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Modelling and Simulation of Nano Grid System using MATLAB SIMULINK

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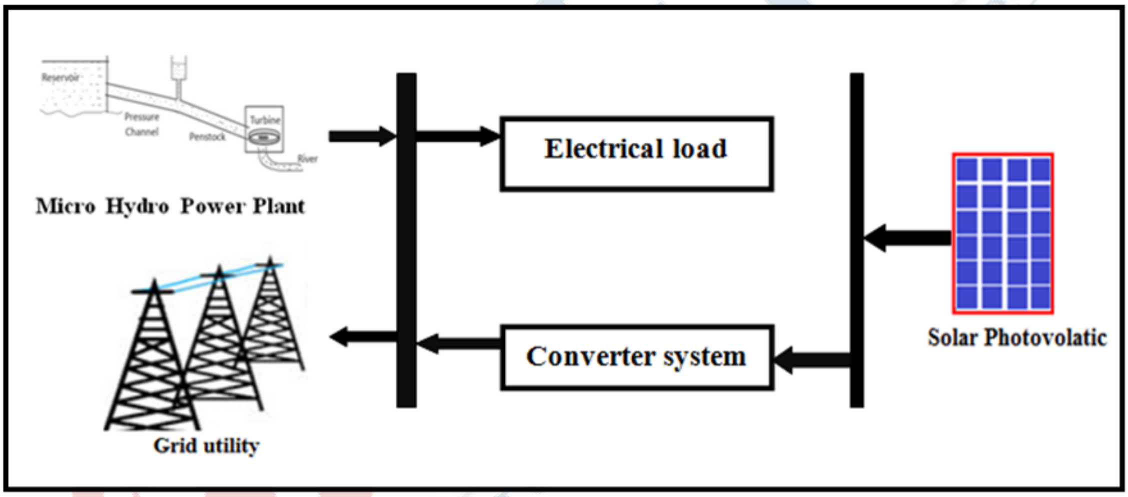
Abstract— *In order to maximise the usage of renewable energy for on-grid systems, this article investigates the feasibility of creating an efficient nano-grid model concept. Photovoltaic (PV) and micro hydro power (MHP) systems connected to the grid serve as renewable energy sources for power plants in the proposed nano-grid concept. The MATLAB and HOMER applications are used to analyse the modelling findings. The HOMER mimics a nano-grid model with three distinct possibilities for MHP capacity: 50 kW, 100 kW, and 150 kW, depending on loads and water supply availability. The nano-grid model with MHP design showed the largest percentage of renewable energy, lower energy costs, and responsible CO2 emission depletion as the peak load capacity (150 kW) drew near. The model nano-grid with the largest MHP capacity (150 kW) produced the least amount of energy at the lowest energy prices, the largest reduction in carbon emissions, and the best use of the electric output from renewable energy power plants, according to the simulation results.*

Index Terms— *Nano grid, Photovoltaic, micro hydro power, MATLAB SIMULINK. HOMER, Carbon emission.*

***Graphical* Abstract:**



I. INTRODUCTION

The primary forms of energy used worldwide are fossil fuels like coal, natural gas, and oil. Due to their widespread use in transportation, these sources (with the exception of coal) will eventually run out. Additionally, burning fossil fuels releases tonnes of carbon dioxide into the atmosphere, which pollutes the ecosystem and alters the climate. The advancement of renewable energy sources might pave the way for clean, environmentally friendly technology. Coal, oil, gas, and are considered to be the prime energy sources for conventional power plants. The increase in carbon emissions brought on by the application of fossil fuel powered power plants would be impacted by this situation. To reduce carbon emissions produced from fossil fuels, usage of renewable energy sources are need to be increased. The remote renewable energy power plants demands to boost electricity supply due to uneconomical and reliable system. The application of renewable energy fluctuates according on the weather conditions. In contrast, the rate of generated energy for plants that rely only on sources of renewable energy is superior to the cost of electricity sold on the local grid. Such type of condition arrived due to government subsidising the retail price of electricity in the grid system. Additionally, rural areas have lesser load factors for electrical loads [2], therefore employing a stand-alone power system. An effective strategy to maintain the dependability of the energy supply from renewable energy sources is to use hybrid power systems, that integrate multiple power plants with different energy sources [3-5]. Nano grids are described as hybrid power plants that combine sources of renewable energy including photovoltaic (PV), wind, micro-hydro (MHP), biomass, in addition with traditional diesel engines or battery storage. Figure 1 shows a block diagram of nano hybrid grid system using renewable sources. Such type of power plants can run independently or in conjunction with the grid. In

