International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-09, Issue-10, Jan 2024

Design and Performance Analysis of Hybrid Solar PV System

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Abstract - Energy is essential for the progress of a nation and it needs to be conserved in a most efficient way. The most important concern is that not only the technologies need to be developed for producing energy in environment friendly manner from the fuels available but also energy resources should be conserved efficiently. Energy is the crucial aspect for both industrial and agricultural progress. The practice of using renewable energy technology to meet the energy demands is drastically increasing for the previous few years. Also, the contribution of nation towards meeting the global standards according to Paris agreement have boomed the growth of the renewable energy sector. India has declared to achieve 500 GW of non-fossil energy resources by 2030 and achieve net zero carbon emission by 2070. The various power sector ministries like the Ministry of Power and Ministry of New and Renewable Energy are also trying to promote the renewable energy growth in every possible manner. The ministry has obligated every distribution licensee/captive consumer/open access consumer to purchase some percentage of their consumption from renewable energy strictly called as renewable power purchase obligation (RPO). The ministry has come up with a trajectory for RPO whose percentage go on increasing year to year. Also the developed/developing countries are planning to participate in one sun one world one grid (OSOWOG) to harness the solar energy at its potential all over the world. However, the important downsides related to the renewable energy systems are their incapability to assure reliability and being lean in nature [1][2][3][4]. Import of petroleum products from foreign countries comprises a major part of our economy. Renewable sources are the only solution to overcome these challenges. It is clear that fossil fuels reserves in the world are depleting drastically [2][5][6][7]. The prominence of renewable energy sources gained its importance in 18th century. From past three decades, a noteworthy effort was made which resulted in the progress, test and introduction of a diversity of renewable energy technologies for being used in different sectors [3]. In order to make the renewable energy sources reliable and firm in nature we need to hybridize two or more resources for better, reliable and economic system.

Keywords — Energy, Renewable Purchase Obligation, Grid Connected Systems, Hybrid Technology, Co-generation, Net metering/Billing, Banking, Time of Day.

I. INTRODUCTION

The three main renewable sources of energy are:-

A. Solar Energy

Solar energy is extremely huge and inexhaustible source of energy. The earth can intercept approximately 18×10^9 MW power from solar energy [1][3][6], which is almost thousand times more than the current rate of consumption. In India solar energy installed capacity is 72 GW as on 31st October, 2023 but has the potential of 750 GW [1][3][8][9]. Solar energy is the only energy which has the capability of supplying the present as well as the future need of energy to whole world and that too continuously. Solar energy is considered as the most promising and environment friendly non-conventional source of energy having negligible emissions. The energy from the sun can be harnessed in two ways which is the only classification i.e. using PV modules or collectors which are then named as electrical source and thermal source of solar energy.

Solar Photovoltaic is a technology used to convert energy from sun directly into electrical energy by absorbing the energy packets. Solar PV has got numerous advantages like it has got no noise, no wear and tear due to lack of movable parts and the most important advantage is that it is environmental friendly and can be installed in the far flung areas where there is no concept of electricity or the places which are usually cut off from conventional grids. [10][11][12] Solar PV is gaining importance drastically because of its variety of advantages like absence of use of fuel as both fuel cost as well as fuel supply is a big problem. PV technology is extremely reliable with less or no maintenance. Various small and medium standalone

 DOI : 10.35291/2454-9150.2024.0003

applications as well as grid connected power systems have verified the performance and reliability of the solar PV technology. The only hindrance for not using solar PV technologies on larger scale is the high initial cost of PV modules. The SPV system can be operated in various modes like standalone with or without battery, grid connected and can be also operated in hybrid with other sources of energy, which can be decided keeping in view the applications. [13][14][15] The performance of the system depends upon various factors like available solar energy of the location and load parameters. The incident solar energy depends upon the location, time, latitude angle, pitch etc. The SPV system output depends on temperature. More the temperature less will be the cell efficiency.

B. Wind Energy

Wind energy is also considered as an important source of renewable energy which is also capable of compensating the energy crisis of the world. Taking the average wind speed as 7 m/s, approximately 60 million kWh wind energy can be harnessed annually which is more than sufficient to electrify a village or a town. The emissions from wind energy are negligible. [16] Wind energy is the important source of energy for future. India has presently installed 45 GW of wind energy but has got the potential of 100GW [8][9][17][18][19]. Wind energy harnessing technologies are advancing day by day which is a positive sign for the whole world. The only disadvantage of the wind energy is that its power output varies with climate and usually depends on monsoon.

C. Biomass Energy

Biomass is the oldest and common source of renewable energy almost known to everyone. Biomass is a broader term which comprises of variety of materials like wood, agricultural wastes, municipal wastes, animal wastes and human wastes. As India is an agricultural based country thus the main source of biomass are the agricultural residues. In villages animals are used for milk and for ploughing land, therefore animal dung is also the main source of biomass. Biomass stores energy of the sun through photosynthesis and when it is burned the same energy is released in the form of heat. Different forms of biomass produce different outputs like electricity, bio-diesel, ethanol and biofuels. [20][21][22]

Biomass can be converted by three processes:

1. Combustion: It is a process of converting biomass directly into heat in the availability of excess air by making use of furnaces and boilers. This heat generated can be used to produce electricity.

2. Pyrolysis: It is a thermochemical process of converting biomass into a valuable product in the absence of air.

3. Gasification: It is a process of converting organic matter to syngas, without combustion and in presence of controlled supply of oxygen.

D. Hybrid systems

The hybrid power generation is a concept of producing electricity from two or more than two sources integrated with one another. Hybrid power generation is an attractive solution especially for standalone systems. Integration of various sources of renewable energy like solar-wind, solar-biomass and wind-biomass help in providing improved reliability, thus making the system effective and economical as the weakness of one source is compensated by another source. [23][24][25][26][27] Further the integration of renewable hybrid system with grid also improves the economy and reliability of the system to supply the power to load. Also by integrating a standalone renewable energy system, the size and quantity of energy storage devices reduce by larger extent and also enhances the continuous supply of power. [28][29][30]

Hybrid renewable systems can be broadly classified as: Standalone system and grid integrated system. In standalone system the load is met by the system alone without any support from the grid while as in case of grid connected system the power generated by the hybrid system is fed to grid which helps in reduction in yearly electricity bills by making use of net metering.

