An Internship Report

on

“Manufacturing Industry of Solar PV Modules”

At,

Aatmanirbhar Solar Pvt. Ltd.

Submitted in Partial Fulfillment of the Requirements for the Degree

of

Bachelor of Technology

in

Electrical Engineering

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CERTIFICATE

This is to certify that the Summer Internship Report entitled "_____" submitted by Mr./Ms._____ (Roll No._____) 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 activities carried out by him/her. The work submitted is presented in front of the examiner(s) and has responded satisfactorily to the questions/queries raised.

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Attach Summer Internship Certificate issued by the Company towards the completion of the internship

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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.

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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.

- A. K. Shah (15BEE0XX)

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LIST OF ACRONYMS

DC	: Direct Current
AC	: Alternating Current
SVC	: Static VAR Compensator

LIST OF NOMENCLATURE

V_i	: Input Voltage
V_o	: Output Voltage
i_h	: Harmonic Current

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CHAPTER 1

INTRODUCTION

1.1 SOLAR OVER OTHER ALTERNATIVES

- Solar energy is one of the most abundant energy resources on Earth. As a renewable CO2-free power source, the environmental impact of solar power is significantly smaller than other power generation methods. A few reasons to choose Solar over other alternatives is as follows:

  - It is a free energy source
  - It does not emit greenhouse gases
  - It Can Make Use of the Underutilized Land
  - It Can Cause Less Electricity Loss

- Solar power is a powerful energy resource that can provide suitable electricity for your home. It's the cleanest and most abundant renewable resource that can efficiently power your place cost-effectively.

- The industry is expanding exponentially each year. The advent of EV technology and the government initiative to promote Renewable energy over Oil and thermal alternatives will surely grow the solar industry even further.

- Therefore, it is beneficial to learn the particularities of the Solar module industry, thus I have decided for an internship in solar module manufacturing industry.

1.2 ABOUT THE COMPANY

- Aatmanirbhar Solar Pvt. Ltd. is an emerging young solar manufacturing unit at kapadvanj (Gujarat) - India, Manufacturing High efficiency Solar PV Modules with the high-tech fully automated manufacturing plant of 150 MW per annum capacity which is expandable up to 300 MW for MBB panels.

- Our products can be used across India as Ground Mounted and Roof Top. is is also serving to the agriculture industries as a Pumping Solution by using ASPL solar panels.

- Our aim is to contribute to India's Green Energy as well as Climate Goals which brings affordable & accessible solutions for the nation.

- We use MONO crystalline and POLY crystalline (DCR and Non DCR) solar cells for the manufacturing of PV Modules. We Manufacture as per MNRE guidelines and also have national and international certificates which include BIS, IEC, ISO 9001:2015, 14001:2015.

AATMANIRBHAR
ENERGY FOR NATION

1.3 BRIEF THEORY OF SOLAR MODULE

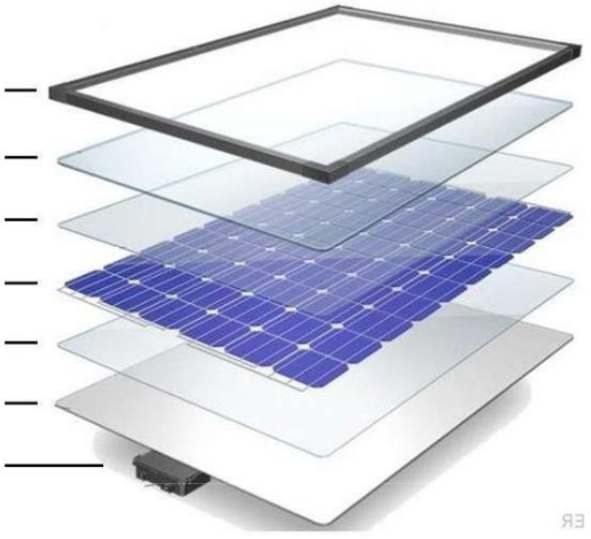
- A PV module consists of several interconnected solar cells encapsulated into a single, long-lasting, stable unit. The key purpose of encapsulating a set of electrically connected solar cells is to protect them and their interconnecting wires from the typically harsh environment in which they are used.

