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Case Study on Grid Integrated Solar PV for National Dasarath Stadium

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Abstract

Energy demand trend is always growing with the pace of development in Nepal. However, there is a lack of sufficient electricity supply to both rural and urban areas of Nepal. This situation compels different organization to use fossil fuel based technology which is not desirable. Since, the climatic conditions of Nepal are ideal for solar energy technology, grid connected PV plants could substantially contribute in making the national power supply system more diversified and independent and more ecologically and economically sustainable. The aim of this study is to conduct case study on grid integrated utility scale Solar Power plants in the National Dasarath Stadium(NDS) in Kathmandu, Nepal.

At present, the stadium day time average nominal load is 157 kW per day and it has two 100 kVA and 250 kVA diesel generator as an alternative power source during load shedding. But the stadium has enough spaces at Oval parapet and VIP parapet roof for installation of PV plant. So, PV installation at south oriented 30^o tilt at VIP parapet and 4°tilt at Oval shape parapet that acts as parapet roof of stadium and meet the daily power demand of stadium during the day time and excess power is supplied to NEA main grid. There are three grid tied Power plant that injects all energy generation to the grid and one hybrid power plant that acts as backup power source for stadium daily activity both day and night time. The proposed designed of 998.4 kW plant can generate 1414 MWh electrical energy annually with the reduction of 1131.2 tons of GHG emissions annually. The total fuel consumption by diesel generator is 91,980 ltrs per year and that is equivalent to 246.5 tons of CO_2e each year. The implementation of hybrid Solar plant reduces 246.5 tons of CO_2e that is being produce each year. The cost of Operation and Maintenance (ONM) of Generator including diesel consumption per year is NRs. 90,94,113.70. So, the implementation of Stadium PV plant not only saves annual ONM cost of generators but inject Solar energy to the grid and saves day time NEA electricity expenses. Hence, the available net solar energy that is injected to the grid is 1012.86MWh per year & net annual sale of solar electricity to the grid is NRs. 81,02,920.00 (at NRs. 8.00 per kWh) and Stadium NEA electricity saving at day time (i.e., T2 time frame) on average is NRs. 5,28,508.206 per year. The Levelized cost of electricity(LCOE) of utility scale hybrid grid tied stadium PV plant is found to be NRs.18.00 per kWh for 20 years and LCOE of purely grid tied stadium PV plant is found to be 12.5 per kWh for 20 years. Hence grid tied PV plant displaces the use of diesel generators and minimizes the day time NEA electricity bill, leading to sustainable operation of nation's only one national stadium.

Keywords

Stadium grid-connected PV systems – Parapet roof-top plants – Battery integrated hybrid grid tied PV plant

1. Introduction

Nepal is suffering from the lagging energy supply and the energy demand is increasing at a faster pace than the energy supply rate from year to year. It is difficult to meet current and future demand without stimulating the energy vision. Over past decade Nepal is facing load shedding from 5 hours a day to maximum 18 hours a day [1, 2]. So most of People in Nepal are fully dependent on alternative fuel resources like Diesel Generators. Study of Nepal Oil Corporation on 2015 showed that Total Net sale of diesel only was 921,262 KL Diesel on fiscal year 2071/72.

As a result, Nation's only one National Dasarath Stadium is also facing this problem and forced to use diesel generator to fulfill their daily energy demand. Proper energy mix and use of a renewable energy is a way to tackle the burning issues of energy crisis. To increase energy availability at a quicker rate, grid tied utility scale PV plant can be fruitful as it's construction period is minimum than other sources. Grid tied PV plant can be utilized to fulfill energy demand by utilizing available open oval shaped parapet and VIP parapet roof that can minimize use of the diesel generator. Also this grid integration solar plant can inject generted available power to the grid.

1.1 National Dasarath stadium

Dasarath Rangasala Football Stadium is National Football Stadium of Nepal situated in Tripureshwor, Kathmandu. It is a multi-purpose stadium built in 1956 and opened in 1958 in Tripureshwor, Kathmandu, Nepal holding 25,000 audience[3]. It is the biggest stadium in Nepal. It is named after Dashrath Chand, one of the martyrs of Nepal.

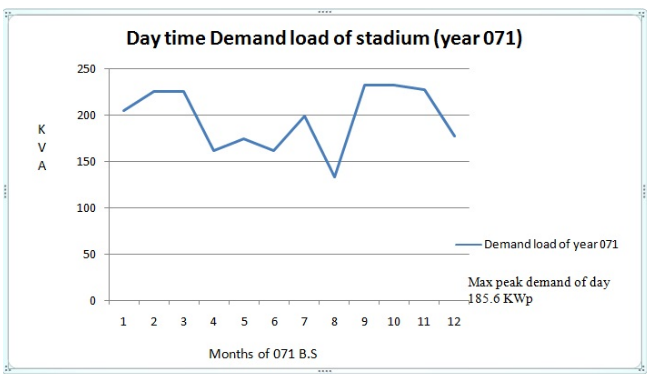

Figure 1: Peak demand of stadium during day time

The existing power detail of stadium are as follows:

- Stadium has dual set of air cooled 500 kVA transformer.
- High capacity LV distribution Box with capacitor bank.
- 54 nos. of high wattage of metal halide flooded light of 2000W in each Tower. There are four number of Light tower.
- Backup generator of capacity 100 kVA is used to run cover hall and 250 kVA to run whole stadium office load, sound system and other load.
- There is 625 kVA diesel genset that is dedicated to run Stadium flooded light for International event and live matches at evening

1.2 Grid Integrated Solar Plant

Electricity is produced by the PV array most efficiently during sunny periods. With grid interactive systems, the grid acts as the battery, supplying electricity when the PV array cannot. During the day, the power produced by the PV array is supplied to main grid. A power condition unit(inverter) converts direct current (DC) produced by the PV array to alternating current (AC) and step up transformer stepped up the voltage level as need for export to the grid. Grid interactive PV systems can vary substantially in size. However all consist of solar arrays, inverters, electrical metering and components necessary for wiring and mounting.

