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Design of 50 MW Grid Connected Solar Power Plant

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***Abstract*-This paper aimed at developing a convectional procedure for the design of large-scale (50MW) on-grid solar PV systems using the PVSYST Software and AutoCAD. The output of the 50MW grid-connected solar PV system was also simulated using PVsyst software and design of plant layout and Substation to transmit it to 132Kv Busbar using AutoCAD was done with all standard measures. The project began with a collection of databases of various renewable energy systems components from different producers. In this paper the standard procedure developed was affirm in the design of a 50MW grid connected solar PV. This paper contains the different diagrams and single line diagrams that are required for the design of 50MW grid connect solar power plant.**

Key words: Solar power plant, power system, Plant Layout, Substation, Substation design, AutoCAD Design, PVsyst performance prediction.

1. INTRODUCTION

Now day's conventional sources are rapidly depleting. Moreover, the cost of energy is rising and therefore solar energy is one of the most economical and exploitable renewable sources of energy that can be harnessed for generation of power. There are several advantages of using solar energy like low establishment period, no raw material expenses, non-polluting and renewable form of energy, etc. India has very good conditions for the development of photovoltaic solar power systems due mainly the geographical location and it receives solar radiation almost throughout the year, which amounts to 3000 h of sunshine. This is equal to more than 5000 trillion kW h. Almost all parts of India receive 4–7 kW h of solar radiation per sq meters. The country's solar installed capacity reached 34.045 GW as of 31 January 2020. The Indian government had an initial target of 20 GW capacity for 2022, which was achieved four years ahead of schedule. In 2015 the target was raised to 100 GW of solar capacity (including 40 GW from rooftop solar) by 2022, targeting an investment of US$100 billion. India has established nearly 42 solar parks to make land available to the promoters of solar plants. Photovoltaic modules or panels are made of semiconductors that allow sunlight to be converted directly into electricity. These modules can provide you with a safe, reliable, maintenance-free and environmentally friendly source of power for a very long time. A successful implementation of solar PV system involves knowledge on their operational performance under varying climatic condition and also the adequate knowledge of overall plant layout design and design of substation with an appropriate rating of all the equipment used in the plant.

1.1 SYSTEM DESIGN AND OBJECTIVE

A study was conducted for optimise Design of 50MW solar power plant considering all Electrical regulation and standards. The general objective in designing a Solar Power Plant to adequately match the capabilities to the load requirements of the consumer, at a minimum cost of the system to the consumer. In order to accomplish this, the designer will need to know the following types of questions about the system.

(1) Power Requirements, (2)Solar Data Availability, (3)Type and Size of Solar Power Plant Required, (4) Cost of Energy Produced, (5) Solar Power Viability, (6) System Characteristics, (7) System Requirement, (8) Evaluation Criteria, (9) Design Optimization, (10) Economic Viability and (11) Prospects of Cost Reduction.

2. DESCRIPTION OF SOLAR- PV GRID SYSTEM

Photovoltaic (PV) refers to the direct conversion of sunlight into electrical energy. PV finds application in varying fields such as Off-grid domestic, Off-grid non-domestic, grid connected distributed PV and grid-connected centralised PV. The proposed 50Mw AC is a utility scale grid interactive PV plant.

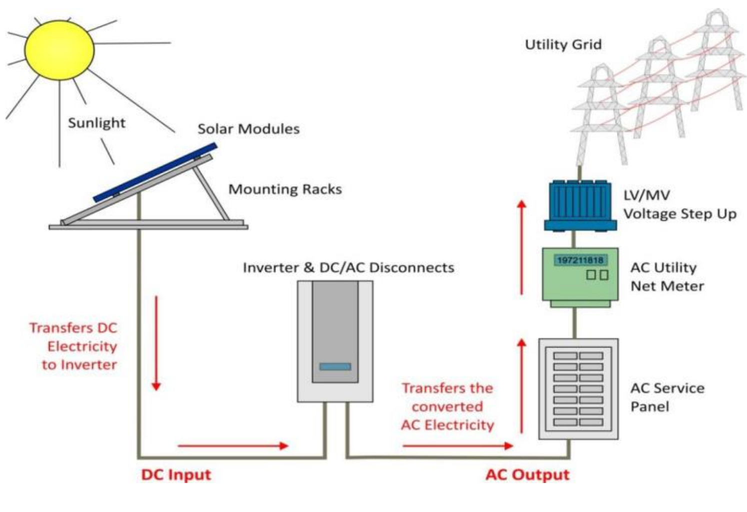

Fig 2.1 Overview of typical Solar PV project

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2.1 SOLAR PLANT DC COMPONENTS

- **Solar PV modules**

A PV cell is the principal building block of a solar PV plant. Basically, a semi-conductor, PV cells convert sunlight into useful Direct Current (DC) electrical energy. PV cells are small in size and capable of generating only a few Watts (W) of energy. However, PV plants are highly modular (i.e.) modules can be combined together to generate power ranging from a few watts (W) to tens of megawatts (MW). Due to the electrical properties of PV cells, their manufacturing is restricted to a handful of raw materials. Each material has its unique characteristics which impact PV module performance, manufacturing process and cost. PV cells may be based on either wafer (manufactured by cutting wafers from a solid ingot block of material) or “thin film” material (which is deposited onto low-cost substrates).Module Structures allow PV modules to be securely attached to the ground at a fixed tilt angle, or on sun-tracking frames which orient sun. PV cells can further be characterised according to the long-range structure of the semiconductor material used:

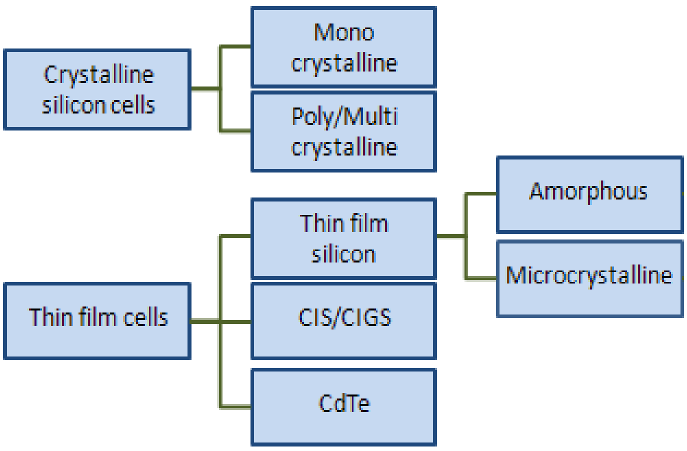

Fig 2.2 Classification of PV Technology

- **Inverter**

  Inverters are solid state electronic devices. They convert DC electricity generated by the PV modules into AC electricity. Inverters can also perform a variety of functions to maximise the output of the plant. These range from optimising the voltage across the strings and monitoring string performance to logging data, and providing protection and isolation in case of irregularities in the grid or with the PV modules.
  There are two broad classes of inverters:
  i) String Inverters ii) Central Inverter
  Considering all the losses in inverter from DC to AC, in cables and other transmission losses Solar plant will be designed with 45% overloading of inverter

3.GENERAL LAYOUT AND DESIGN OF DC PART OF 50MW SOLAR PLANT

- Before Making layout of the Solar power plant, study and analysis is done of the given land.