Standalone hybrid systems are of three types:

1. Solar PV and wind

2. Solar PV and Biodiesel generator

3. Wind and Biodiesel generator

The choice of which system to opt for depends upon the location and availability of sources. For a location like Ladakh J&K where solar resources are in abundance it is better to install a solar hybrid system. Similarly in Kythar TamiNadu where wind is in abundance, one should go for wind hybrid systems. In order to make the hybrid systems work more effectively, its optimization is necessary. There are various methods of optimization for optimum technical and economic analysis like Graphic construction method, Linear programming method or probabilistic approach method.

II. PROBLEM STATEMENT

As the use of renewable energy technologies for meeting the energy demand is drastically increasing throughout the world but the most important disadvantage, of being intermittent and inability to provide reliability still persists. [3][27][28] Renewable sources being intermittent and unpredictable, therefore their integration with the existing power system results in technical challenges usually for weaker grids. This intermittent nature can be reduced by

 DOI : 10.35291/2454-9150.2024.0003

integrating different renewable sources with each other in optimum way, which will help in making the system reliable and economical to run. [31][32][33][34] Presently world is promoting standalone solar and wind power systems but these systems lack in providing continuous round the clock power supply. Standalone PV system can provide power during sunny days/solar hours, not during non-sunny days/non-solar hours. Similarly standalone wind power system can supply power during windy days only. Also the wind speeds fluctuate continuously throughout the day. The continuous supply of biodiesel to biodiesel generator is hectic process. Therefore there are two solutions for this either the use of energy storage devices (that makes the system a bit uneconomical) or the use of integrated renewable energy systems.

III. OBJECTIVE

The objective of this study is to design and study the performance of solar PV and diesel generator hybrid system. Because of intermittent and unpredictable nature of solar it cannot supply round the clock power, therefore integration of these two sources can overcome this challenge. While integrating the various sources with each other, proper optimization should be done so as to ensure optimality. Usually hybrid systems are designed based on weather data like solar radiations, wind speed etc. but the problem is that long term weather data is not available all the time, therefore techniques like artificial intelligence are mostly used. Further, it becomes very important to project various parameters like NPV, EI reliability, energy cost before implementation of a plant that will provide a view whether to proceed or not and it will also help in predicting the reliability of the project.

Various software's e.g. Homer, Tansy's, PV Syst etc. are available in the market for modelling of a power system and its various parameters like physical behavior and its life time cost, that covers the installation cost, operating cost etc. These software's usually perform three basic tasks i.e. simulation, optimization and analyze the sensitivity of the system. The simulation process determine the performance of a system which in turn determines the feasibility and lifecycle cost of the system. Different varieties of power systems can be simulated ranging from small hydro to a MW based PV plant, off grid or on grid, whether supplying electrical or thermal load.

The simulation process is used to serve two purposes:-

1. To determine whether the system is feasible.
2. To estimate the life cycle cost of the system.

Based on availability of the data, this study is based on Solar PV hybridized with Diesel generators of SMVDU Katra J&K where I tried to simulate the 900 KW solar plant installed in the university with the diesel generators already present in the campus using Transys software. Optimizing sizes of various components and designing the hybrid system is the most important factor taken into consideration. The key features of the optimization are:-

1) To maximize use of renewable sources.
2) To minimize energy generation cost.
3) To minimize emissions.

A. Overview of the Load Profile and Generators

The study started by calculating/estimating the load/demand of the whole campus area. The load assessment was carried out manually as well as matching of the data with the electricity bill of the campus. Considering the above two data sources, the overall load of the university was estimated to be 1600 kWp.

Generator is an electrical equipment which converts mechanical energy to electrical energy thus producing electricity for commercial as well as residential purpose. Generators are mostly used as a substitute to meet the demand electricity. Generators work efficiently when run on full load. If we have more than one generators it is better to use them in synchronization mode so as to reduce the losses, therefore increasing the overall efficiency. While synchronization following parameters are to be taken into consideration: phase angle, phase sequence, frequency, voltage. These parameters are called as coupling parameters. The need for synchronization comes when two or more than two alternators work together to supply power to the load. This is because the electrical charges are variable and may vary from time to time and therefore require alternators to operate in parallel to provide larger loads. For Synchronization process, load can be shared among the generators according to their capacities. The heat loss from the generators after coupling also gets reduced by 50 % approximately.

All the four generators installed in the campus were considered for the study. It was estimated that for each of them to work separately the overall losses will increase significantly which include different types of losses namely wire losses, internal resistance, heat dissipation, voltage drops etc., hence result in some kind of wastage of energy which could have been easily minimized if the systems were in some connected state so that the cumulative losses would have been reduced. After calculating the Q-waste (heat loss) at full load and Q-waste (heat loss) at half load, efficiency before and after the synchronization process and the diesel consumption of each generator before and after synchronization, the generators in the coupled mode connected to the Solar PV already installed in the university has been considered in this study.

The main purpose of a synchronizer is to seizure the frequency voltage and difference in phase between the

 DOI : 10.35291/2454-9150.2024.0003

DG's in a very precise and fast way. The established automatic synchronization unit is fast, economical, reliable and precise to be used in the verification, calculation and synchronization processes of the synchronous generators.

The ratings of the various generator considered for this study are as under:-

1. G1 rated as 50 kVA
2. G2 also rated as 50 kVA
3. G3 rated as 100 kVA
4. G4 rated as 380 kVA

B. Introduction to Transys

TRNSYS is an entire and extensive reproduction environment for transient framework recreation, which incorporates the multi-zone structures. This is utilized by specialists and scientists all around the globe to confirm new vitality thoughts, from basic household high temperature water frameworks to the plan and rebuilding of structures and related gear, incorporates control procedures, inhabitant conduct, elective vitality frameworks (wind control), sun oriented, photovoltaic, hydrogen frameworks), and so forth. One main factor in the success of TRNSYS in the previous 30 years is its exposed and sectional structure. The kernel based source code and component models are delivered to end users. This simplifies the expansion of existing models to adapt them to specific user needs. The DLL-based design enables clients and outsider engineers to effectively include custom segment models, utilizing all normal programming dialects (C, C++, PASCAL, FORTRAN, and so on.). Besides, TRNSYS can be effortlessly associated with numerous different applications, for pre or post preparing or through intelligent calls amid recreation (for instance, Microsoft Excel, MATLAB, COMIS, and so on.). TRNSYS components include:

1. Solar based systems (Solar PV and Solar Thermal)
2. Low energy buildings and HVAC systems with advanced design features
3. Systems related to Renewable Sources
4. Fuel Cells and Co-generation
5. Anything which requires dynamic simulation

TRNSYS comprises of a group of projects. The simulation of the Transys, the motors (TRNDll.dll) and its executable (TrnExe.exe), the Building input information visual interface (TRNBuild.exe), and the Editor used to make remain solitary redistributable projects called as Transys applications (Trnedit.exe).

