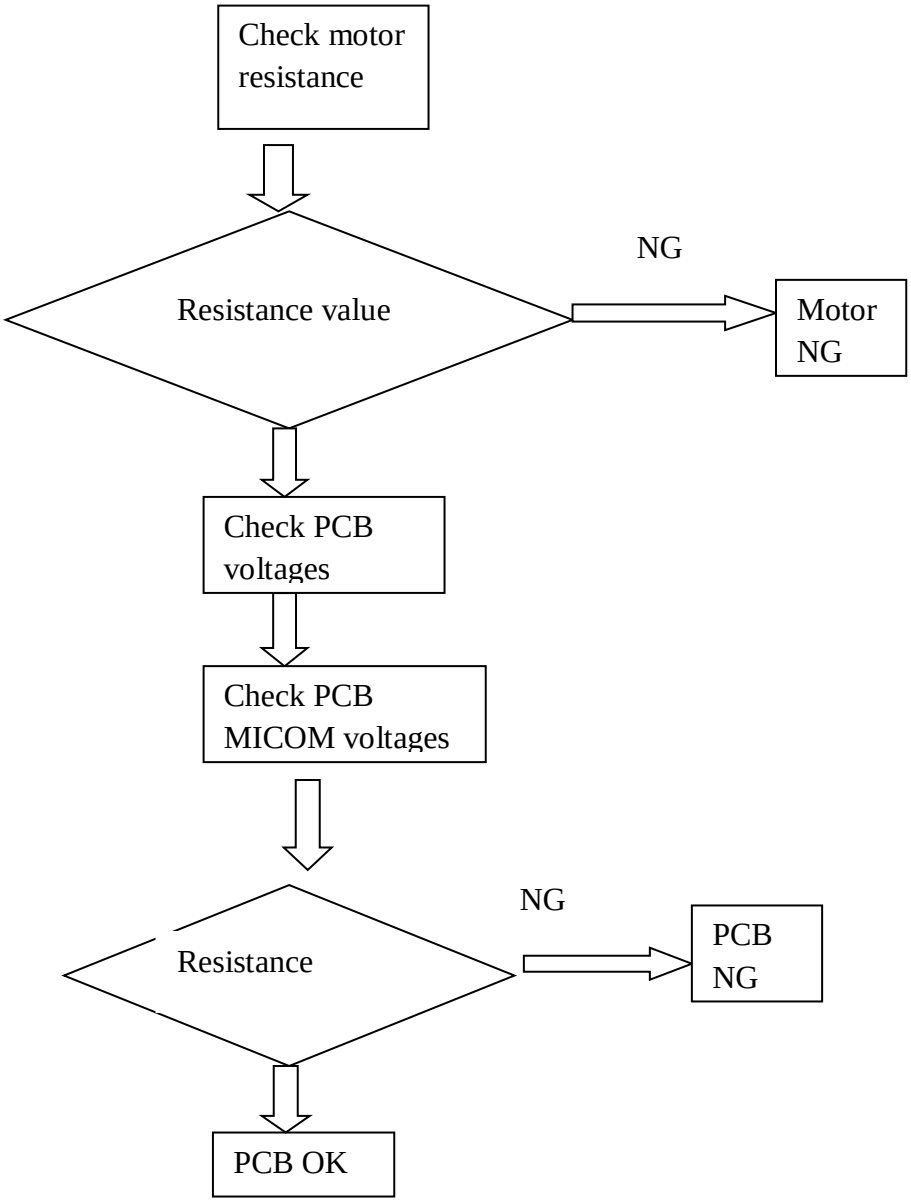
- Indoor unit middle Pipe sensor Error

For this error we check the resistances , mostly the resistors are NG that cause NG voltage at the pin making indoor sensor NG.

