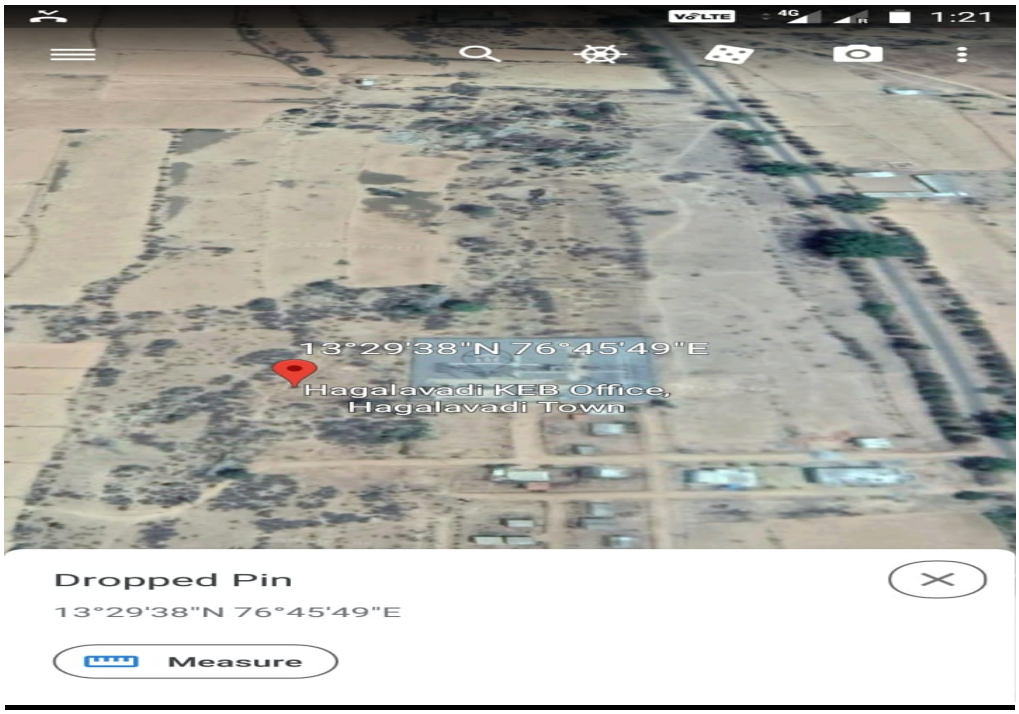
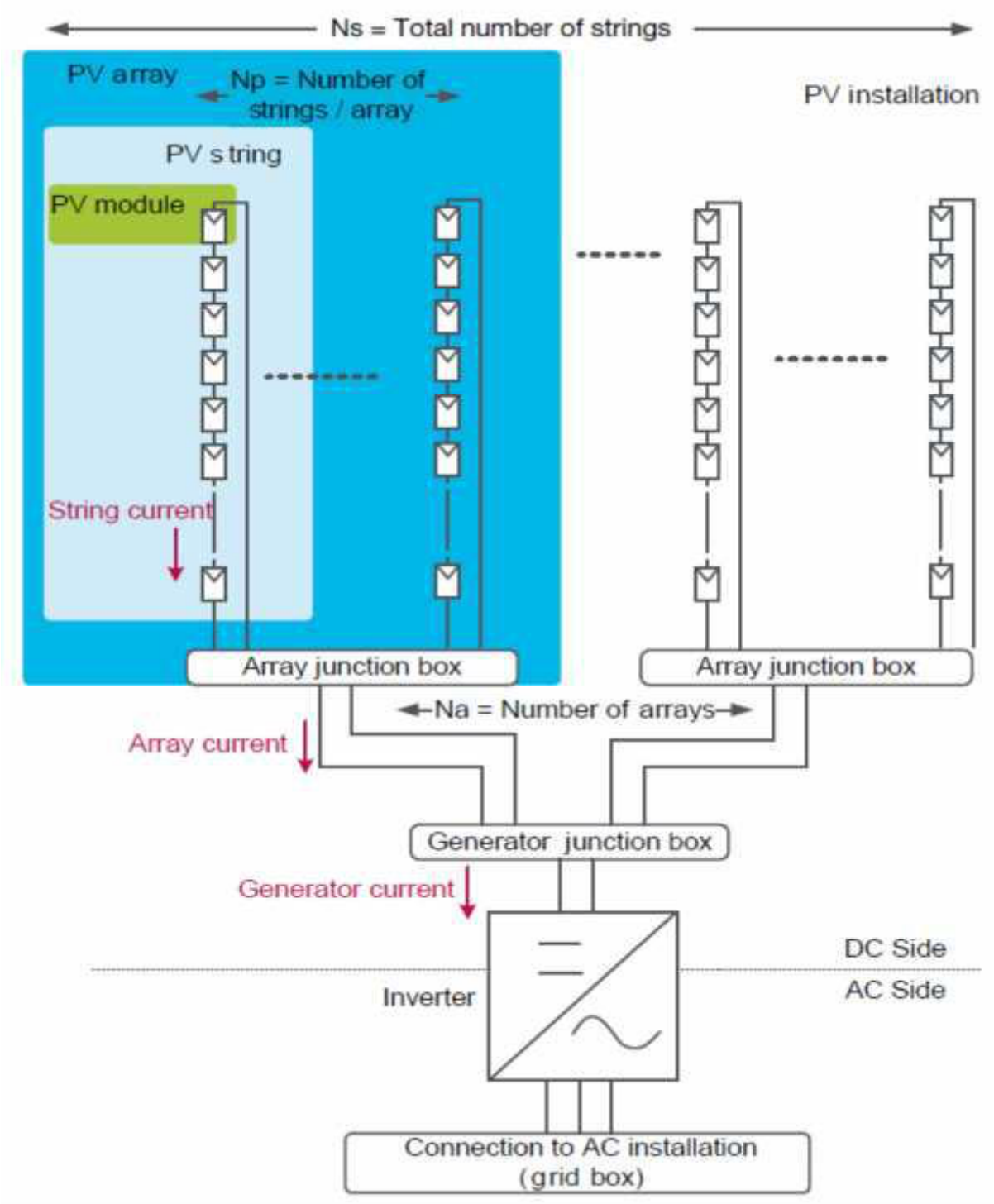
SLD & SOLAR-GIS YIELD ASSESMENT REPORT OF 10 MW ROOFTOP SOLAR POWER PLANT AT HAGALVADI GRID, KARNATAKA, INDIA