C. The TRNSYS Simulation Studio

The fundamental optical interface is the TRNSYS reproduction examine. Now from that point, will make extends through moving segments into the workspace, connecting them together and designing worldwide re-enactment parameters. Reproduction Studio spares venture data in a Transys venture document (*.tpf). When running a reproduction, Studio likewise makes an information document TRNSYS (content record that contains all the data in the recreation however not the realistic data). The Studio recreation likewise incorporates a yield administrator from which it is conceivable to control which factors are coordinated, printed and/or graphically spoke to and a registry/mistake chief that permits to think about in detail what occurred amid a re-enactment. You can likewise perform numerous extra assignments in the Simulation Studio: generate ventures utilizing the "New Project Wizard", produce a skeleton for new parts utilizing the Fortran Wizard, see and alter the segments Performa's (a Performa is the information/yield/parameters portrayal of a segment), see yield documents, and so forth.

D. The TRNSYS Simulation Engine

The simulation is customized in FORTRAN and the source is dispersed. The motor is aggregated into a Windows dynamic connection library (DLL), Trnd11. The Trnsys bit peruses all reproduction data (which segments are utilized and how they are associated) in the TRNSYS input record, known as the stage document (* .dck). It likewise opens extra info records (for instance, climate information) and makes yield documents. The simulation engine is called by an executable program, TRNExe.exe, which also implements the online plotter, a very useful tool that allows you to see tens of variables during the simulation process.

E. Main components

1. Bus bar - Electrical Bus bar (AC/DC) - Type 188
2. Diesel Engine - Electrical-Diesel Engine (DEGS)-DEGS Dispatch Controller -Type 102
3. Photovoltaic Panels: Electrical - Photovoltaic Panels - Type 194

IV. RESULTS AND DISCUSSIONS

The model was developed by integrating the diesel generators with the PV plant installed in the university wherein, the weather data of Katra was imported, PV was arranged according to the existing configuration and the diesel generators were synchronized with each other and outputs from both the bus bars 1 and 2 were obtained. The study was analyzed by taking whole load of the university campus into consideration.

The various inputs to the model considered for the model are as under:

- Module Short-Circuit Current at reference conditions
- Module Open-Circuit Voltage at reference conditions
- Reference Temperature
- Reference Insolation
- Module Voltage at Max Power Point and reference conditions

 DOI : 10.35291/2454-9150.2024.0003

- Module Current at Max Power Point and reference conditions,
- Temperature
- Coefficient of Isc at reference conditions,
- Temperature Coefficient of Voc at reference conditions
- Number of cells wired in series
- Number of modules in parallel
- Mode of operation
- Type of fuel
- Maximum and minimum power of PV
- Maximum and minimum of Diesel generators
- Load profile.
- Weather Data

The Load Equation is given as:

Load = input 1×input 2×1000 kW

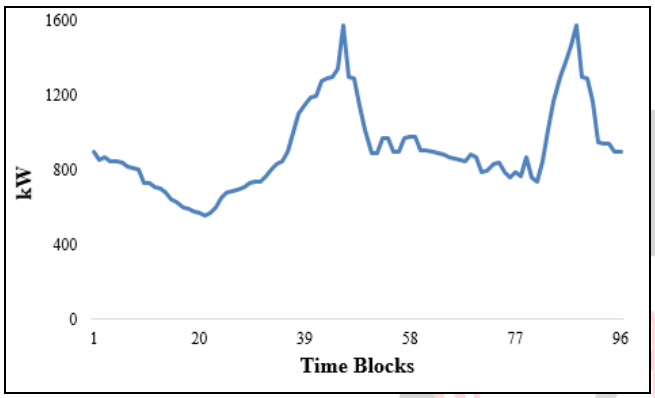

Figure 1: Overview of the average Load Profile

Figure 1 above shows the overview of the daily load profile of the campus over 96 time blocks of a day.

The simulation results were satisfactory, wherein the hybrid model developed was reliably meeting the whole load of the university by using Diesel generators as a backup. The outputs obtained are shown in the figures below.

Figure 2 shows the model designed in Transys by integrating the diesel generators with the PV plant installed in the university. Figure 3 shows the output power generated by Solar PV only whereas Figure 4 shows the output power generated by set of generators operated in synchronization and after hybridizing with one another. A considerable amount of surplus power was also observed after simulation as depicted in Figure 5.

Apart from this there were other important findings like, overall heat loss, fuel efficiency and the electrical efficiency of the system.