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off-grid locations, diesel generator works with the micro-grid combined with number of power plants employs various sources of renewable energy. Numerous studies on nano-grid and hybrid power generation systems have been conducted globally using experimental research, control strategies, computer modelling, and feasibility studies. The system layout, control strategy, and various nano-grid implementations across the globe were examined in the previous research [3]. The studies [4-9] looked at the utility of nano-grids that combined micro hydro turbines with photovoltaic energy sources. Previous works have also covered the feasibility and optimization of HOMER based nano-grid/hybrid model, appropriate for remote rustic areas [9-12]. The building industry heavily relies on renewable energy sources and energy-saving measures to reduce conventional energy usage. A time zone-based survey of local residential and commercial buildings is conducted to analyze energy consumption and load pattern studies. Solar PV and battery systems are recalculated to determine savings in investment if buildings share their production and storage [13]. The popularity of solar PV-based DC Nano-grids in residential and commercial buildings is driven by energy efficiency and environmental friendliness. However, traditional solar photovoltaic systems (SPV) are unreliable due to external factors and module mismatch losses. A bidirectional modular PV battery system (BMPBS) is proposed to address these issues and enhance the reliability of SPV systems. The system uses non-isolated buck and boost converters and a battery storage system for efficient power extraction [14]. A unique adaptive control technique based on the ANOVA Kernel Kalman Filter (AKKF) is used in a grid-integrated solar energy conversion system (SECS) to provide precise harmonic support. The AKKF is hybridized to increase estimation accuracy, and the system functions as a Distribution Static Compensator (DSTATCOM) when solar power is unavailable. Experiments validate the control approach's performance under adverse grid conditions, solar insolation variations, and load imbalance conditions [15]. A steepest descent Laplacian regression (SDLR) based adaptive control technique for optimal operation of a three-phase single-stage grid-tied solar photovoltaic system is proposed. The technique aims to mitigate harmonics and improve grid currents, with an additional feature of DSTATCOM for reactive power support during night or zero power generation [16]. The perturb & observe (P&O) algorithm is widely used for maximum power point tracking in solar photovoltaic systems. However, it faces issues with varying irradiations and oscillations around the maximum power point. A circle center-line concept-based P&O (CCCP&O) algorithm is introduced, combining the concept of a circle and its center with the P&O algorithm, reducing iterations and settling time. The algorithm's performance is demonstrated in simulation and experimental testing [17]. A novel DFOGI-based control algorithm for grid-integrated solar photovoltaic systems is introduced, using the HPO algorithm for GMPPT tracking. The algorithm provides rapid and accurate global maximum power peak searching, ensuring steady-state and dynamic performance even in rapid solar irradiance changes. The goal is to transfer solar power to the grid at unity power factor, maintaining power quality during abnormal conditions. Experimental results meet the objectives and meet IEEE-519 standard parameters [18]. A model predictive-based control for a solar PV system integrated into the grid, aiming to optimize power transfer and management is studied. The controller uses a modified-dual second-order generalized-integrator to estimate power requirements based on system parameters. The controller's performance is validated through simulation and hardware implementation, adhering to the IEEE-519 standard, demonstrating remarkable performance [19]. This study reveals a simplified nano-grid model that enhances the utilisation of solar photovoltaic renewable energy with micro hydro power plant. The application of non conventional energy sources causes environmental problem therefore to reduce the global warming issues the use of renewable energy sources are adopted for power generation and connected to grid supply system to enhance clean and green energy technologies for nano grid systems.