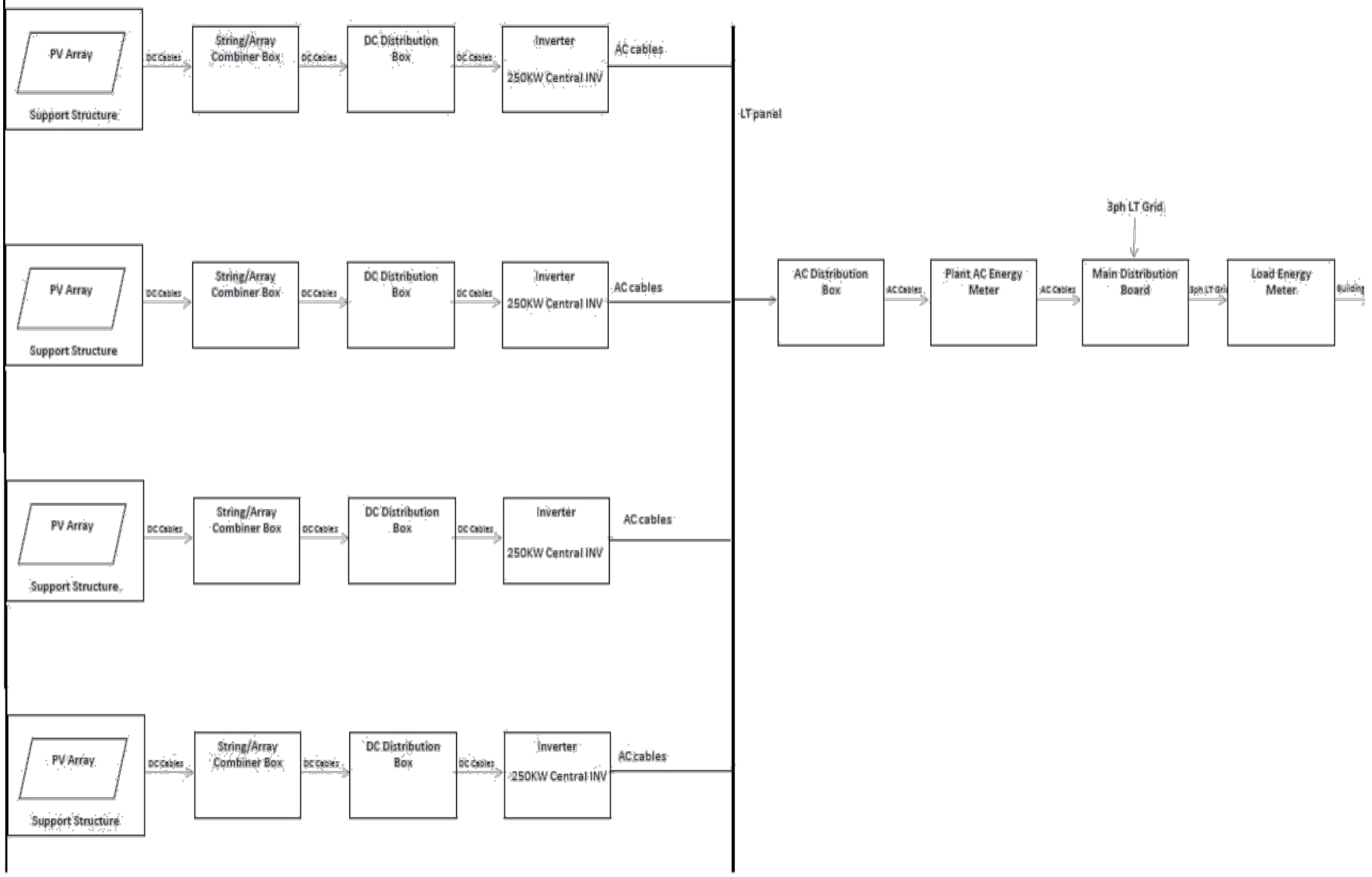
PREPARED FOR SAURYAJYOTI RENEWABLES DIVISION OF M/S