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TECHNO- ECONOMIC- ENVIRONMENTAL FEASIBILITY ANALYSIS OF A HYBRID STANDALONE SYSTEM USING A CYCLE CHARGING DISPATCHED STRATEGY: A CASE STUDY OF AN EDUCATIONAL CAMPUS, INDIA.

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ABSTRACT: Across the globe autonomous grid using hybrid power sources is a most prominent option for self-reliant electrical power system where frequent grid outage occurred. In this point of view, a techno-economic- environmental feasibility study has been executed using cycle charging dispatched strategy for an Educational institute located in tribal area of Gujarat, India. In this paper, different feasible combination of hybrid source (Solar PV & DG) and storage system (Li-Ion battery) has been optimised. Also, the proposed study deal with the sensitivity effect of these financial parameter including inflation rate, discount rate and various diesel fuel price on the hybrid system overall costs. The Hybrid PV-DG- Battery Standalone system has been found most feasible system rather than other hybrid system. The suggested standalone optimal PV-DG-Battery hybrid system was found with an NPC of $ 699793 and a COE of 0.0879 $/kWh respectively. The Sensitivity analysis the effect on diesel price increment on Hybrid system performance has been investigated. It is also found that Hybrid PV-DG- Battery standalone system was the most environment responsive rather than other cases by having lowest amount of CO_2 , SOx, and NOx emissions are emissions 9495 (kg/year), 23.2 (kg/year) and 55.7 (kg/year) respectively.

Keywords: Cost of Energy, Solar PV, Cycle charging strategies, Hybrid power system, optimization & Sensitivity Analysis

1. INTRODUCTION:

As we know that Population in the world is currently growing at a rate of around 1.05 % in year 2020 [1], the electricity demand rate is growing. With the resource degradation and the environmental pollution of fossil fuels, searching for alternative clean energy is needed to meet the current energy demand.[2] According to the Global Trends in Renewable Energy Investment in the last decade, solar PV costs were reduced by 81%, onshore wind by 46% and offshore wind by 44%. When compared with traditional energy sources, the low ongoing running costs of renewable energy sources become apparent, making them attractive choices to countries aiming to lower their emissions long-term. [3][7] The hybrid power systems exhibit higher reliability and lower cost of generation than those that use only one source of energy. A power generating system which combines two or more different sources of energy is called a hybrid system.[8] The hybrid energy generating systems (such as wind -diesel, pv-diesel, wind-pv-diesel etc. with and without battery storage options) for standalone and grid connected are not new technologies or systems rather existed in practice for the last two decades. Solar and wind resources are abundantly available in Gujarat, India. In India, Till May, 23, 2020 the total installed electric power capacity in respect of Renewable Energy Sources is 87,269 MW. Solar and wind power plants contributed 34,627 MW and 37,693 MW respectively.[3]

In this paper, a focused has been made to assessment and performance of techno-economic- environmental analysis of a standalone electric system using hybrid power sources. The proposed different combination of hybrid system made with considerations of feasibility of sources with optimum component sizing using cycle charging controlled strategy with least cost and least effect on environment. Also, all feasible combination of

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standalone hybrid system has been investigated using input parameters like inflation rate, discount rate and impact of increasing diesel fuel prices in sensitivity analysis. The results summarized information of components sizing especially maximum use of Renewable sources, optimized simulation studies based on cycle charging and economic – environmental evolution of hybrid power system without grid connection. The output results are very valuable for the existing site for Trustworthy, efficient & economic operation, less usage of conventional sources and increase non-conventional energy utilisation with less polluted environment at site located in tribal area of Gujarat, India.

The main motivation behind this study has to utilisation of maximum usage of renewable sources, which are available at the site, which is located in tribal area, and family income of nearby area is low. Institute i.e. study site has vision to become self-sustained in electricity at campus with maximum utilisation of renewable energy and reduce pollution to save environment as well as not to depend on grid because frequency of power outages from grid is high. Therefore, based on said vision, we did the research study on hybrid Standalone system using renewable power sources and identified most feasible solution for the site in terms of technical, economic and environmental parameters.

The paper structure is as follows. Section 2 explains mathematical modelling of hybrid system components. Sections 3 covers Modelling of Economic Parameters of Hybrid System and Section 4 provides the details of Power dispatched Cycle Charging (CC) control strategy. Section 5 gives the details of Site Description, Resources details and components specification. Section 6 shows the results and discussions and Section 7 concludes the paper.