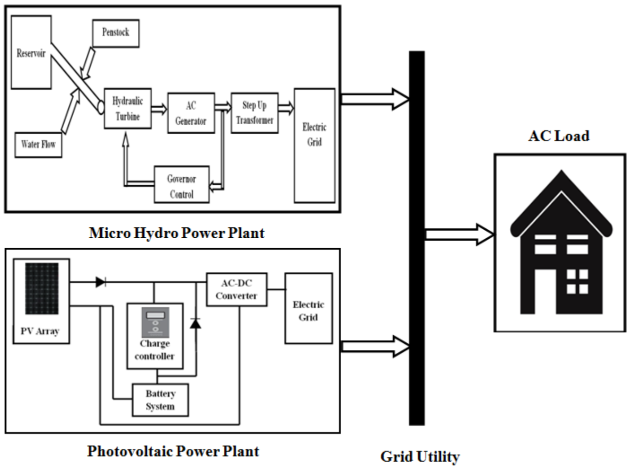

Fig. 1. Block diagram of Nano-Hybrid Grid system using Renewable sources

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

- The opportunity of developing an elementary design of nano-grid model that enhances the application of specific renewable energy for on-grid locations is explored.
- The HOMER software is employed to optimise the scale and different types of energy conversion technology.
- The costing of energy and the reduction in carbon emissions are significant variables in the meantime.
- In addition, overall performance the nano-grid model is examined using Simulink-MATLAB software.

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II. METHODOLOGY

The performance of the micro-grid is observed using SIMULINK-MATLAB model. The simulink model diagram of proposed system is revealed in Figure 2. The model is framed by using MHP, PV power generation, Grid and load block.

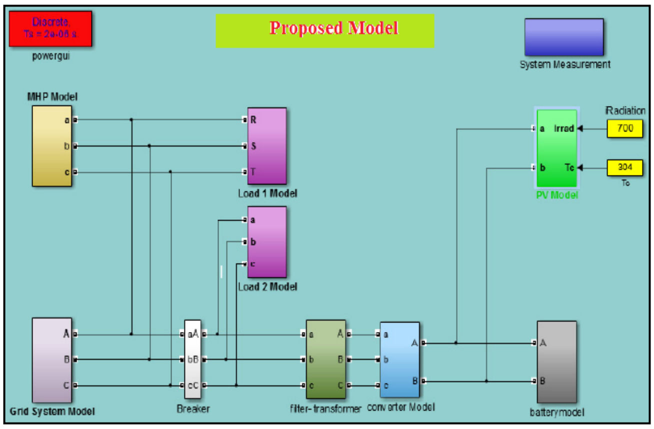

Fig. 2. Simulink model of proposed work

The river stream flow was suggested as a source of power for a micro hydro power plant (MHP). The flow of stream was lowest during the month of April (2141 L/s. 1251 L/s, or 1.28 m^3/s) 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.

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

Where, 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, η is MHP efficiency. 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 [13-17]. 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:

$$P_{PV}=K_{PV}G_{PV}I_S/I_R \qquad (2)$$

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_{PV}, and I_R is the standard amount radiation in $1kW/m^2$. 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 are included in the capital cost (USD 2000) per kW [9]. The overall age of a solar module is estimated to be 25 years based on the specifications [18-20]. To enhance the performance of nano grid, battery system is necessary to respond to transient disturbances and fluctuations in solar irradiation.

The number of batteries with rated power is used to match the power and voltage ranges of the photovoltaic generator. Also, converter may be used for electrical power flow in two directions (bidirectional) [21-24]. Therefore, depending on the flow of power, the power converter can function as both a rectifier and an inverter. A 10.5kW converter is used for steam power plants that serve as electric source for the grid emit gases during normal operation. The carbon dioxide (CO_2) emissions have dangerous impact on global warming [25]. 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 [26-27]. It is necessary to model the performance parameters of the nano-grid using Simulink-MATLAB for validation process. Figure 3 displays Homer software based model of nano grid system. A Photovoltaic power, MHP, the grid and the load are used to build such model.