- study of the proposed site through satellite images to assess the suitability of the site for development of a 50MWAC solar PV plant is done. Also, by the help of PVsyst software all land analysis and generation prediction are done of the given land.

- Thus, by all the analysis and study it was concluded that for Design of 50Mw Solar plant components to be used are:
  i)330Wp Solar Module
  ii)160Kw String Inverter (with 45%overloading)

- Array of Module that is a set of Table is of 2x16

- Approximately 250 Acers of land will be used to place a 50Mw Solar power plant.

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- ✓ As mentioned above per Module is of 330wp, and each table have such **32 modules** so per Table capacity=**10.56K**
- ✓ For 50 Mw plant, one Block of 858 tables having capacity of **6.25Mw** is selected. So, total such 8 blocks are required to reach 50Mw AC
- ✓ As mentioned above 160Kw inverter is used in this 50Mw plant. But overloading of 45% is considered so per Inverter capacity would be **160*1.45= 232 DC**
- ✓ Number of inverters for 50Mw plant = **312 units**
- ✓ Total inverter capacity of plant: 312*232=**72384Mw DC**
- ✓ AS per table is of 10.56 Mw, total number of tables in 50Mw plant will be **6864 units**

- Layout of the tables on the given land is done with a standard measurement. Such that shadows are avoided of the surrounding tables or other structure.

Horizontal distance between 2 tables = **0.100m**

Vertical distance between 2 table = **3.5860m**

Pitch = **7.500m**

3.1 STUDY OF ONE BLOCK OF 6.25 MW:

Each block consists of total 858 tables and 39 inverters. So, for per inverter 22 tables are connected. The grouping of tables is done 22 table in one group connected to one inverter. Total such 8 blocks are made for 50Mw plant.

Per block **- 6.25Mw**

Inverter **- 160Kw(45%overloading)**

Therefore, **6.25 / 0.160 = 39 Number of inverters** per block

Per Inverter capacity – **22 tables**

So, for total 39 inverters in one block and total tables in one block – **858 units**

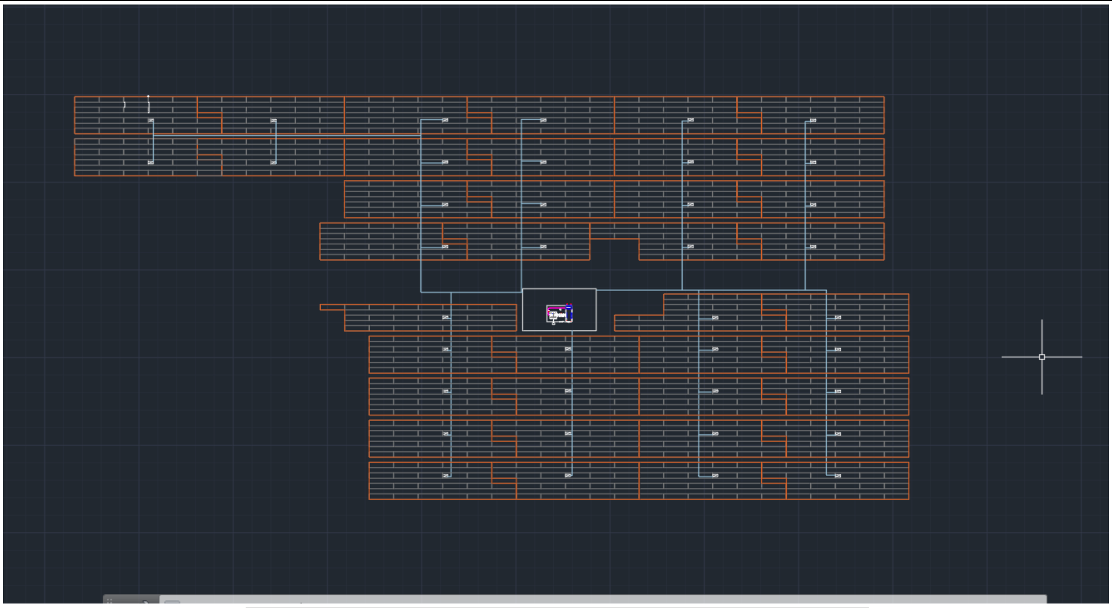

Fig 3.1 Single Block layout

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3.2 OVERALL DESIGN OF 50MW SOLAR POWER PLANT