GANAPATI PRODUCTS

A schematic of the protection system

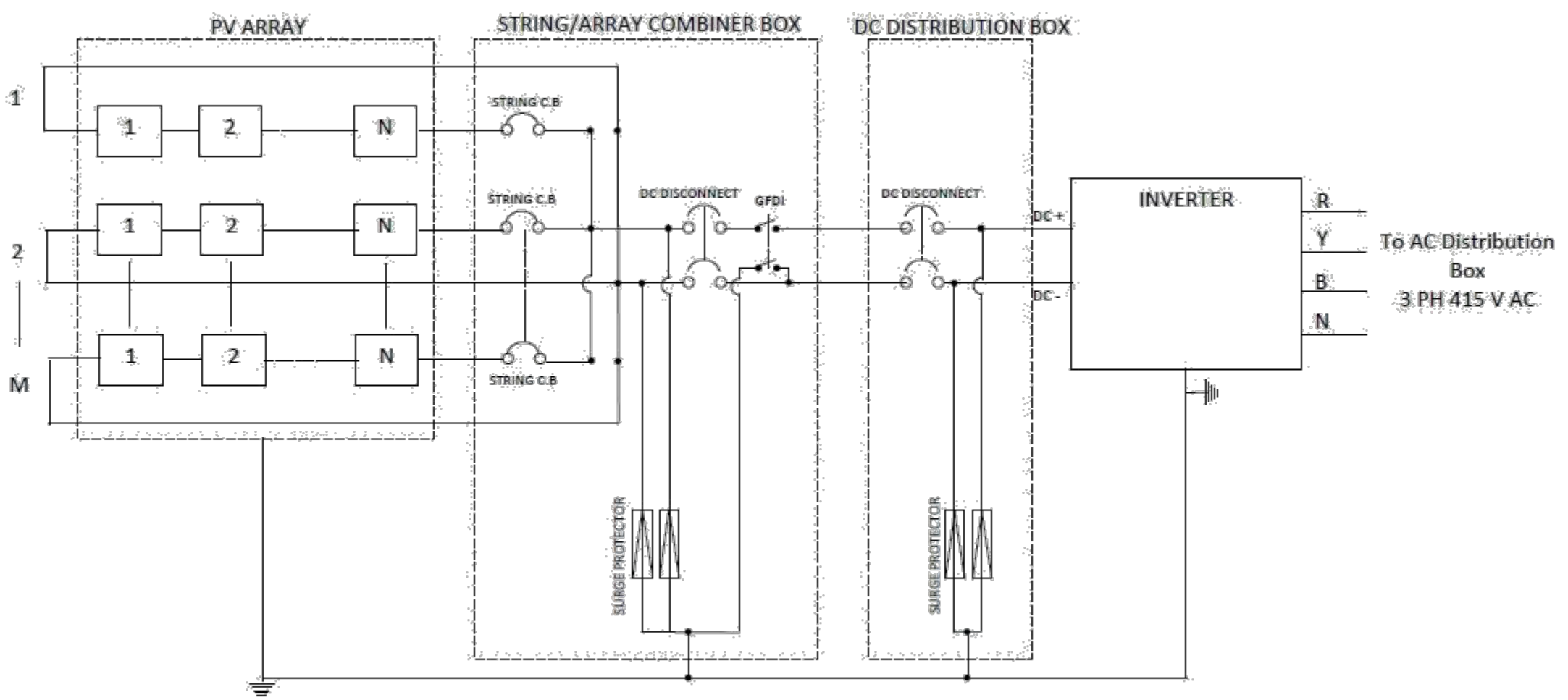