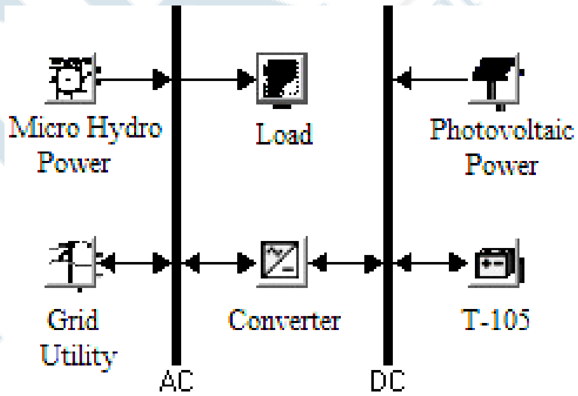

Fig. 3. Homer software based model of nano grid system

The converter, transformer, filter, and PV module build the PV power generation block. Such 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 as MHP block. A block grid is used to simulate the amount of power distributed from the substation to the nano-grid.

III. RESULT AND DISCUSSION

The results of the simulation grid performance using Simulink MATLAB are revealed in Figure 4(a) shows 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 {Figure 4(b)}. The active power is increased upto the value of 4123W at time t=0.32, while no change is considered in reactive power during this period. And, at t=0.4s and the active reduces from 4123 to 3984 W. On the other hand, the grid will boost power for the micro-grid to prepare for the rising load {Figure 4(c)}, photovoltaic and micro hydro power keep power at standard level. In this situation, the grid, MHP and photovoltaic

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systems will contribute to powering the load. At t=0.7s, it is observed that real and reactive power increased up-to 3852W and 4798VAr respectively (MHP). Since the supply of micro hydro power and photovoltaic can satisfy various requirements of load side{Figure 4 (d)} , 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.