➢ **CH10 Error**

IDU motor Error occurs due to PCB Failure, Motor Failure, Poor Connection

➢ **CH10 debugging approach.**

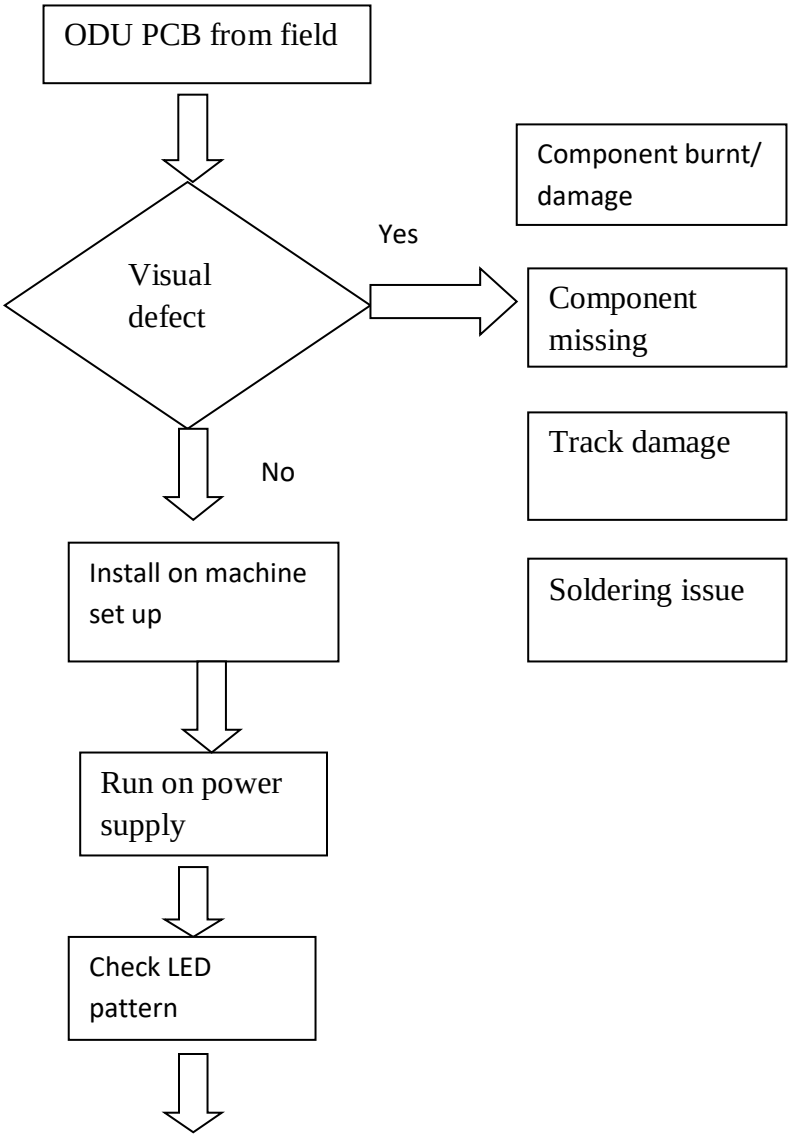


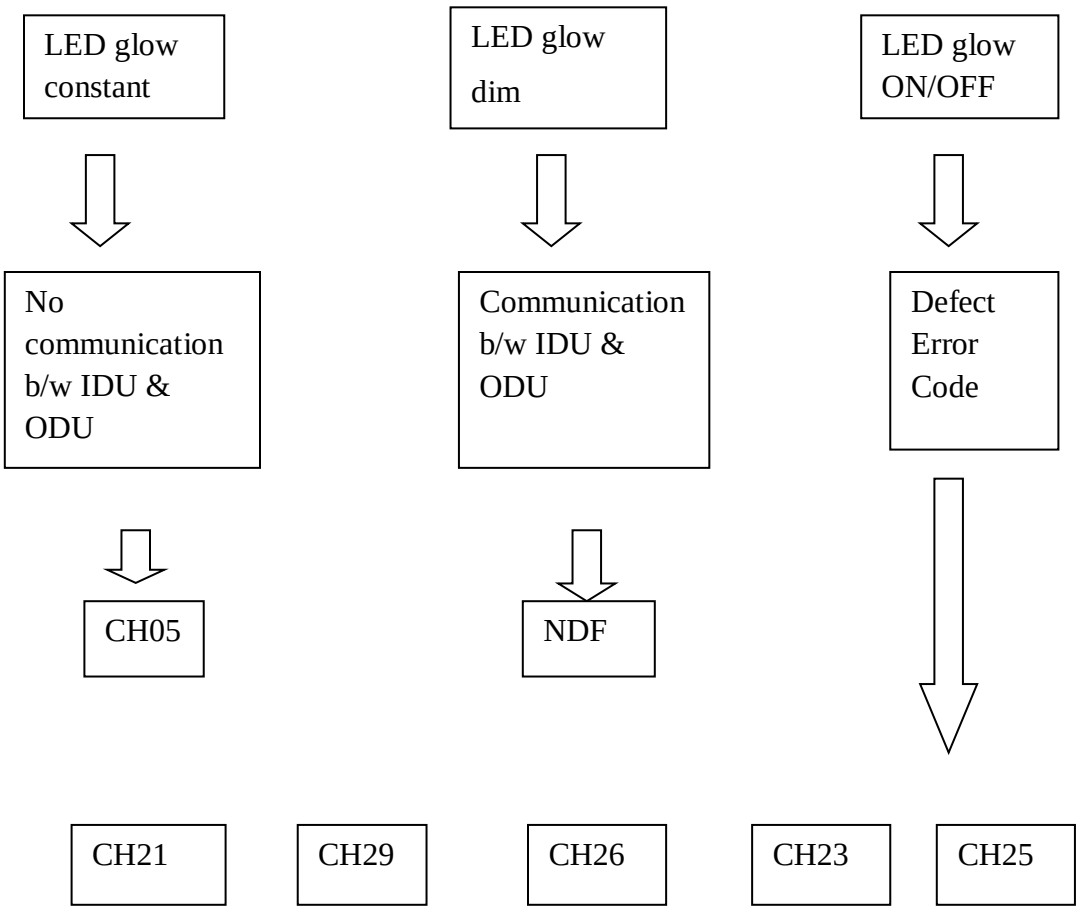
3.3 ODU PCB Analysis

3.3.1 Requirements:

- Complete set up of indoor and outdoor unit.
- Multi meter
- Schematics
- Magnifying lens
- Error reference guide

3.3.2 Testing Methodology





- The control boxes that are failed in the field are handed over to FFR team for the analysis of defect or error.
- Sometimes the PCB needs to be installed and run to check the error and defect.
- Every defect in the PCB cause the malfunctioning of one or the other components which is then shown as an error code by a small LED mounted on board.
- The LED blinking pattern is used to identify the error code.
- Each code denotes some component's malfunctioning which is then further analyzed accordingly .
- The PCB undergoes a visual testing with the reference PCB to check for missing/damaged component ,pattern crack, shorting issues etc.

- In case of no visual defect , PCB is installed in the machine set up and tested by giving direct supply and measuring the voltage and current values at specified checkpoints.
- The analysis report is then shared with vendor and other departments for counter measures.

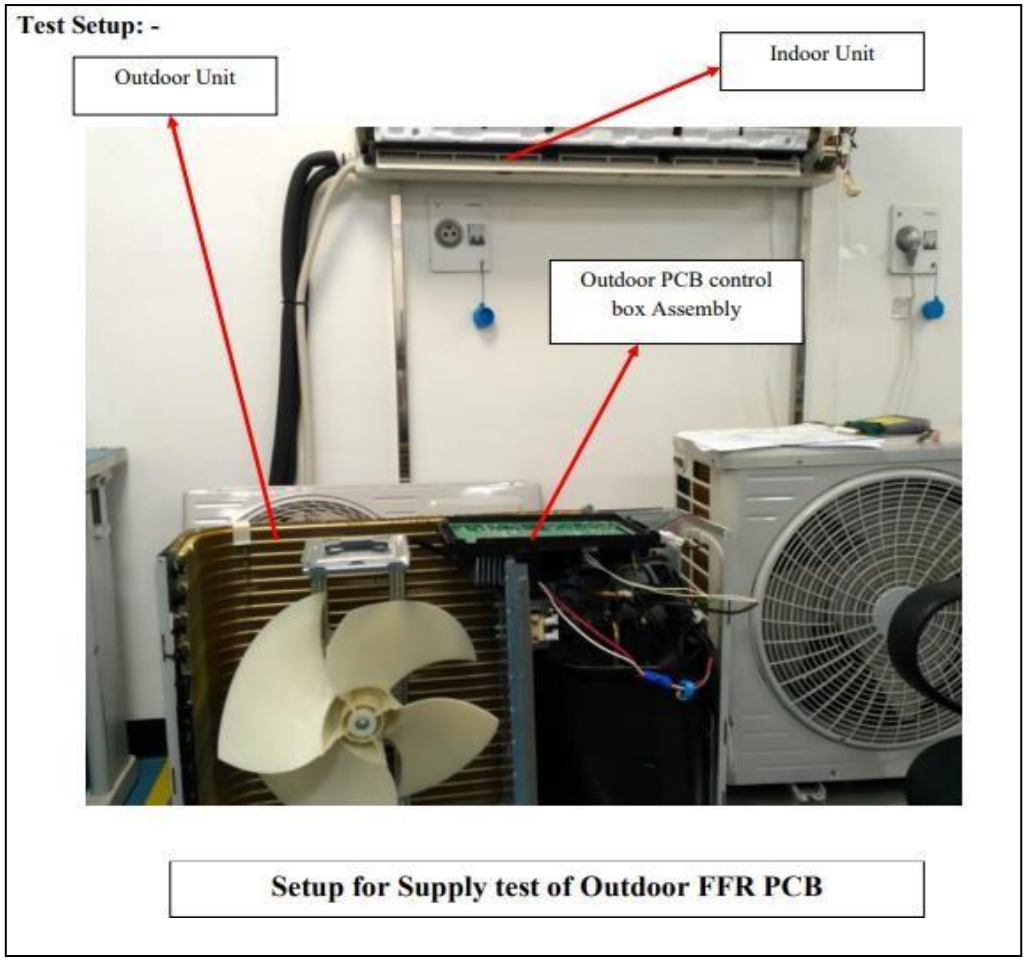


Fig 3.3 ODU PCB Test Setup

3.3.3 LED Status Checking:

The error code is identified by the ODU PCB LED blinking pattern.

Like for CH21 , LED Blinks 2 times and then with a pause blink again for 1 time . It indicates that there is CH21 error.

Table 4: Inverter AC ODU codes and faults[12]

Error Code	Description
21	DC Peack (IPM) fault
22	CT2 (Max CT)
23	DC link low voltage
26	DC Comp position error
27	PSC fault
29	Comp phase over current
32	Inverter compressor D pipe overheat
34	High pressure sensor high
35	Low pressure sensor low
36/38	Refrigerant leak detection
37	Exceed the compression ration limit
40	CT sensor error
41	Discharge pipe sensor error
42	Low pressure sensor error
43	High presure sensor error
44	Outdoor air sensor error
45	Cond middle pipe sensor Error
46	Suction pipe sensor Error
51	Excess capacity (Mismatch between IDU and odu unit)
53	Communication error
61	Cond. Pipe high
62	Heat sink sensor temp. High
67	BLDC motor fan lock
72	Detect 4 way valve transfer failure
93	Communication error

3.3.4 Common Errors related to ODU PCB:

- **CH-21/CH-29 Error**

Error CH 21 is for DC peak i.e. Inverter compressor malfunction or IPM fault. Error CH 29 is for Compressor phase over current.

- **Error CH 26**

The error is for DC Comp Position error. It was the one of the errors with highest frequency.
In some of the cases it was very tough to find out the fault because ofvery minor issues.

- **Error CH 23**

The error come up when the DC link voltage is less than 140V or higher than 400V. The error code is identified by blinking of LED mounted on the outdoor PCB. The PCB was first tested on function testing jig in IQC for the NG or OK status. The NG PCB is than further analyzed for the fault.

- **Error CH 25 and CH 23**

The error CH23 come up when the DC link voltage is less than 140V or higher than 400V while error CH 25 occurs when AC input voltage is abnormal.

3.4 IDU MOTOR DEFECT ANALYSIS

3.4.1 Objective: To determine the root cause of defect in IDU motor found to be faulty at the field.

3.4.2 CH10 ERROR

IDU motor Error occurs due to PCB Failure, Motor Failure, Poor Connection, Terminal and line resistances out of limits, harness failure etc.

The above IDU PCBA set up in fig 3.2 is used with reference IDU PCB to check the proper working of IDU motor.