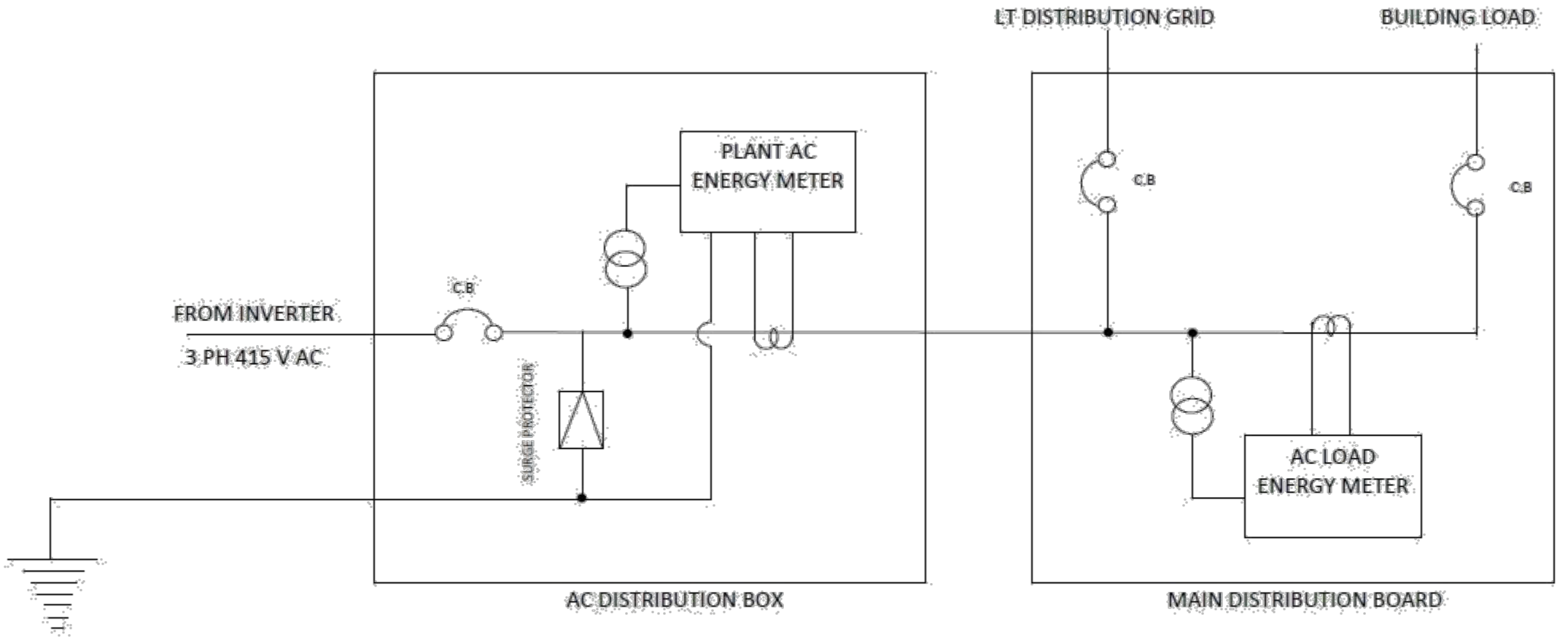
The diagram is made for 1MW block calculation