1.3 Hybrid mini grid solar plant

Mixing different technologies with different energy sources provides competitive advantages compared with using a single technology. The combination of renewable energy sources with a genset has proven to be the least-cost solution for rural communities as the benefits and advantages of each technology complement each other. Since renewable operate "fuel free," they are not subject to fuel price or supply volatility. However, renewable systems are non-dispatchable, which means that they depend on the availability of the resource at a specified time. Diesel gesets, in contrast, are dispatch able, and can deliver electricity when scheduled. By combining these two sources, a variety of shifting load profiles can be covered[4]. Furthermore, the combination of various renewable sources simply makes sense in many scenarios. For example, a mix of energy sources can accommodate seasonal resource fluctuations, with solar PV collectors complementing wind power during the months with less wind, or picking up when NEA supply drops during the dry season. Where daily energy variations are concerned, solar energy has a production peak around noon, while wind power facilities can operate whenever the wind is blowing. Batteries add stability to the system by storing the energy for peak consumption when there is insufficient production from renewable sources (i.e., to offset lack of solar power during nighttime hours). In case of

Stadium solar hybrid plant, Hybrid means combination of solar PV, battery and NEA grid line. So when there is load shedding at stadium then there won't be any disturbances of power due to available battery and solar PV backup both day and night time. This backup is specially design for cover hall and stadium office load only.

2. Methodology

After thorough review of literatures, National Dasarath stadium (NDS) was considered for case study of grid tied solar plant as it was at the centre of Kathmandu valley. The possible space for PV installation was stadium parapet roof for utility scale grid tied PV system. The effective area was surveyed and calculated using AutoCAD and the total area was found to be 7740 square meter. Major data about electricity Bill of year 2071 B.S of stadium were obtained. Stadium Power system like Transformer capacity, existing load capacity, detail of existing diesel generator and other power related data were obtained.

Monthly solar Irradiance data were obtained from online map of NASA, SWERA and PVSYST. Parapet area was selected for panel installation and three Inverter room were also selected at the stadium premise. The components for grid tied 1 MWp utility scale PV System was selected. Structure analysis was done on the basis of IS800 code and using different indicators, software like AutoCAD, STAAD Pro., etc. Simulation of designed PV system was made using PVSYST V5.03 and energy generation from the plant was obtained by calculation. Economical analysis of complete PV system was done using Microsoft Excel as well as PVSYST.

3. System Design

The PV sizing was done by getting available area. The Oval shape open parapet uses solar PV system as parapet roof that also protect audience from Sun and rainwater during summer season. No extra shading space was needed. Solar spacing was done as per designed system voltage and oval parapet width. Hence no. of solar panel used in Oval shape is 3200 and that in VIP parapet is 640. A photo voltaic installation will be done in south oriented 30°tilt at VIP parapet and 4 °tilt at Oval shape parapet after tilt angle analysis was done using Pvsys 5.0 software as per figure 2. Design system uses 20 no. of module in series with Min ^{m} System Voltage of 480 V and Max 608 V. It was decided to make a 12 cluster of solar Bank due to Oval parapet is limited by width span of 16.3m. In each 12 Bank, there will be 16 Nos. of string parallel., i.e. $16 \times 20 \times 260 = 83.2$ KWp peak energy generation from each cluster of solar bank as per figure 4. So total capacity after calculation is 998.4 KWp (83.2×12). But possible nominal capacity will be 812 KWp after using Pvsys V5.03 software. Below table 1 and figure 2 will give more clear picture.

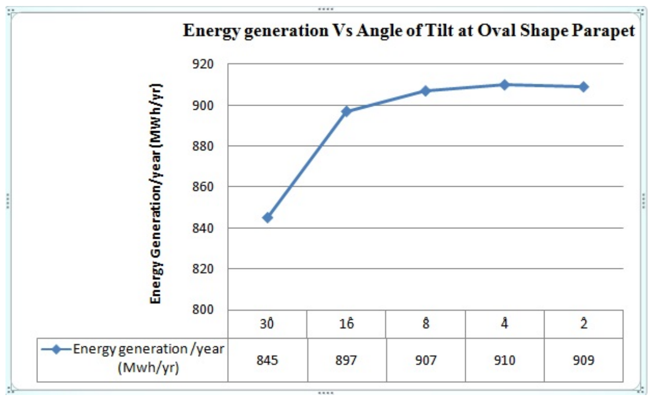

Figure 2: Angle of tilt analysis done using PVSYS

It is clear from figure 2 that angle of tilt at oval shape parapet roof is 4° rather than 30°. This is due to azimuth angle of 75° at eastern part of oval parapet and 150° at southern part of oval parapet as per table 1. Azimuth angle was taken using GPS status apps. Hence 4 degree angle of tilt for PV generated maximum energy as well as cost of roof truss structure also get minimized.