2. MATHEMATICAL MODELLING OF COMPONENTS OF STANDALONE HYBRID SYSTEM:

2.1.1. Solar PV Module:

Using the amount of solar radiation and the temperature available, the Solar PV output power can be calculated according to the following equation (1)[5]

$$P_{spv} = S_{spv} * f_{spv} \left(\frac{R_t}{R_{t,std}} \left[1 + \alpha_p \left(T_c - T_{c,std}\right)\right] \right. \qquad (1)$$

Where,
S_{spv} = The PV rated capacity under standard test conditions (kW)
f_{spv} = The derating factor of Solar PV.
R_t = The solar radiation incident on the PV array in the current time step (kW/m^2)
$R_{t,std}$ = The incident irradiance at standard test conditions (1 kW/m^2)
α_p = The temperature coefficient of power(%/^{o}C).
T_c = The temperature of the PV cell (^{o}C) in the current time step.
$T_{c,std}$ = The temperature of the PV cell under standard test conditions (25^{o}c).

2.1.2. Power Convertor:

The power convertor is employed to maintain the flow of energy between DC and AC. The converter size is chosen based upon peak load demand, and the inverter rating can be calculated according to the following equation (2)[5]

$$P_{inv} = P_{maxL} \, / \, \eta_{inv} \qquad (2)$$

Where, $P_{max\,L}$. is the peak load demand and η_{inv} is inverter efficiency.

2.1.3. Diesel generator:

The diesel generator is used to provide the peak load demand of the system. Hourly Diesel Consumption of diesel generator is expanded as below equation (3).[5]

$$DG_{fuel}\ (t) = \alpha * P_R + \beta * P(t) \qquad (3)$$

Where,
$DG_{fuel}(t)$ =The fuel consumption of diesel generator (1/h)
$P_{(t)}$ I = the diesel generator power at a certain time
P_R = the rated power of diesel generator
α, β = constants and range start from 0.08 & 0.24

2.4 **Storage Battery:**
The Storage battery is used to serve the required load. Maximum charge or discharge power at any time is the main factor to optimize a renewable system and can be calculated by the following equation (4).[6]

$$P_{batt,Max} = \frac{N_{batt} * V_{batt} * I_{max}}{1000} \qquad (4)$$

Where,
V_{batt} = the voltage of a single battery.
I_{max} = battery's maximum charging current
N_{batt} = the number of batteries

3. MODELLING OF ECONOMIC PARAMETERS OF HYBRID SYSTEM:
3.1.1 Net Present Cost (NPC) :
The total net present cost (NPC) of a system is the present value of all the costs the system incurs over its lifetime, minus the present value of all the revenue it earns over its lifetime. Costs include capital costs, replacement costs, O&M costs, fuel costs, emissions penalties, and the costs of buying power from the grid. Revenues include salvage value and grid sales revenue. NPC is calculated by using equation (5) [6]

$$C_{NPC} = \frac{C_{ann,tot}}{CRF\ (i, R_{Proj})} \qquad (5)$$

Where, $C_{ann,tot}$ is the total annualized cost, i the annual real interest rate (the discount rate), R_{proj} the project lifetime, and CRF is the capital recovery factor. CRF is calculated by using (6). Where, i is the real discount rate, and it is calculated by using (7) [6].

$$C_{ann,tot} = C_{ann,cap} + C_{ann,rpl} + C_{ann,o\&m}$$

$$\boldsymbol{CRF(i,N) = \frac{i(1+i)N}{i(1+i)N - 1}} \qquad \textbf{(6)}$$

$$\boldsymbol{i = \frac{i\prime - f}{1+f}} \qquad \textbf{(7)}$$

Where, i′ is the nominal discount rate and f is the expected inflation rate.

3.1.2 Cost of Electricity (LCOE):
COE is the ratio of total system discounted annualized cost to total energy served by the system (E_{serve}), which includes energy served to the load and energy supplied to the grid. COE is calculated by using Equation (8) [6].

$$\mathbf{COE} = \frac{\mathbf{CRF(i,N)} \times \boldsymbol{C_{NPC}}}{\boldsymbol{E_{serve}}} \qquad \textbf{(8)}$$

Where N is the project lifetime. C_{NPC}, is the net present cost of the hybrid power system.

