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Techno-Economic Analysis of Grid Connected Rooftop Solar PV System at Head Office of Nepal Bank Limited

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Abstract
Grid tied rooftop solar photovoltaic (PV) is an economical, clean and reliable source that generates electricity at the organization for its regular consumption and surplus amount gets injected into the grid thereby generating revenue for the organization. The grid dependency of organization is also reduced. Moreover, as the power generated don't have to travel longer distances, which happens in conventional hydropower supply system, the losses and voltage drop occurring in the utility grid feeder are greatly minimized. The proposed grid tied rooftop solar PV system has the DC capacity of 179.58kWp and the AC capacity of 160kW. For the PV system analysis, simulation was done in PVSyst software from which it was seen that after the proposed rooftop solar PV installation there was yearly saving of NRs. 32,43,759.4 by reducing yearly import of 2,68,718 units from the grid and exporting surplus 9,153 units to the grid. The financial analysis of the proposed system was done in excel sheet which showed that Internal Rate of Return (IRR) was 20.61%, Net Present Value (NPV) was NRs. 51,61,724.78, Levelized Cost of Electricity (LCOE) was NRs. 4.98 per unit and the payback period was 7.5 years. To study the impact of the proposed installation on the grid feeder, Time Domain Load Flow (TDLF) analysis in Electrical Transient Analyzer Program (ETAP) was done, which showed that the yearly losses occurring in the feeder was minimized by 4.6MWh. As the power is generated locally, the voltage drop occuring in the grid feeder is also minimized.The results showed that the rooftop solar PV generation is worthy for commercialization in the country for improving reliability of power supply, increasing energy mix and energy security of the country.

Keywords
Rooftop Solar PV, Grid Conencted, Time Domain Load Flow, ETAP, PVSyst, Financial

1. Introduction

Nepal has the theoritical hydropower potential of 83000MW but techno-economically feasible power is 42000MW [1]. The power generation heavily depends upon hydro, in which hydropower accounts for 94.91%, thermal 3.63% and Solar 1.46% of total grid-connected power generation mix [2]. The sole dependency of Nepal in hydroelectricity is a threat to energy security because of the frequently occurring natural calamities like flood, landslides etc. and political instability of the country that leads to time-cost overrun.

Furthermore, the World Energy Trilemma Indices published by World Energy Council on 2021, ranked Nepal 96 out of 101 rankings provided among 127 countries based on energy security, energy equity and environmental sustainability [3]. The main reasons given in this report for such low rank for Nepal are mainly due to poor energy security and lack of generation diversity. In order to improve the grid energy mix and increase energy security of the country, we need to focus on the alternative sources of electricity generation. After hydropower, it is the solar that is available easily and abundantly all over the country.

The average global solar radiation in Nepal varies from 3.6-6.2 kWh/m^2day, sun shines for about 300 days a year, the number of sunshine hours amounts almost 2100 hours per year and average insolation intensity about 4.7 kWh/m^2/day(=16.92 MJ/m^2day) it is greater than 4.38kWh/m^2day (15.8 MJ/m^2day) [4]. The potential of Solar PV Energy in Nepal is about 2,100 MW for 4.5 kWh/m^2/day radiation and if 2% area is taken as suitable [5]. Nepal has agreed to expand clean energy generation from around 1,400

MW to 15,000MW, of which 5-10 % from renewables like mini and micro-hydro power, solar, wind and bio-energy and ensure 15% of the total energy demand is supplied from clean energy sources by 2030 as its Nationally Determined Contribution (NDC) to the Paris Agreement [6]. At the 26th Conference of Parties (COP 26) Nepalese Prime Minister stated that Nepal aims to reach a net zero emission by 2045 and ensured that 15% of country's total energy demand will be supplied from clean energy sources and maintain 45% of country under forest cover by 2030.