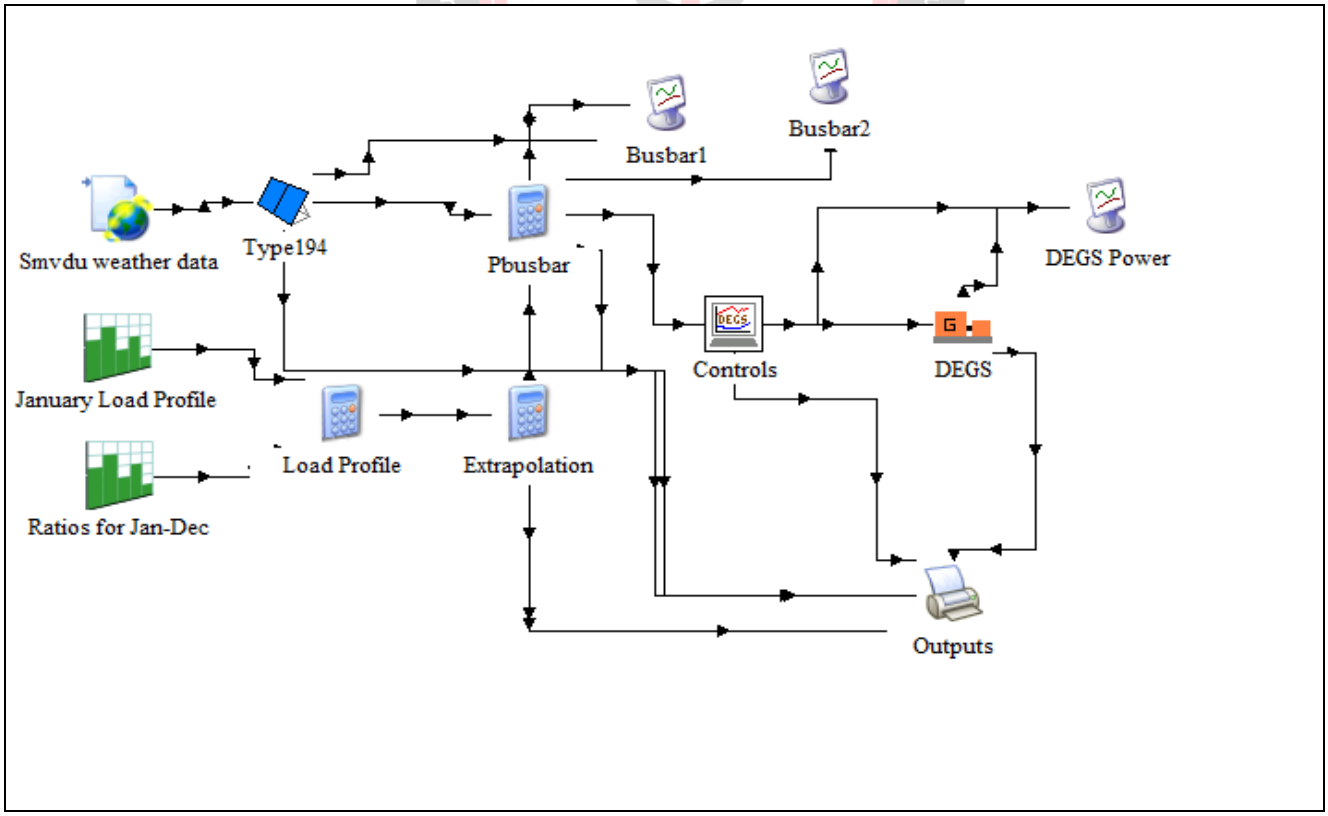

Figure 2: Transys Model for Hybrid Plant

 DOI : 10.35291/2454-9150.2024.0003

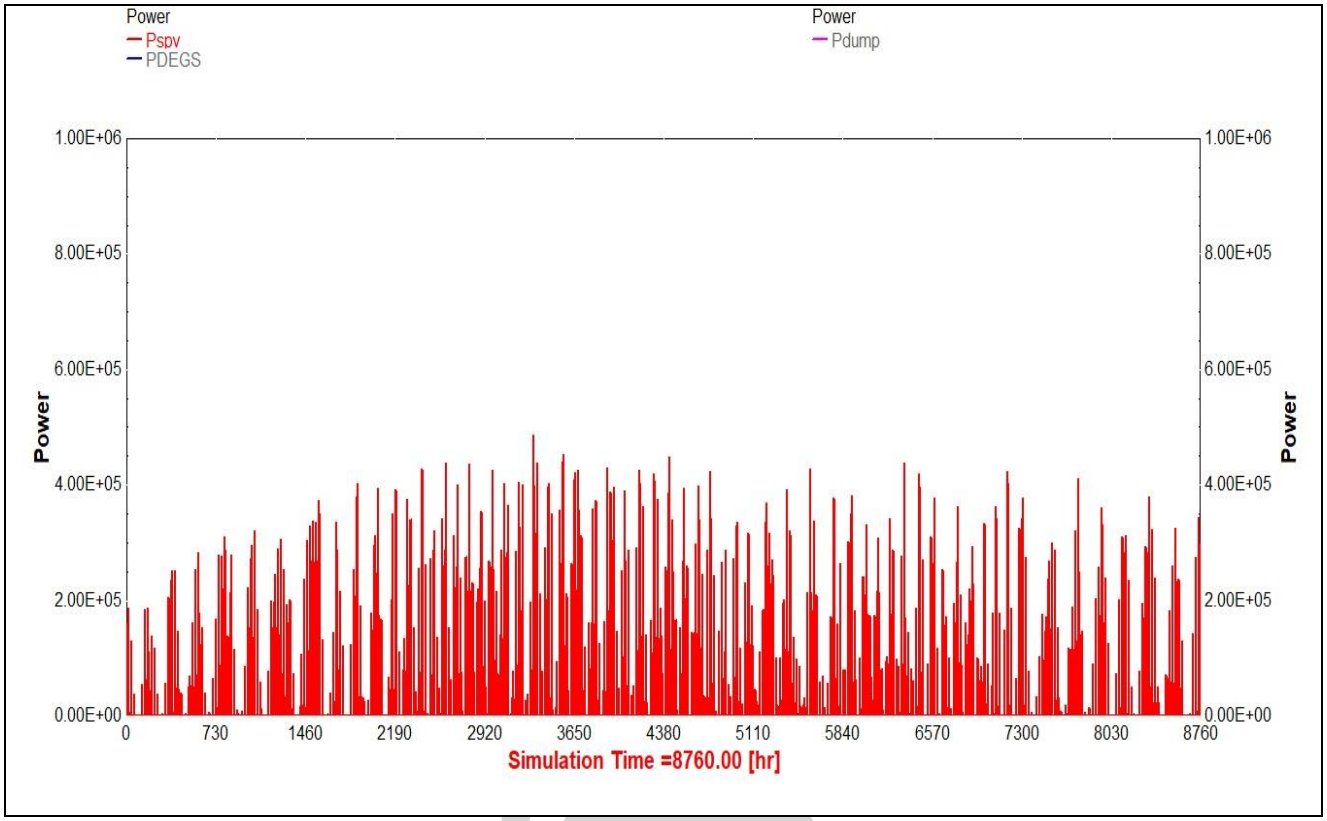

Figure 3: Power generated by PV plant

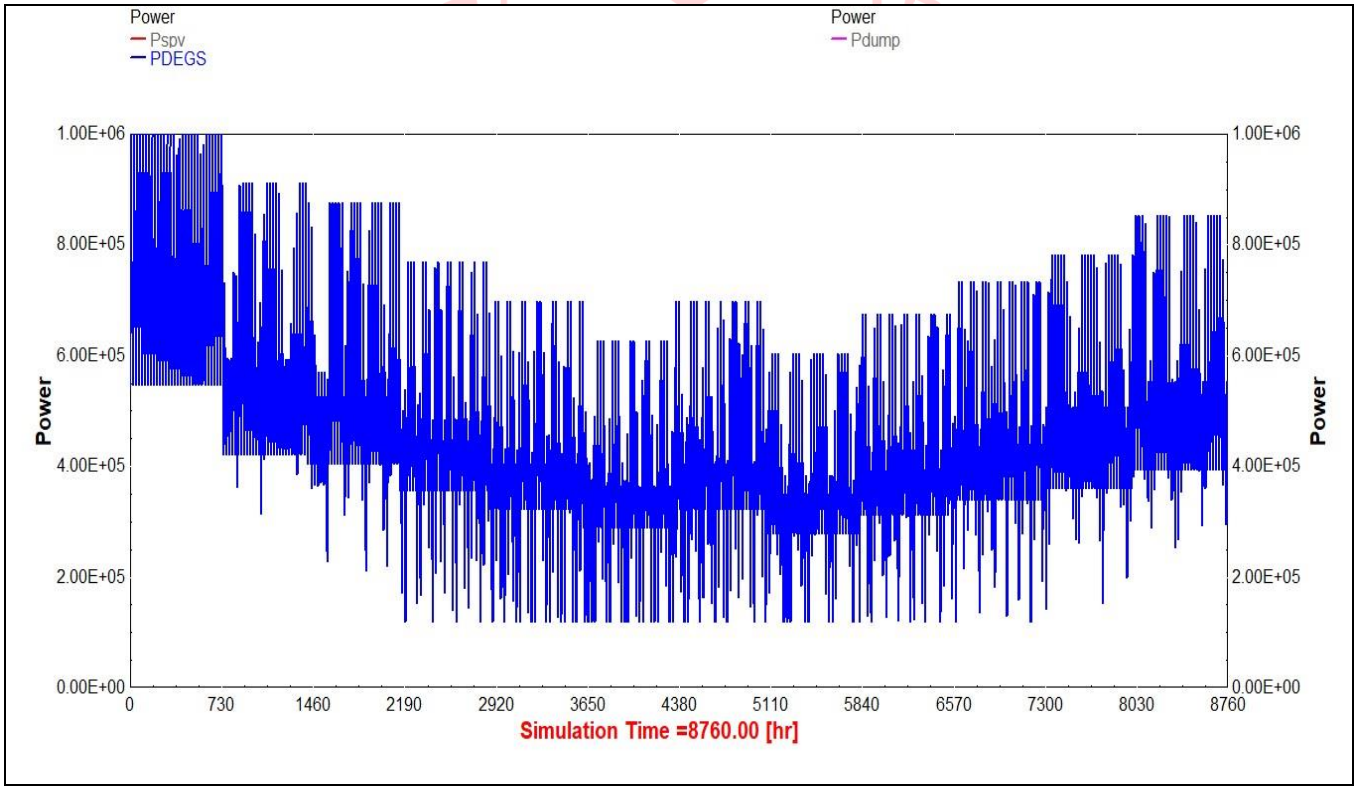

Figure 4: Power generated by diesel generators

 DOI : 10.35291/2454-9150.2024.0003

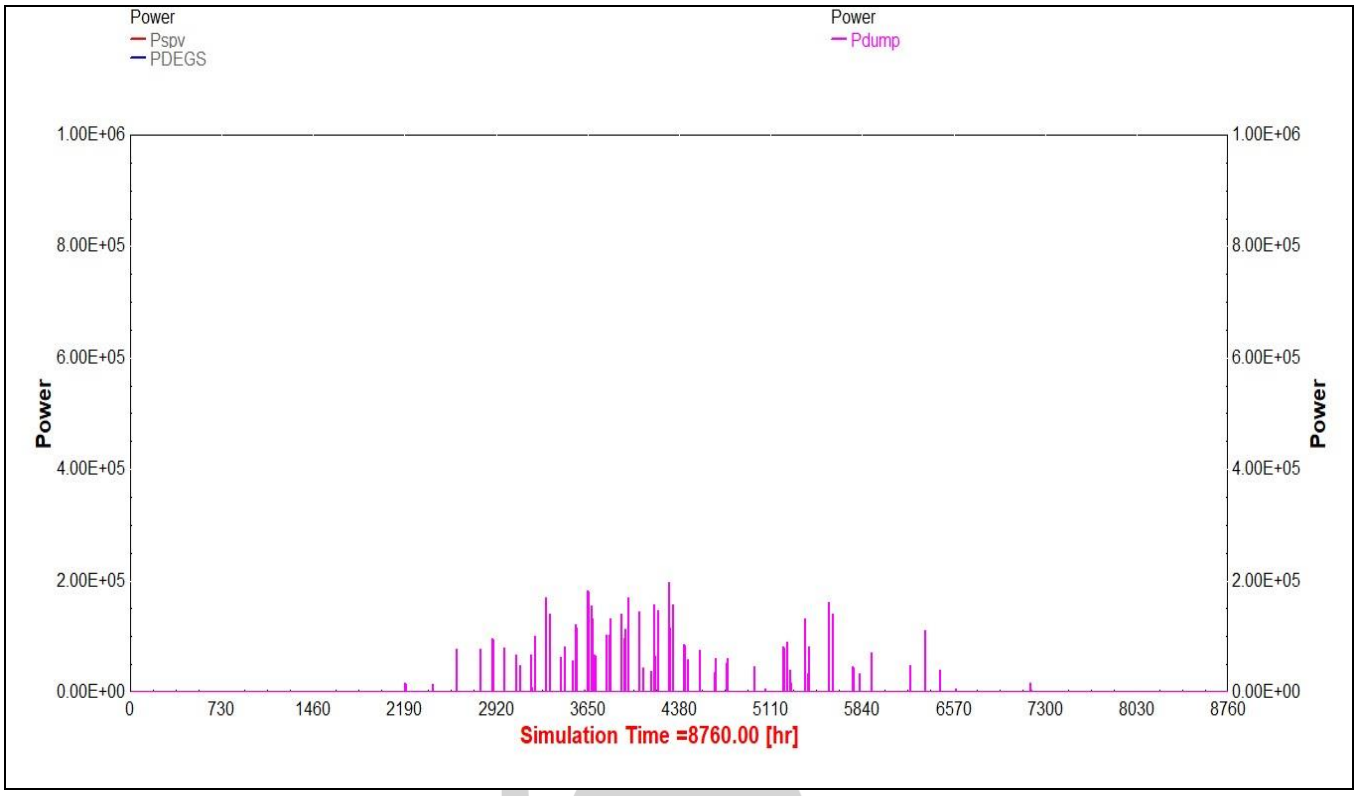

Figure 5: Surplus Power generated

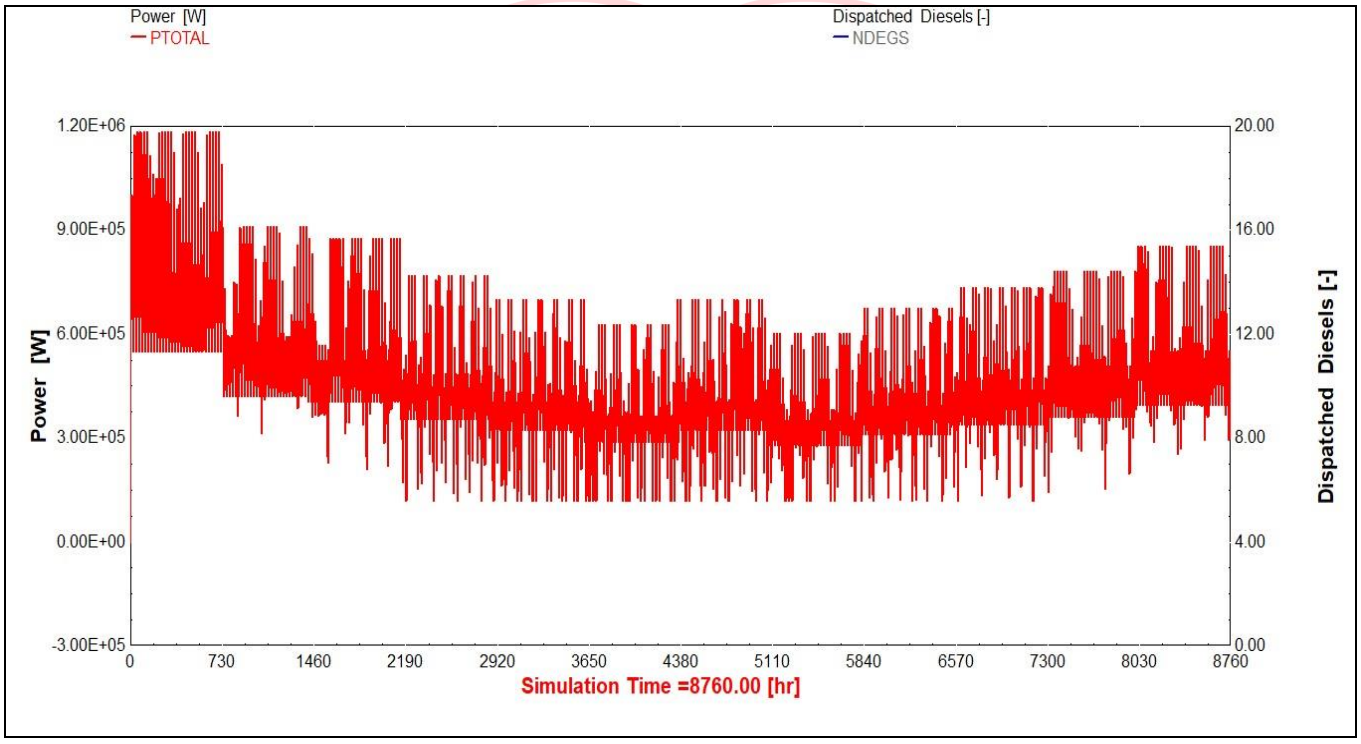

Figure 6: Total Power generated by Hybrid Plant

 DOI : 10.35291/2454-9150.2024.0003

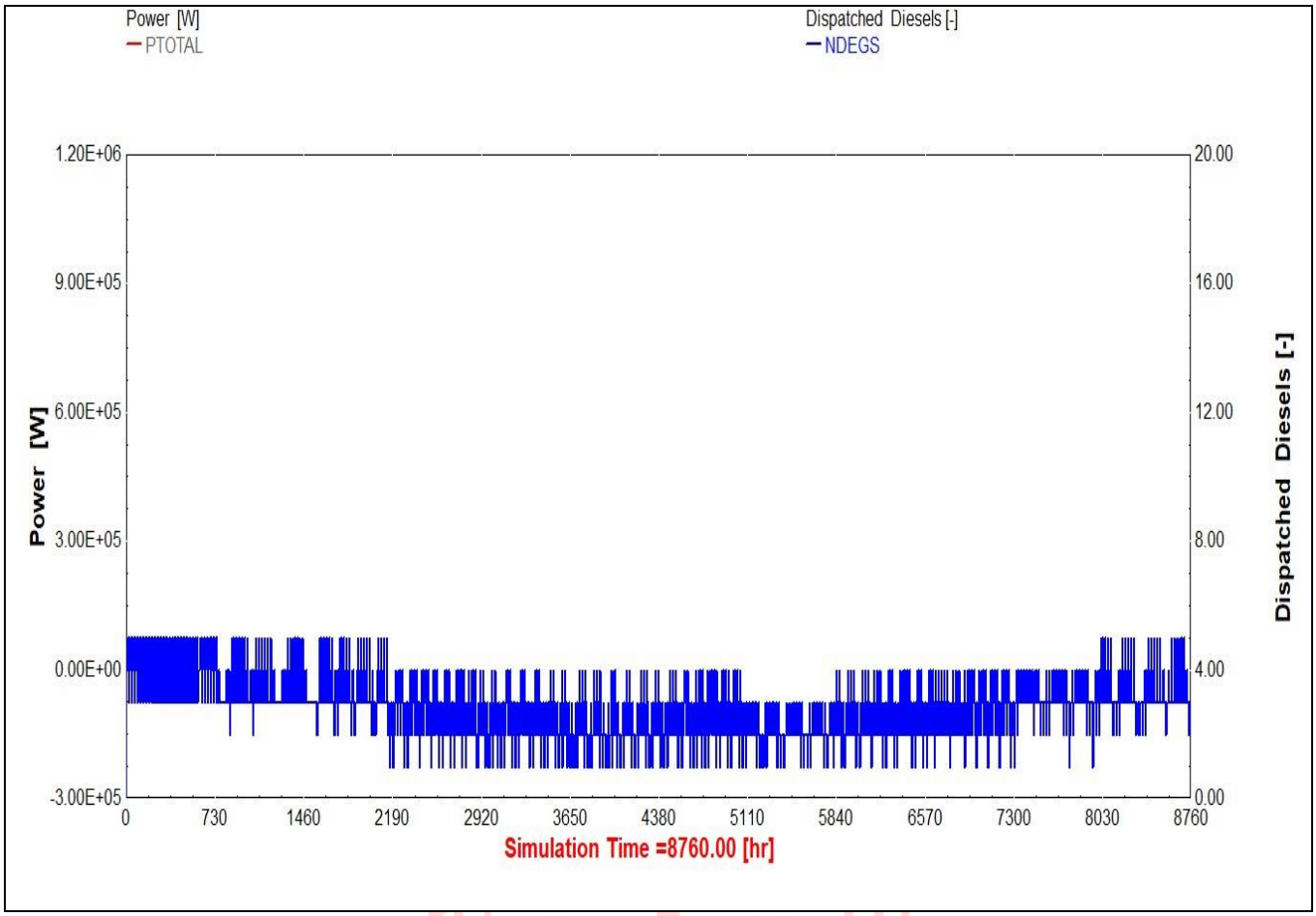

Figure 7: No. of diesel dispatch units used in Hybrid Plant

CONCLUSION

The world is facing the problem of scarcity/shortfall in meeting the peak electricity demand and increase in environment pollution. The use of renewable energy resources can overcome both these problems for which their use in the world is increasing drastically. Presently the whole world is concerned about energy security and sustainable development that is why renewable energies are gaining importance day by day. The developed countries of the world have already shifted from conventional fossil fuels to renewable sources of energy. But while introducing the renewable energies with lots of advantages, they also have a disadvantage that is their intermittent and unpredictable nature which becomes a main challenge for grid connected as well as standalone system. This problem can be partially resolved by integrating two or more resources in an optimum