The stadium power plant is divided into Four Solar Power Plant , three are grid tied solar plant and one is hybrid solar power plant to meet the daily day time average load demand of 157.6 KWp (Load demand is as per NEA electricity monthly bill).The no. of solar bank is connected to each PCU as shown in Table 2. For safety reason each solar bank junction Box is protected by DC SPD as well as AC SPD at AC current side. The PCU 1, 2 and PCU 4 are purely grid tied plant that is connected to new 400V LT switching and distribution Panel. This distribution panel then supplies power to new Step-up Transformer of capacity 1000 kVA. There is HT switch gear after transformer that is connected to Net meter and check meter. The HT output cable is connected to grid. The hybrid Power conditioning Unit is connected to existing distribution panel. This distribution panel

Table 1: Table for angle of Tilt, Azimuth angle, yearly yield and losses

SN	Area sq.m	Parapet and solar position	Power System with Solar Bank No.	Tilt Angle	Azimuth Angle	Yearly Yield per m^2	Losses (%)	Transposition Factor
1	1575	VIP	PCU1, B11, B12	30	0	1941 KWh	0	1.11
2	1919	Oval shape at south face	PCU2, B01, B02, B03	4	0	1790 KWh	7.8	1.03
3	2325	Oval shape at west face	PCU3, B04, B05, B06, B07	4	75	1752 KWh	9.7	1.01
4	1912	Oval shape at North face	PCU4, B08, B09, B10	4	150	1694 KWh	12.7	0.97

*Nomenclature: PCU1: Power conditioning Unit 1
B11: Solar Bank 11, B01: Solar Bank 01

is also connected to NEA main grid. So the remaining energy that is available after consumption from stadium load is also injected to grid via., existing LT distribution panel to the main grid. Figure 3 gives detail idea about electrical layout of Solar powered stadium.

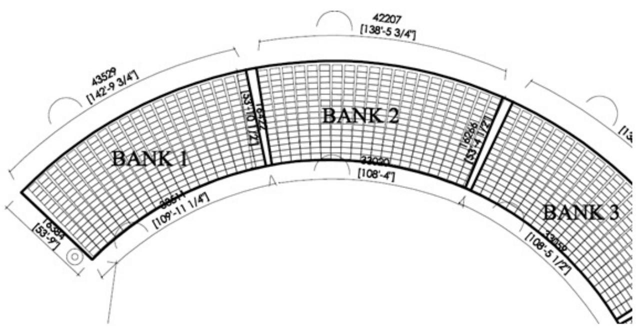

Figure 4: Portion snapshot of Oval shape Pv arrangement

4. Distribution of PV and Analysis of energy generation at Various Part of stadium

Since the design solar Power plant of stadium is divided into 4 parts. So there are Four Power Conditioning Unit (PCU) where PCU 1 is connected with two solar bank (B11 & B12) of VIP parapet roof, PCU2 is connected with three solar bank(B01, B02 & B03) of south face oval parapet, PCU 3 hybrid plant is connected with four solar bank (B04, B05, B06 & B07) of west face oval parapet and PCU 4 is connected with three solar bank(B08, B09 & B10) from North face oval parapet. Detail of solar bank is already mention in section 3. But each solar bank has different orientation i.e., tilt angle and azimuth angle is not same. For VIP Parapet (i.e., existing closed parapet) at west part of stadium, the azimuth angle will be zero and tilt angle will be 30°south face . The Solar bank covers 1573 sq.m area and solar bank no. at VIP parapet are B11 and B12. The total energy generation per year was found to be 274 MWh/year and maximum power capacity is about 177 kWp as per figure 6. The average Global horizontal annual Irradiance is 4.8 kWh/m^2/day. The spacing arrangement for solar panel at VIP parapet is shown in figure 5.

Similarly solar Bank that is connected to PCU 2 has an area of 1919 Sq. m and angle of tilt of 4°south face with zero azimuth angle. The solar bank that is connected to PCU 2 are B01, B02 and B03. The PCU1 and PCU 2 will be located under the ground floor power room of VIP parapet. The total energy generation per year by Plant 2 was found to be 353MWh/year and maximum power capacity is about 250 kWp as per figure 7. The average Global horizontal annual Irradiance is 4.8 Kwh/m2/day as per PVSYS.

There is battery integrated hybrid grid Tied PCU 3 that is located at eastern part of Oval parapet. The PCU 3 will be located at Power room 3 at eastern part of oval shape parapet. PCU3 is connected by Solar Bank No. B04, B05, B06 & B07. All these solar bank are located at eastern part of stadium oval shape parapet with an angle of tilt 4°with 75°Azimuth angle (i.e., orientation of these panel is in west direction).The area covered by these solar bank will be 2325 sq.m. The total energy generation per year was found to be 456MWh/year and maximum power capacity is about 333 kWp as per figure 8. PCU 4 will be located at Main power room of stadium. PCU4 will be connected by Solar Bank No. B08, B09 & B10. All these solar bank are located at southern part of oval shape parapet with an angle of tilt 4°with 150°Azimuth angle (i.e., orientation of these panel is in North direction). The total energy generation per year was found to be 331 MWh/year and maximum power capacity is about 250 KWp as per figure 9. The average Global horizontal annual Irradiance is 4.8 Kwh/m^2/day. Figure 6, 7,8 and 9 are the break down analysis of stadium solar plant using Pvsys.