2. Solar PV System

2.1 Cost Trend

In the global market scenario, solar PV technology is gaining wide popularity, mainly because of its decreasing cost and increasing efficiency. The last decade has shown a sharp, though now steadying, decline in costs, driven largely by photovoltaic (PV) module efficiencies (now 23%, up from 19.2% in 2019) and hardware and inverter costs [7]. Since 2010, there has been a 64%, 69%, and 82% reduction in the cost of residential, commercial-rooftop, and utility-scale PV systems, respectively [7]. As in previous years, soft costs remain a large and persistent portion of installation costs, for both solar and storage systems, and especially for commercial and residential systems [7]. A significant portion of the cost declines over the past decade can be attributed to an 85% cost decline in module price [7]. A decade ago, the module alone cost around $2.50 per watt, and now an entire utility-scale PV system costs around $1 per watt [7]. With similar reductions in hardware costs for storage systems, PV and storage have become vastly more affordable energy resources across the world.

2.2 Grid Connected Solar PV System

The major components of this system are solar panel, inverter or power conditioning unit, battery (if required), net meter provided by the utility and we can have an extra meter at the solar generation side to monitor the amount of energy generated by the solar system. Solar PV panels generate electricity when sunlight strikes them and an electronic device called inverter that converts the direct current (DC) electricity from the solar panels to alternating current (AC) that is synchronized with that of the grid. Grid connected PV systems are designed to operate parallel with the grid or the main utility line with the concept of bidirectional power flow in the presence of bidirectional meter. Grid connected PV system can have the provision of energy storage batteries to power the critical loads during the utility outage or without any battery storage that operates parallel with the grid. Whenever an outage occurs during the day time, the system gets disconnected from the utility and supplies power to the loads to which it is connected, provided that the sun is shining. In grid tied rooftop solar PV system, PV arrays are mounted on the roof of buildings for electricity generation.

2.3 Grid Connected Solar in Nepal

At present, Nepal Electricity Authority (NEA) is doing Power Purchase Agreement (PPA) with solar power project at constant flat tariff of 7.30 Nepali Rupee per unit [8]. There have been few numbers of solar power plants that are connected to the grid and getting paid through the net metering principle as shown below.

- 1.3MW rooftop solar at Singh durbar [9].
- 680 kW solar at Kathmandu Upatyaka Khanepani Limited (KUKL) [10].
- 1kW solar at Pulchowk Engineering Campus [5].
- 100 kW solar at NEA training center in Kharipati [11].
- 65 kW solar at Nepal Telecom in Sundhara [12].
- 60 KW solar at Bir hospital in Kathmandu [13].
- 960kW Bishnu Priya Solar Farm Project in Nawalparasi [2].
- 8500kW Butwal Solar Project at Rupandehi [2].
- 10000 kW Mithila Solar PV Electric Project in Dhanusha [2].

3. Site Details

3.1 Location

The proposed site was Head Office of Nepal Bank Limited, New Road, Kathmandu, which has latitude of 27.70N and 85.31S. Out of six, four buildings at the site had adequate rooftop area for solar PV installation, they are B1, B2, B3 and B6.

Figure 1: Rooftop View of Buildings at the Site

Table 1: Rooftop Area Available for Solar PV

Building	Rooftop Area (sq. ft.)
Building 1 (B1)	6282
Building 2 (B2)	4462
Building 3 (B3)	14452.61
Building 6 (B6)	6464

3.2 Energy Consumption at the Site

Energy consumption at the site during the sun shine time is of prior importance for our research. Following table 2, shows the energy consumption at NRs. 11.60 per unit during the time 5am to 5pm for the year 2078 B.S (source-Electricity Bill from Nepal Electricity Authority (NEA)).

Table 2: Monthly Energy Consumption

Month	Energy Consumption(kWh)	Bill NRs.
Baisakh	20954	232589.4
Jestha	22606	250926.6
Asadh	26854	298079.4
Shrawan	28332	314485.2
Bhadra	30386	337284.6
Ashoj	24700	274170.0
Kartik	19267	213863.7
Mangsir	21865	242701.5
Poush	22689	251847.9
Magh	21545	239149.5
Falgun	32272	358219.2
Chaitra	23847	264701.7
Total	29,53,17	32,78,018.7

4. Design of Solar PV System

4.1 Solar Panel

We have selected Jinko Solar Cheetah (JKM410M-72H-V) PV panel as it uses latest mono perc half cell technology and is easily available in the market. Table 3, shows the characteristics of the panel.