GRID CONNECTED SOLAR PV POWER PLANT SCHEMATIC DIAGRAM



DC SIDE LAYOUT





LT DISTRIBUTION GRID SUPPLY SCHEMATIC DIAGRAM

YIELD ASSESSMENT OF THE PHOTOVOLTAIC POWER PLANT

Report number: PV-2158-1518-4
Issued: 12 December 2018 16:12 IST

1. Site info

Site name:	Hagalvadi Grid Karnataka, India
Coordinates:	**13° 29' 28" N, 76° 45' 41" E**
Elevation a.s.l.:	4 m
Slope inclination:	1°
Slope azimuth:	30° southeast

Annual global in-plane irradiation: **1942 kWh/m^2**
Annual air temperature at 2 m: **26.3 °C**

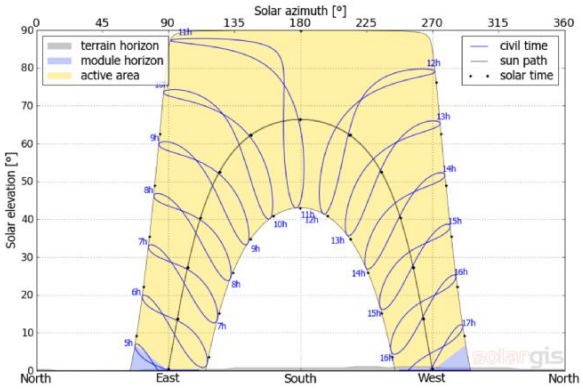
2. PV system info

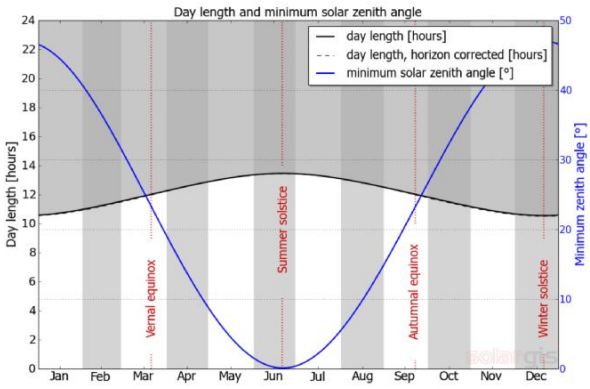
Installed power:	**10000.0 kWp**
Type of modules:	crystalline silicon **(c-Si)**
Mounting system:	**fixed mounting, free standing 2 angles**
Azimuth/inclinations:	**180° (south) / 18°** (winter)**, 14°** (summer)
Inverter Euro eff.:	97.5%
DC / AC losses:	5.5% / 1.5%
Availability:	99.0%