Table 2: Selection of inverter table

SN	Inverter Brand	Model	Capacity (kW)	Solar Bank Connected	Used as	Remarks
1	Leonics	APOLLO (GTP)512 HETL(P)	275	B11, B12	Central Grid tied	Used as direct grid connection at VIP parapet (PCU1)
2	Leonics	APOLLO (GTP)512 HETL(P)	275	B01, B02, B03	Central Grid tied	Used as direct grid connection at Oval parapet(PCU2)
3	Leonics	APOLLO (MTP)6211 HP	350	B04, B05, B06, B07	Hybrid Grid tied	Use for Existing load backup at oval parapet (PCU3)
4	Leonics	APOLLO (GTP)512 HETL(P)	275	B08, B09, B10	Central Grid tied	Used as direct grid connection at Oval parapet (PCU4)

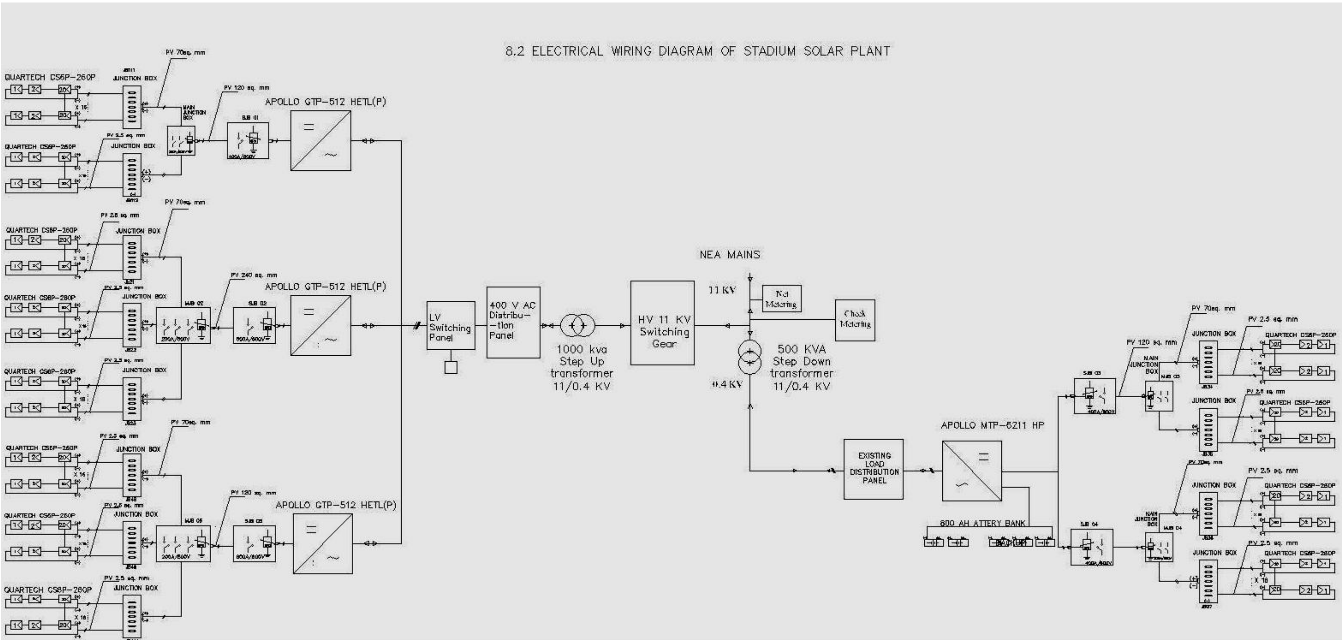

Figure 3: Electrical layout of stadium power plant

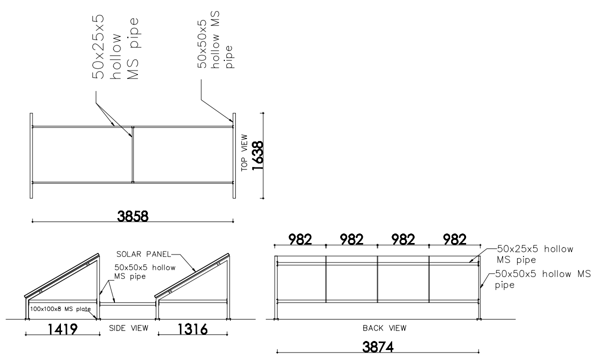

Figure 5: Mounting Design for panel at VIP parapet

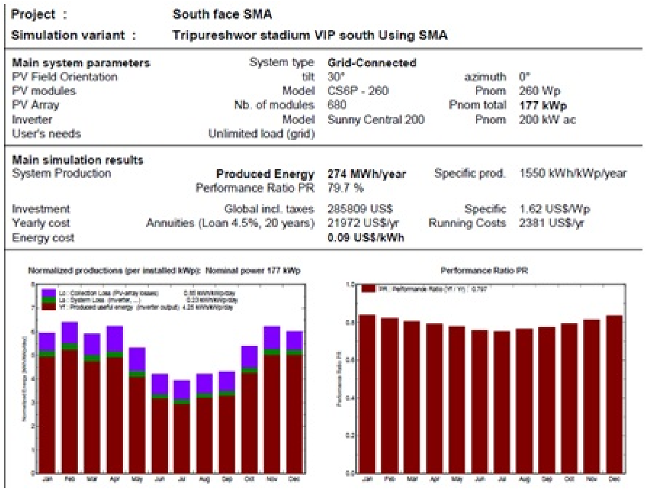

Figure 6: Plant 1 detail analysis using PVSYST

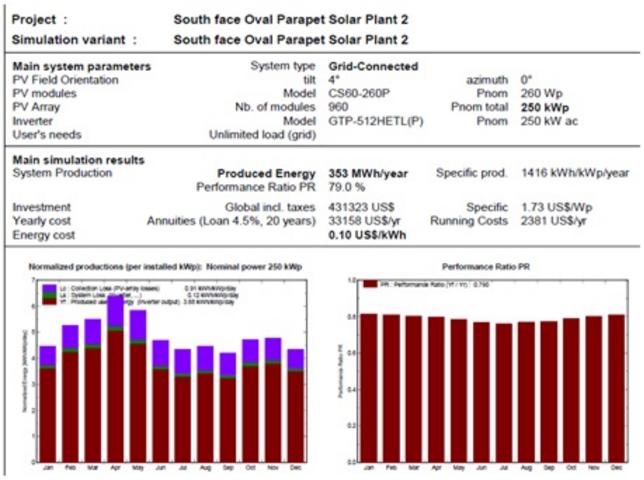

Figure 7: Plant 2 detail analysis using PVSYST

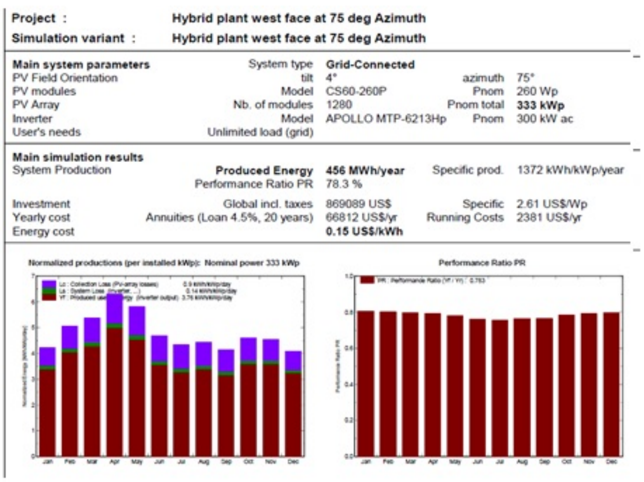

Figure 8: Plant 3 detail analysis using PVSYST

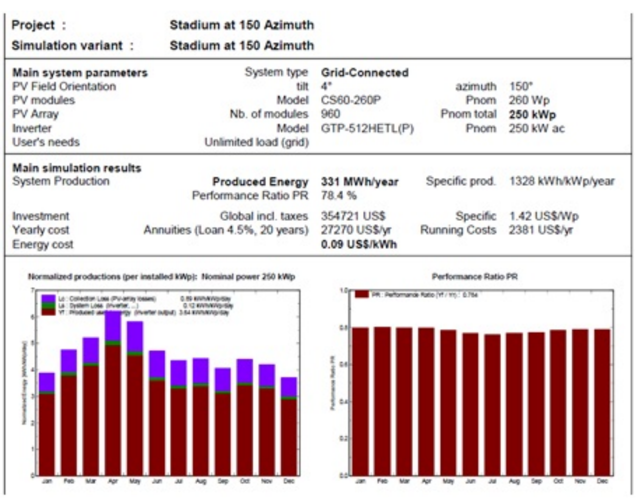

Figure 9: Plant 4 detail analysis using PVSYST

5. Oval Parapet Truss Design

The Roof Truss structure for solar panel at Ovalshaped parapet is shown in figure 10 and 11. The Truss structure was design by manual hand calculation based on IS800 code [5] and using STAAD pro software . The input parameter