Optimization of micro hydro and solar photovoltaic system nano hybrid system

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Abstract-*This article investigates the possibilities for creating an effective nano-grid model concept in order to maximise the use of renewable energy for on-grid systems. The proposed nano-grid design includes power plants that use photovoltaic (PV) and micro hydro power (MHP) systems connected to the grid to generate electricity from renewable energy sources. Software like HOMER and MATLAB are utilised to analyse the modelling findings. The HOMER replicates a nano-grid model with three various options, such as MHP capacities of 50 kW, 100 kW, and 150 kW depending on the loads and the availability of water resources. As it got closer to the peak load capacity, the nano-grid model with MHP architecture showed lower energy costs, responsible depletion in* CO_2 *emissions, as well as the biggest share of renewable energy. According to the simulation results, the nano-grid model with the maximum MHP capacity achieved the lowest energy prices, the greatest reduction in carbon emissions, and the best use of renewable energy power plant output for electricity.*

Keywords*: Micro hydro power, Nano grid, Photovoltaic, micro hydro power, Nano grid, MATLAB. HOMER, Carbon emission.*

1. Introduction

Nowadays, it makes sense to use less of the increasingly scarce fossil fuels and to fully utilise renewable energy sources. Considered to be the main energy sources for power plants are coal, oil, and gas. This condition would have an effect on the rise in carbon emissions brought on by the use of fossil fuel-powered power plants. We should increase the use of renewable energy sources to reduce carbon emissions caused by electric energy generated from fossil fuels. Due to their uneconomical and unreliable nature, remote renewable energy power plants struggle to increase their electricity supply. It has to do with the way that the ease of using renewable energy varies depending on the weather. On the other hand, the rate of energy production for plants that only use renewable resources is greater than the price of power supplied on the local grid. The government's subsidy of the retail price of power in the grid system is the cause of this situation. Additionally, electrical load factors in rural areas are lower [2], necessitating the use of stand-alone power. Utilizing hybrid power systems, which combine numerous power plants with various energy sources, is an efficient way to preserve the dependability of the energy supply from renewable energy sources [3-5]. Nano grids are defined as hybrid power plants that combine conventional diesel engines or battery storage with renewable energy sources like photovoltaic (PV), wind, micro-hydro (MHP), biomass, and others. A block diagram of a nano hybrid grid system that uses renewable resources is shown in Figure 1. These power plants can operate separately from the grid or in tandem with it. The diesel generator works in off-grid areas with the micro-grid, which includes a variety of power plants that utilise diverse renewable energy sources. The combination in the area connected to the grid system would be improved by the grid system's electrical supply. Using experimental research, control techniques, computer modeling, and feasibility studies, several investigations on nano-grid and hybrid power generating systems have been carried out globally. The system layout, control strategy, and various micro-grid implementations across the globe were examined in the preview research [3]. The studies [4-9] looked at the utility of nano-grids that combined micro-turbines with renewable energy sources from plants. Previous works [9-12] have also covered the practicability learning and model optimization of HOMER based nano-grid/hybrid model, appropriate for remote rustic areas. This study reveals at the phase of developing a simplified nano-grid model that enhances the utilisation of confined renewable energy locations for on-grid area. The preview research looked at the system architecture, control approach, and numerous micro-grid implementations around the world [3]. The research [4–9] examined the practicality of nano-grids that incorporated micro-turbines and plant-based renewable energy sources. The HOMER-based nano-grid/hybrid model's practicability learning and model optimization, which are suitable for remote rural areas, have also been discussed in earlier publications [9–12]. This study shows that we are in the process of creating a simplified nano-grid model that maximises the use of restricted renewable energy places for on-grid area.