- Module lifetimes and warranties on bulk silicon PV modules are over 20 years, indicating the robustness of an encapsulated PV module. A typical warranty will guarantee that the module produces 90% of its rated output for the first 10 years and 80% of its rated output up to 25 years.

- Many different types of PV modules exist and the module structure is often different for different types of solar cells for different applications. The most common modules have either 72 cells or 144 cells with three bypass diodes.

- The modules are assembled layer by layer in a sandwich pattern, as seen in the figure the different layers are as follows.

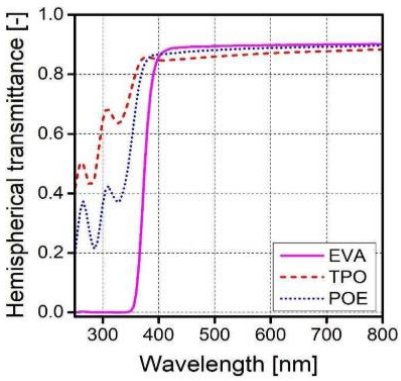
1. Frame
2. Tempered Glass
3. First EVA layer
4. Solar cell layer
5. Second EVA layer
6. Current-collector busbars
7. Backsheet
8. Junction Box and Connecters



- **Tempered Glass:**

Protects the solar panel from falling debris and makes it weatherproof. For silicon solar cells, the glass surface must have high transmission of light, in addition, the reflection from the front surface should be low. For tempered glass this reflection is as low as 5% of the incident light. The reflection could be reduced by applying a coating to the top surface or roughening the texture of the surface. However, in this case, the dust and dirt are more likely to settle.

- **Encapsulant:**

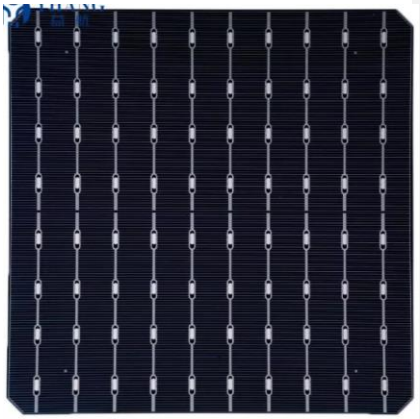


An encapsulant is used to provide adhesion between the solar cells, the top surface, and the rear surface of the PV module. The encapsulant should be stable at elevated temperatures and high UV exposure. It should also be optically transparent and should have a low thermal resistance. EVA (Ethylene-vinyl acetate) is the most commonly used encapsulant material. It polymerizes at 150o C and bonds the cells and module together. In case bifacial cells and a transparent back sheet are used in a module then POE (Poly-Olefin Elastomer) encapsulant is used instead of EVA. POE shows properties like higher transparency and light transmission. POE-based modules maintain low leakage current, enhancing electrical performance and module reliability.

- **Solar Cell Layer and Busbars:**

  This is the layer of solar cells that converts the sunlight into electricity through the photovoltaic effect. A series of such cells in a single line are collectively called a string. In this layer, the solar cells are aligned in series or parallel connections connected with conducting material of string and tab wires, which are soldered to busbars.

  The Silicon solar cells are metalized with thin strips printed on the front and rear of a solar cell. These busbars are placed on both the front side and the backside of the cell. Usually, solar cell busbars are made of a silver paste or similar high conductivity materials.



  Perpendicular to the busbars is the metallic and super-thin grid fingers, which are connected by the busbar. The fingers collect the generated DC power and deliver it to the busbars.

  The maximum amount of current that can be safely carried is determined by the size of the busbar. It can be as small as 5*0.2 mm. The number of busbars in a cell is represented by BB. It is recommended not to increase or decrease the number of busbars in the cell too much because the increase in the number of BB reduces the cell area and a decrease in the number of BB causes loss of productive energy.

  The company works with different types of cells such as mono and poly crystalline 5BB, 9BB bifacial, 10BB bifacial, etc.