Table 3: Solar Panel Characteristics [14]

Dimensions (mm)	2008x1102x40
Weight	22.5 kg
Maximum Power (Pmax)	410Wp
Temp.Coef. Pmax (%/deg.Celcius)	-0.35
Open Circuit Voltage (Voc) Volt	50.4
Temp.Coef. Voc (%/deg.Celcius)	-0.29
Short Circuit Current (Isc) Amp.	10.6
Temp.Coef. Isc (%/deg.Celcius)	0.048
Maximum Power Voltage (Vmp)Volt	42.3
Maximum Series Fuse Rating (A)	20

4.2 Orientation and Power Output of Array

The tilt angle for solar panel was taken 30° close to the latitude of the site and the solar elevation angle at was taken as on 22nd December which was 24°

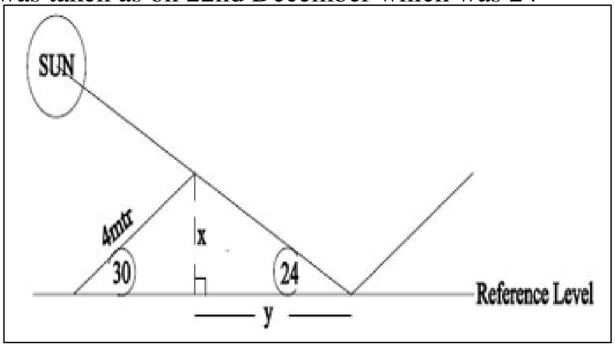

Figure 2: Panel Orientation

The panels were portrait oriented with 2x2 frame size and the inter row spacing of the panels were calculated according to figure 2. Using the geometry, y = 4.5m was the inter row spacing of the arrays. Now, after placing the arrays we had the following output from four buildings shown in the table 4 below:

Table 4: Number of Arrays and Power Output

Building	Panel	Power (kW)	Combined Power (kW)
B1	120	49.2	88.56 (B2&B3)
B2	48	19.68	91.02 (B1&B6)
B3	168	68.88	
B6	102	41.82	

The power output from B2 and B3 was named as

Nepal Bank Limited Part-1 and that from B1 and B6 was named as Nepal Bank Limited Part-2 for PVSyst simulation.

4.3 Inverter

In order to maintain the DC to AC ratio more than 1.1, 2 sets of string grid tied inverter were selected of capacity 80kW AC. Following table 5 shows the characteristics of the inverter:

Table 5: Inverter Characteristics

Max.PV Input Voltage	1100 V
MPP Voltage Range for nominal power	570-950V
No. of Independent MPP Inputs	1
Maximum Number of PV Strings per Input	18
AC Output Power	80kW
Max.Efficiency	98.90%

5. Analysis of Proposed System

5.1 PVSyst Analysis

The number of panels in one string was selected between 16 and 18 so that the operating voltage window of 80kW inverter didn't exceed. The number of string at each inverter input was 10.On the basis of planned power of 88.56kW from Nepal Bank Limited Part-1 and 91.02kW from Nepal Bank Limited Part-2, simulation was done in PVSyst 7.2.

5.2 Financial Analysis

The total cost estimate of the proposed installation was NRs. 1,32,23,744 with VAT shown in table 6 and 7. The financial parameters like loan period, interest rate, discount rate, construction period etc. that act as major inputs for financial analysis are shown in table 8.

Table 6: Cost Estimate of Proposed System

Item	Unit	Quantity	Amount (NPR)
A	kWp	179.58	7,255,032
B	Set	6	3,60,000
C	Set	2	13,44,512
D	kWp	179.58	20,31,409
E	m	250	375,000

Table 7: Cost Estimate of Proposed System(cont..)