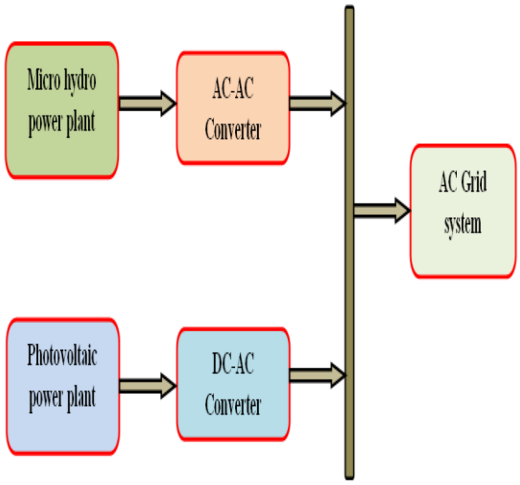


Fig.1. Block diagram of nano grid system using micro hydro and photovoltaic power plant

In this work, following are objectives are taken into consideration:

- The potential for creating a simple micro-grid model that improves the deployment of particular renewable energy for on-grid locations is investigated.
- The scale and several energy conversion technology types are optimised using the HOMER programme.
- In the short-term, two key factors are the cost of energy and the decline in carbon emissions.
- Simulink-MATLAB software is also used to assess the micro-grid model's overall performance.

2. Methodology

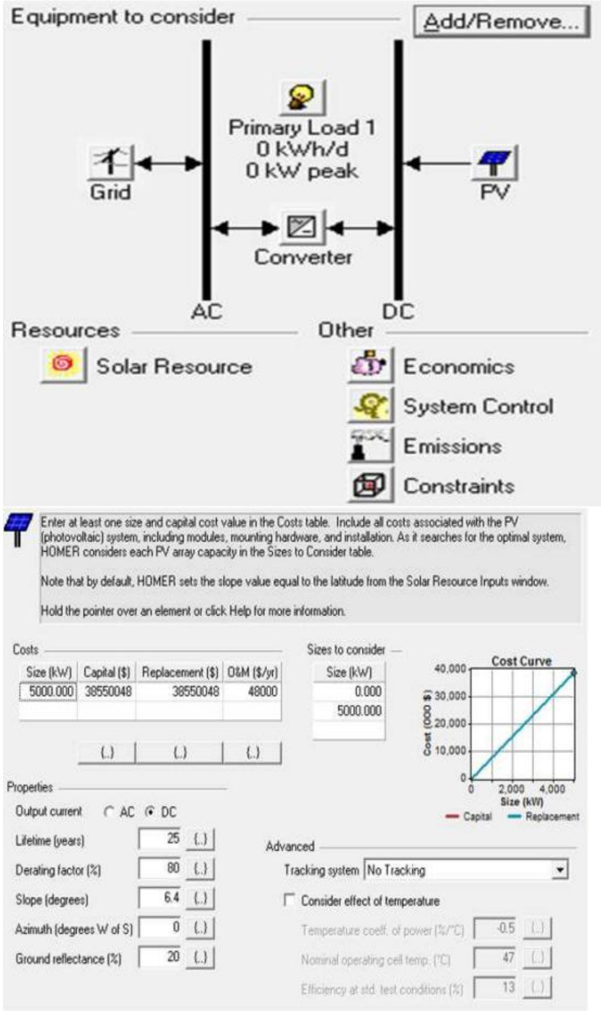
The river stream flow was suggested as a source of power for a micro hydro power plant (MHP). The flow of stream was at its lowest in April and was 2141 L/s. 1251 L/s, or 1.28 m^3/s, of the stream flow can be utilised to generate power when the remaining flow of 1000 L/s is taken into account. Equation [1] can be used to determine the nominal power of MHP.

$$P_{MHP}=g\,\eta.h.Q_d \qquad (1)$$

g is the acceleration caused by gravity [m/s^2], P_{MH} is the power output of the micro hydro power plant in kW, Q_d is the design flow[m^3/s] and h is the gross head in meter. The design flow alternatives for the micro hydro power plant and simulated as 0.8, 0.7, and 0.5 m^3/s while taking the loads and water resources accessibility into account. Meanwhile, the average gross head for all phases was 25m. For 50–150 kW power [12-16]. The replacement cost is used to determine the cost of replacing energy equipment. Using the following equation, HOMER calculates the PV power generation's power output:

$$P_{pV}=K_{PV}GI_S/I_R \qquad (2)$$

Where: I_s is the solar radiation (kW/m^2), K_{PV} is the rated capacity of PV (kW), the derating factor of photovoltaic cell is G, and I_R is $1kW/m^2$. Photovoltaic modules are connected in different connection (i.e. series and parallel connection). The cost of purchasing solar panels, mounting panels, control systems, wiring, and installation is included in the capital cost per kW, which is USD 2000 [9]. The age of a solar module is estimated to be 25 years based on the specifications [17-18]. To boost the micro-system grid's performance, a battery is necessary. This apparatus is used to respond to transient disturbances and fluctuations in solar irradiation. The total number and power of batteries are used to match the power and voltage of the photovoltaic generator. A battery has been taken into account in this model. The converter may move electrical power in two directions (bidirectional). On the other hand, depending on the flow of power, the power converter can function as both a rectifier and inverter mode. This type uses a 10.5kW converter steam power plants that serve as electric source for the grid emit gases during normal operation. CO_2 emissions are among those that have the greatest impact on global warming [19]. As a result, the current analysis exclusively considers CO_2 emissions. The grid's emission coefficients are calculated by considering two major factors i.e emission coefficient and the electrical power system [20-21]. It is necessary to model the performance parameters of the nano-grid using Simulink-MATLAB for validation process. Figure 2 displays Homer software based model of nano grid system. MHP, Photovoltaic power, the grid and the load are used to build this model. Figure 2(a) reveals the PV grid-connected system modelling using HOMER software [22].



Enter at least one size and capital cost value in the Costs table. Include all costs associated with the PV (photovoltaic) system, including modules, mounting hardware, and installation. As it searches for the optimal system, HOMER considers each PV array capacity in the Sizes to Consider table.

Note that by default, HOMER sets the slope value equal to the latitude from the Solar Resource Inputs window.

Hold the pointer over an element or click Help for more information.

Costs

Size (kW)	Capital ($)	Replacement ($)	O&M ($/yr)
5000.000	38550048	38550048	48000

Sizes to consider

Size (kW)
0.000
5000.000

Properties

Output current ○ AC ● DC
Lifetime (years) 25
Derating factor (%) 80
Slope (degrees) 6.4
Azimuth (degrees W of S) 0
Ground reflectance (%) 20

Advanced

Tracking system No Tracking
☐ Consider effect of temperature
Temperature coeff. of power (%/°C) -0.5
Nominal operating cell temp. (°C) 47
Efficiency at std. test conditions (%) 13

Fig. 2 (a). Solar PV grid-connected system modeling by HOMER [22]

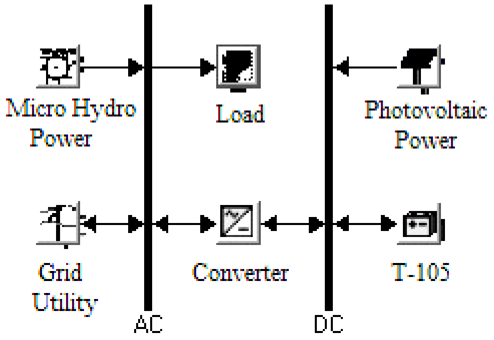


Fig.2 Homer software based model of nano grid system

The converter, transformer, filter, and PV module make up the PV power generation block. This model puts phase II configuration into practice. PV modules were connected in both series and parallel. An induction machine supplied by the MATLAB software was employed by the MHP block. A block grid is used to simulate how power is distributed from the substation to the nano-grid.

3. Result and Discussion

The results of the suggested simulation grid performance using Simulink MATLAB are revealed in Fig.3. The micro hydro power has been providing electricity to grid and load system before t=0. At t = 0 photovoltaic power coupled to the grid. This graph illustrates photovoltaic and micro hydro grid system shared power to grid and load. The load is increased at t = 0.4s. On the other hand the grid will boost power for the micro-grid to prepare for the rising load, photovoltaic and micro hydro power keep power at standard level. In this situation, the grid, MHP and photovoltaic systems will contribute to powering the load. The load is decreased at t = 0.7s. Since the supply of micro hydro power and photovoltaic can satisfy various requirements of load side, the grid system will be divided from the nano-load grid's system. In a nutshell, the planned micro-electricity grid's supplied by renewable energy sources were optimised, and the grid system's power was adjusted with the demands of the load.