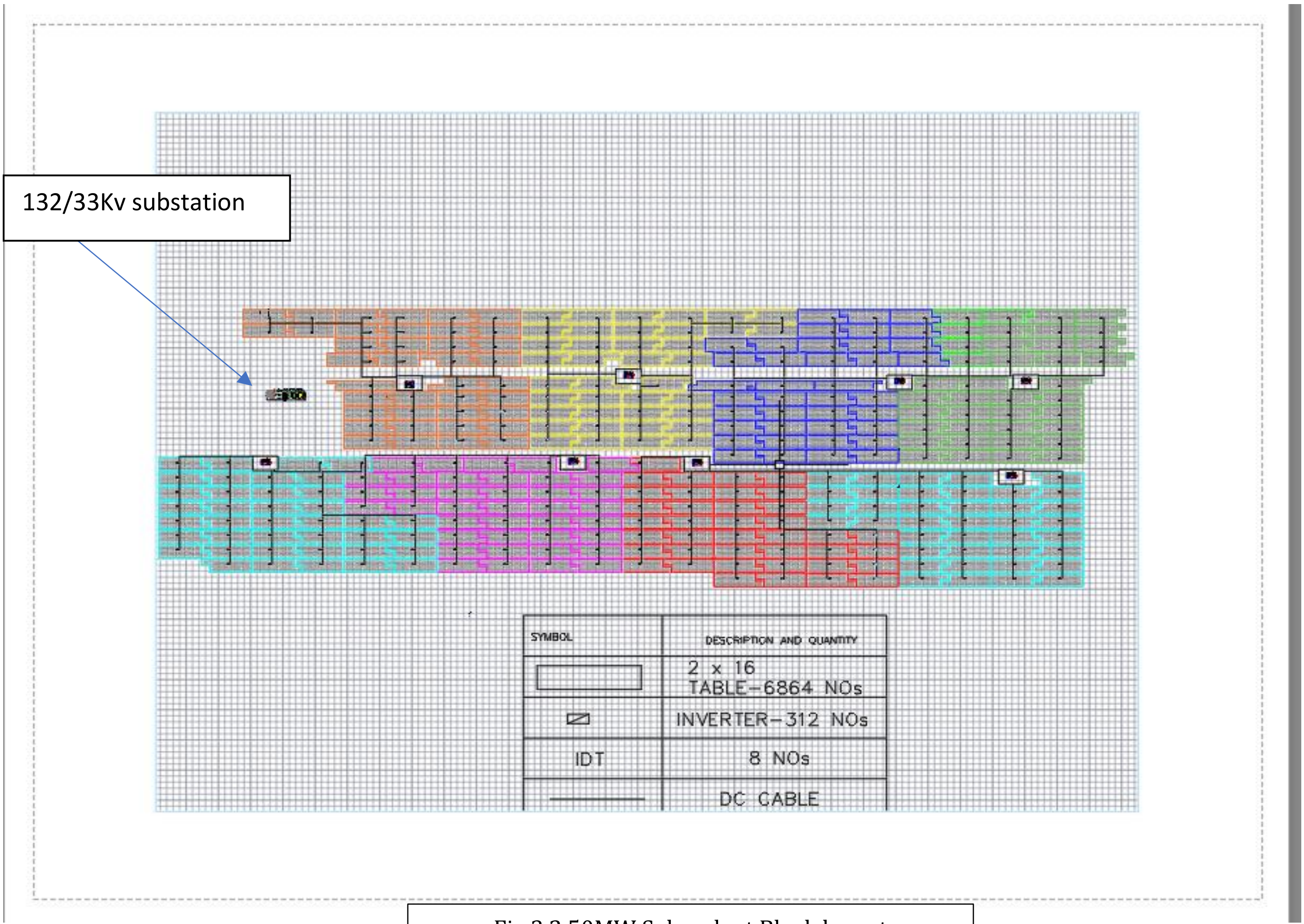

Fig 3.2 50MW Solar plant Block layout

BLOCK	COLOR IDENTIFICATION
BLOCK 1	ORANGE
BLOCK 2	YELLOW
BLOCK 3	BLUE
BLOCK 4	GREEN
BLOCK 5	LIGHT BLUE
BLOCK 6	PURPLE
BLOCK 7	RED
BLOCK 8	LIGHT BLUE

EQUIPMENTS	QUANTITY
TABLES	6864 UNITS
INVERTERS	312 UNITS
IDT STATION	8
BLOCKS	8

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- Hence, by standard dimension and land allocated all the tables, Inverter and IDT (Inverter Duty Transformer) are place. Now DC cables are to be placed from every inverter to IDT in an optimise way in which minimum cable are stretched so as to set minimum DC cable losses and minimum digging work.

- In Inverter DC power from solar generation is inverted to AC power which is collected and pass to the Inverter Duty Transformer. By the help of LT cable power from inverter to IDT is transferred where power is stepped up by the transformer. After step up using HT cable it is passed to 33kv switchgear.

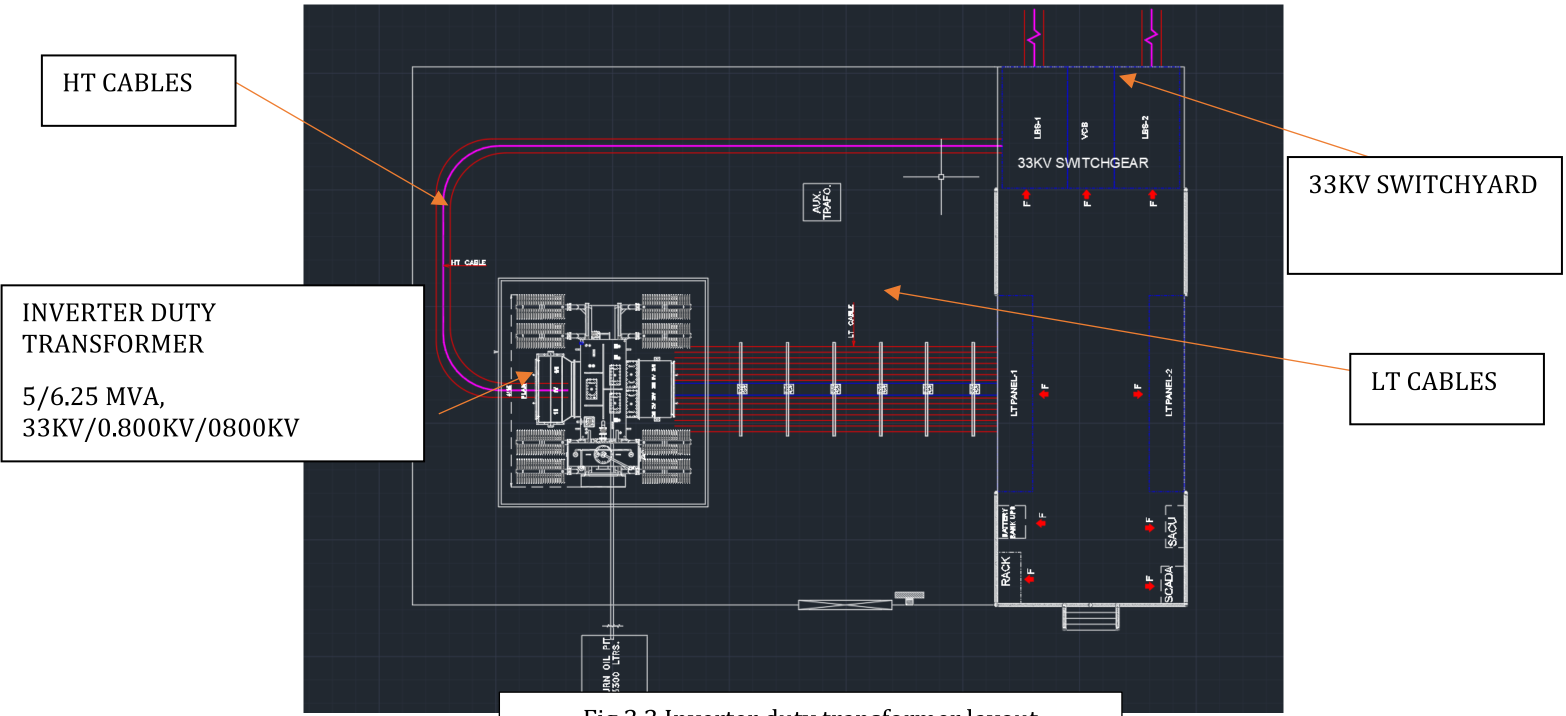

Fig 3.3 Inverter duty transformer layout

3.3 STRING INVERTER CONNECTION

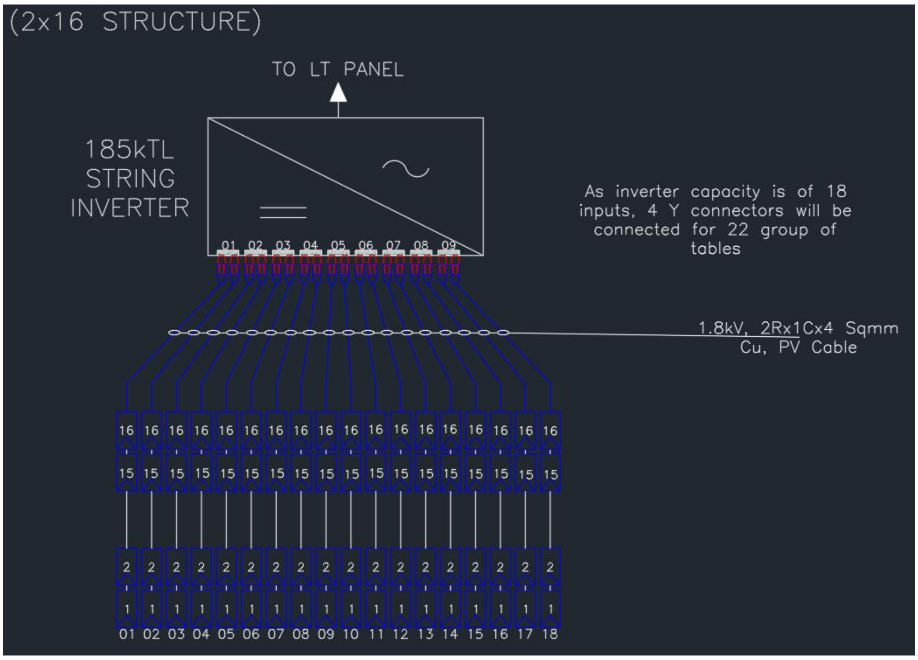

Fig 3.4 String Inverter Connection diagram

For 160kw inverter, Huawei 185kTL is selected. (Datasheet of this inverter is provided at the end) As input capacity of this inverter is 18, 4 Y connectors will be used to connect the connection of 22 tables with an Inverter.