Annual average electricity production: **16700.7 MWh**
Average performance ratio: **75.8%**

Location on the map: http://solargis.info/imaps/#loc=23.543845,87.379074&tl=Google:Satellite&z=14

3. Terrain horizon and day length





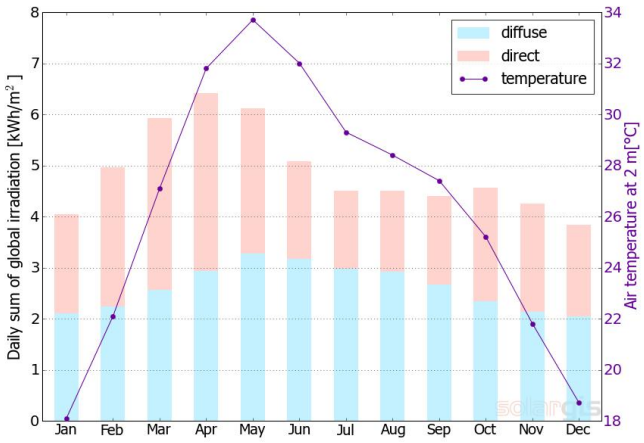
Left: Path of the Sun over a year. Terrain horizon (drawn by grey filling) and module horizon (blue filling) may have shading effect on solar radiation. Black dots show True Solar Time. Blue labels show Local Clock Time.

Right: Change of the day length and solar zenith angle during a year. The local day length (time when the Sun is above the horizon) is shorter compared to the astronomical day length, if obstructed by higher terrain horizon.

Site: Hagalvadi Grid, Karnataka, India, lat/lon: 13.29°/76.45°
PV system: 10000.0 kWp, crystalline silicon, fixed 2 angles, azim. 180° (south)

4. Global horizontal irradiation and air temperature - climate reference

Month	Gh_m	Gh_d	Dh_d	T_{24}
Jan	126	4.05	2.10	18.1
Feb	139	4.96	2.23	22.1
Mar	184	5.93	2.56	27.1
Apr	192	6.42	2.93	31.8
May	190	6.12	3.28	33.7
Jun	152	5.08	3.17	32.0
Jul	140	4.51	2.98	29.3
Aug	140	4.51	2.92	28.4
Sep	132	4.40	2.66	27.4
Oct	141	4.56	2.34	25.2
Nov	127	4.25	2.13	21.8
Dec	119	3.83	2.04	18.7
Year	**1782**	**4.88**	**2.61**	**26.3**



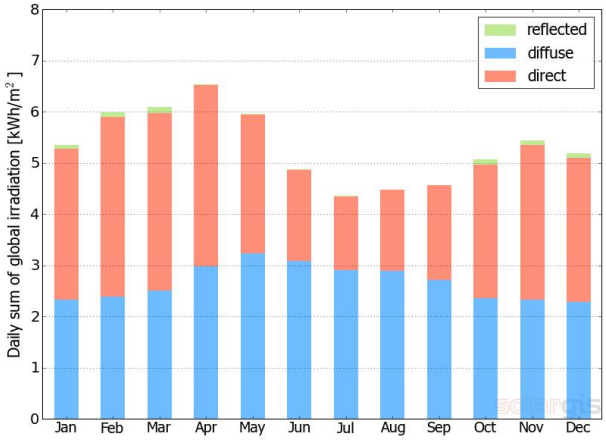
Long-term monthly averages:

Gh_m Monthly sum of global irradiation [kWh/m^2]
Gh_d Daily sum of global irradiation [kWh/m^2]
Dh_d Daily sum of diffuse irradiation [kWh/m^2]
T_{24} Daily (diurnal) air temperature [°C]