4. POWER DISPATCHED CYCLE CHARGING (CC) CONTROL STRATEGY:
The The cycle charge dispatch strategy operates as follows: if the electric power (Pgen) from renewable energy sources is insufficient to meet the load demand (P_L) for the site, the diesel generator (DG) starts at full load to supply the load, and the remaining electric power is utilized to recharge the energy storage battery system. The flowchart of the proposed algorithm based on the operational cycle charging control strategy for optimal sizing and techno-economic analysis of standalone hybrid energy systems is depicted in Figure 3.4 Proposed

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algorithm based on CC control strategy for Standalone HES.The system operation of proposed hybrid system configurations can be classified into the following three conditions.

- Condition 1: Pgen = P_L, When the output electrical power generated from the renewable energy sources matches the load power demand of the site (i.e. Pgen = P_L), the batteries do not draw any energy, and the generator remains off. In this scenario, no excess power exists.
- Condition 2: Pgen > P_L, When the output electrical power generated from the renewable energy sources exceeds the load power demand of the site (ie.e Pgen > P_L), the surplus power is supplied to the load, resulting in excess energy. If the battery energy storage system is fully charged, this surplus power will be dissipated. However, if the battery is not fully charged, the surplus output power is utilized to charge the battery. In this condition, the diesel generator (DG) remains inactive.
- Condition 3: Pgen < P_L, When the output electrical power generated from the renewable energy sources is less than the load power demand of the site, two sub-possibilities are observed:
  - Possibility 3.1: If SOC ≥ SOCmin, in the scenario where there is insufficient renewable energy to meet the electric load, the energy storage battery system supplies electric power to the load. This ensures continuous power supply to meet the demand, even when renewable energy sources are inadequate.

    Possibility 3.2: If SOC < SOCmin, In critical conditions where there is a lack of electric energy supply to the load, it becomes necessary to start the diesel generator (DG) at full load to meet the load demand of the site and charge the energy storage battery system simultaneously. Once the energy storage battery system has accumulated sufficient charge, the DG is turned off. This ensures that the load demand is met consistently, and the energy storage system is adequately replenished.

5. Site Description, Resources details and components specification:

5.1.1 Site Description & Load profile:

Shroff S R Rotary institute of Chemical technology (SRICT) is an Engineering institute located in Vataria, a small village in tribal area of Gujarat, India, having the geographical coordinates of 21.565875N and 73.118107E. SRICT Campus have one academic block and one hostel with a total connected load 130 kW. The scaled annual average load profile of SRICT Campus around 715.19 kWh/day, 96.6 kW peak demand, 29.8 kW Avg. demands for 24 hrs and a load factor of 31 %. In this study, the day-to-day (10%) and time step to time step (10%) random variability of load is taken as zero. The energy requirements vary daily and monthly depending on many factors like institute & hostel operating time, vacations, events, working recess and seasonal changes etc. the figure 1 showing the yearly load profile of the site and figure 2 showing geographical location of the site . The life of whole project considered 25 years with expected inflation rate 3.34 % and nominal discount rate 5.40 % considered for the various feasible combination of hybrid system.

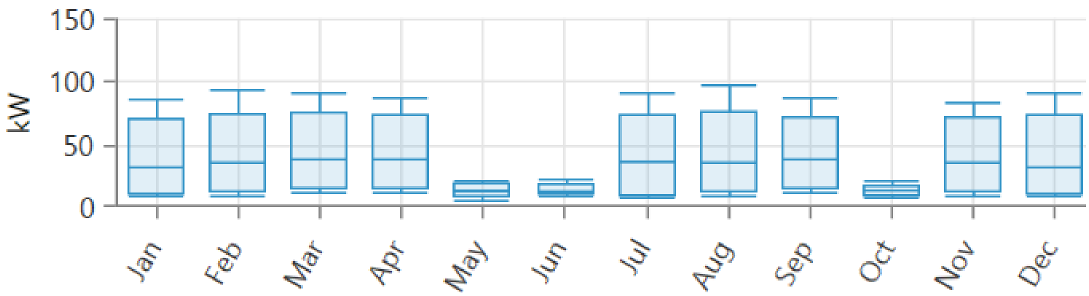

Figure 1: Yearly Load Profile of the Site.