for truss design were wind load, Live load and dead load. The assumed wind velecity to calculated wind load was 25 m/s. Dead load for design are solar panel load of 20 kg and assumed self truss load. Detail analysis was done by combination of Live load vs dead load, Wind load vs dead load in STAAD pro software. Table 3,Table 4, Table 5 shows result of detail design analysis obtained by both Hand calculation and STAAD pro software. Table6 and figure 10 shows the detail arrangement of TRUSS components.

Table 3: Dead Load at panel point of truss

SN	Description	Values	Unit
1	Wt. of sheet and tiles with battens per panel	4900.5	N
2	Load due to wt. of purlin per panel	1353.675	N
3	Total dead wt. per panel	6254.175	N
4	Dead load at each end panel joint	3127.087	N

Table 4: Imposed Load at panel point of truss

SN	Description	Values	Unit
1	Live load per panel	3267	N
2	Live load at end panels	1633.5	N

Table 5: Wind Load at panel point of truss

SN	Description	Values	Unit
1	Wind load (uplift) per panel	-3529.83	N
2	At end panels	-1764.92	N

Table 6: Table for Input Parameters of truss

SN	Description	Values	Unit	Remarks
1	Angle	4	Degree	Analysis
2	No. of purlin	15	Nos	calculated
3	Width/Span	16.57	M	Measured
4	No. of panel (not solar panel, Vertical channel that support horizontal pipe)	14	Nos	
5	spacing of Purlins	1.21	M	
6	spacing of trusses	8.4	M	
7	Total length	42.3	M	Measured