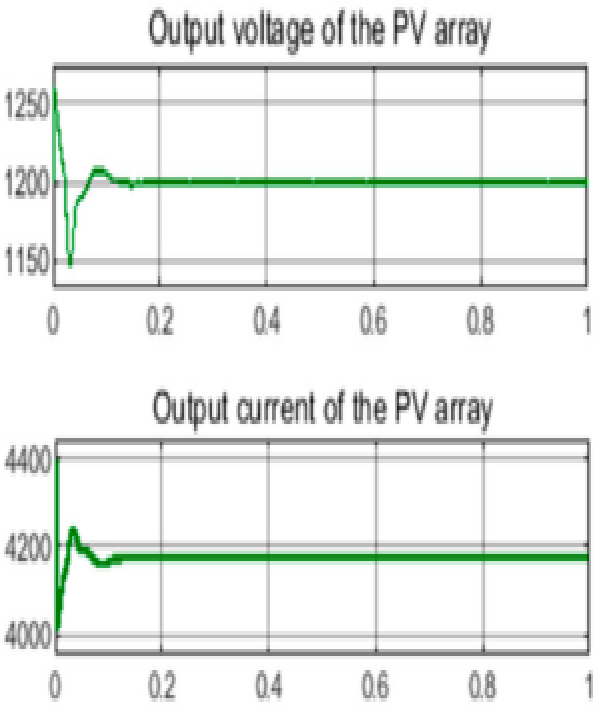
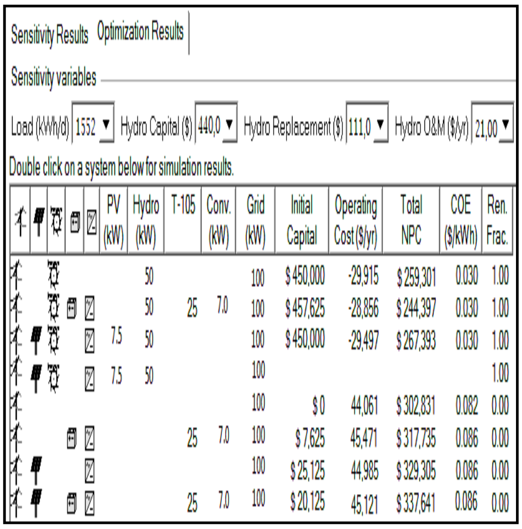


Fig.3. Power and reactive power profile of (aPhotovoltaic system using MATLAB simulation

Fig. 4 shows optimization results of nano grid using considering 50 KW MHP utilising the

HOMER. It has been observed that nano-grid model with 150 KW MHP reduces CO_2 emission, and share largest load as it approached the peak load capacity.



Sensitivity Results Optimization Results

Sensitivity variables

Load (kWh/d) 1552 Hydro Capital ($) 440,0 Hydro Replacement ($) 111,0 Hydro O&M ($/yr) 21,00

Double click on a system below for simulation results.

PV (kW)	Hydro (kW)	T-105	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
	50			100	$ 450,000	-29,915	$ 259,301	0.030	1.00
	50	25	7.0	100	$ 457,625	-28,856	$ 244,397	0.030	1.00
7.5	50			100	$ 450,000	-29,497	$ 267,393	0.030	1.00
7.5	50			100					1.00
				100	$ 0	44,061	$ 302,831	0.082	0.00
		25	7.0	100	$ 7,625	45,471	$ 317,735	0.086	0.00
				100	$ 25,125	44,985	$ 329,305	0.086	0.00
		25	7.0	100	$ 20,125	45,121	$ 337,641	0.086	0.00