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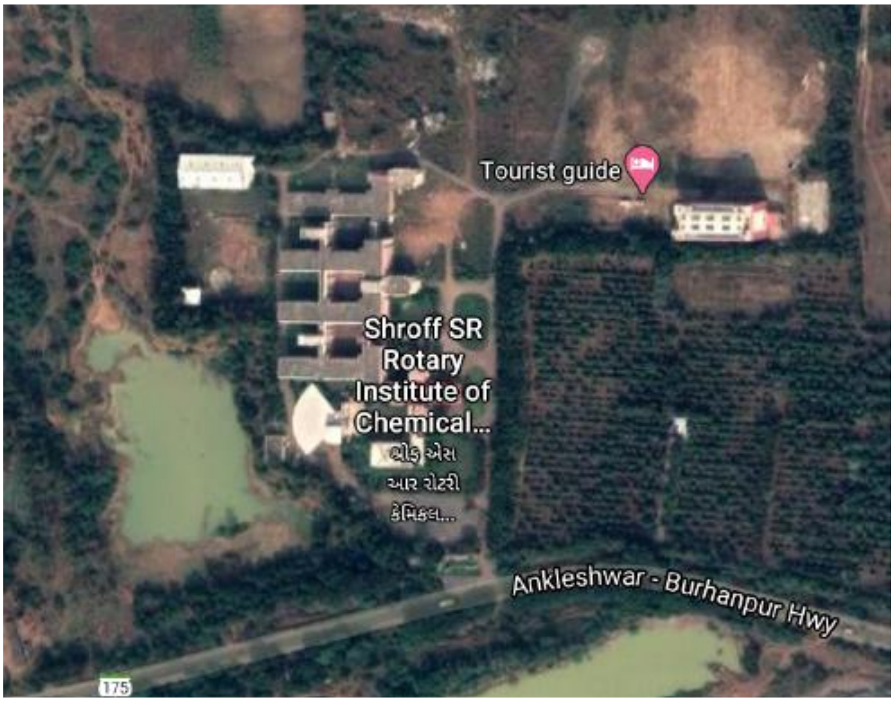

Figure 2: Geographical location of Site

5.1.2 Solar Radiation data:

The solar radiation data for SRICT Campus site was obtained from the NASA surface meteorology and solar energy database. [4]. Figure 3 shows the Yearly Solar Radiation Data with clearness index. It can be seen that the solar daily radiation ranges from 3.55 kWh/m^2 /day (August) to 6.65 kWh/ m^2 /day (April), and the annual average of the solar daily radiation is estimated to be 5.18 kWh/m^2 /day.

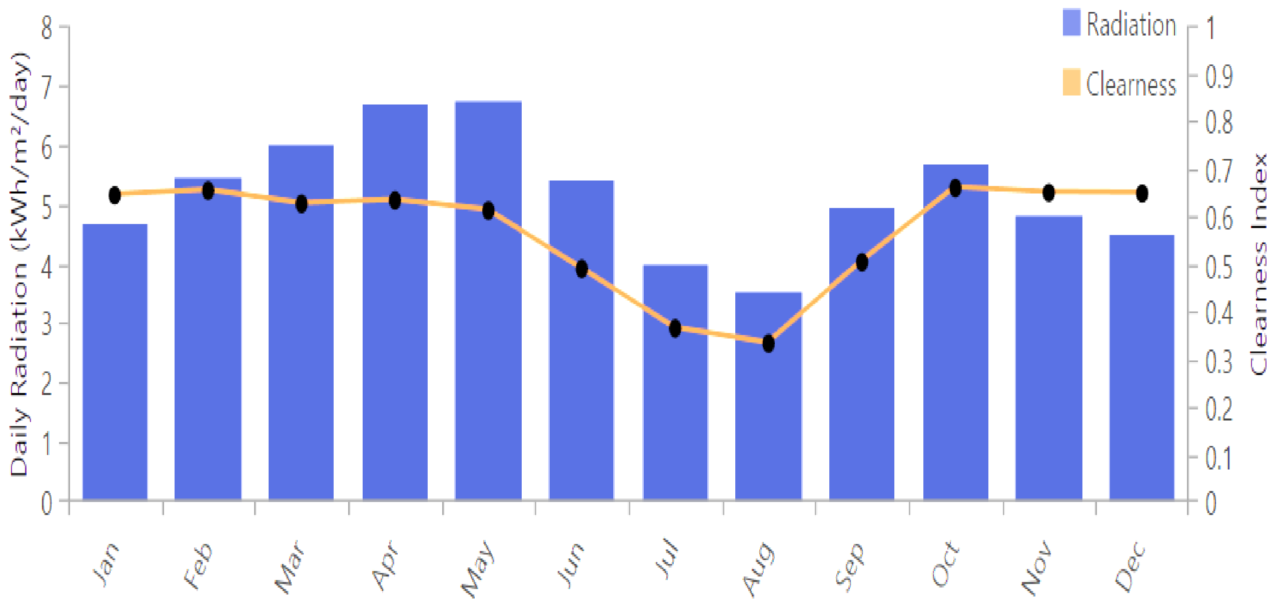

Figure 3 shows the Yearly Solar Radiation Data with clearness index.