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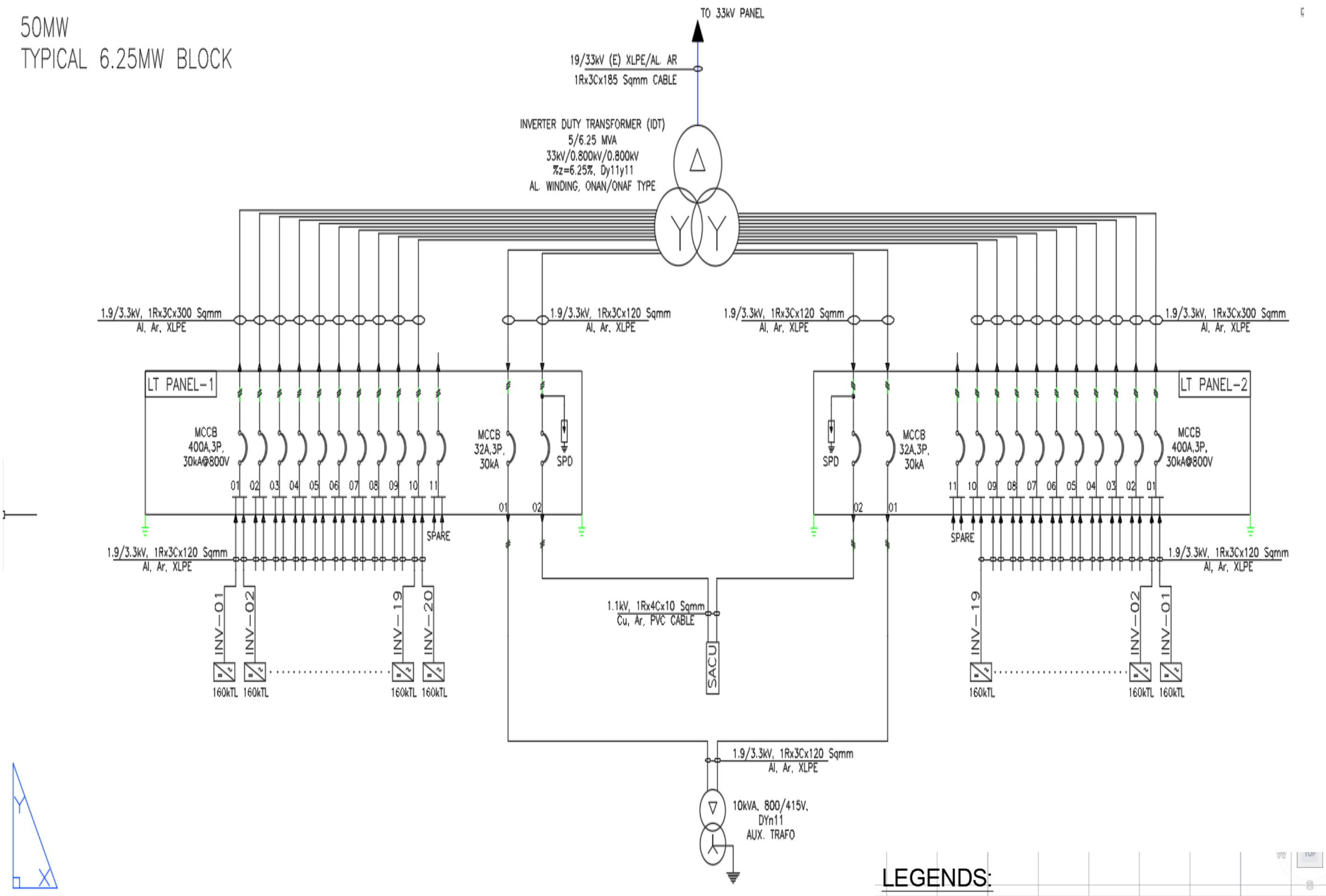
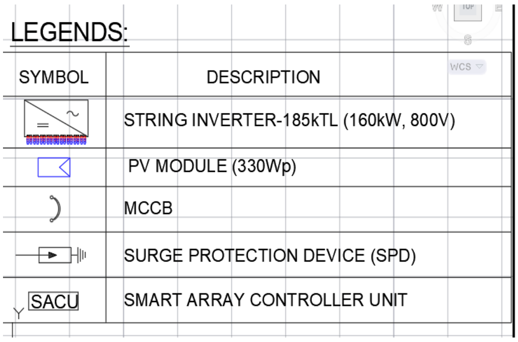
3.4 INVERTER TO IDT CONNECTION DIAGRAM





LEGENDS:

SYMBOL	DESCRIPTION
	STRING INVERTER-185kTL (160kW, 800V)
	PV MODULE (330Wp)
	MCCB
	SURGE PROTECTION DEVICE (SPD)
SACU	SMART ARRAY CONTROLLER UNIT

Fig 3.5 String inverter to IDT connection diagram

Equipment	Ratings and Type
Inverter Duty Transformer (IDT)	5/6.25 MVA 33kv / 0.800kv/0800kv Dy11y11 ONAN /ONAF type
MCCB	400A ,3P ,30kA@800v AND 32A,3P,30kA
Auxiliary Transformer	10kVA, 800/415V, DYn11
Cable	1.9/3.3kv, 1Rx3Cx120 sq mm
	1.9/3.3kv, 1Rx3Cx300 sq mm
	19/33kV, 1Rx3C185 sq mm

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4.DESIGN OF AC PART OF 50MW SOLAR POWER PLANT

Up till now, DC portion of plant was discussed that is up to IDT. After inverting the power from DC to AC power it is to be step up so as to meet the voltage level and frequency of the line grid where the generated power is to be transferred. In AC portion of plant voltage level is quite higher so lots of protecting systems are required. In the power plant most important and costliest equipment is transformer which is to be protected first.

Following are the electrical equipment used in the substation for protecting and metering purpose:

i. MV Switchgear
ii. Bus-Bar Schemes
iii. Switchyard
iv. Circuit Breakers
v. Isolators
vi. Instrument Transformers
vii. Surge Arresters
viii. Insulators
ix. Metering
x. Earthing System
xi. Lightning Protection

5.SINGLE LINE DIAGRAM (SLD)

5.1 SLD OF 33KV PANEL

Power in IDT after step up to 33Kv it is passed to 33Kv switchgear panel. Here power is pass through the protecting system before transferring to 132kv Substation. Below SLD shows the flow of power in 33kv panel.