CHAPTER 2

MANUFACTURING PROCESS

2.1 TABBING AND STRINGER MACHINE

- The tabbing and stringing is the process in which the cells are lined up together and connected in series with the help of ribbons forming a string. A string generally consists of 12 cells in series. This process is carried out by using a tabbing and stringing machine. This machine is automated and increases the string generation speed several times as opposed to manual stringing.
- The tabbing and stringing machine shortly abbreviated as TS machine is configured based on cell BBs. The TS machine makes use of air pressure, vacuum, and heat to carry out its Processes.
- There are rolls of ribbons that has 15,600m of ribbon in 1 roll. The ribbon is a thin wire of Copper and Silver coating.
- The cells are loaded at both the sides of the machine.
- The cells are unloaded from the load box by robot. They are kept on conveyor belt and moved further. After that the cells are scanned through the red light. If they are NG then they are kept on NG plate.
- There is camera on the top to determine the cell is whether NG or OK.
- If they are OK then they are picked up by the robot along with the frame at the side.
- The ribbons are dipped into flux which is a liquid .
- After dipping, the ribbons are rolled ahead for stringing.
- They are cut into specific length.
- The cell is kept on conveyor and the ribbon is pulled by the machine which holds the ribbon like clip and kept it on the cell. Another cell is kept on the conveyor and the previous ribbon goes below the cell. Another ribbon is pulled and kept on the 2nd cell. This process is continuous.
- As the ribbon is laid on the cell , the frame is kept on it so that the ribbon does not dislocate form its position. The frame is also kept to solder the ribbon with the cell.
- When 12 half cells are connected in series, they are called a String. The gap between each cell is 1.2 mm.
- The string is moved forward for soldering. For soldering, Xenon lamps are used. They are in a box type structure through which exhaust pipe is also connected and at top are 4 fans.
- The soldering is done in pairs of cells. The frame has spring points which are pressed along the cell for soldering.
- The heat generated is pulled by the hose pipe and thrown out through the Exhaust Motor. The fans are placed on the top of the lamps to cool them down. The press time is 1.7 to 2.6 seconds.

- The soldering temperature is around 150ºC.
- After soldering, the string is moved forward and the pairs of frames are pulled up by 2 pairs of magnets on each side and kept on conveyor and moved again to the starting part.
- The string is cut at the end to separate the 12th cell of 1st string and 1st cell of 2nd string. They are moved forward through conveyor.
- Each string is pulled and hold through a robot through vacuum. They are moved and pushed against two points with conducting screws. Both the ends of the string is slightly pushed against this conducting material to get the EL (Electoluminous) image. These images are seen on the monitor screen. There are 2 buttons – OK and NG.
- If it is NG then it is kept on the NG plate by pressing NG button.
- If it is OK then it is kept on the conveyor. They are kept one on one.
- As 12 strings are kept, the conveyor is moved and the strings are carried to the other machine. The machines are of Lead Company.
- There are 2 types of machines – LDDS 3600B AND 3600C.

2.2 Glass Loader

- The glass is the main part of the Solar Module. The bunch of **100 Front Glasses** are loaded in the Glass loading machine.
- The dimension of the glass is – **2267 mm × 1128 mm & 3.2mm thick.**
- This glass is called ARC glass because it has **Anti Reflective Coating** on it.
- Two groups of 100 – 100 glasses are loaded in the machine. The machine has 2 robots.
- One robot has vacuum at its end and the other has Rubber at its 4 ends.
- 1 st robot come and pickup the glass. First the glass are picked only from the two edges and the speed is slow. After that all the vacuum works equally and pick the glass at some speed and put it on the conveyor.
- During this cycle, the 2nd robot come and catches the butter paper through its rubber tips and put it on the right side.
- The butter paper is provided to protect the glass from scratching each other.
- The glass is further moved to EVA cut machine.

2.3 EVA Cutting Machine

- In this machine, a large roll of EVA is connected in the input side.
- It is used for Lamination purpose. The thickness of the sheet of EVA is **0.7 mm**.
- The machine has rollers which pulls the EVA from the role. A specific dimension is set in the machine of the size of the EVA sheet.
- After pulling appropriate size of the EVA, the machine has inbuilt blade which cuts the EVA.
- After cutting of the EVA, its sheet is laid on the glass.
- The glass is moved further through the conveyor belt to the Auto Layup Machine.