Item	Unit	Quantity	Amount (NPR)
F	m	50	175,000
G	Set	3	30,000
H	Set	1	20,000
I	Set	4	80,000
J	Set	4	32,000
K	Set	5	150,000
L	Set	1	150,000
M			200,000
N			25,000
O			600,148
VAT (13%)			395,643
Grand Total Cost (NPR)			13,223,744

Where,

- (A)-Solar Photovoltaic Array of Total Minimum Capacity 179.58 kWp (Size of individual PV module should be greater or equal to 410Wp, Mono PERC Half Cell Crystalline Silicon, Suitable for Rooftop Installation)
- (B)-16 input string combiner boxes with DC fuse and DC SPD in the input, MCB and isolator in the output with earthing with complete set
- (C)-Two Sets of 80kW AC Three Phase Grid Support String Inverter
- (D)-Mounting Structure: MS Steel in the RCC Roof Nepal Bank Head Office: Double Coat of Red Oxide and Double Coat of Enamel
- (E)-2 core DC copper armored cable of 25mm^2 from Solar Array to Control Room
- (F)-4 core, 50mm^2 XLPE insulated AC copper armored cable
- (G)-AC SPD Type 1+2 of 230V Imax 20kA which shall be used at all Inverter Output and Main Distribution Box. The SPD should comply IEC 61643-11
- (H)-3 Phase Energy Meter to measure energy generated by Solar System
- (I)-2 meter Copper Vertical Air Terminal with Multiple Spikes of dia 12 mm confirming to IS/IEC 62305-3 with complete Support and down conductor of 25x3 mm copper strip
- (J)-3 m, 4inch dia, 4mm thickness high mast to install Vertical Air Terminal
- (K)-Rod Earthing Set: Maintenance Free

Copper coated Earth rod of 2.5 mtr length having the dia of 25mm mm with copper coating thickness of 250 microns

- (L)-Online Monitoring System with Monitoring Portal, Router and Smart LED TV of 32” size
- (M)-Installation, Testing and Handover
- (N)-Transportation Cost
- (O)-Contingencies

Table 8: Inputs for Financial Cashflow Analysis

DC capacity of plant (kWp)	179.58
AC capacity of plant (kW)	160
Project Period (Years)	25
Equity (%)	30%
Loan (%)	70%
Loan Payback Period (years)	7
Loan Interest Rate (%)	10%
Discount Rate (%)	10%
Depreciation (%)	4%
Capital Cost with Custom Duty and VAT (NRs/kW)	73,637.06
Loan (NRs.)	8,247,351.06
Equity (NRs.)	3,534,579.02
Tendering & Construction Period (months)	1
Interest During Construction (NPR)	34,364
O&M Cost (NPR/Year)	52,894.98
O&M Escalator (%)	3%
CUF of Plant	19.35%
Annual Energy Degradation from second year	0.8%
PPA Rate (NRs. /kWhr)	7.3
Auxiliary Consumption (% of total energy generated)	0.50%
Corporate Tax for first 10 years	0%
Corporate Tax for 11-15 years	10%
Corporate Tax after 15 years	20%

Where,

- Capital Cost with Custom duty and VAT (NRs/kW) = (Total Cost of Plant (NRs))/(AC Capacity of Solar Plant (kW))
- Loan (NRs.) = (% of Loan for Solar) *[Capital Cost with Custom duty and VAT (NRs/kW)] *(AC capacity of plant (kW))
- Equity (NRs.) = (% of Equity for Solar) *[Capital Cost with Custom duty and VAT (NRs/kW)] *(AC capacity of plant (kW))
- Interest during Construction (NRs.) = Loan (NRs.) *(Construction Period in Months)/12* Interest Rate on Loan Amount (%) *1/2
- Operation and Maintenance (O and M) Cost (NRs/Year) = 0.4% * Total Cost of Plant (NRs.)
- Capacity Utilization Factor (CUF) = (Actual Annual Output of Plant (kWh))/(Installed Capacity of Plant(kW)x365x24)

5.3 ETAP Analysis

Following table 9 shows the detail about the New Road feeder having Rabbit conductor in which the load and transformer (Tr.6) of Nepal Bank Limited was connected. The distribution transformers installed in the route of New Road feeder are shown with their rated capacity and daily peak load.Also, Bus-1 is the initial bus from which the feeder originates and Bus-22 represents the bus where feeder terminates. (Note-Tr. means transformer)