3.4.3 Major defect Outcomes:

- Motor Dead
- Motor RBH
- Noise
- Harness NG
- Terminal and line resistances NG

Fig 3.4 IDU Motor

3.5 REMOTE ANALYSIS

Fig 3.5 Remote

- Visual Checking (LCD, Button, case etc)
- Check the IR-LED

3.5.1 Battery Case Checking:

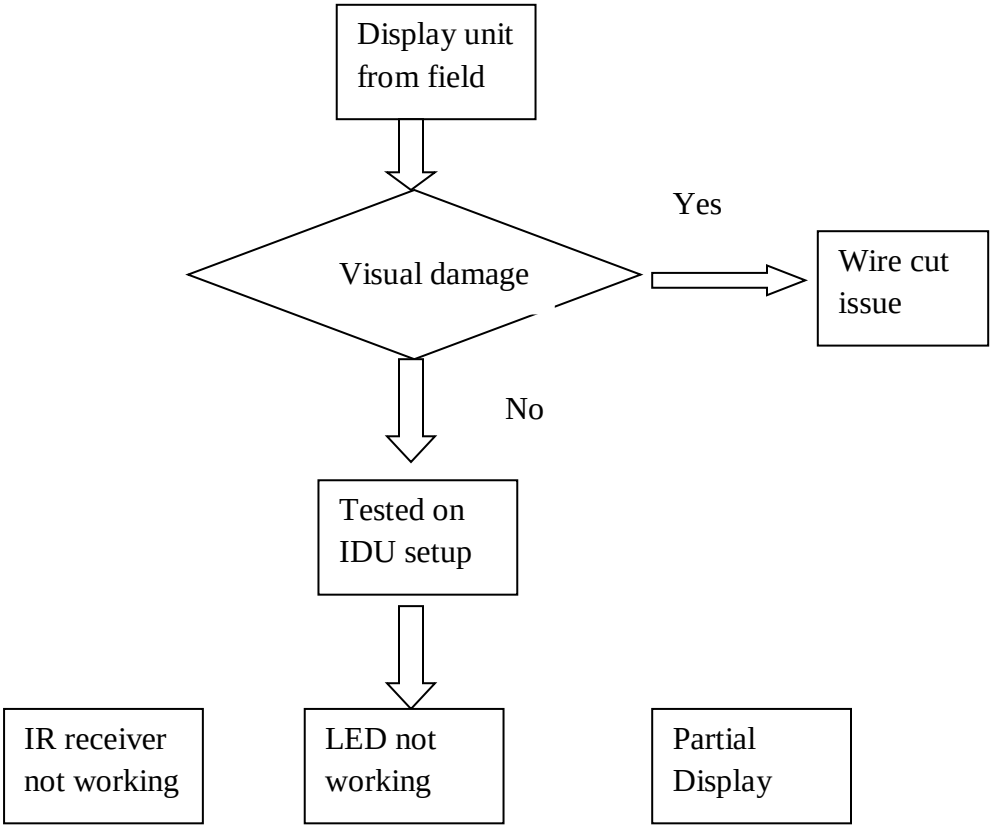
- Backside Spring & Battery (No need to open backside case, just open battery Cover)
- Replace Battery of the remote controller. After Change , becomes normal (SVC reject)
- Check the Battery to Liquid Fluid defect (leakage)
- SVC Reject
- Check the Battery Expiration date. (In case of expiration battery, Liquid defect probability is higher than recent parts)
- Also case can be insertion of wrong things like water, beverages etc

3.6 DISPLAY ANALYSIS (Split AC)

Display PCB Assembly is the sub assembly of the indoor PCB assembly. It consists of an IR receiver, segmented displays and notification LED.

The display work is to show the set temperature necessary notifications like power status, outdoor unit running status, Indoor unit error codes if any and to receive the user commands from remote and forward it to the Indoor PCB for processing.

3.6.1 Testing Methodology



- The Display PCB received from field failure is usually found to have no visual damages except for wire cut issue.
- The received display PCB assemblies are directly tested by connecting it to indoor PCB test setup.
- The system is then run and the display PCB Assemblies are tested for:-

    - IR receiver not working.

- Notification LED not working.

- Partial Display

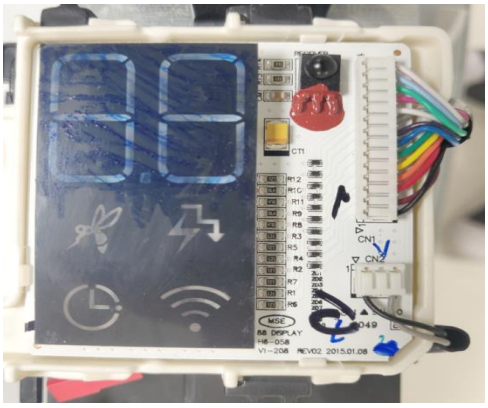


Fig 3.6 Display

CHAPTER 4

RESULTS and DISCUSSIONS

4.1 IDU PCB Improvement

- ✓ There are cases of components damage due to overvoltage in which capacitor, IC , diodes are found to be burnt. Those are clearly taken into consideration that they need to be redesign, replace or modify their ratings . the analysis is clearly shown in the table below
- ✓ Sometimes there comes cases of " no damage found". In that cases the PCB circuit is compared and traced with respect to the reference board and detailed analysis is done .
- ✓ Other kind of failures are defined in the given table.
- ✓ Below table shows how the field samples failure data is collected.

Table 5: Defect analysis of IDU PCB

Sr. No	Defect	Count	Defect (%)	Cause	Count	Defect (%)
1.	Over voltage	58	53%	C03J capacitor	25	23%
				TNY IC	26	24%
				Fuse	28	25%
				Line filter	3	3%
				SMPS Trans	3	3%
				D01J	11	10%
				ZNR01J	2	2%
				RY comp	1	1%
				NTC	7	6%
2.	NDF	14	13%	NDF	14	13%
3.		10	9%	CH12(R01H)	2	2%
				5V and Ground Short	1	1%
				CH10, Q01B(Internal Resistance NG)	2	2%

	Component Fault			CH10, Q02B NG	1	1%
				CH12, R04H, R08H NG	2	2%
				Supply ok, PCB working NG	1	1%
				IC02D opto NG	1	1%
4.	Environmental Effect	12	11%	Component oxidation	6	5%
				SMT side comp oxidation but NDF	6	5%
5.	Process Fault	12	11%	IC01S pin not inserted	1	1%
				CH10(Micom 28 Pin NG)	1	1%
				Soldering Short	10	9%
6.	Old Wrong Sample	3	3%	Scrap	3	3%
7.	Physical tampering	1	1%	Components Removed	1	1%
Total Sum		110	100%			

- **Cause and Analysis**

  - **Overvoltage (53%)**

From the obtained field analyzed data after testing, over voltage damage is found to be the main issue.

Below table shows the reason of different failures and how their improvement action has been taken.

Table 6: Cause and counteraction of IDU PCB defects

Causes	Counteraction
1.Over Voltage Improvement - PCB damaged due to OV input - Switching IC damage - Transformer damage	- Redesigned SMPS Trans leakage inductance. - Imp(76 turns to 83 turns) - Primary inductance reduced 1.3mH to 900uH - Addition of resistor R01D for cross regulation of SMPS IC
2. NTC Burnt - NTC Damage due to lesser in- rush current tolerating capacity	- Max steady current improved from 1 to 1.5 ampere.
3. Varistor NG - Varistor burnt due to surge	- Surge ampere rating(10000A to 12000A)
4.Fuse NG - Fuse burnt due to over current or spike	- To endure 7 KV surge

Design Improvisation:

There are two improvements done in order reduce the failures in the PCB. They are:

1) SMPS trans leakage inductance redesigned (76 turns → 83 turns) & primary inductance (1.3 mH → 900uH) and a resistor added.
2) Max steady current improved from 1 to 1.5 ampere of NTC(50 Ω → 100 Ω)
3) Varistor surge ampere rating improved (10kA→12kA)
4) Fuse rating improved(15A → 20 A)

Fig 4.1 Switching IC burnt

Fig 4.2NTC burnt

Fig 4.3 Varistor burnt

Fig 4.4 Fuse burnt

- **Switching IC :** The TNY Switch controller IC consists of an oscillator, enable circuit (sense and logic), current limit state machine, 5.8 V regulator, BYPASS pin under voltage circuit, over temperature protection, current limit circuit, leading edge blanking and a 700 V power MOSFET. TNY Switch- incorporates additional circuitry for line under voltage sense, auto-restart and frequency jitter.

TNY Switch IC devices operate in the current limit mode. When enabled, the oscillator turns the power MOSFET on at the beginning of each cycle. The MOSFET is turned off when the current ramps up to the current limit or when the DC max limit is reached. Since the highest current limit level and frequency of a TNY Switch-IC design are constant, the power delivered to the load is proportional to the primary inductance of the transformer and peak primary current squared. Hence, designing the supply involves calculating the primary inductance of the transformer for the maximum output power required. If the TNY Switch-IC is appropriately chosen for the power level, the current in the calculated inductance will ramp up to current limit before the DC max limit is reached.