5.2Components specification of Hybrid System:

5.2.1.1 Solar PV Module:

The Flat Plate Polycrystalline (Tata Power Solar Systems300TP300LBZ) with No tracking Solar PV panel having module Rating, efficiency and derating factor are 300 watt, 15.40 % and 85 %, respectively is selected for analysis. The capital and replacement cost of 1 kW PV modules are considered as 514 $/kW and O&M cost of PV module is 1 $/kW/Year. The life of panel module is considered as 25 year. The degree panel slope and ground reflectance are considered 22.57 degree and 20 % respectively.

5.2.1.2 Diesel Generator Set:

The generic 1 kw rating Diesel generator is considered to generate base and peak load power respectively, under emergency conditions. The Property of DG set, lower heating value, Density and Carbon content are 43.2 MJ/Kg, 820 kg/M^3 , 88% respectively and The capital & replacement cost and maintenance cost of generators are 110$/kW, 100 $/KW and 1 $/kW/Year, respectively. A lifetime of 15000 operating hours has been considered with a minimum load ratio of 20 %. The Diesel fuel prices increasing from 0.950 ,0.965, 0.994 and 1.113 $/Litre has also considered in this analysis as a sensitivity input parameter.

5.2.1.3 Converter:

A converter is required for a hybrid power system to maintain the flow of energy between DC and AC components. Its inverter and rectifier efficiency are 80% and 95% respectively and lifetime about 15 years. In this paper, the capital cost, replacement cost and O&M cost for a 1 kW converter considered are 410$/kW, 350 $/kW and 1 $/kW/year respectively.

5.2.1.4 Battery Storage:

A Generic 1kWh Li-Ion battery has considered as a storage bank in standalone hybrid system. Nominal voltage (V) and nominal capacity of each batter (Ah) and Min. state of charge are 6V, 166 Ah and 20% respectively. The capital cost, replacement cost and O&M Cost are 183 $/kW, 125 $/kW & 1 $/kW/Year respectively. The lifetime (hours) is considered 15000 Hrs. The round-trip efficiency of1kWh Li-Ion battery is 90 %.

6 RESULT AND DISCUSSION:

Mathematical Modelling , optimisation and sensitivity analysis using cycle charging control strategies of the different standalone hybrid system has been carried out based on assessment of load profile and system resources in HOMER Pro software, which is a software developed by the National Renewable Energy Laboratory (NREL), USA and is considered one of the most powerful tools for the optimization of HESs through performing a techno-economic analysis of the system with a project lifetime of a certain number of years. [9][10]

6.1.1 Sensitivity Analysis:

Sensitivity analysis was performed to find out the effects the changes in various factors such as Discount rate, Inflation rate, fuel price, PV cost, battery costs etc. will have on the system performance. As per the historical trend of diesel price in India found continuously up So In this research study to determine the impact of diesel price increment on the size to the optimal PV-DG- Battery Standalone hybrid system, the diesel price ($/L) 0.98, 0.99, 1,1.1 are considered as a sensitivity input variable for analysis at constant discount rate and inflation rate 4.75 % and 6.25 % respectively.

In this study a Standalone hybrid system has selected various components like Solar PV Modules, Diesel generator, battery, and converter with considering various technical, economical, sensitivity input data using cycle charging control strategies for performance in HOMER Pro.

Diesel Price ($/L)	PV (KW)	DG (KW)	Battery (Li-Ion)	Conv. (KW)	Initial Capital($)	Operating Cost ($/yr)	Ren Frac (%)	Total NPC($)	COE ($/kWh)	Diesel (L/Yr)
0.98	529	50	478	100	395859	9930	95	698093	0.088	3768
0.99	532	50	484	104	399866	9834	96	699179	0.088	3538
1	531	50	484	101	398145	9911	96	699793	0.088	3627
1.1	536	50	497	103	403958	10093	96	711147	0.090	3345

Table 1: Impact of diesel prices on size of PV-DG-Battery standalone hybrid system using cycle charging control strategies.