combination, which in turn improves the overall system efficiency and reliability and makes the system cost effective. The hybrid PV-Diesel with batteries has been found as cost effective and reliable for isolated systems. The Wind-Diesel hybrid system can be used for meeting the peak demand. The strategies should be made to ensure minimum, maximum efficiency and reliability of the system. For making the system work better planning should be best so as to forecast accurate weather, exact solar radiation and wind speed. For hybrid systems whether grid connected or standalone, voltage and frequency fluctuations and harmonics impose a serious issue which can only be resolved by having proper design, advanced fast response control facilities, and good optimization of the hybrid systems. The system designed can also be operated by incorporating net metering/net billing methodology that strictly depend upon the regulations by the State Electricity Regulatory Commissions of the particular state where the system is being installed, thus reducing the overall energy cost of the electricity of the willing consumer. Moreover, the energy generated from the renewable energy systems is also allowed to be banked by paying some amount as banking charges to be used later based on Time of day/use. The integration of solar PV hybrid system improves the overall sustainability of the system. Also the hybrid system improves reliability and redundancy, guaranteeing uninterrupted power supply. The key factors like cost-effectiveness, system control, flexibility and optimization should be the primary concern while designing the system. Few other findings like total power generated, overall heat loss, fuel efficiency (approximately equal to 40%) and the electrical efficiency (approximately found to be 87%) of the system were also observed as shown in Figure 8 below and it was observed that when the generators were made to operate individually, the total heat loss on full load was recorded to be 40 to 50 % that kept on increasing to 60- 70

 DOI : 10.35291/2454-9150.2024.0003

% as the generator was operated on partial load. It was also observed that after synchronization of the generators the overall heat loss was reduced by approximately 50% in both the cases. The important concern here is that the heat loss still persists to some extent even after synchronizing the generators. To further improve the system it is suggested to operate the above designed system in co-generation topping cycle mode where the system will primarily generate electricity and the heat loss will be utilized as secondary form of available energy.

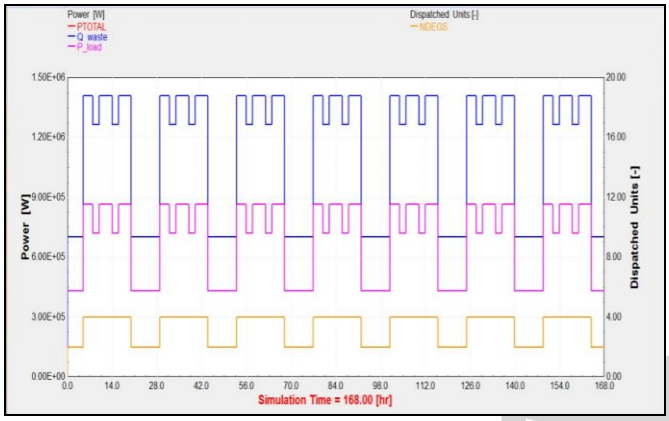

Figure 8: Waste Heat generated by synchronized generators

REFERENCES

[1] K. Reiniger, T. Schott and A. Zeidler. Optimization of Hybrid Stand-alone Systems European Wind Energy Association Conference and Exhibition. 1986.