- **NTC:** It stands for Negative Temperature Coefficient Resistor. Their resistance varies with ambient temperature changes. It comprises 2 or 4 kinds of metal oxides of iron, nickel, cobalt, manganese and copper, being shaped and sintered at high temperature(1200℃ to 1500℃).

- **Varistor :** MOV is simply a variable resistor which changes its resistance based on the applied voltage**.** MOVs with a fuse are used in parallel with the circuit to be protected from high voltage spikes. They can handle short surges, they are unable to protect from sustained surges.

Improvement: As Fuse, varistor , NTC are initial components of IDU input circuit which are responsible for protection from high inrush current and voltage surges. Also switching IC helps in attaining the different dc voltage levels.

Currently 1A Steady current NTC is changed to 1.5 A in IDU PCB and 10KA surge ampere rating varistor is changed to 12KA surge ampere rating , which will have following benefits:

1) Better protection in normal operation.
2) Better surge protection

Change point : Technical specifications revised.

- **Testing:**
  These tests are performed in compliance with standard IS-1391.

No.	Test	Detail	NTC(50Ω)	NTC(100Ω)	Comparison Result
1	SPIKE TEST	170V for 1hr	No malfunction	No malfunction	Similar
		230V for 4hrs	NTC burn out	No malfunction	NTC(100Ω)
		350 V for 1hr	310V	220V	NTC(100Ω)
		230V for 5 min	310 V	450V	NTC(100Ω)
		470V for 1sec	Burn out	No malfunction	NTC(100Ω)

No.	Test	Detail	Fuse check
2.	FUSE TEST JIG	200% of rated current	check blow off within 2 min

		135% of rated c urrent	Check blow off within 1 hr
		110% of rated c urrent	Check shouldn't blow off within 4 hrs.

No.	Test	Detail	Purpose
3.	VOLTAGE VARIABLE TEST	240V,270V 185 V, 310V, 165V, 285V for 4hrs	To ensure parts performance due to voltage vari ation in field

Results: 100Ω NTC, 20A fuse and the SMPS primary inductance modified specs have passed all the above performed tests.

4.2 ODU PCB Improvement

Like in IDU PCB, ODU PCB data also needs to be collected for any kind of improvement .

Table 7: Defect analysis of ODU PCB

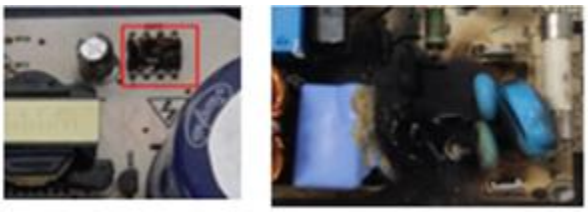
Sr. No	Defect	Count	Defect (%)	Cause	Count	Defect (%)
1.	**Over voltage**	**68**	**63%**	**C06D capacitor**	**10**	**9%**
				TNY IC	**16**	**15%**
				SMPS Trans	**8**	**7%**
				Fuse	**22**	**20%**
				D01D	**2**	**2%**
				ZNR01J	**4**	**4%**
				ZNR02J	**3**	**3%**
				R32S	**1**	**1%**
				R31S	**1**	**1%**

				R22D	**4**	**4%**
				D04D	**2**	**2%**
				Power Cap, pad burnt	**7**	**6%**
				Supply region burnt	**5**	**5%**
				NTC	**30**	**28%**
2.	**NDF**	**14**	**13%**	**NDF**	**5**	**5%**
3.	**Component Fault**	**19**	**18%**	**R02K Break**	**1**	**1%**
				Fuse fan break	**1**	**1%**
				COMM terminal break	**1**	**1%**
				Comp CO8F, C05F Break	**1**	**1%**
				5V, 15V NG, IC02D NG	**2**	**2%**
				15V Unstable, ICU1 Issue	**2**	**2%**
				RY_Start break	**1**	**1%**
				CN_UVW wafer break	**1**	**1%**
				CH27	**1**	**1%**
				C06D Short,IC01V NG CH23	**3**	**3%**
				CH21(IPM fault)	**1**	**1%**
				Comm. Ckt NG	**1**	**1%**
				CH45	**1**	**1%**
				IC01S NG	**1**	**1%**
				IPM resistance NG, CH 29	**1**	**1%**
4.	**Environmental Effect**	**12**	**11%**	**MICOM Pin 1-20 rusted**	**1**	**1%**
				Environmental Effect	**4**	**4%**

5.	**Process Defect**	**1**	**1%**	**C01D not soldered**	**1**	**1%**
6.	**Old Wrong Sample**	**10**	**9%**	**Scrap**	**10**	**9%**
Total Sum		**108**	**100%**			

- **Cause and Analysis**

Table 8: Cause and counteraction of ODU PCB defects

Causes	Counteraction
1.Over Voltage Improvement Symptom: Abnormal voltage in the field **1. SMPS section burnt** - SMPS IC burnt due to voltage surge - Varistor burnt due to voltage surge  **Fig 4.5 SMPS section burnt**	**TNY IC Spec revised** Over voltage improved from 650V to 800V R22D resistance increased from 0.8 to 1 ohm **ZNR02J,3J Varistor spec revised** 6.5 KV to 10 KV surge rating Varistor maker changed. - Surge ampere rating 10kA to 12kA
2. NTC Burnt - NTC burnt due to higher inrush current.  **Fig 4.6 NTC burnt**	**NTC** - Max steady current improved from 1 to 1.5 ampere(50Ω → 100 Ω)

Component & Process Fault **1. Compressor connector break** - IPM fault error CH21  **Fig 4.7Connector break**	**Compressor Connector** - The wrap with sleeve to be added to avoid direct impact on compressor connector
2. IGBT misinsert/ leg bend - CH23 occurs causes open connection of IGBT leg with PCBA	**IGBT misinsert** - IGBT autobending jig installed to avoid any leg lift of IGBT due to manual bending.
3. OP- Amp IC NG - OP-amp IC damage causing CH22 when IC01S is damaged. - OP-amp IC damage causing CH23 when IC01V is damaged	**OP- Amp IC NG** - MLCC filtering capacitor values changed from 100nF to 1uF for better filtering. - Bare Board pattern improvement for IC01V for CH23 improvement.
4. CH21 due to IPM damage and CH22 due to IC01S damage - Damage due to surge transfer from FCT jig to PCBA while testing on line	**Damage due to FCT jig surge** Jig test route modified to prevent surge flow to PCBA from FCT jig

As Fuse, varistor, NTC are initial components of IDU input circuit which are responsible for protection from high inrush current and voltage surges. Also switching IC helps in attaining the different dc voltage levels.

Currently 1A Steady current NTC is changed to 1.5 A in IDU PCB and 10KA surge ampere rating varistor is changed to 12KA surge ampere rating , which will have following benefits:

1) Better protection in normal operation.
2) Better surge protection

4.3 IDU Motor Improvement:

IDU motors obtained from the field are checked by applying supply to the IDU board , cases like dead, run by hand and terminal resistance NG are found . Data sheet is prepared according to the defect found.

- **Causes and Analysis**

Table 9: Defect analysis of IDU motor[15]

Issue Details

Defect: CH 10 Error
IDU Motor defective


Branch	Model	Serial No.	Motor :IDU	PCB
GHA	LS-Q18ENXA	001NAKM018181	Y	X
DES	LS-Q18ENXA	001NAJE018428	Y	Y
AGR	LS-Q18ENXA	001NAAD009760	Y	X
GHA	LS-Q18SWZA	001NAXU007770	Y	X
AHM	LS-Q18ENXA	001NANZ022455	Y	X
BHU	LS-Q18KNYA	003NARV063638	Y	X
CHA	LS-Q18CNXD	001NAVX012887	Y	X
JAI	LS-Q18KNYA	002NAGA007479	Y	X
LUD	LSNQ18KNYA	003NALJ094056	Y	X
PAT	LS-Q18SWZA	001NAWN007793	Y	X
RAN	LS-Q18FNZD	001NAJE040724	Y	X
UDA	LS-Q18GWZA	001NAFY130555	Y	X

IDU motor CH-10 Error	Shaft Lock/Not Working	Initial not operating(28%)
		IC defect (22%)
		Connector burnt (11%)
		NDF (19%)
		Abnormal Voltage(14%)
		Process issue (5%)
		Others (1%)