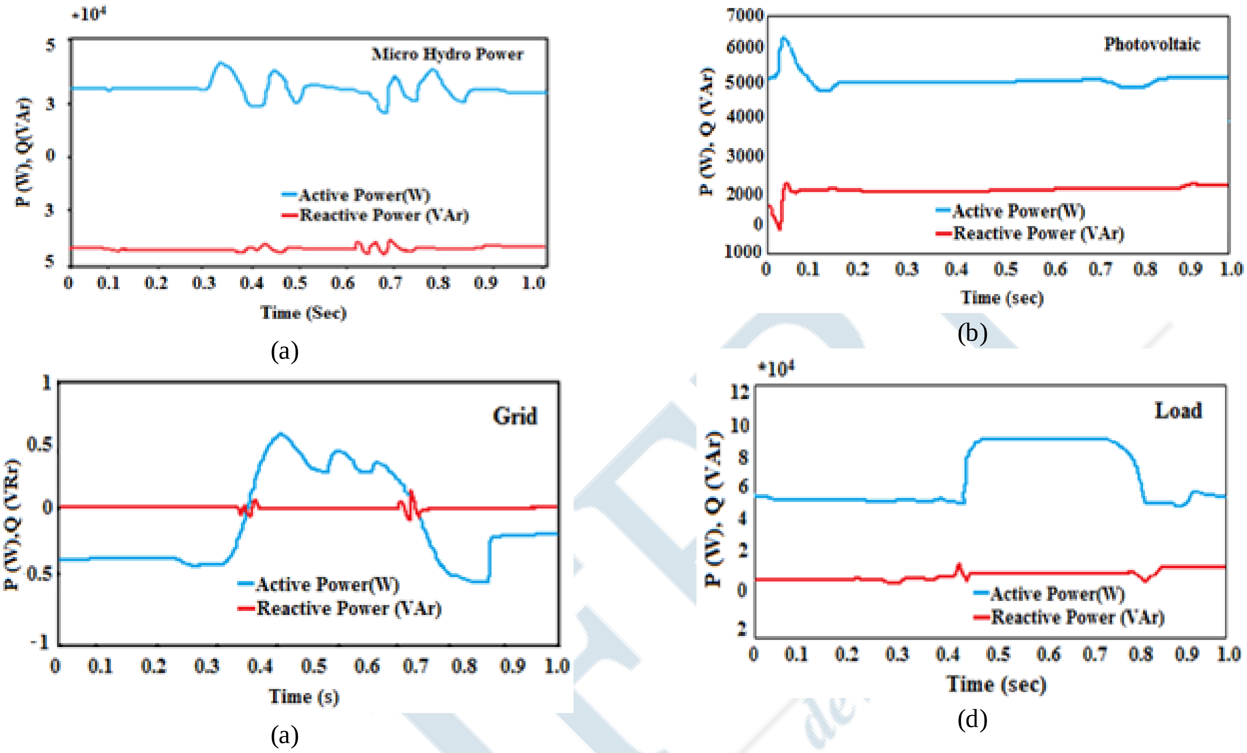


Fig. 4. Power and reactive power profile of (a) micro hydro power, (b) Photovoltaic system (c) Grid (d) Load using MATLAB simulation

Fig. 5 (a) shows optimization results of nano grid using considering 50 KW MHP utilising the HOMER whereas Fig.5 (b & c) reveals optimization results of nano grid using considering 100 and 150KW MHP respectively. 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. Additionally, a minimum capacity of 5kW for PV systems was usually recommended.

Sensitivity Results | Optimization Results

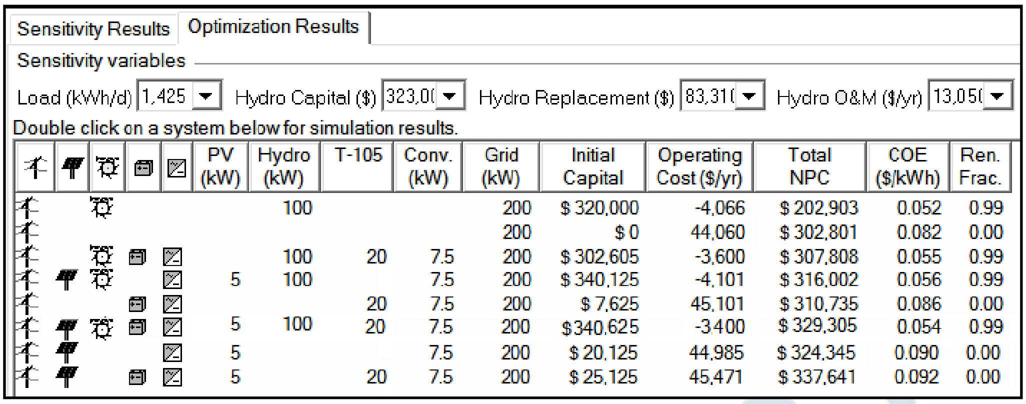
Sensitivity variables

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. 5 (a) Optimization results of nano grid using considering 50 KW MHP