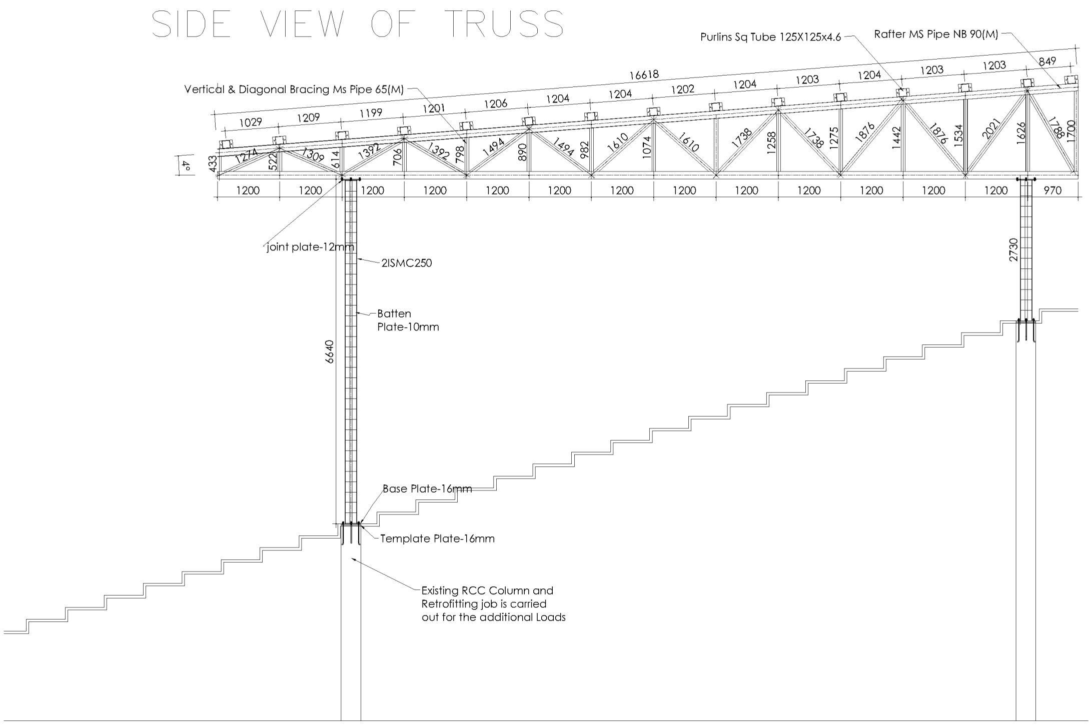

Figure 10: Side view of final design of truss structure for proposed Oval shape parapet

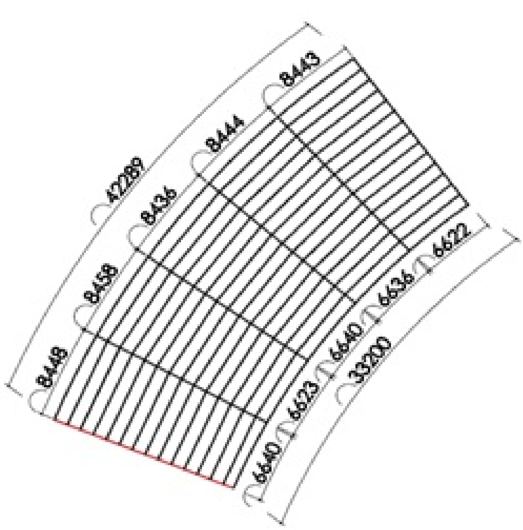

Figure 11: Top view of final design of truss structure for proposed Oval shape parapet

6. Economic Analysis

Economic analysis was done using PVSYS and Microsoft Excel. Economic analysis was done for all four Plant separately. During economic analysis NPV, IRR, Payback period and LCOE were analyzed for proposed Hybrid grid tied stadium Solar Power Plant.Also separate analysis were done for purely grid tied stadium Solar Power Plant without use of battery backup. Below table 7 is cash flow Summary of Hybrid Grid tied stadium solar plant. Cost estimate was done based on market study, expert suggestion, reference from existing plan.

For calculation of NPV, IRR, Payback period [6] first the yearly operating and maintenance(ONM) expenses of existing generator of capacity 100 kVA and 250 kVA were analyzed and was found to be USD:86,610 per year. This value was taken for analysis and it is assumed that generator ONM will increased by 10% each year. So after installation of hybrid Solar plant all these expenses needed for genset each year becomes the saving amount. This amount is thus analyzed for 20 years as solar plant revenue.

The electricity expenses of the stadium at day time (i.e., at T2 time frame) were found to be USD 5,593 (57,572 kWh energy). So after Installation of Hybrid solar Plant, the expenses at day time of USD 5,593 (57,572 kWh) will be saved but for worst condition due to weather, it

Table 7: Table for Cash Flow Summary of Hybrid Grid tied stadium plant

System	Energy generation per year (KWh/yr)	Consumption (KWh/yr)	Available energy for grid (KWh/y)	Energy sale in USD	Annual Expenses for Bank loan (Annuity beak down at 4.5% interest)	Net Investment (Principal) in USD	Net Investment (Principal) in NRs.
SP1	274,000	0	274,000	20,876	24,353	285,809	30,009,945
SP2	353,000	0	353,000	26,895	35,539	431,323	45,288,915
SP3	456,000	401,135	54,865	4,180	69,193	869,089	91,254,345
SP4	331,000	0	331,000	25,219	29,651	354,721	37,245,705
Total			1,012,865	77,171	158,736	1,940,942	203,798,910

is assumed that 10% of total day time NEA electricity per year will be used. So the remaining 90% electricity is fully utilised from solar energy i.e., 51,815 kWh and saves the electricity expense of $5033.41.