Table 9: Feeder Details

From	To	Feeder (km)	Transformer Capacity& Peak Load (kVA)
Bus-1	Bus-2	0.1897	
Bus-2	Bus-3	Tr.1	200&109
Bus-1	Bus-4	0.0949	
Bus-4	Bus-5	Tr.2	200&118
Bus-4	Bus-6	0.1863	
Bus-6	Bus-7	0.012	
Bus-7	Bus-8	Tr.3	200&105
Bus-7	Bus-9	0.049	
Bus-9	Bus-10	Tr.4	200&104
Bus-6	Bus-11	0.1049	
Bus-11	Bus-12	Tr.5	500&261
Bus-11	Bus-13	0.0929	
Bus-13	Bus-14	0.0281	
Bus-14	Bus-15	0.035	
Bus-15	Bus-16	Tr.6	315&122
Bus-14	Bus-17	0.003	
Bus-17	Bus-18	Tr.7	300&108
Bus-17	Bus-19	0.0451	
Bus-19	Bus-20	Tr.8	100&40.37
Bus-13	Bus-21	0.0735	
Bus-21	Bus-22	Tr.9	250&105.6

Moreover, the load on all the 9 distribution transformers of the feeder and the solar irradiance keep varying throughout the day, so TDLF analysis needs to be carried in ETAP software. The irradiance varies throughout the day and has different values in different seasons. The irradiance values of 24hrs for four months March, June, September and December were taken from PVGIS-5 geo temporal irradiation database.

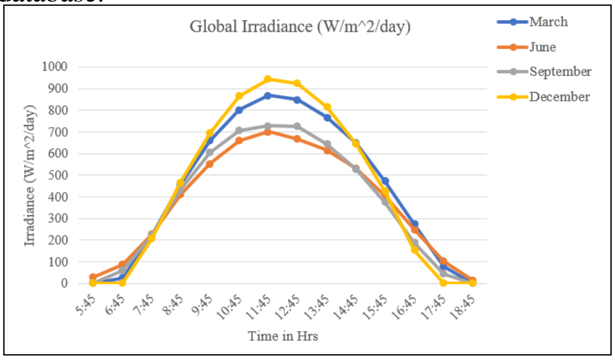

Figure 3: Daily Global Irradiance for 4 Months

According to the solar irradiance; Output from solar panels (Wp) = (No. of panels) *(Area of a panel in m^2) *(Irradiance in W/m^2) *(Conversion Efficiency of Solar Panel in %)

6. Results and Discussions

6.1 PVSyst Simulation

The power output 88.56kW from B2 and B3 was named as Nepal Bank Limited Part-1 and 91.02kW from B1 and B6 was named as Nepal Bank Limited Part-2 for PVSyst simulation.

Table 10: Results for Nepal Bank Limited Part-1

	GlobHor kWh/m²	E Grid MWh	Performance ratio
January	118.1	13.77	0.909
February	114.2	11.45	0.884
March	165.0	14.17	0.856
April	160.7	12.03	0.849
May	181.0	12.50	0.846
June	159.2	10.72	0.854
July	146.5	10.12	0.864
August	156.6	11.39	0.856
September	136.3	10.86	0.855
October	149.0	13.93	0.858
November	127.8	14.24	0.881
December	123.2	15.36	0.899
Year	1737.8	150.51	0.868

Table 11: Results for Nepal Bank Limited Part-2

	GlobHor kWh/m²	E Grid MWh	Performance ratio
January	118.1	14.07	0.908
February	114.2	11.70	0.883
March	165.0	14.49	0.856
April	160.7	12.30	0.848
May	181.0	12.79	0.846
June	159.2	10.96	0.854
July	146.5	10.35	0.864
August	156.6	11.66	0.856
September	136.3	11.10	0.854
October	149.0	14.24	0.858
November	127.8	14.56	0.881
December	123.2	15.71	0.898
Year	1737.8	153.94	0.868

The useful energy injected into the grid (E Grid) as per Nepalese calendar month can be calculated by taking the average of the two corresponding months in English calendar. For Baisakh month we can average the E Grid of months April/ May and similar approach applies for the remaining months.Now,from this analysis we can calculate the yearly savings by reducing the import of electricity from the grid and revenue generated by exporting surplus electricity for Head Office of Nepal Bank Limted from the proposed installation as shown in table 12.