[2] J.S. Park, T. Katagi, S. Yamamoto and T. Hashimoto, Operation control of photovoltaic/diesel hybrid generating system considering fluctuation of solar radiation, Solar Energy Materials and Solar Cells 67 (2001) 535-542.

[3] M.H. Nehrir, B.J. Lameras, G. Venkataramanan, V. Gerez and L.A. Alvarado, An approach to evaluate the general performance of stand-alone wind/photovoltaic generating systems, IEEE Transactions on Energy Conversion 15 (2000) 7.

[4] S. Ashok, Optimised model for community-based hybrid energy system, Renewable Energy 32 (2007) 1155-1164.

[5] E.M. Nfah and J.M. Ngundam, Feasibility of pico-hydro and photovoltaic hybrid power systems for remote villages in Cameroon, Renewable Energy 34 (2009) 1445-1450.

[6] R. Ruther, A.L. Schmid, H.G. Beyer, A.A. Montenegro and H.F. Oliveira, Cutting on Diesel, boosting PV: The potential of hybrid Diesel/PV systems in existing mini-grids in the Brazilian Amazon 2003.

[7] N. Phuangpornpitak and S. Kumar, PV hybrid systems for rural electrification in Thailand, Renewable & Sustainable Energy Reviews 11 (2007) 1530-1543.

[8] https://mnre.gov.in/physical-progress/

[9] https://cea.nic.in/?lang=en

[10] C.V. Nayar, M. Ashari and W.W.L. Keerthipala, A grid-interactive photovoltaic uninterruptible power supply system using battery storage and a backup diesel generator, IEEE Transactions on Energy Conversion 15 (2000) 348-353.

[11] R. Ruther, D.C. Martins and E. Bazzo. Hybrid Diesel/Photovoltaic Systems without Storage for Isolated Mini-grids in Northern Brazil. In Photovoltaic Specialists Conference, 2000. 2000. Anchorage, AK.