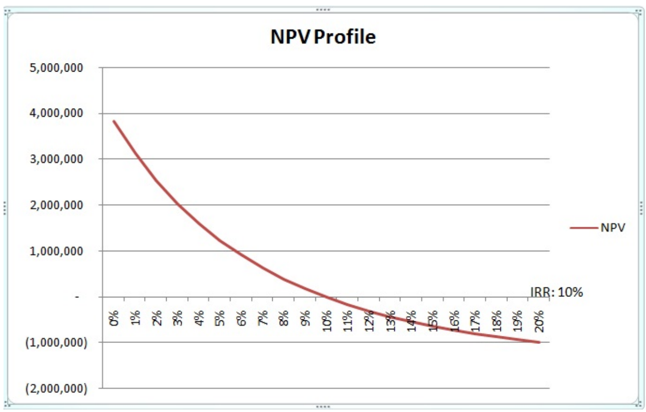

Figure 12: NPV profile for HGTSPP

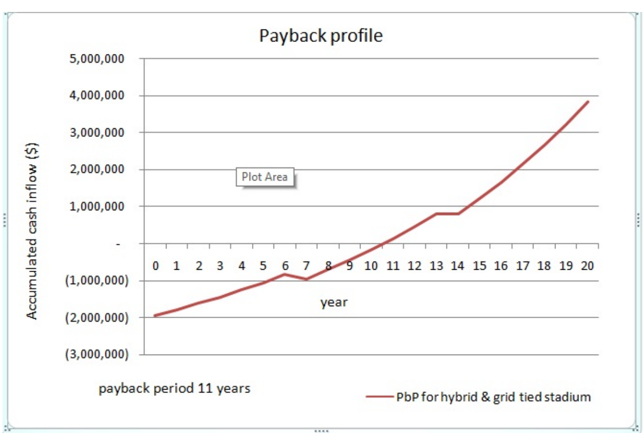

Figure 13: Payback profile for HGTSPP

The net energy injected by grid tied plant and hybrid power plant is 1012.86 MWh/yr. This revenue generated from energy sale by Stadium of amount is USD 77,170. per year (at NRs 8.00 per kWh). It is assumed that electricity tariff will increase after 5 years interval for 20 year period. Below are the NPV profile and Payback profile of Hybrid grid tied stadium power plant(HGTSPP).

Levelise cost of electricity (LCOE) [7] was calculated by taking project cost through out project life of 20 years like Initial capital cost, battery cost, Operation and maintenance, bank interest, 2.5% capital expenditure and energy generation for 20 years.

The NPV profile, IRR and Payback profile [6] shows that IRR of 10.00% and Simple payback period of 11 years. So Project discounted rate must be less than 10.00% to make the project acceptable. Since the design include detail design of truss structure, hybrid power plant for the reliability of PV to meet day time power demand of stadium and grid integrated Solar PV system. Hence this design is mix solar Plant design due to which the payback period is slightly greater than normal trend. Figure 12 and figure 13 shows clear picture for proposed Hybrid Grid Tied Stadium Solar Power Plant. If the plant was purely Grid Integrated Solar Plant without use of battery integrated hybrid plant then the payback period decreased to 8 years and its IRR increased to 14.47%. Figure 14 and 15 are the NPV profile and Payback period for purely grid integrated power Plant of National Dasarath stadium.

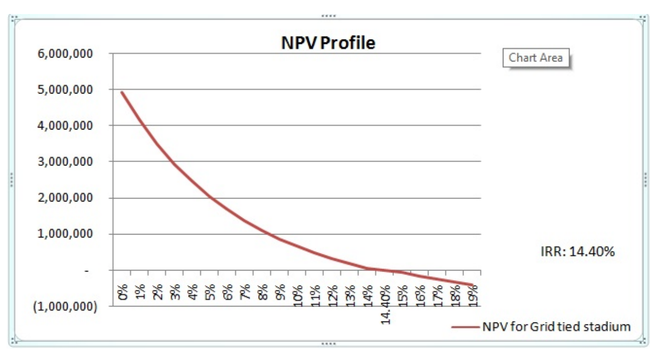

Figure 14: NPV profile for GTSPP

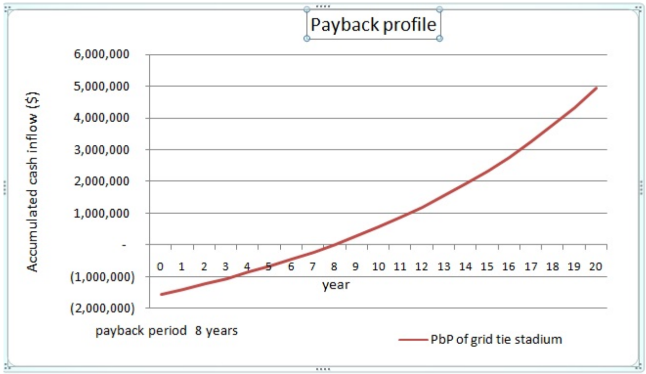

Figure 15: Payback profile for GTSPP

7. Result after analysing NPV, IRR and LCOE

Since its utility owned project, assumption is that there is no any Custom duty in Solar Inverter, no VAT in Battery and Solar Panel. Insurance cost is also not considered.

Table 8: Summary from Economic analysis

SN	Description	Values	Unit
1	PPA Rate	8	NRs
2	Discount rate	4.5%	Percent
3	Plant life	20	year
4	NPV	147,745,605	NRs
5	*IRR	10%	Percent
6	*LCOE	18	NRs./kWh
7	*Payback Period	11	Year
8	*Initial Capital Cost	20.38 crores	NRs.