Table 12: Savings from the Proposed Installation

Month	A	B	C	D	E
Baisakh	24.81	20.95	23.26	3.9	2.81
Jestha	23.49	22.61	25.09	0.9	0.64
Asadh	21.08	21.08	23.39	0	0.00
Shrawan	21.76	21.76	24.15	0	0.00
Bhadra	22.51	22.51	24.98	0	0.00
Ashoj	25.07	24.7	27.42	0.4	0.27
Kartik	28.49	19.27	21.39	9.2	6.73
Mangsir	29.94	21.87	24.27	8.1	5.89
Poush	29.46	22.69	25.18	6.8	4.94
Magh	25.5	21.55	23.91	4	2.88
Falgun	25.91	25.91	28.75	0	0.00
Chaitra	26.5	23.85	26.47	2.7	1.93
Total	304.5	268.72	298.28	9.2	26.10

Where,

- A-Useful Energy Produced from both Nepal Bank Limited Part-1 and Part-2 (MWh)
- B-Energy Saved by Solar Production to be imported from Grid (MWh)

- C-Savings in Multiple of Ten Thousands NRs from Solar Production at NRs. 11.60 per unit as per NEA tariff.
- D-Energy Exported to Grid (MWh)
- E-Revenue in Multiple of Ten Thousands NRs. Gained by Export of Energy to Grid at current PPA rate of NRs. 7.3 per unit.

From Table 2 and 12, we saw that total expense of Nepal Bank Limited on electricity import in a year was NRs.32,78,018.7.After the installation of the proposed system, there was saving of NRs. 32,43,759.4 for Nepal Bank Limited. Also, the performance ratio of the system was found to be 0.868.

6.2 Financial Analysis

Following table 13 shows us the result of the financial cashflow analysis.

Table 13: Results of Financial Analysis

IRR	20.61%
NPV (NRs.)	5,161,724.78
LCOE) (NPR/kWhr)	4.98
Payback Period	7.50

From the above results, tabulated above we see that, IRR is double than interest rate (10%), NPV of all the cash flow is positive, LCOE is less than PPA rate (7.3 NRs/kWhr) and Payback Period is 7.5 years. These all financial indicators suggest us that the given project is financially feasible for the given organization.

6.3 ETAP Simulation

Following table 14 and15 shows us the results from TDLF simulation ETAP, which was carried out for 4 months of 4 different seasons of a year. It should also be noted that in the following table PV Out means the active power losses in the system when there is no solar generation and PV In means the active power losses when there is solar generation in the system.

Table 14: Results of TDLF ETAP Simulation

Month	Losses(kWh/day)
March PV Out	194.5
March PV In	181.4
Loss Minimized	13.1
June PV Out	194.5
June PV In	181.8
Loss Minimized	12.7

Table 15: Results of TDLF ETAP Simulation

September PV Out	194.5
September PV In	182.1
Loss Minimized	12.4
December PV Out	194.5
December PV In	182.1
Loss Minimized	12.4

The irradiance for a particular season is almost similiar, so we can approximate the results of a month for the remaining three months of the season. In Spring season we have three months March, April and May,hence we see that in spring season the loss minimized=13.1(kWh/day)*30(day)*3(month)=1179 kWh.Similar calculation follows for Summer, Fall and Winter seasons respectively each having three months, thus the yearly loss minimised in the grid feeder (New Road Feeder) was 4.6MWh after the proposed installation.