5. Global in-plane irradiation

Fixed surface, azimuth 180° (south), inclination. winter 48°, summer 17°

Month	Gi_m	Gi_d	Di_d	Ri_d	Sh_{loss}
Jan	166	5.35	2.33	0.08	0.0
Feb	168	5.99	2.39	0.10	0.0
Mar	189	6.09	2.51	0.12	0.0
Apr	196	6.54	2.98	0.02	0.0
May	185	5.96	3.23	0.02	0.0
Jun	146	4.87	3.08	0.01	0.0
Jul	135	4.35	2.90	0.01	0.0
Aug	139	4.48	2.89	0.01	0.0
Sep	137	4.57	2.71	0.01	0.0
Oct	157	5.06	2.35	0.09	0.0
Nov	163	5.44	2.32	0.09	0.0
Dec	161	5.18	2.28	0.08	0.0
Year	**1942**	**5.32**	**2.67**	**0.05**	**0.0**



Long-term monthly averages:

Gi_m Monthly sum of global irradiation [kWh/m^2]
Gi_d Daily sum of global irradiation [kWh/m^2]
Di_d Daily sum of diffuse irradiation [kWh/m^2]
Ri_d Daily sum of reflected irradiation [kWh/m^2]

Sh_{loss} Losses of global irradiation by terrain shading [%]

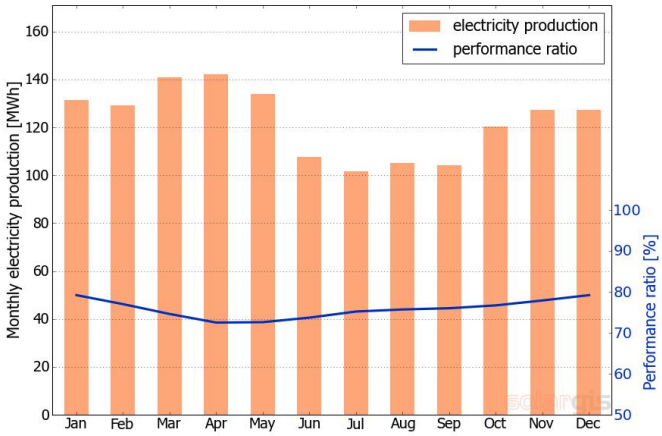
Average yearly sum of global irradiation for different types of surface:

	kWh/m^2	relative to optimally inclined
Horizontal	1782	93.5%
Optimally inclined (24°)	1905	100.0%
2-axis tracking	2256	118.4%
Your option	**1941**	**101.9%**

Site: Hagalvadi Grid, Karnataka, India, lat/lon: 13.29°/76.45°
PV system: 10000.0 kWp, crystalline silicon, fixed 2 angles, azim. 180° (south)

6. PV electricity production in the start-up

Month	Es_m	Es_d	Et_m	E_{share}	PR
Jan	131	4.24	131.3	8.9	79.2
Feb	129	4.61	129.1	8.8	77.0
Mar	141	4.55	141.0	9.6	74.6
Apr	142	4.74	142.1	9.7	72.5
May	134	4.32	134.0	9.1	72.6
Jun	107	3.59	107.7	7.3	73.7
Jul	101	3.27	101.5	6.9	75.2
Aug	105	3.39	105.1	7.1	75.7
Sep	104	3.47	104.1	7.1	76.0
Oct	120	3.88	120.3	8.2	76.7
Nov	127	4.24	127.3	8.7	77.9
Dec	127	4.10	127.2	8.6	79.2
Year	**1470**	**4.03**	**1470.7**	**100.0**	**75.8**



Long-term monthly averages:

Es_m Monthly sum of specific electricity prod. [kWh/kWp]
Es_d Daily sum of specific electricity prod. [kWh/kWp]
Et_m Monthly sum of total electricity prod. [MWh]
E_{share} Percentual share of monthly electricity prod. [%]
PR Performance ratio [%]