Root Cause / Analysis

1. NDF (Moisture)
LG Analysis:
Motor tested Humidity.
Test condition:
Humidity : 90-95 %RH
Temperature : 33-35 degree Celsius
Time : 12 Hrs

Nidec Analysis:
Cut open analysis: Water trace mark observed

2. CH 10 error & High RPM
Why 1: Winding coil cut / damage
Why 2 : No process fool proof

Why 1 : Poor soldering
Why 2 :Solder dross not removed

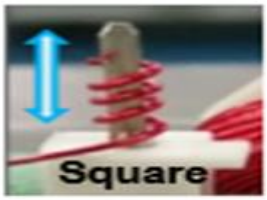
Improvement Action

1. Water entry path close with silicon.

2. Winding wire cutting process improved.

Fig 4.8 Si closed path

Fig 4.9 Inspection with CRO



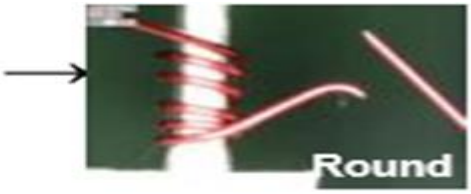


Fig 4.10 Design change

- winding pin design improve(square to round)
- inspection method improve(visual to CRO)

3. Solder process improvement

- Dross cleaning freq(180 to 60 unit)
- Solder bath replacement

4. Motor cut open inspection added in DQA testing

ANALYSIS OF DEFECTIVE IDU MOTORS

Summary of hand run motors:

Below table shows the results compared with standard values.

Table 10: Defect testing of IDU motor

Sr. No.	Defect	U-Phase (70.54~77.97Ω)	V-Phase (70.54~77.97Ω)	W-Phase (70.54~77.9Ω	Judgment
1	Hand run & Back EMFNG	∞	74.1Ω	71.56Ω	U Phase wire cut

2	Current graph NG	73.45Ω	72.5Ω	73.17Ω	PCB Burnt
3	PG graph NG	74.12Ω	76.0Ω	71.70Ω	PCB Burnt
4	Hand run & Back EMFNG	∞	75.0Ω	72.22Ω	U Phase wire cut
5	Hand run & Back EMFNG	∞	75.3Ω	76.11Ω	U Phase wire cut
6	Hand run & Back EMFNG	∞	72.2Ω	73.22Ω	U Phase wire cut
7	Hand run & Back EMFNG	∞	73.7Ω	76.71Ω	U Phase wire cut
8	Not run	72.22Ω	75.6Ω	73.09Ω	PCB Burnt
9	Not run	74.46Ω	75.2Ω	72.30Ω	PCB Comp Burnt

➢ Hand run & Back EMF NG Analysis

- At our outgoing setup, we observed motor Hand run & back EMF is NG.
- Further for more analysis we cut and open the motor to find out the cause of failure of this motor.
- After cut & open analysis it is observed U-phase wire cut.

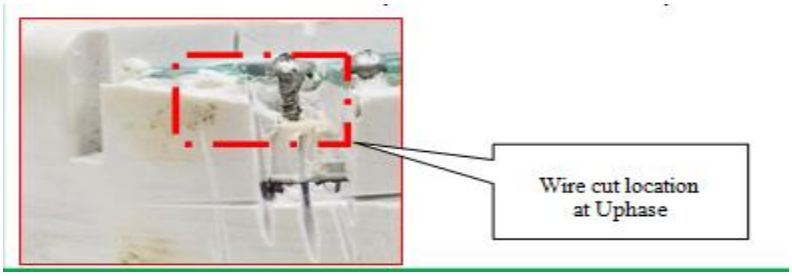


Fig 4.11:Wire Cut

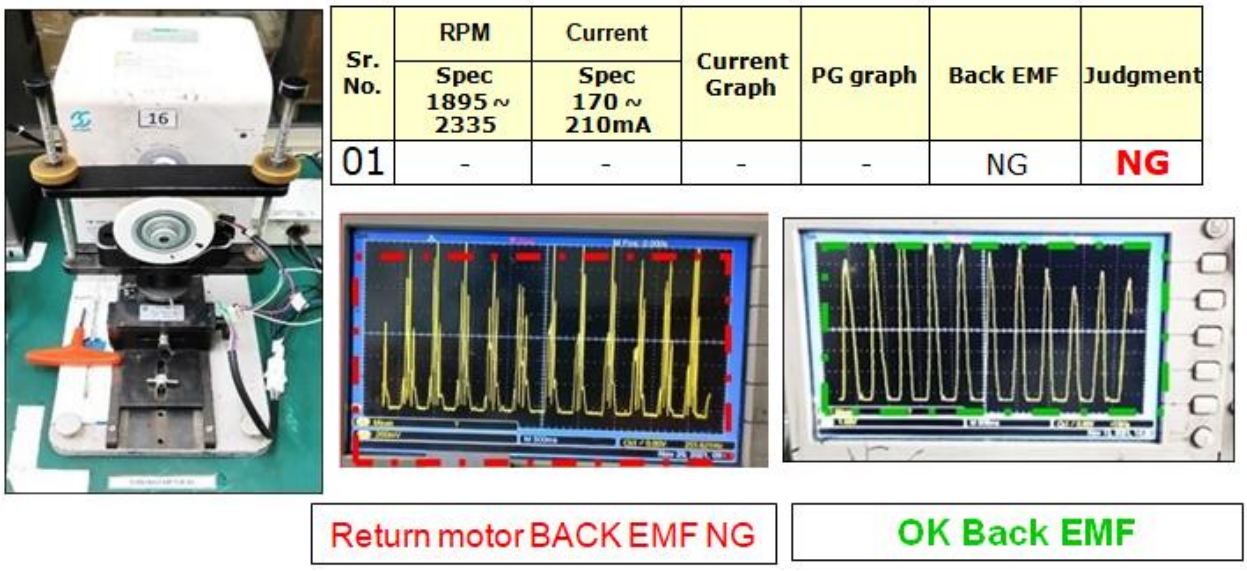


Fig 4.12: Outgoing set up 1 and results

Analysis of dead motor

- At our outgoing setup, we observed motor Current graph NG.

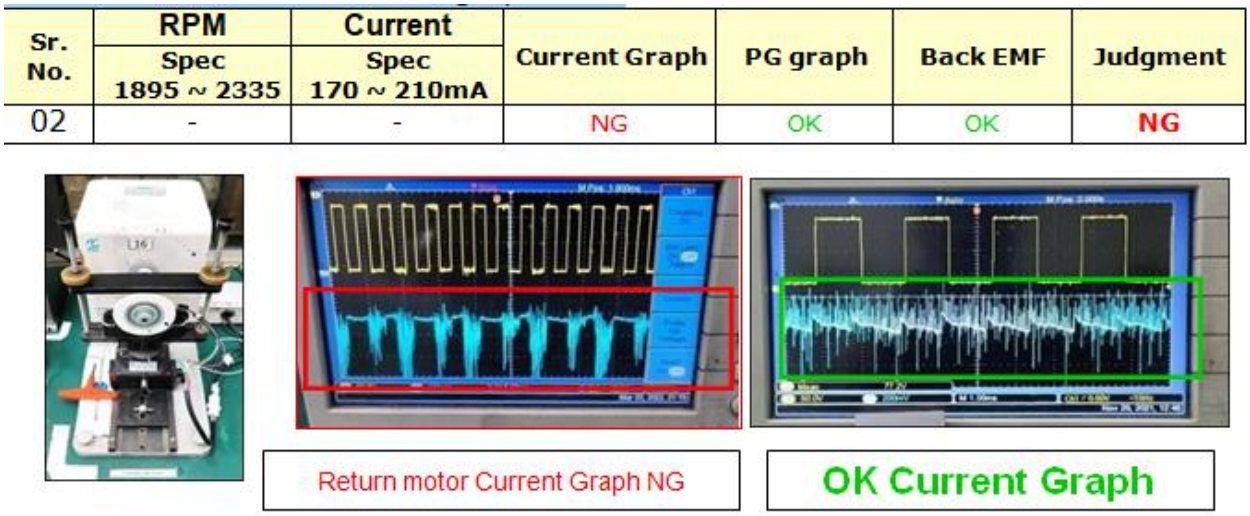


Fig 4.13 Outgoing set up 2 and results

Further for more analysis we cut and open the motor to find out the cause of failure of this motor.

In this motor, we observed PCB burnt**.**

This damage occurred due to electrical over stress / over current enter into the PCB circuit in running condition.