*For purely grid tied stadium Valve of IRR is 14.4%, LCOE is NRs.12.49/kWh, Payback Period is 8 years and initial Capital Cost is NRs. 163,022,265.00 only.

Thus project seems to be attractive as NPV is positive and IRR is high and good enough. The levelized cost of electricity (LCOE) [7] was calculated based on eq^n(1)

$$\text{LCOE} = \frac{\text{Sum of cost over life time}}{\text{Sum of electricity produced over life time}} = \frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_T}{(1+r)^2}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^2}} \qquad (1)$$

where,
I_t : investment expenditures in the year t
M_t : operations and maintenance expenditures in the year t
F_t : fuel expenditures in the year t
E_t : electricity generation in the year t
r : discount rate
n : expected lifetime of system or power station

Table 9: Summary of result from PVsys

SN	Parameter	Result	Unit
1	Max. Energy Output per year	1414	MWh
2	Nominal Energy Output	1170	MWh
3	Available capacity	998.2	kWp
4	Nominal Capacity	812	kWp
5	Capacity Factor	16.45%	Percentage
6	Performance Ratio	79.7%, 79%, 78.3%, 78.4%	Percentage
7	System Yield 1, 2, 3, 4	4.25, 3.88, 3.76, 3.64	kWh/kW/day

Specific Yield = 1414000/998.4 = 1416.27 kWh/kW Capacity factor = 1414*1000/(8760*998.4) = 16.17% which is better factor of utilization.

GHG emission reduction=1414 x 0.8= 1131.2 tons per year

8. Conclusion

It can be seen at National Dasarath Stadium,Tripureshwor, Kathamndu that Stadium Oval Parapet and other open space are not utilised properly by Stadium management. So from this study, it was found that these unused space have a potential of Installation of 998.4 kWp of utility scale PV plant. This study also presents a design of a grid tied 998.4 kWp utility scale PV plant at the premises of NDS. The designed plant is found to be both technically and economically viable. The plant has been designed with 3840 numbers of 260 Wp panels, Twelve smart combiner box, three 275 kW power conditioning unit, one 350 kW Smart Hybrid power conditioning Unit, one 1000 kVA Step Up transformer, appropriate cables, protective devices and the power controlling station. It is found that the plant nominal capacity is 812 kW and Peak Power of 998.4 kWp. Economic analysis of the plant shows that at the tariff rate of NRs 8.0 per unit, the plant has a positive net present value of USD 1,407,101, internal rate of return of 10.00%. The designed 998.4 kW plant has the performance ratio of 78.85% on average. The proposed plant generate 1414 MWh electrical energy annually with the reduction of 1131.2 tons of GHG emissions annually. Further, installing higher capacity plant will result in decreased cost per unit depending upon site insolation.

Since the existing two set of diesel generator of capacity 100 and 250 kVA are used to meet day time average nominal Load of 157 kW during load shedding. The current fuel consumption per hour by these genset is 16 and 20 lts/hr respectively. It is assumed that if average Load shedding per year is 7 hours a day and operating days is 365 days then total fuel consumption per year is 91,980 Ltrs/year. Since 1 ltr of diesel produces 2.68 kg of CO_2e [8]. So the total CO_2e produces by diesel Generator per year is 246.5 tons of CO_2e. So the implementation of hybrid solar plant reduces 246.5 tons of CO_2e that is being produced each year. The cost of diesel consumption per year is NRs78, 64,290.00 (USD: 74,898) and Operation and maintenance cost is NRs. 12,29,823.70 (USD: 11,712.61). So Total operating cost per year by both diesel generators is NRs. 90, 94,113.70 (USD: 86,610.61). So, implementation of Stadium PV plant not only saves annual cost of diesel generator of USD 86,610.61 but also inject Solar electrical energy to the grid and saves day time NEA electricity expenses. Hence, the net available solar energy that is injected to the grid is 1012.8617MWh per year & net annual sale of solar electricity to the grid is USD 77,171 i.e., NRs. 81,02,920.00 (at NRs. 8.00 per kWh) and Stadium NEA electricity saving at day time (i.e., T2 time frame) is on average is USD 5,033.41(NRs. 5,28,508.206) per year. The reliability of Solar Power to meet daily stadium load is done by battery integrated hybrid Power Conditioning Unit. Solar panel shading at oval shape parapet also saved football audiences from rain water and Sun.

From this case study, grid tied PV plant displaces the use of diesel generator and minimizes the day time NEA electricity bill, leading to sustainable operation of nation's only one national stadium.

Finally, it is concluded that utility scale photovoltaic plants are suitable for Nepal due to favorable meteorological, climatic conditions. Also, they are technically and economically viable. Levelized cost of electricity (LCOE) of utility scale hybrid grid tied stadium PV plant is found to be NRs.17.97 per kWh($171.14/MWh) for 20 years and LCOE of utility scale purely grid tied stadium PV plant is found to be NRs.12.49 per kWh ($118.9/MWh) for 20 years which is better than the polluting, GHG emitting thermal based plant and diesel generator. Hence the use of solar electricity is beneficial for the stadium and use of diesel generator can be displaced by enhancing clean, renewable solar energy through grid tied PV system.

9. Recommendation

The study considered only open parapet areas of National Dasarath Stadium. There are other vacant spaces at stadium premise, Coverhall roof can also be modified to Solar plant roof and space available near Swimming pool. Further study can be done at other Stadium, Bigger apartments, Malls, department stores etc. With further study, research, planning, proper energy mix policy must be developed to obtain maximum optimum benefit from the utility scale PV plants.

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