In the given panel surge arrester is connected to protect from any short period surge power. Next comes CT for metering and protection. Then circuit breaker is placed to break the circuit in case of fault. Further on PT is placed to measuring and protection. From this power is transferred to main 33Kv panel.

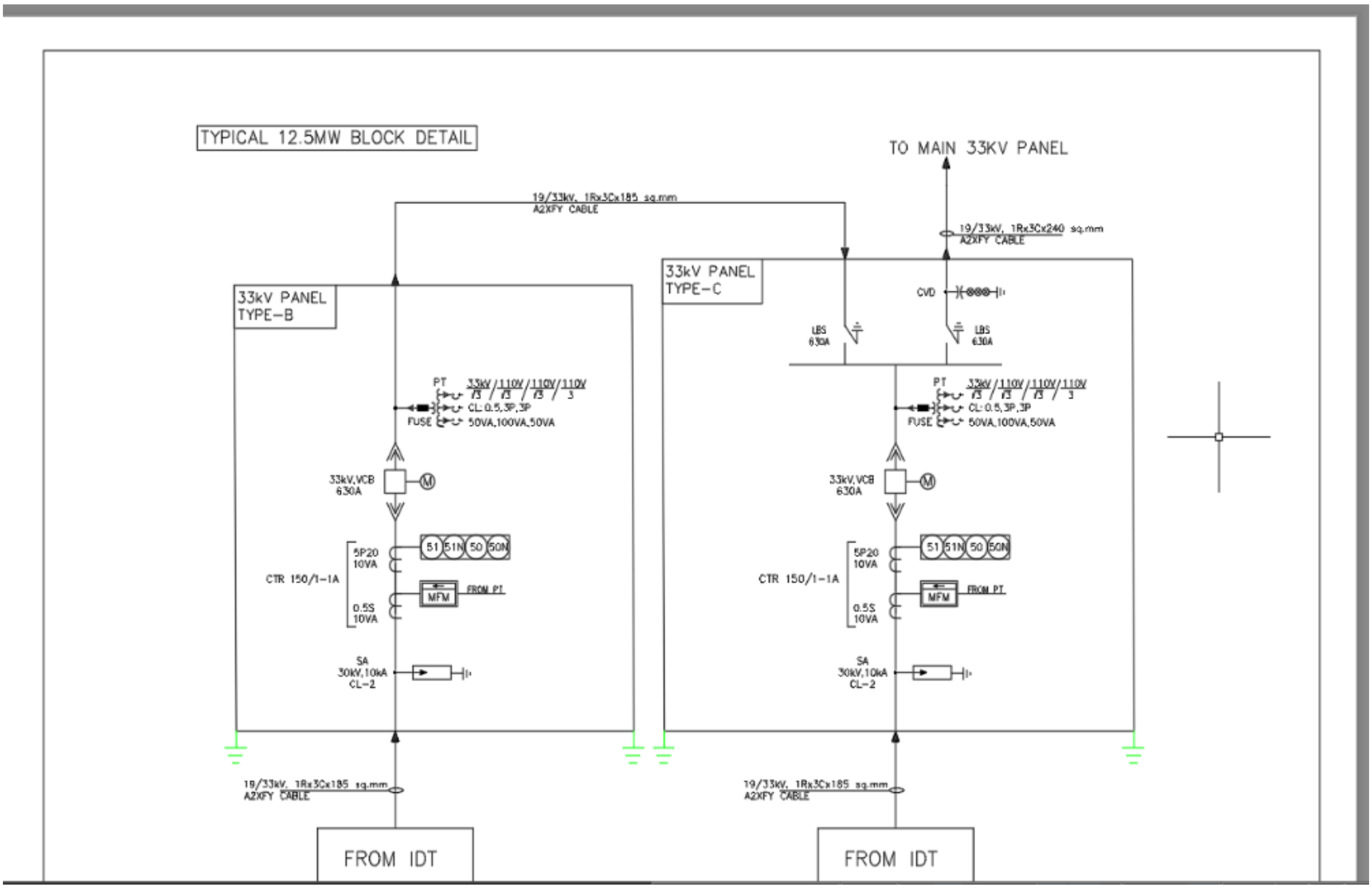

Fig 5.1 33Kv panel Single line diagram

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5.2 GENERAL SUBSTATION SLD

As discussed above, substation is equipped with the rated and fast responding protection equipment to make the smooth flow of power without any breakdown due to faults.