Looking at the historical trend of diesel prices, it is found that diesel prices are continuously going up. In order to determine the effect of diesel price increment on the size of optimal system. The prices considered for sensitivity analysis are $0.98, $0.99, $1 and $1.11 per litre of diesel.

The effect of rising diesel price on important parameters like Total NPC, COE, PV capacity, and Diesel consumption shown in Table 1 average size of solar PV (KW) is 532 for diesel price variation from 0.98 $/L to 1 $/L. When diesel price increased to 1.1 $/L, then sudden rise solar PV capacity 536 KW. When price gets 1.1 $/L, size of PV module & batteries increases due to which the Initial Capital cost also get boosted and value of NPC & COE get increased 0.090 $/kWh but diesel consumption (L) has been down up to 12 % in Cycle charging strategy and When price gets 1.11 $/L, size of PV module increased due to which the Initial Capital cost also gets decreased and value of NPC & COE get almost constant but diesel consumption (L) have been decrease up to 24 % in load following strategy.

6.2OPTIMIZATION ANALYSIS & RESULT:

6.2.1.1 Economic Analysis:

Optimal Standalone hybrid system performance have been carried out with HOMER Pro to evaluate the performances of a various combination of Hybrid PV-DG-Battery, PV-DG, DG-Battery, and DG only systems. HOMER Pro software have been used for the optimum sizing of sources for producing the continuous power at a lowest cost using cycle charging control strategies under different technical and economical parameters. Table 2 shows simulation results to give a picture of all the proposed feasible combination for standalone hybrid energy system, whereby all feasible combination of hybrid system have been analysed.

Combination of Standalone Hybrid system	**Case 1 PV-DG-Battery**	**Case 2 PV -Battery**	**Case 3 DG-Battery**	**Case 4 PV-DG**
Parameters				
System Configuration				
PV (KW)	530	1062	0	0
DG (KW)	50	0	50	50
Battery LI	484	756	698	0
Conv. (KW)	101	103	102	0
Economic performance				
Total NPC ($)	699793	849595.9	8297209	23960300
COE ($/kwh)	0.0879	0.1456536	1.4220	4.1064
Technical performance				
Renewable fraction (%)	95.6	100	0	0
PV Production(kWh/year)	825019	1651677	0	0
Batteries throughput (kWh/year/battery)	86,480	75277	145953	0
batteries autonomy (hours)	13	20.29563	18.73	0
Diesel Fuel (L/Year)	3627	0	76759.23	105465.8

Table 2: Result of sizing optimization of Standalone Hybrid systems using Cycle charging control Strategies

The comparative results analysis of Standalone hybrid system for COE , NPC, DG operation hours, batteries autonomy, Renewable fraction and PV production using cycle charging strategies shown in table 2. The above analysis clearly indicates that the Hybrid PV-DG – Battery system gives the most feasible results for site with respect to the performance parameters of hybrid system. It found that COE ($/kWh) are 0.0879, 0.145, 1.422 and 4.10 for case 1, 2, 3 & 4 respectively. DG fuel (L/Year) are 3627, 0, 76759.23 and 105465.8 for case 1, 2, 3 & 4 respectively. It has been observed that the capacity of DG is fixed of 50 kW for all combination of hybrid system, but DG operation hours are different based on cycle charging control strategies for all above combinations. DG operation hours zero in case 2 (Hypothetical case) but minimum usage of DG hours in case

1 and Maximum in case 4. So, Hybrid PV- DG- battery Standalone system found most feasible hybrid system for the site in terms of technical and economical parameters concerned.

6.2.1.2 Environmental Assessment:
DG set fuel diesel consumption has an adverse impact on the environment and is dangerous to human health, since several types of smoky pollutants are produced during the DG operation. These emissions include nitrogen oxide (NOx), sulfur dioxide (SO_2), particulate matter (PM), unburned hydrocarbon (UHC), carbon monoxide (CO), and carbon dioxide (CO_2) [8]. The different feasible combination of hybrid system has investigated and released of annual emission under cycle charging control strategies. Table no 3 present the Result of pollutant emissions of Standalone Hybrid systems using Cycle charging control. It has been observed that standalone hybrid system has positive effects on the environment. It is observed that Hybrid PV-DG-Battery standalone system was the most environment friendly rather than other cases by having lowest amount of CO_2 , SOx, and NOx emissions are 9495 (kg/year), 23.2 (kg/year) and 55.7 (kg/year) respectively, in difference to the system with Hybrid PV-DG standalone system had highest CO_2 , SOx, and NOx emissions are 276,069 (kg/year), 676 (kg/year) and 1,635 (kg/year) respectively which indicates that the DG under the case 4 generated a diesel consumption 105465.8 (L/year). Finally, least greenhouse emissions were obtained in Hybrid PV-DG-Battery standalone system using cycle charging dispatched strategies.