2.4 Auto LAYUP Machine

• After the TS machine, the strings are passed to the auto layup machine through conveyor. The glass with the EVA is also loaded in this machine.

• The glass is moved to the layup part. The strings are kept on the conveyor in the unloading part.

• Robot is used to pick up the strings. The strings have two sides positive and negative.

• The part from which the strings are coming from down is called the negative part and the part from which the strings are coming from upwards is called the positive part.

• The robot first picks up on string and then rotate 180 degree and then pick up the second string together and put it in a particular manner. Both positive sides or both negative sides are faced towards each other.

• They are captain of plate to arrange them in a straight order. After this time the another robot from the layer part comes and picks up the strings and place it on the EVA on the glass. All the 12 strings are placed on a single glass total 144 half cells.

• After laying up the tab module more through the conveyor belt to the Auto Bussing Machine.

• It takes 45 to 50 seconds to place solar cells on the glass.

PARAMETERS	**SPECIFICATIONS**
Cell to cell gap	1.4 ± 0.2 mm
String to string gap	2 ± 0.5 mm
Top & Bottom gap between cell edge & glass edge	23 ± 1.0 mm
Width side gap between cell edge & glass edge	15 ± 1.0 mm
Cell edge to Busbar	3 ± 0.5 mm
Busbar width	5 ± 0.1mm OR 6 ± 0.1 mm
Centre gap	12 ± 0.5 mm

2.5 Auto Bussing Machine

In this machine the module is bussed. There are rolls of bus bars which are made up of copper and coated with silver.

- The bus bars come in rolls like ribbon. The bus bars are first stretched and cut into appropriate length.
- The bus bar is cut at two sides of the machine. Three types of bus bars produced.
- I type, U type and L type bus bars are produced by the machine.
- At one side I, L and U type bus bars are made and other side only I type was bar is made.
- The bus bars are stretched cut and then they are pressed in the machine through robot to get the appropriate shape.
- Then this bus bars are taken by the robot using vacuum.
- The I type bus bars are laid on the sides of the module. The U and L bus bars are laid in the middle of the module. 27
- After laying the bus bars , they are soldered with solar cells through ribbons.
- The solder press hold down time is between 2 seconds to 5 seconds. After soldering , the bus bars are cooled within 6 to 7 seconds to avoid hard soldering.
- To cool the bus bar, small chiller is also attached with the machine and its temperature is set to 17.9^{o}C.
- The whole process takes 32 to 35 seconds. Total 10 bars are shoulder with the panel.
- The length of U bus bar is 400 mm. (360 + 20 + 20)
- The length of I bus bar is 350 mm.
- The length of L bus bar is 195 mm. (175 + 20)

2.6 Auto Tapping Machine

- After the bussing of the module it is loaded into Auto Tap Machine.
- The module is arranged in a proper position for tapping.
- The cello tape is already fixed in the machine in the robot at 2 sides. As the module is arranged, the tapping starts and total 36 tapes are taped by the robot in the module, 18 on which side.
- This machine takes 28 to 35 seconds to tap the module.
- There is one screen to control this machine. Controller has three operations namely- Holding operation, Shield operation and Immediacy operation.
- In shield operation, there is shield warming which rings the alarm if taping is not done.
- The main function of the vacuum in this machine is to hold tape and then it press it to the cells.

2.7 Placing EVA & Backsheet / Backglass

- After the tapping, again the EVA sheet are laid before the backsheet / backglass.
- This EVA sheets have pre-cut holes for the busbars.

- Some customers also demand for solar POE film. (Polyolefin Elastomer).
- POE is more efficient than EVA.
- The sticker of ASPL is sticked to the glass and unique barcode is also sticked.
- Now as per requirement the “Backsheet” or “Glass” is laid to backside of the module.

- Bifacial cell gives some extra gain due to back glass.
- After all this process, the module goes through a conveyor to the EL & VI inspection machine, known as pre-lam inspection.