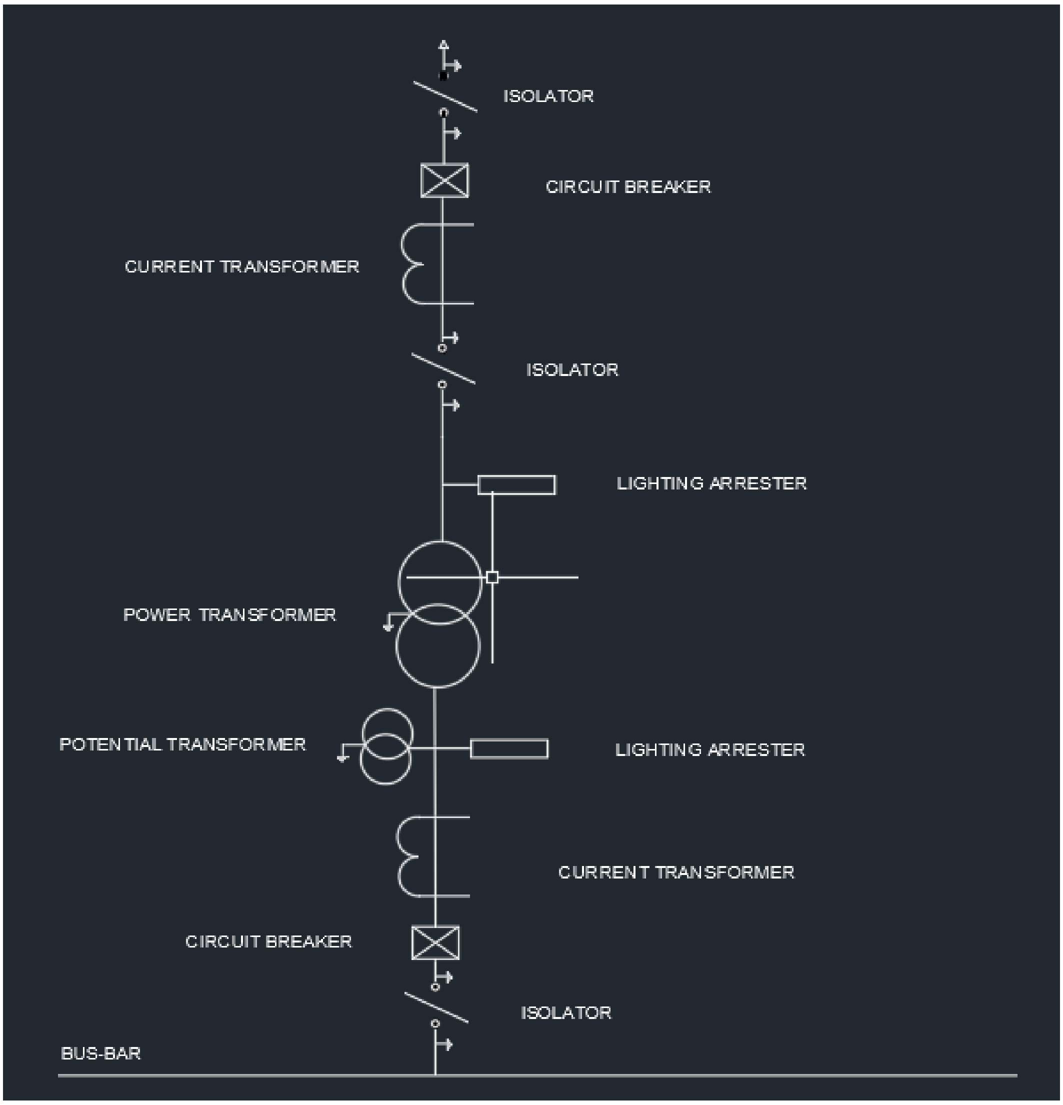

Fig 5.2 Substation general Single line Diagram

5.3 132 KV / 33KV POOLING SUBSTATION

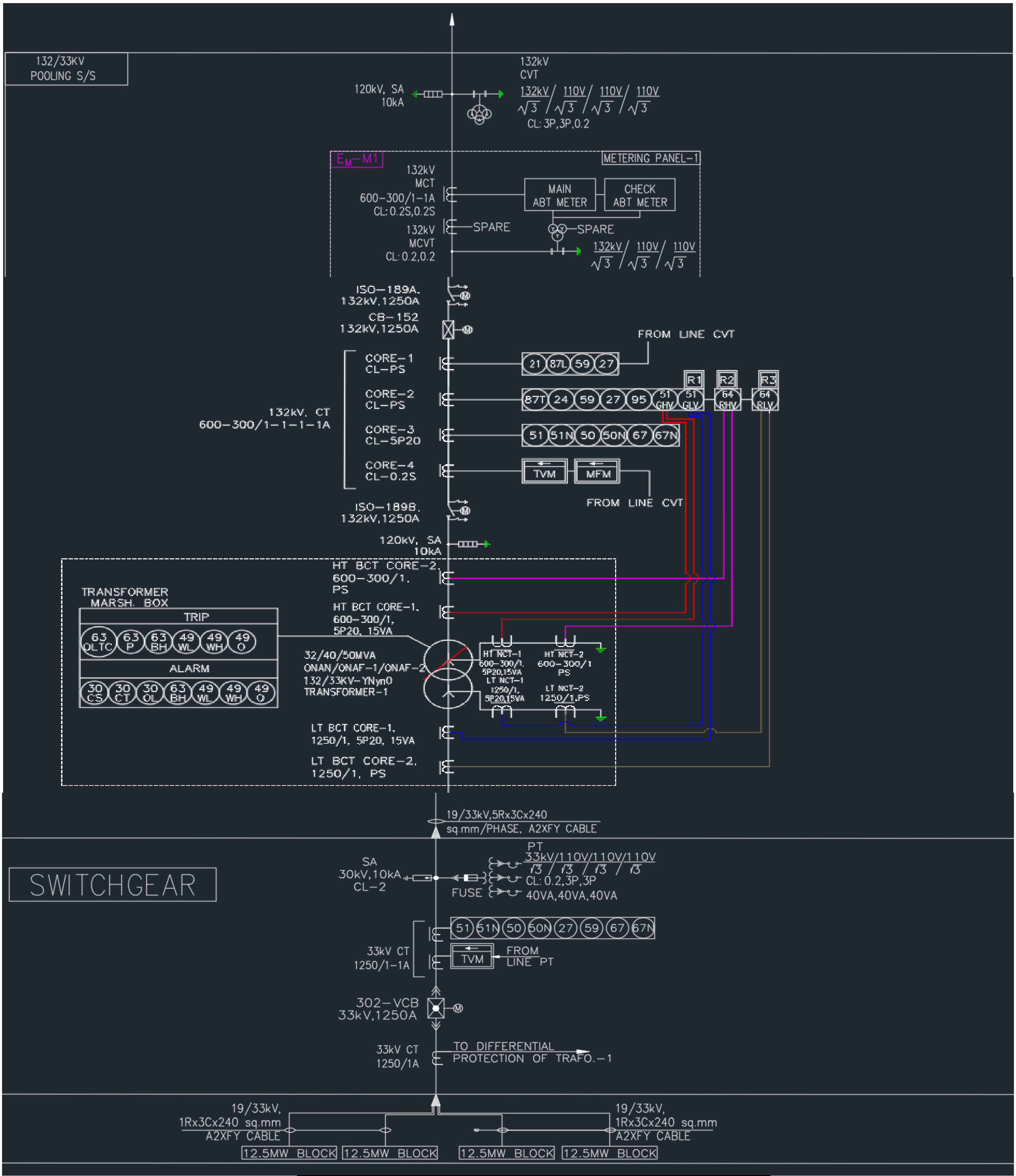

Fig 5.2 132Kv/33Kv pooling substation SLD with Metering M1

5.4 132 KV SUBSTATION SLD

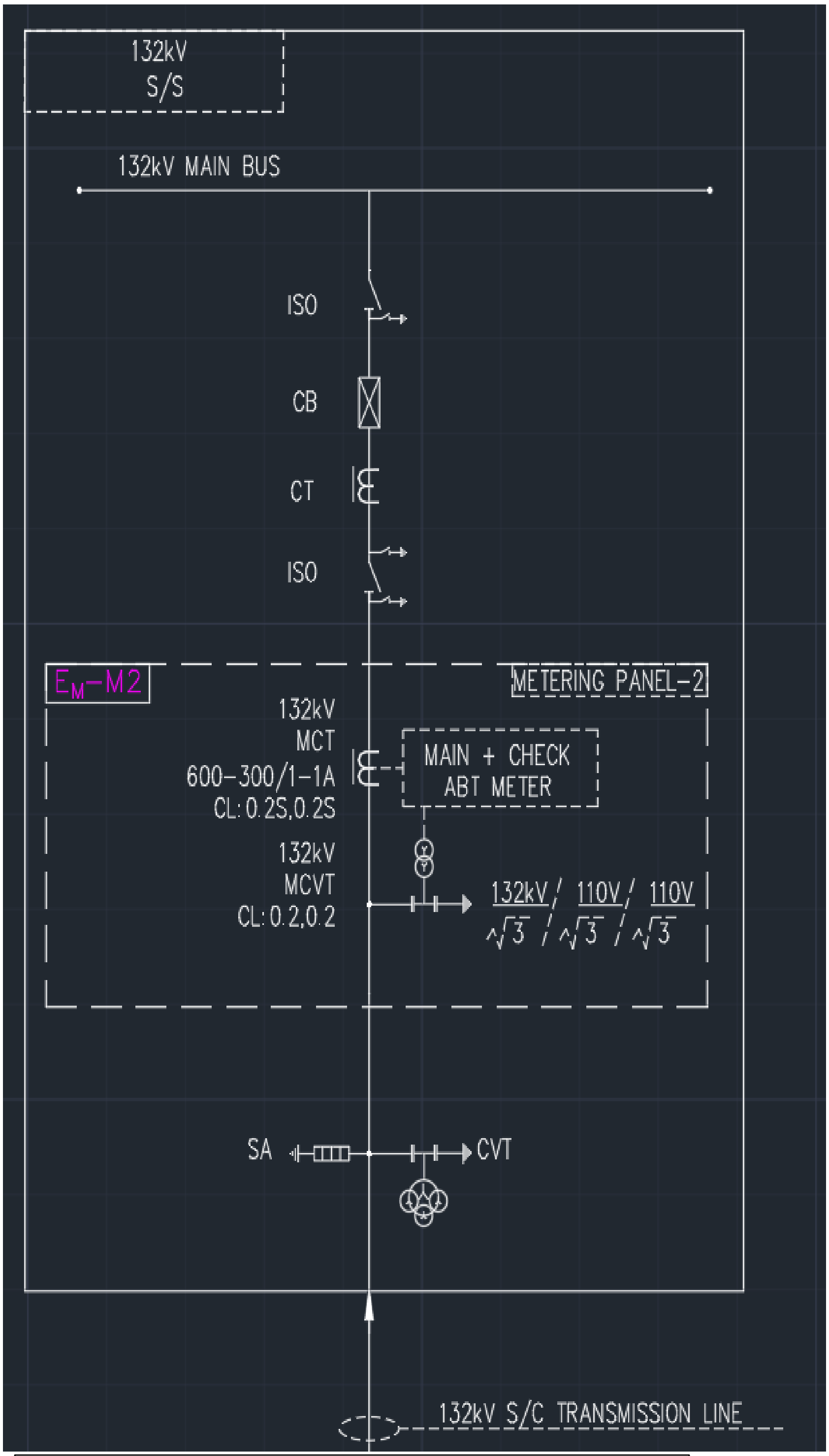

Fig 5.3 132Kv substation SLD with Metering M2

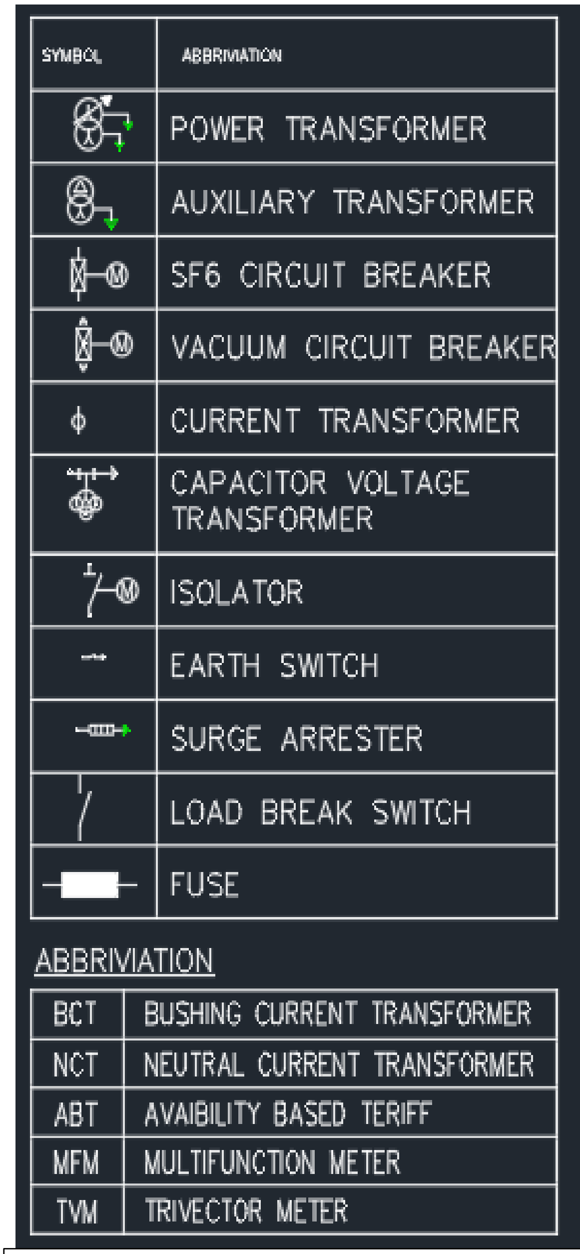

Fig 5.4 Symbols and Abbreviations

M1 = Energy values in ABT Meter at 132kv plant end.
M2 = Energy values in ABT Meter at 132kv Remote end.
Total Losses (L) = M1-M2

6. SIMULATION USING PV SYST SIMULATION SOFTWARE

Data obtained for irradiation on collector plane, PV module and inverter specifications and plant configuration are input into the PV modelling software PV Syst to calculate DC energy generated from the modules in hourly time steps throughout the year. This direct current is converted to AC in the inverter. A number of losses occur during the process

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of converting irradiated solar energy into AC electricity fed into the grid. The losses may be described as a yield loss factor. They are calculated within the PV modelling software and calculated from the cable dimensions.

6.1 MONTH-WISE ENERGY YIELD PREDICTION (P50)

Table: Month-wise breakup of P50 energy yield

Month	**50 MW Project Total MWh Generation**
January	6,872
February	9,142
March	11,923