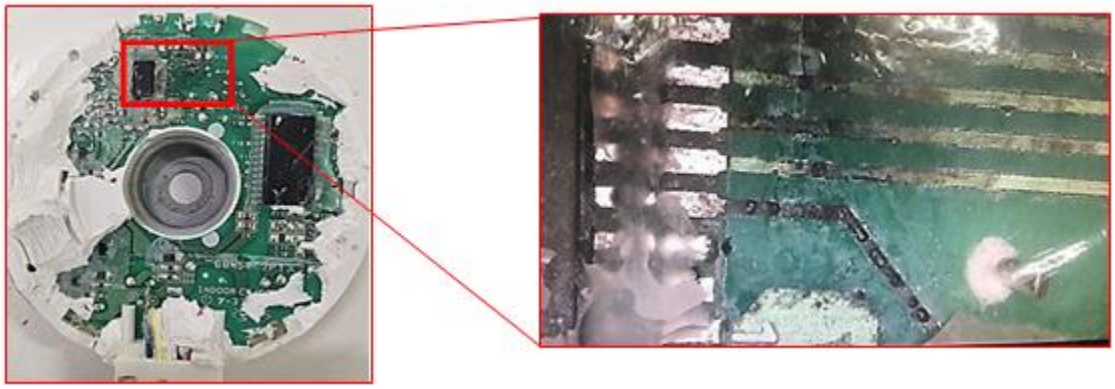


Fig 4.14 Burnt PCB

Change points for Wire Cut Issue

- Winding pattern has been change to reduced the direct torque stress.

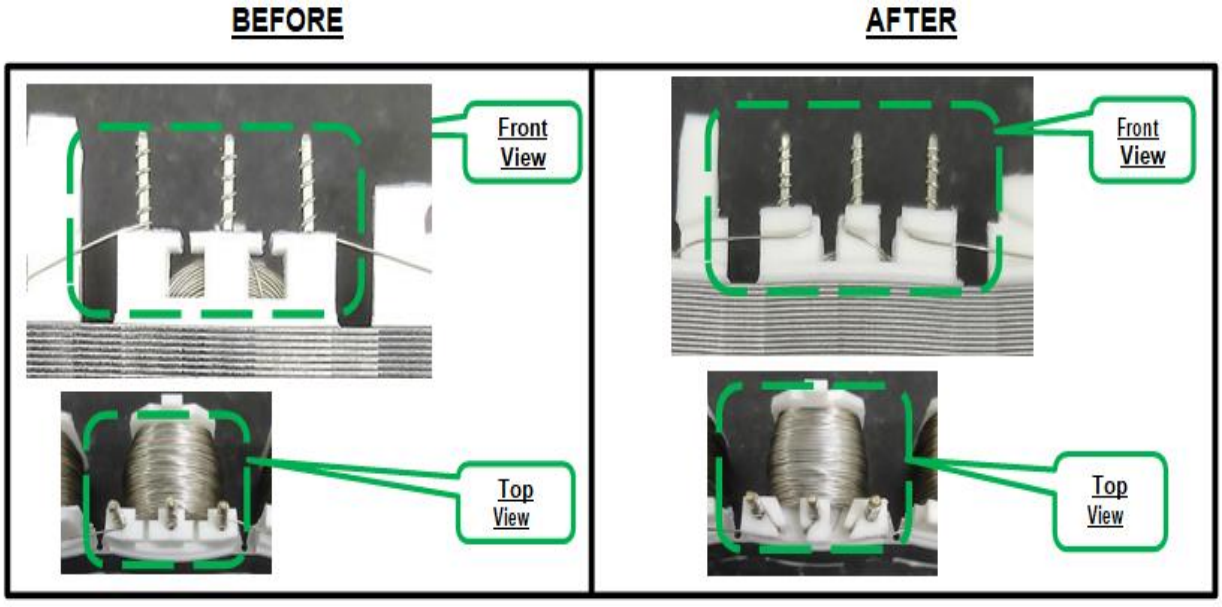


Fig 4.15 Changed Winding Pattern

Change point for PCB Related issue

This damage occurred due to electrical over stress / over current enter into the PCB circuit in the running condition.

- Silicon application started
- 5.1 Ohm SG Series Resister Addition planned in Vcc Line

CHAPTER 5

CONCLUSION

Air Conditioner as a product, its working principle and functional behaviour is learnt to find scope for reducing field defects in order to increase the effectiveness and efficiency. Visual and functional analysis of IDU and ODU PCB , Motor IDU and remote is done for optimization of RAC parts' performance. Thoroughly examination of error code generated by IDU PCB ,ODU PCB and analysed them for tracing and troubleshooting the circuit accordingly. A look through the BLDC motor, working and its significance in order to reduce the power losses and understanding about power supply, protection circuit components and frequency controlling circuit. The main work area was to identify the issue faced at the customer end and then realizing the defect in residential air conditioners parts through testing procedures framed for different parts . Based on the analysis data, improvement in design and technical specifications is suggested and validated.

With the ongoing testing project, I also get the chance to work on the following software of the company

GPDM (Global Product Development Module)

DQMS (Data and Quality Management System)

PIMS (Part Information Management System)

GQIS(Global Quality Information System
Global LG Standard System
Global Service Front System(GSFS)
LG Customer Service Portal

5.1 IDU PCB optimization:

- Redesigned SMPS Transformer leakage inductance , impedance is increased by increasing the no. of turns(76 turns to 83 turns), primary inductance improved from 1.3mH to 900uH . These changes are made to reduce Vds voltage from 480V to 415V.

- Varistor specifications enhancement (surge ampere rating10kA to 12kA) in order to overcome overvoltage .
- NTC maximum steady current improved from 1 to 1.5 A for overvoltage protection.
- A resistor is added for cross regulation of SMPS IC.
- Fuse rating is improved to endure 7 kV surge.

5.2 ODU PCB optimization:

- TNY IC Spec revised results in overvoltage protection enhanced from 650V to 800V .
- Varistor surge ampere rating improvement (10k Amps to 12k Amps) for protection against surges.
- R22D resistance increased from 0.8 to 1 ohm
- Max steady current of NTC improved from 1 to 1.5 A(50Ω → 100 Ω) to control NTC damage due to lesser inrush current tolerating capacity.

5.2.1 Component and process fault improvement in ODU PCB

OP- Amp IC :

- MLCC filtering capacitor values changed from 100nF to 1uF for better filtering.
- Bare Board pattern improvement for IC01V for CH23 improvement.

Compressor Connector

- The wrap with sleeve to be added to avoid direct impact on compressor connector in order to prevent the connector breakage issue.

Damage due to FCT jig surge

- Jig test route modified to prevent surge flow to PCBA from FCT jig.

5.3 IDU Motor optimization:

- Hand run and back EMFNG motors are analyzed and found that there is wire cut issue in the U- phase . The design of the winding pin is changed from square to round and the winding pattern has been changed to reduced the direct torque stress which results in improvement of wire cut damage.

- In case of dead motors , PCB is damaged or burnt due to t electrical over stress / over current enter into the PCB circuit in running condition. To overcome this problem, a series resistor of 5.1 is added in Vcc Line which increases its withstand capability.
- Also surge withstand capability is enhanced from 500µsec to 1000 µsec.

CHAPTER 5

FUTURE SCOPE

6.1 Future Scope

All these changes help reduce field failures. The equipments in the future must have better performances and functionality than the previous ones, such as higher efficiency, low power usage, no EMI(electromagnetic interference), size compactness, environment friendly and so on; all these improvements must be attained simultaneously keeping the cost as low as possible. Brush-Less Direct Current (BLDC) motors, occupied its place in many appliances in various application fields due to its lots of advantages and optimum features, proposing as excellent for assuring the strict demands mentioned previously. The work done in analyzing the field failure issues in the project are used for further quality enhancement of the product in order to ensure reduction in cost to company for failures and for enhancing customer satisfaction.