Combination of Standalone Hybrid system	**Case 1 PV-DG-Battery**	**Case 2 PV -Battery**	**Case 3 DG-Battery**	**Case 4 PV-DG**
Emissions				
CO_2 emissions (kg/year)	9,495	0	200,926	276,069
SO_2 emissions (kg/year)	23.2	0	492	676
NO_x emissions (kg/year)	55.7	0	1,190	1,635

Table 3: Result of pollutant emissions of Standalone Hybrid systems using Cycle charging control Strategies

CONCLUSION:
Renewable resource-based hybrid system is a Techno- commercial effective, less polluted, and trustworthy solution for continuous supplying electrical energy to isolated areas. In this paper, the technical, economic, and environmental features of a standalone hybrid system with different feasible combination have been investigated under cycle charging control strategies. The proposed investigation deal with the effect of these financial parameter including inflation rate, discount rate and various diesel fuel price on the hybrid system overall costs. The Hybrid PV-DG- Battery Standalone system is more cost effective compared to other hybrid system for the Educational institute located in tribal area of Gujarat, India. The suggested standalone optimal PV-DG-Battery hybrid system was found with an NPC of $ 699793 and a COE of 0.0879 $/kWh respectively. The Sensitivity analysis the effect on diesel price increment on Hybrid system performance has been investigated and found that size of PV-DG Battery standalone hybrid system remain unchanged diesel price from 0.95 $/L to 0.99$/L, but when price reaches 1.11$/L found rise in COE and NPC of system with difference of 0.66 % due to initial capital investment in PV modules and batteries and consumption of diesel (L) reduced up to 66% that to reduced pollutant emission. It is also found that Hybrid PV-DG- Battery standalone system was the most environment responsive rather than other cases by having lowest amount of CO_2 , SOx, and NOx emissions 9495 (kg/year), 23.2 (kg/year) and 55.7 (kg/year) respectively This study is limited for the educational institute located in tribal area to become self-reliant in electricity due grid power outage as well as maximised used of renewable energy for electricity production and reduce pollution to save environment. There is a huge scope in future to study operation of hybrid system with different sources, with grid integration, different sensitivity input variables and different dispatched control strategies.

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REFERENCES:
1. Current World Population. http://www.worldometers.info/world-population/

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2. Das B.K., Hoquea N., Mandala S., Pal T.K., Raihana Md A: A techno-economic feasibility of a stand-alone hybrid power generation for remote area application in Bangladesh. Energy 134, 775–788 (2017). https://doi.org/10.1016/j.energy.2017.06.024
3. The Ministry of Power, Government of India. https://powermin.nic.in/en/content/power-sector-glance-all-india
4. Surface meteorology and solar energy. http://eosweb.larc.nasa.gov/sse.
5. Khulna T., Roy N.K.: Grid connected hybrid power system design using HOMER. Int. J. Renew. Energy Res. 19–22 (2016).
6. Homer renewable energy software documentation. https://www.homerenergy.com/products/pro/docs/latest/ index.html
7. Arévalo P, Benavides D, Lata-García J, Jurado F. : Energy control and size optimization of a hybrid system (photovoltaic hydrokinetic) using various storage technologies. Sustain Cities Soc 2019.
8. Fazelpour F.; Soltani N.; Rosen M.A.: Economic analysis of standalone hybrid energy systems for application in Tehran, Iran. Int. J. Hydrogen Energy 2016, 41, 7732–7743.
9. Barzola, J., Espinoza, M., Cabrera, F.: Analysis of hybrid solar/wind/diesel renewable energy system for off-grid rural electrification. Int. J. Renew. Energy Res. 6(3) (2016)
10. Jung T.; Kim, D. Moon, J. Lim, S.: A scenario analysis of solar photovoltaic grid parity in the Maldives: The case of Malahini resort. Sustainability 2018, 10, 4045.