April	11,927
May	11,624
June	9,510
July	8,064
August	9,182
September	9,426
October	10,030
November	8,387
December	7,440
Total Estimated MWh Generation	1,13,527

6.2 GENERATION AND CAPACITY UTILISATION FACTOR (CUF)

The Capacity Utilization Factor (CUF) also known as Plant Load Factor (PLF) of a PV power plant (usually expressed as a percentage) is the ratio of the actual output over the period of a year and its output if it had operated at nominal power the entire year, as described in the formula below.

CUF(AC)= Energy Generated per annum (MWh) / (8760 x Installed AC Capacity in MW)

The Year 1 Generation and aggregate CUF (AC) on cumulative project capacity is as below:

Year 1 Generation and CUF	**50 MW Project Total**
P90 Generation	107,596 MWh
P90 % CUF (AC)	24.56 %
P75 Generation	102,246 MWh
P75 % CUF (AC)	23.34 %
P50 Generation	113,527 MWh
P50 % CUF (AC)	25.92 %

6.3 PERFORMANCE RATIO

The quality of a PV power plant may be described by its Performance Ratio (PR). Usually expressed as a percentage, can be used to compare PV systems independent of size and solar resource.

The PR is expressed as:

% PR = (Energy generated per annum x 100%) / (Installed Capacity x Plane of Array Irradiation)

By normalising with respect to irradiation at Standard Temperature Conditions (STC), the PR quantifies the overall effect of losses on the rated output and allows a comparison between PV plants.