7. System losses and performance ratio

Energy conversion step	Energy output [kWh/kWp]	Energy loss [kWh/kWp]	Energy loss [%]	Performance ratio [partial %]	Performance ratio [cumul. %]
1. Global in-plane irradiation (input)	1941	-	-	100.0	100.0
2. Global irradiation reduced by terrain shading	1941	0	0.0	100.0	100.0
3. Global irradiation reduced by reflectivity	1886	-55	-2.8	97.2	97.2
4. Conversion to DC in the modules	1637	-249	-13.2	86.8	84.3
5. Other DC losses	1547	-90	-5.5	94.5	79.7
6. Inverters (DC/AC conversion)	1508	-39	-2.5	97.5	77.7
7. Transformer and AC cabling losses	1486	-22	-1.5	98.5	76.6
8. Reduced availability	1471	-15	-1.0	99.0	75.8
Total system performance	**1471**	**-470**	**-24.2**	**-**	**75.8**

Energy conversion steps and losses:

1. Initial production at Standard Test Conditions (STC) is assumed,
2. Reduction of global in-plane irradiation due to obstruction of terrain horizon and PV modules,
3. Proportion of global irradiation that is reflected by surface of PV modules (typically glass),
4. Losses in PV modules due to conversion of solar radiation to DC electricity; deviation of module efficiency from STC,
5. DC losses: this step assumes integrated effect of mismatch between PV modules, heat losses in interconnections and cables, losses due to dirt, snow, icing and soiling, and self-shading of PV modules,
6. This step considers euro efficiency to approximate average losses in the inverter,
7. Losses in AC section and transformer (where applicable) depend on the system architecture,
8. Availability parameter assumes losses due to downtime caused by maintenance or failures.

Losses at steps 2 to 4 are numerically modeled by pvPlanner. Losses at steps 5 to 8 are to be assessed by a user. The simulation models have inherent uncertainties that are not discussed in this report. Read more about simulation methods and related uncertainties to evaluate possible risks at http://solargis.info/doc/pvplanner/.

8. SolarGIS v1.8 - description of the database

SolarGIS is high-resolution climate database operated by GeoModel Solar s.r.o. with geographical extent covering Europe, Africa and Asia. Primary data layers include solar radiation, air temperature and terrain (elevation, horizon).

Air temperature at 2 m: developed from CFSR data (© NOAA NCEP); years: 1991 - 2009; recalculated to 15-minute values. The data are spatially enhanced to 1 km resolution to reflect variability induced by high resolution terrain.

Solar radiation: calculated from Meteosat satellite data; years: 1999 - 2011; 30-minute values - global horizontal and direct normal irradiance.

This estimation assumes year having 365 days. Occasional deviations in calculations may occur as a result of mathematical rounding and cannot be considered as a defect of algorithms. More information about the applied data and algorithms can be found at: http://solargis.info/doc/pvplanner/.

9. Service provider

GeoModel Solar s.r.o., Milana Marečka 3, 84107 Bratislava, Slovakia; Registration ID: 45 354 766, VAT Number: SK2022962766; Registration: Business register, District Court Bratislava I, Section Sro, File 62765/B

10. Mode of use

This report shows solar power estimation in the start-up phase of a PV system. The estimates are accurate enough for small and medium-size PV systems. For large projects planning and financing, more information may be needed:
1. Statistical distribution and uncertainty of solar radiation
2. Detailed specification of a PV system
3. Interannual variability and P90 uncertainty of PV production
4. Lifetime energy production considering performance degradation of PV components.

More information about full PV yield assessment can be found at: http://solargis.info/doc/pvreports/.

11. Disclaimer and legal information

Considering the nature of climate fluctuations, interannual and long-term changes, as well as the uncertainty of measurements and calculations, GeoModel Solar s.r.o. cannot take full guarantee of the accuracy of estimates. The maximum possible has been done for the assessment of climate conditions based on the best available data, software and knowledge. GeoModel Solar s.r.o. shall not be liable for any direct, incidental, consequential, indirect or punitive damages arising or alleged to have arisen out of use of the provided report.

12. Contact information

This report has been generated by M/S SAURYAJYOTI RENEWABLES. , KOLKATA, 700032 WEST BENGAL, INDIA