- **Trends in RACs**

RAC producers keep going on investigating and developing modern technologies in order to enhance performance with maintaining the costs as low as possible. For instance, speed- varying (inverter) appliances that used to increase RACs efficiency and make it productive already excel developed RAC markets which includes countries like Japan, , Europe, Australia and the U.S.. Now-a-days seasonal efficiency metrics are being designed to evaluate RAC performance conditional on operations are full load or part load under regional weather conditions. These metrics are designed to better shows the device's efficiency within a year operation. Due to which manufacturers are likely to have turned their pivot to enhance seasonal efficiency which better shows part-load efficiency, rather than enhancing full-load efficiency. Although seasonal efficiency metrics of some local RACs are compatible with each other, some vary mainly owing to the temperature outside profiles utilized to combine steady-state and cyclic ratings into a seasonal efficiency value. The performance of high-efficiency RACs tends to be upgraded for local-specific test standards. [16]

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APPENDIX

ABOUT THE COMPANY

Fig : LG Electronics Greater Noida Plant

LG ELECTRONICS PVT. LTD. is a multinational organization headquartered in South Korea. It is South Korean second biggest electronics manufacturer and the third largest appliance creator in the world, which has head office located at LG Twin Towers on Yeouido, Seoul, South Korea. LG Electronics is the chief corporation of LG group, one of the huge chaebols containing 75 subsidiaries throughout the world. They design and fabricate televisions, mobiles, home appliances and telecommunication devices. It owns up Zenith Electronics and controls, also LG features a joint endeavor with Philips Electronics

LG –THE HISTORY

- LG, Lucky Gold Star, which is former name of this international corporation that used to make cosmetics. Later in 1958, LG started electronic manufacturing business under the Gold star brand. During the same year, the company also manufactured initial Korean telephone, refrigerator and black & white television set . The current name of the company stands for "LIFE IS GOOD" which also serves as its slogan .
- Before its name changed to LG, household products were sold with brand name " Lucky", and the electronic goods were sold by the brand name " Goldstar". In 1995 Goldstar was relabeled as "LG ELECTRONICS", and owned Zenith Electronics of the United States. .[17]

Fig : LG Electronics Seoul Headquarter

LG ELECTRONICS INDIA

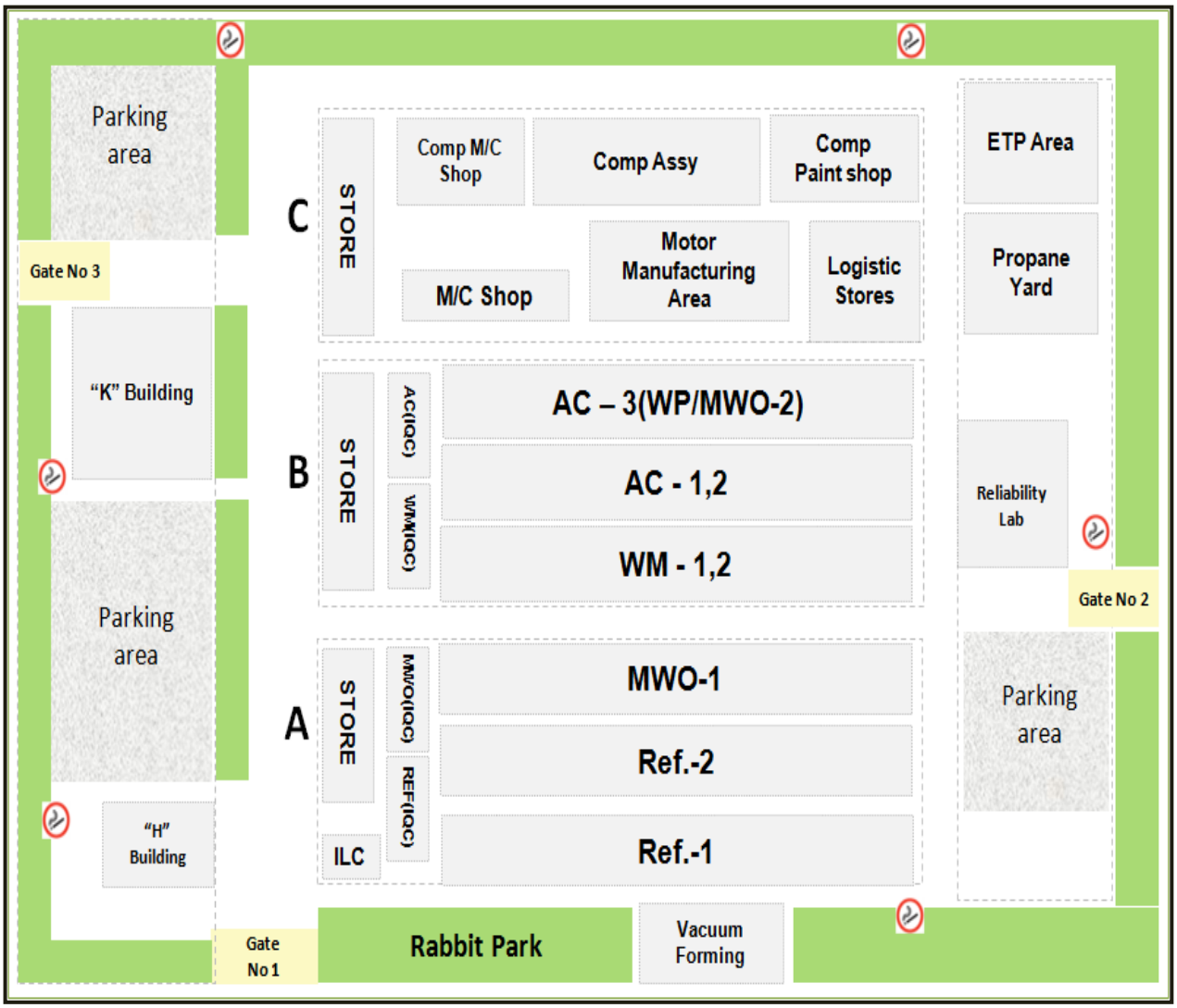
LG Electronics India Pvt. Ltd., a wholly acquired branch of LG Electronics, South Korea was established in January, 1997 after clearance from the Foreign Investment Promotion Board (FIPB).

The trend of beating industry norms started with the rapid ever-widespread launch by LG with the onset of operations in May 1997 in a time period of four and a half month . LG build up a state-of-the art manufacturing plant at Greater Noida in 1998, by investing around Rs 500 Cr. This facility produced Color TV, WMs, RACs and MWOs Throughout the year 2001, LG also

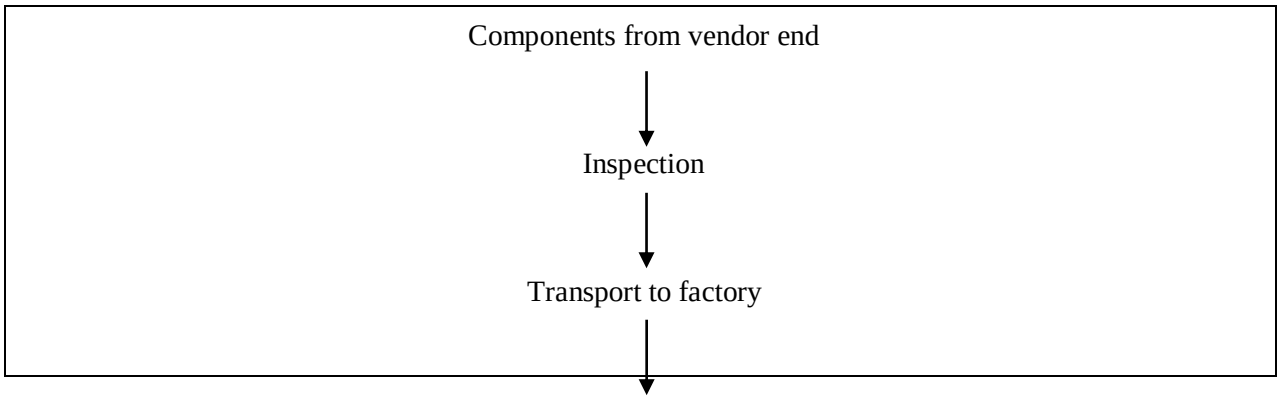
started the home manufacturing for its environment friendly Refrigerators and rooted its assembly line at its Noida manufacturing unit. In the starting of year 2003 ,first locally manufactured DC (direct cool) Refrigerator by the plant at Greater Noida was launched. Then another Greenfield manufacturing unit was set up at Pu/ne, Maharashtra in 2004.The Pune unit manufactures Televisions, ACs, Refrigerators, Washing Machines, MWOs, Monitors and Phones.The Greater Noida Production unit is the foremost environmentally safe units in comparison with other LG units. LG attained a status of most desirable brand among others. LG is one of the consumer friendly companies who recognized the advanced change in customer needs and decided their appliances based on health welfares. The products provided by LG has consumer friendly features like:

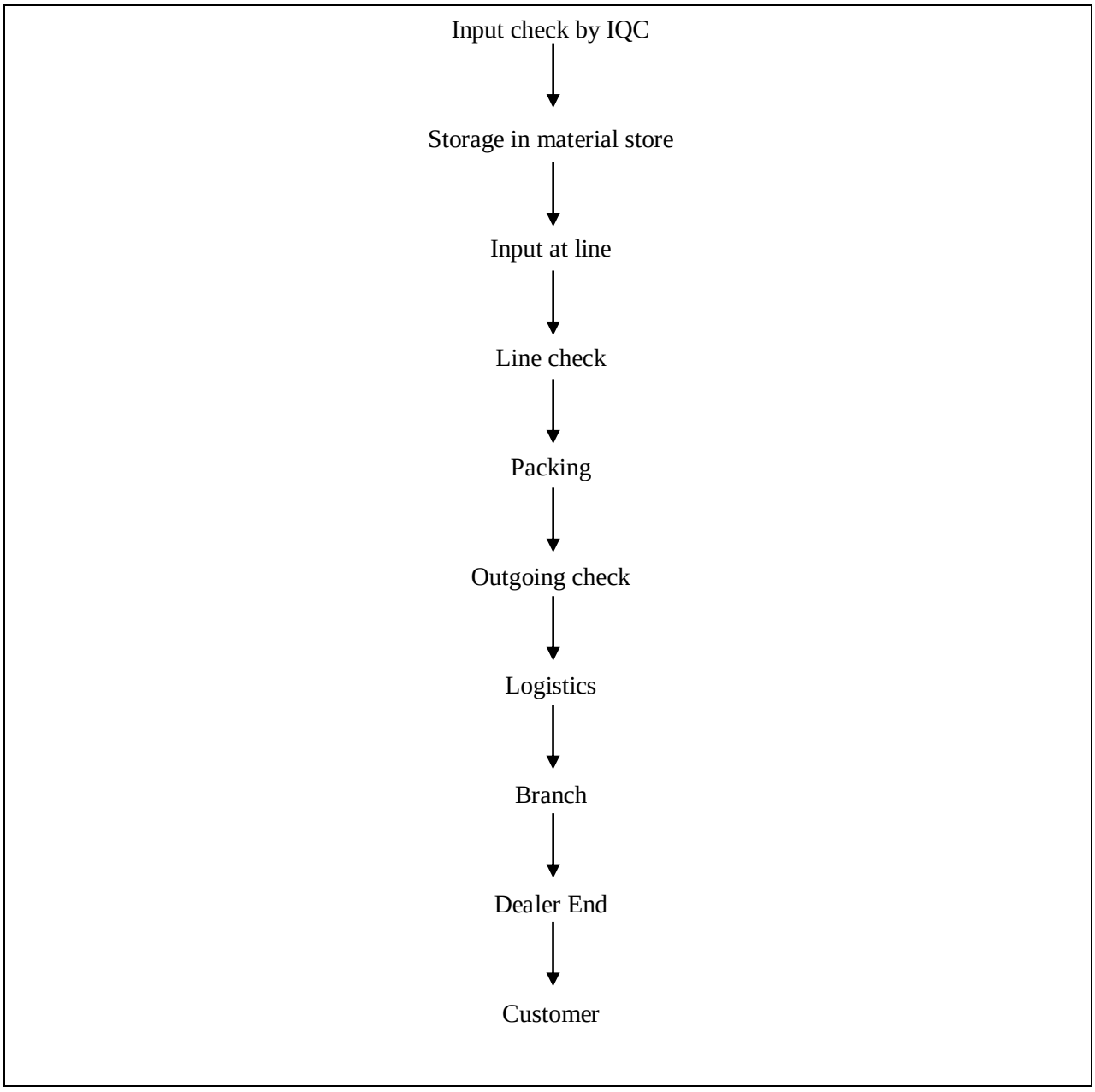
The Color TV possess 'Golden Eye' technology, the Air conditioners offers 'Healthy Air System' that cools, MW oven offers the 'Health Wave System', refrigerator maintains the 'PN System', washing machine got the 'Fabricare System'.

PLANT LAYOUT:



PRODUCTION CYCLE





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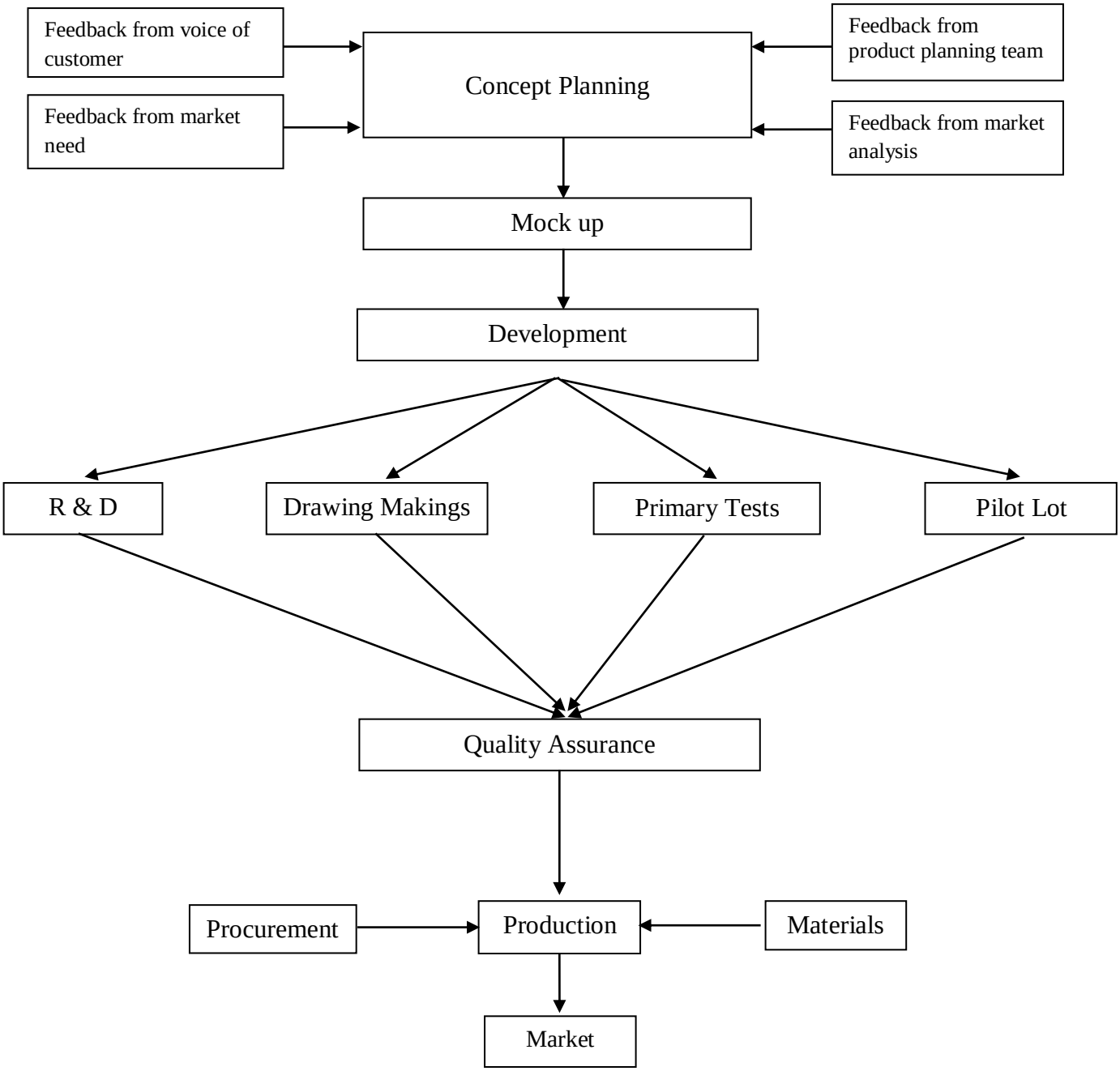

ABOUT QA DEPARTMENT

There are five parts in QA

1. Development QA

- Development approval test, reliability test

- Pre-development evaluation, Development quality evaluation, software quality

2. Part quality

-Incoming inspection

- part approval test , 4M management

- Supplier Q-gate audit

3. Process quality

-100% product inspection

-line stoppage management

-fool proofing at LQC stages

4. Outgoing quality

-line process audit

-sample wise product inspection

-3F product audit

5. Field quality

-Field issue speedy solution

-failure cost analysis and improvement

-daily field quality management

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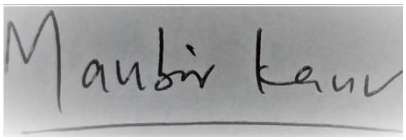

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