CHAPTER 3

INSPECTION (TESTING WITH EL & VI MACHINE)

3.1 Pre-lam inspection

- After all this process, the module is inspected before lamination and hence the name is pre-lam inspection.

- In this inspection machine, there are total 8 cameras to click pictures of the module. Two large LED screens are also placed to check the module.
- Two types of images are produced in this machine. **EL** [ELECTOLUMINOUS] (X – RAY)& **Visual**
- 4 cameras are for EL image and the other 4 for Visual image.s

- The EL image is like x-ray image of the module and this image is generated by giving power to the three bus bar ends.

- This inspection is necessary to determine the fault in the module.
- If the module is faulty or the cells are broken then these modules are sent for Rework at Rework Station.
- If the module is OK then it is directly sent for Lamination.
- The fault is first mark on the screen in the inspection and then send for the Rework. The Barcode is stick to (-) side of Solar cell.
- The faults are given some unique codes to simply the process.
- At Rework as they scan the barcode, the workers come to know about the fault and they solve it.
- After Rework, the modules are once again inspected at other inspection station and if they are OK then they are sent for lamination.
- If any fault is there again then it is again sent for Rework.

3.2 EL faults

Laminator

After the inspection, the module goes to the laminator chamber for lamination.

There are total 3 stages in the laminator.

The **first stage** is the **vacuum stage** in which the module is **vacuumed** for **370 seconds.**

The **second stage** is the **lamination** in which the module is **heated and laminated. EVA melts** down in this stage.

The **third stage** is the **cooling stage.** The modules are cooled at **50 degree Celsius.**

- The vacuum is used in all the three stages
- For glass to back sheet module, the temperature in the laminator is 150 degree Celsius for first 2 stages.
- In the cooling stage, that temperature is 50 º C.
- For glass to glass model, the module is vacuumed at 125 degree Celsius for 350 seconds.
- After stage 1, the module moves towards stage 2 in which the temperature is 150 degree Celsius. The lamination takes place in this stage and EVA melts.
- At stage 3, the module cools down at 50 degree Celsius.
- It took 27 to 30 minutes to complete the whole process of lamination

Auto Trimming Machine

- After lamination, the module travels through the conveyor to the auto trimming machine.
- During lamination as the EVA melts, some extra part comes out from the edge of the glass which needs to be removed.
- Auto trimming machine have 4 blades on the robot on 4 sides. As the module is loaded in the machine, it is perfectly arranged and then trimming is done automatically by the robot.
- The robot cuts down the extra unwanted edges and the module now only contain glass at the edge.
- This trimmed part is disposed of by the company.

90 Degree Visual Inspection

- After auto trimming of the module, they are then moved to 90- degree inspection station.
- There are Two slots for 90-degree inspection. The module is first moved in the machine. After this the machine holds the module and flip it to 90 degree.
- After flipping 90 degree, the tube lights are turned on in the machine automatically.
- At this stage, the modules are checked visually by human.
- If there is any fault in the module, it is considered as NG and then it becomes scrap because nothing can be changed after lamination.
- The NG modules are moved aside.
- The OK modules are moved further to Auto Framing Machine.

Auto Framing Machine

- After the inspection, the module is loaded in this machine for framing.
- Framing is very essential to protect the module from breakage and also from weather conditions.
- The frames are of **Aluminium.** There are total 4 frames to be fitted on the module. Two groups of two frames of same size.
- Two frames are smaller and the other two are larger.
- The dimension of **larger** frame is – **2272*35*35.**
- The dimension of **smaller** frame is – **1133*35*20.**
- These frames are moved forward through machine automatically.
- There is a gun like machine which fills sealant in the gaps of the frame. The sealant used as a glue to stick the module in the gaps in the frame.
- These frames are moved into the machine. The module is also brought into the machine.
- The frames are adjusted by the robot on the edges of the module

JB Fixing

The junction box is a device which carries out the electrical power from the module.