Fig.4 Optimization results of nano grid using considering 50 KW MHP

The optimal configuration for each choice was solved as eight items as a result of the optimization. Additionally, a minimum capacity of 5kW for PV systems was usually advised. In order to create the suggested nano-grid model, the configuration incorporating all nearby renewable energy sources (PV and MHP) was selected for each phase (Table 1). The suggested nano-system grid's performance needed to be improved, which necessitated the battery system. Phase I was more expensive in terms of initial capital expenses. As opposed to phase III, which has a higher energy cost compared to the power grid's tariff, phases I and II have lower energy prices. The phase I and phase II have negative operating costs as a result of the sale of electrical power generated by surplus power to grid-system. The system's operational expenses will be covered by the earnings from the sale of excess power. Furthermore, the cost of MHP for phases I and II was still less expensive than the grid electricity rate. The measure of carbon emissions produced by nanogrid system as well as number of carbon emissions reductions on the environment were connected with the percentage of renewable sources. The CO_2 emissions created by phases I and II for the nano-grid are pessimistic. It refers to a nano-grid that lowers grid system CO_2 emissions as a result of supplying the grid with electrical energy from renewable energy sources. The measure of renewable energy produced overall as well as the carbon emission coefficient of the economy together define the overall amount of CO_2 reduction on the environment. In phase I, renewable energy sources (MHP and PV) met the whole demand for electricity. The nano-grid system sells roughly 56% of the energy it generates to the grid in sellback price that exceeds the MHP cost.

Table 1

Phases of nano grid svstem

Phases	Photovoltaic power (KW)	MHP (KW)	Grid power (KW)	Photovoltaic (Reduction in CO_2 emission)	MHP (Reduction in CO_2 emission)	Grid (Reduction in CO_2 emission)	Carbon emission
Phase I	5	150	200	6,956	1,,110,744	10	765,321
Phase II	5	150	200	6,956	798,385	10,938	498,986
Phase	5	150	200	6,956	399,230	150,529	301.332

The nano-energy grid's cost will drastically fall as a result of this circumstance. Additionally, phtovoltaic and MHP power generation cost is greater than the rate of grid. Energy prices for this choice will be higher due to this requirement than the tariff of grid electricity.

4. Conclusion

In order to maximise the use of local renewable energy for on-grid areas, this article has examined the potential for developing a straightforward nano-grid model. Three design alternatives for the MHP model—150 kW, 100 kW, and 50kW—are taken into consideration depends upyon the load profile and the accessibility of water supply. The nano-grid model with MHP design generated economic energy at minimum cost, biggest decrease in carbon emission, and maximum share of renewable energy as it approached the peak load capacity (150 kW). Contrarily, this requirement demanded the high preliminary capital expense. While a model of nano-grid using MHP design that approaches load capacity (50 kW) needs cheap initial capital expenditures, it often has high energy costs and limited CO_2 emission reduction. However, the advancement of photovoltaic units on the planned nano-grid is extremely promising in the expectations given the increase in electriccal load and the descending drift in the levelized price of photovoltaic. MATLAB-SIMULIK simulation was used to monitor the nano-grid performance. According to the simulation's findings, renewable energy power plants produced the most efficient amount of electricity. In order to maximise the use of local renewable energy, this research requires to be sustained with the creation of a nano-grid control plan.

References

[1] [1]Singh M., Khadkikar V., Chandra A., Varma R.K., 2011. Grid interconnection of renewable energy sources at the distribution level with power-quality improvement features. IEEE Trans. Power Delivery 26 (1), 307–315.

[2] Torrey, D.A., Al-Zamel, A.M.A.M., 1995. Single-phase active power filters for multiple nonlinear loads. IEEE Trans. Power Electron. 10 (3), 263–272.

[3] Venkatramanan, D., John, V., 2013. Integrated higher-order pulse-width modulation filter-transformer structure for single-phase static compensator. IET Power Electron. 6 (1), 67–77.

[4] Wu, T.-F., Sun, K.-H., Kuo, C.-L., Chang, C.-H., 2010. Predictive current controlled 5-KW single-phase bidirectional inverter with wide inductance variation for DC microgrid applications. IEEE Trans. Power Electron. 25 (12), 3076–3084.