[12] R.L.G. E.L. Maxwell, A Climatological Solar Radiation Model, in the 1998 American Solar Energy Society Annual Conference, T.C. R. Campbell-Howe, B. Wilkins-Crowder, Editor. 1998, American Solar Energy Society: Albuquerque, NW. pp. 505-510.

[13] S.A. Incorporated, Sunny Island 5048U Installation and Instruction Manual. 2007: Grass City, CA.

[14] C.D. Barley and C.B. Winn, Optimal dispatch strategy in remote hybrid power systems, Solar Energy 58 (1996) 165-179.

[15] F. S. Javadi, B. Rismanchi, M. Sarraf, O. Afshar, R. Saidur, H. W. Ping, and N. a. Rahim, "Global policy of rural electrification," Renew. Sustain. Energy Rev., vol. 19, pp. 402–416, Mar. 2013

[16] Vivek Kapil, Fernandez E. and Saini R.P. (1999) 'Design of Photovoltaic system for remote areas', Proceedings of the 23rd National Renewable Energy Convention of the SESI, pp. 145-147.

[17] Bhattacharaya N.K. and Mukherjee D. (2001) 'A simplified Design approach and economic appraisal of a solar photovoltaic powered rural health center in West Bengal', Proceedings of the 25th National Renewable Energy Convention of the SESI, pp. 158-164.

[18] Kaushika Anil K. Rai, Kshitij Kaushik and Mishra A. (2001)'Knowledge based approach to the design of solar PV systems', Proceedings of the 25th National Renewable Energy Convention of the SESI, pp. 165-170.

[19] Hamid Marafia A. (2001) 'Feasibility study of photovoltaic technology in Qatar', Renewable Energy, Vol. 24, pp. 565-567.

[20] Mohanlal Kolhe, Sunita Kolhe and Joshi J.C. (2002) 'Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India', Energy Economics, Vol.24, pp.155-165.

[21] Usha Bajpai and Suresh C Bajpai (2003) 'Some aspects of array and storage battery sizing in

 DOI : 10.35291/2454-9150.2024.0003

standalone photovoltaic power systems', Proceedings of the 26th National Renewable Energy Convention of the SESI, pp. 222-227.

[22] Aydogan Ozdamar, HasanYildiz and OzgurSar (2001) 'Wind energy utilization in a house in Izmir, Turkey', International Journal of Energy Research, Vol. 25, pp. 253-261.

[23] Kanat A. Baigarin and Andre de Boer 'Potential of renewable energy resources in Central Asia', a text book on Renewable Energy, pp.7380.

[24] Suresh H., Jangam shetti, and Guruprasada Rau V. (2001) 'Optimum siting of wind turbine generators', IEEE Transactions on Energy Conservation, Vol. 16, pp. 8-13.

[25] Wen-jei Yang and Orhan Aydin (2001) 'Wind energy-hydrogen storage hybrid power', Generation International Journal of Energy Research, Vol. 25, pp. 449-463.

[26] Bhave A.G. (1999) 'Hybrid solar-wind domestic power generating system-a case study', Renewable Energy, Vol. 17, pp. 355-358.

[27] Habib M.A., Said S.A.M., El-Hadidy M.A. and Al-Zaharna I. (1999) 'Optimization procedure of hybrid photovoltaic wind energy system', Energy, Vol. 24, pp. 919-929.

[28] Francois Giraud and Zyiad M. Salameh (2001) 'Steady-state performance of a Grid-connected roof top hybrid wind-photovoltaic power system with battery storage', IEEE Transactions of Energy Conversion, Vol. 16, pp. 1-6.

[29] I. Shah, S. Ismail, A. Omar, and H. Hassan, "Pilot Centralized Solar Power Station in Remote," in National Power and Energy Conference (PECon), 2003, pp. 237–242.

[30] D. Yamegueu, Y. Azoumah, X. Py, and N. Zongo, "Experimental study of electricity generation by Solar PV/diesel hybrid systems without battery storage for off-grid areas," Renew. Energy, vol. 36, no. 6, pp. 1780–1787, Jun. 2011.

[31] M. Fadaeenejad, M. A. M. Radzi, M. Z. A. AbKadir, and H. Hizam, "Assessment of hybrid renewable power sources for rural electrification in Malaysia," Renew. Sustain. Energy Rev., vol. 30, pp. 299–305, Feb. 2014.

[32] C. W. Ajan, S. S. Ahmed, H. B. Ahmad, F. Taha, and A. A. B. Mohd Zin, "On the policy of photovoltaic and diesel generation mix for an off-grid site: East Malaysian perspectives," Sol. Energy, vol. 74, no. 6, pp. 453–467, 2003.

[33] H. Jacobus, B. Lin, D. H. Jimmy, R. Ansumana, A. P. Malanoski, and D. Stenger, "Evaluating the impact of adding energy storage on the performance of a hybrid power system," Energy Convers. Manag., vol. 52, no. 7, pp. 2604–2610, Jul. 2011.

[34] P. Cook, "Infrastructure, rural electrification and development," Energy Sustain. Dev., vol. 15, no. 3, pp. 304–313, Sep. 2011.

[35] R. K. Akikur, R. Saidur, H. W. Ping, and K. R. Ullah, "Comparative study of standalone and hybrid solar energy systems suitable for off-grid rural electrification: A review," Renew. Sustain. Energy Rev., vol. 27, pp. 738–752, Nov. 2013.

[36] S. A. Chowdhury, S. Aziz, S. Groh, H. Kirchhoff, and W. Leal Filho, "Off-grid rural area electrification through solar-diesel hybrid minigrids in Bangladesh: resourceefficient design principles in practice," J. Clean. Prod., vol. 95, pp. 194–202, May 2015.

[37] A. M. Mahmud, R. Blanchard, and R. Gottschalg, "Impact Study on Rural Electrification Program Using Solar PV-Diesel Hybrid System for Rural Schools in Sabah, Malaysia," in 4th Symposium small PV-application - Rural electrification and commercial use, 2015, pp. 145–150.

[38] Design and Economic Analysis of PV-Diesel Hybrid System for Particular Section of IUT Campus

[39] Design of Hybrid Power System for an Academic Institution in JK Lakshmipati University.

[40] Design of a PV/Diesel standalone hybrid system for a remote country in Palestine, Journal of Asian Scientific Research 2(11):599-60

 DOI : 10.35291/2454-9150.2024.0003