Expected Performance Ratio (PR)	**50 MW Project Total**
% PR of Year 1	80.70 %

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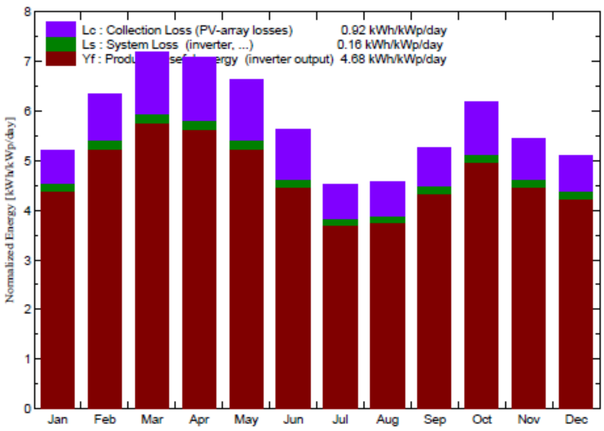


Fig 6.1 Normalized production per installed kwh

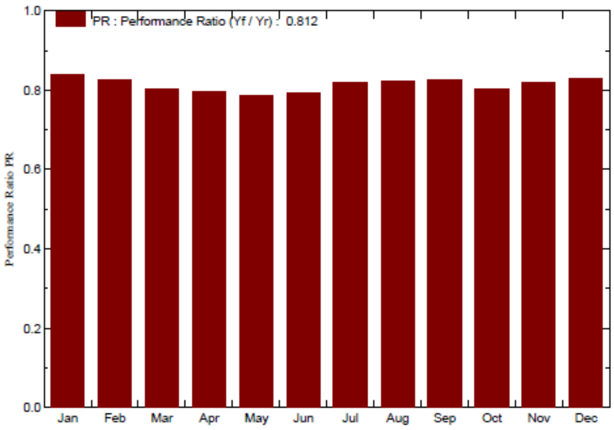
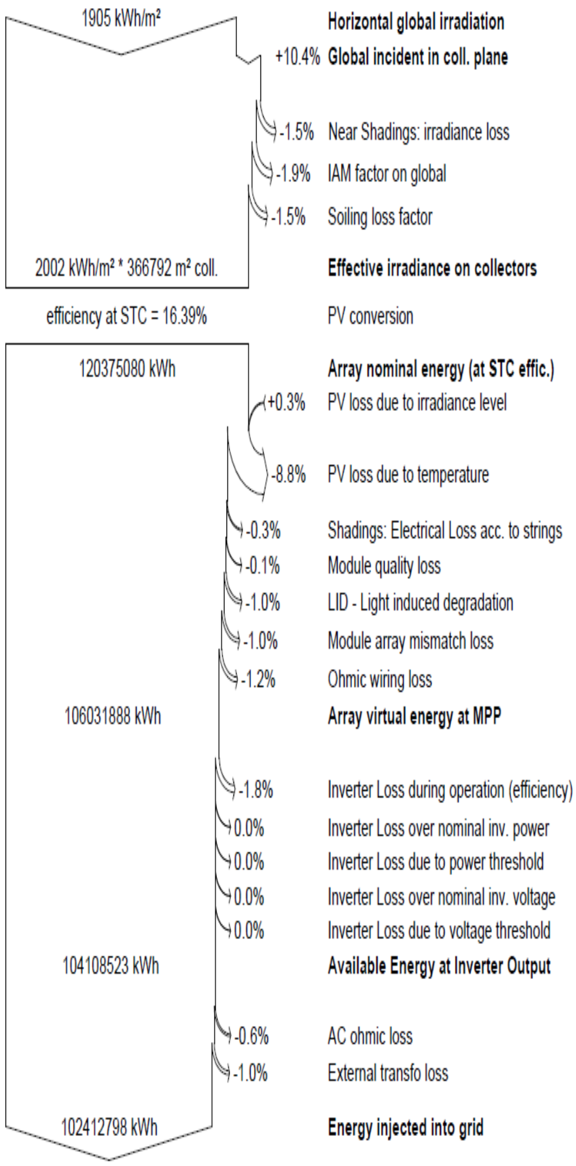


Fig 6.2 Performance ration Pr



7. CONCLUSION

Hence a study was concluded for 50MW on grid Solar power plant. Concluding the overview of solar plant with all the necessary components of DC as well as for AC. With all this analysis a design of 50MW on grid solar power plant was done using AutoCAD. Designs included the plant layout and all the electrical diagrams with electrical standard measures. Also, using PVsyst software plant efficiency and generation prediction was calculated which comes out to be 80.70% for 1 year.

Also, after studying whole plant and its procedure to develop it, some of the research study was done along with this design which can be helpful in future to increase the efficiency of any solar plant. Firstly, using the Black silicon in manufacturing of PV module will increase the module efficiency as black silicon trap and hold maximum solar radiations. And other idea can be implemented in future of Agro Solar plant which include the agriculture of herbs on a cultivated land also can fix solar plant both simultaneously which is said to be Agrosolar plant. Also updating a technology in software used in designing the plant which can reduce man-work and software can calculate and design its own plant design by knowing land coordinates and plant capacity required.

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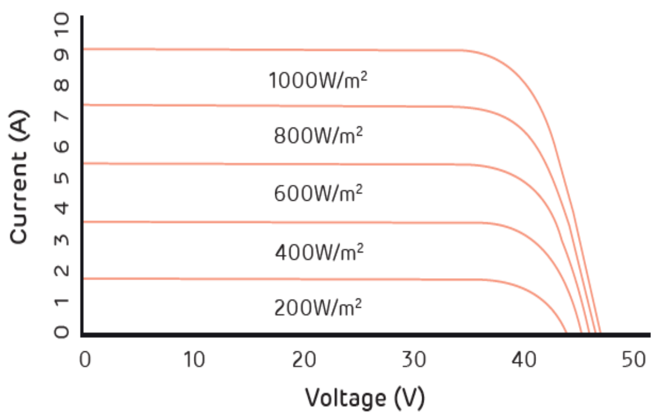
9.TECHNICAL DATASHEET
9.1 SOLAR MODULE DATASHEET

Characteristics	**Value**
Type	Polycrystalline
Nominal Power (PMPP)	330Wp
Voltage at Pmax (VMPP)	37.71V
Current at PMax (IMPP)	8.75A
Open Circuit Voltage (VOC)	46.40V
Short Circuit Current (ISC)	9.24A
Module Efficiency	16.8%
Temperature range	40°C to +85°C
Dimensions Module Area Weight	1,956mm x 992mm x 40mm 1.94m2 26.5kg



9.2 STRING INVERTER DATASHEET

Type	String
Max. Input Voltage	1500V
Max. current per MPPT	26A
Max. Short circuit current per MPPT	40A
Start voltage	550V
MPPT operating voltage range	500V-1500V
Nominal input voltage	1080V
Number of inputs	18
Number of MPP trackers	9
Nominal Ac Active power	175kw @.40°C 160kw @50°C
Max. AC Active power	185kw
Nominal Output voltage	800V
Nominal output current	126.3 @.40°C 115.5 @50°C
Max. Output current	134.9A
Max. total Harmonic Distortion	< 3%
Dimension	1035x700x365mm
Weight	84kg
Operating Temp. Range	-25°C ~ 60°C