- It is also a most important part in the module.
- There are three types of junction box. Positive, Negative and Bypass.
- The junction box is eventually a **diode(20SQ045)**.
- Firstly, the junction box is kept in a machine where sealant is applied on the back of it.
- After the sealant is applied, the JB is stick to the back of the module. The bus bar ends are kept in the middle of the junction box.
- The negative JB is connected to the negative side of the solar cell and positive JB is connected to the positive side of the solar cell. The bypass diode is connected in the middle.
- The bypass diode is connected to bypass the current if hotspot occurs.
- After this the lead wire is used to solder the bus bar and the bus bar are turned from vertical to horizontal and are connected to the junction box. The temperature of the solder machine is 450ºC.
- The JB fitting is done manually.
- to protect the JB from short circuit and other danger.
- In this machine, the gap in the JB is filled with Two Component RTV Silicon.
- Two components are mixed where one is Base which provides water proofing to the JB and another is Catling used to dry the base .
- Where is a pen like structure through which silicon is filled into the JB.
- After potting, the modules are moved through the conveyor for further process.

• After potting , the silicon needs to be dried before moving for the further process. • In this machine, the modules are pick up by the robot and kept systematically on the conveyor of the curing line. • In curing the modules are kept to dry. • Panels are kept on conveyor for 4 hours. The curing line is a room type structure. • The temperature is kept between 22 to 27 degree Celsius and humidity should be greater than 50%. • Generally, the humidity is 72 to 75%. • After curing , the corners of the module are buffed automatically using machine. This is called Corner Buffing. • After corner buffing, a contact block is connected to positive and negative JB of the module for testing. • After this, the modules are 180 degree flipped using 180- degree Flipper. • The modules are flipped for testing.

Final Inspection

6.1 Sun simulator

After flipping of the module, they are moved forward into Sun Simulator. As we know that testing the module with sunlight is not adequate and weather conditions also affects.

- So, we artificially create the sunlight from lamps for testing.
- There are **2 Xenon Lamps** with our faced upwards and their reflection are incident on the module.
- **Filter glass** is also in the middle to divide the light equally.
- The intensity of the light is **1000 W/m².**
- Contact block is connected with electric wires with a directly connected to the monitor screen to get readings.
- After scanning the barcode of the module, the light incidence automatically and eventually gets the **Readings And V-I Graph.**
- The graph shows relation between **Short Circuit Current & Open Circuit Voltage,** the **V-I graph** in **Red** colour & **P-V graph** in **Blue** colour.
- **Imax, Field Factor, Pm** are the readings we got from the test.
- The module with near to **1 FF** gives **more power**. Based on the Imax, the category of the module is given.

6.2 Hi-pot Testing

- This is the testing machine which tests the module at High Voltage.

- The contact block is connected with to screw like conducting materials that are connected with electrical wires with a screen.

- Three types of tests are done in this machine.

- **DC (Dielectric)** – In this test, the module is provided **4.8kV** and the reading is taken in the machine and it is displayed on the screen. The modules are tested at voltage that are **2.5 times** the regular voltage that will be given to the module in industry. This is tested to check whether the module can bare High Voltage or not. In industry generally **1500 V** is supplied.

- **IR (Insulation Resistance)** – In this test, the module is tested at **1.8kV** to measure the **Leakage Current** in the frame. This test is done to check the safety of the module that whether the current is leaked from the frame or not.

- **GD (Grounding)** – In this test, **62.5 A** current is given to the module and it is tested that whether the current in grounded or not.

6.3 Post EL & VI Inspection

- After Hi- Pot Test, the modules are once again inspected.
- The EL and Visual images are displayed on the screen and the modules are check once again.
- Cracks, poor soldering and other defects that has been formed in the module and that were not visible are checked here.
- If there are Cracks or other defects, the module is thrown into scrap.
- If the module is OK, then it is moved further.
- After inspection, the back cover of the JB called Cap is attached. Cap is basically a plastic that is attached to JB to close it.
- The contact block is also removed at the station and the sticker of ASPL is sticked at the back of the module.
- At next station, the barcode of the module is scanned and cardboard is attached at four corners of the module.
- There are special cuttings of the cardboard to cover the corners. Total 4 cardboard pieces are attached with the module.
- After the completion of testing, the panel goes for cleaning and then for packing.

Conclusion