[5] Xinxin, Z., Lan, X., Zilong, W., Yun, L., Chuyang, W., 2015. Control strategy without phase-locked loop based on coordinate transformation for three phase AC/DC converter. IET Power Electron. 8 (9), 1701–1709.

[6] Yang, S., Lei, Q., Peng, F.Z., Qian, Z., 2011. A robust control scheme for grid-connected voltage-source inverters. IEEE Trans. Ind. Electron. 58 (1), 202–212. Souvik, D.,Sanjibkumar, S., Sanjibkumar, P., 2011.

[7] Single-phase inverter control techniques for interfacing renewable energy sources with microgrid-Part I: Parallel-connected inverter topology with active and reactive power flow along with grid current shaping. IEEE Trans. Power Electron. 26 (3), 717–731.

[8] V.B. Foroutan, M.H. Moradi, M. Abedini, 2016. Optimal operation of autonomous microgrid including wind turbines, Renew. Energy 99,315–324.

[9] K. Sureshkumar, V. Ponnusamy, 2020. Hybrid renewable energy systems for power flow management in smart grid using an efficient hybrid technique, Trans. Inst. Meas. Control 42 (11) 2068–2087.

[10] V. Gajula and R. Rajathy, 2020. An agile optimization algorithm for vitality management along with fusion of sustainable renewable resources in microgrid, Energy Sources, Part A: Recov Util. Environ. Eff. 42 (13)1580–1598.

[11] J. Chen, Z. Zhou, V. Karunakaran, S. Zhao, 2020. An efficient technique-based distributed energy management for hybrid MG system: A hybrid QOCSOS-RF technique, Wind Energy 23 (3)575–592.

[12] R. Lingamuthu and R. Mariappan, 2019. Power flow control of grid connected hybrid renewable energy system using hybrid controller with pumped storage, Int. J. Hydrogen Energy 44 (7) 3790–3802.

[13] M. Ansarian, S.M. Sadeghzadeh, M. Fotuhi-Firuzabad, 2015.Optimum generation dispatching of distributed resources in smart grids, Int. Trans. Electr. Energy Syst. 25 (7),1297–1318.

[14] M. Durairasan and D. Balasubramanian, 2020.An efficient control strategy for optimal power flow management from a renewable energy source to a generalized three-phase microgrid system: A hybrid squirrel search algorithm with whale optimization algorithm approach, Trans. Inst. Meas. Control 42 (11),1960–1976.

[15] K. Venkatesan and U. Govindarajan, 2019.Optimal power flow control of hybrid renewable energy system with energy storage: A WOANN strategy, J. Renew. Sustain. Energy 11 (1),015501.

[16] X. Wu, W. Cao, D. Wang, M. Ding, 2019.A multi-objective optimization dispatch method for microgrid energy management considering the power loss of converters, Energies 12 (11),2160.

[17] J. Garcia-Guarin, D. Rodriguez, D. Alvarez, S. Rivera, C. Cortes, A. Guzman, A. Bretas, J.R. Aguero, N. Bretas, 2019.Smart microgrids operation considering a variable neighborhood search: The differential evolutionary particle swarm optimization algorithm, Energies 12 (16) 3149.

[18] H. Qiu, W. Gu, P. Li, X. Zhang, H. Long, Z. Wu, 2019.CRSO approach for microgrid power dispatching, IET Gener. Transm. Distribution 13 (11),2208–2215.

[19] K.Meenakshi Aswathy Elsa Wilson Anjaly Abraham, Jaimol Thomas, Rani Chacko. 2022.Economic feasibility investigation of integrated Nano-Grid with solar PV for community deployment based on load pattern survey. 58, Part 1, 293-298.

[20] A techno-economic investigation of grid integrated hybrid renewableenergysystems.PrashantMalik,MamtaAwasthi,SunandaSinha,. 2022.Sustainable Energy Technologies and Assessments.Volume 51,101976.

[21] P.M. Kassim, K.M. Al-Obaidi, M. A.C. Munaaim and A. M.S.,Feasibility Study on Solar Power Plant Utility Grid under Malaysia Feed-in Tariff. Ameri J. Enginee Appl Sci 8(2)2015,210-222