7. Conclusion

The technical analysis of the poposed rooftop solar PV system was carried out in PVSyst. Without the solar generation the yearly electricity consumption and yearly bill of Nepal Bank Limited (NBL) was 295.32MWh and NRs.32,78,018.7 respectively but after the installation of the proposed system, it showed the savings of 268.72MWh energy to be imported from the grid and 9.2 MWh of surplus energy will be injected to the grid from which there will be total saving of NRs. 32,43,759.4 for the organization. The financial analysis in excel sheet showed that the project has Internal Rate of Return (IRR) of 20.61%, Net Present Value (NPV) of NRs. 5,161,724.78, Payback period of 7.50 years and Levelized Cost of Energy (LCOE) of 4.98 NRs./unit. The load on the nine distribution transformers of the grid feeder as well as the solar generation keeps varying throughout the day, so TDLF analysis was done in ETAP. The results from ETAP simulation showed that with the solar PV generation there was yearly loss minimization of 4.6 MWh in the feeder. As, the losses are minimzed and the power is generated locally,the voltage drop in the grid feeder is minimized.Moreover, whenever there is grid outage then the bank doesn't have to operate its diesel generator consequently there is saving in the fuel, operation and maintenance costs of diesel generator sets. The results showed that the rooftop solar PV generation is worthy for commercialization in the country for improving reliability of power supply, increasing energy mix and energy security of the country.

8. Recommendation

The results showed that the grid tied rooftop solar PV installation is technically and economically beneficial to the banking organization like Head Office of Nepal Bank Limited. The ETAP analysis showed that the as the losses occurring in the feeder was minimized and the voltage drop was minimized, the proposed system is beneficial considering the utility point of view.Thus, it is highly recommended for the proposed organization to install this 179.58 kWp solar PV system. The design of the system should be done considering the optimum tilt angle and for the initial design it is recommended to use the real time location data rather than the data provided by the international satellite sources like NASA, PVGIS, NREL and Solar GIS. When the energy generation is decentralized, the reliability of the energy is increased. Use of solar PV system integrating with the storage type hydro power project is one of the best solutions for the electricity crisis. During the day time water at the reservoir like Kulekhani is saved and that contribution of hydropower due to saved water is fulfilled by solar PV plant. During the peak hour time (morning and evening) the saved water at reservoir is released to meet the demand. Such type of integration of solar PV system with storage type project can significantly reduce the electricity import during the peak hours. During the sunny time the solar PV plant generate the active power. But during the off time the PV plant inverter can contribute to generate the reactive power which improves the voltage profile of the grid. When electric power system is connected to the grid and disconnects at once, it creates a significant disturbance to the grid supply and would greatly reduce the power quality. Especially if it occurs in large number of installations, voltage fluctuation and frequency variation occur; it may cause a reduction in power quality to other customers that are connected to the distribution line. To prevent this, a feature called FRT (Fault Ride Through) is added to prevent sudden disturbances in supply grid for continuing operation with some faulty conditions. Solar Inverters respond to both voltage and frequency variations much faster than conventional sources.

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References

[1] Herath Gunatilake, Priyantha Wijayatunga, and David Roland-Holst. Hydropower development and economic growth in nepal. 2020.

[2] Nepal Electricity Authority. Annual report of fiscal year 2020/21. 2020.

[3] World Energy Council. World energy trilemma index-2021. 2021.

[4] Krishna R Adhikari, Shekhar Gurung, and Binod K Bhattarai. Solar energy potential in nepal and global context. *Journal of the Institute of Engineering*, 9(1):95–106, 2013.

[5] Dr.Jagan Nath Shrestha. Application of clean energy in nepal:prospects and problems. 2014.

[6] Ministry of Health and Population. Second nationally determined contribution (ndc). 2020.

[7] NREL. Documenting a decade of cost declines for pv systems. 2021.

[8] Rashmi Adhikari. Utility scale solar power development in nepal. 2020.

[9] Sanjeev Giri. Singha durbar runs on solar power. 2018.

[10] JICA. Preparatory survey on the project for clean energy promotion using solar photovoltaic system in nepal. 2010.

[11] Bhoj Raj Tiwari, Nawraj Bhattarai, and Ajay Kumar Jha. Performance analysis of a 100 kwp grid connected solar photovoltaic power plant in kharipati, bhaktapur, nepal. In *Proceedings of the IOE Graduate Conference, Patan, Nepal*, volume 5, 2017.

[12] Sajendra Man Bajracharya and Sanjeev Maharjan. Techno economic analysis of grid tied solar system: A case study of nepal telecom, sundhara, kathmandu. In *Proceedings of IOE Graduate Conference*, 2019.

[13] Nepal Electricity Authority. Annual report of fiscal year 2011/12. 2011.

[14] Jinko Solar. Jinko solar panel. 2020.