Sensitivity Results | Optimization Results

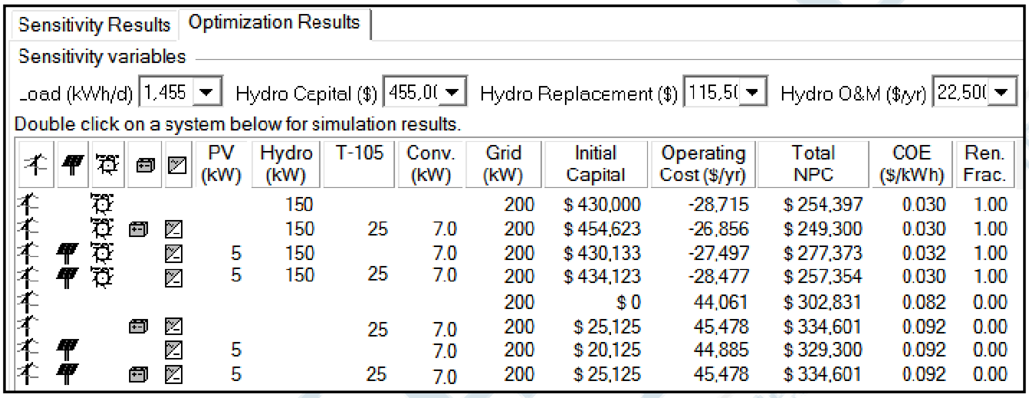
Sensitivity variables

Load (kWh/d) 1,425 | Hydro Capital ($) 323,0(| Hydro Replacement ($) 83,31(| Hydro O&M ($/yr) 13,05(

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.
	100			200	$ 320,000	-4,066	$ 202,903	0.052	0.99
				200	$ 0	44,060	$ 302,801	0.082	0.00
	100	20	7.5	200	$ 302,605	-3,600	$ 307,808	0.055	0.99
5	100		7.5	200	$ 340,125	-4,101	$ 316,002	0.056	0.99
		20	7.5	200	$ 7,625	45,101	$ 310,735	0.086	0.00
5	100	20	7.5	200	$340,625	-3400	$ 329,305	0.054	0.99
5			7.5	200	$ 20,125	44,985	$ 324,345	0.090	0.00
5		20	7.5	200	$ 25,125	45,471	$ 337,641	0.092	0.00

Fig. 5 (b) Optimization results of nano grid using considering 100 KW MHP



Sensitivity Results | Optimization Results

Sensitivity variables

Load (kWh/d) 1,455 | Hydro Capital ($) 455,0(| Hydro Replacement ($) 115,5(| Hydro O&M ($/yr) 22,50(

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.
	150			200	$ 430,000	-28,715	$ 254,397	0.030	1.00
	150	25	7.0	200	$ 454,623	-26,856	$ 249,300	0.030	1.00
5	150		7.0	200	$ 430,133	-27,497	$ 277,373	0.032	1.00
5	150	25	7.0	200	$ 434,123	-28,477	$ 257,354	0.030	1.00
				200	$ 0	44,061	$ 302,831	0.082	0.00
		25	7.0	200	$ 25,125	45,478	$ 334,601	0.092	0.00
5			7.0	200	$ 20,125	44,885	$ 329,300	0.092	0.00
5		25	7.0	200	$ 25,125	45,478	$ 334,601	0.092	0.00

Fig. 5 (c) Optimization results of nano grid using considering 150 KW MHP.

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, that necessitated the battery system. Phase I revealed more expensive in terms of initial capital expenses. As opposed to phase III, that 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 negative, 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, generate to the grid in sellback the price that exceeds the MHP cost.

Table I: Phases of nano grid system

Phases	Photovoltaic power (KW)	MHP (KW)	Grid power (KW)	Photovoltaic (Reduction in CO2 emission) (Kg/Year)	MHP (Reduction in CO2 emission) (Kg/Year)	Grid (Reduction in CO2 emission) (Kg/Year)	Carbon emission (Kg/Year)
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 III	5	150	200	6,956	399,230	150,529	301.332

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

IV. CONCLUSION

This article concluded that in order to maximise the use of local renewable energy for on-grid areas, the potential for developing a simple nano-grid model is used. Three different design alternatives for the MHP model such as 150 kW, 100 kW, and 50kW are taken into consideration depends upon the load profile and the accessibility of water supply. The nano-grid model with MHP design generated economic energy at minimum cost, accountable drop in carbon emission, and maximum share of renewable energy as it approached the peak load capacity (150 kW). Adversely, the requirement demanded high preliminary capital expense. While a model of nano-grid using MHP design approaches load capacity (50 kW) requires cheap initial capital expenditures, in addition, high energy costs and limited CO_2 emission reduction. However, considering the rise in electrical load and the decline in solar unit cost, the development of photovoltaic units on the proposed nano-grid is quite promising. MATLAB-SIMULIK simulation was used to monitor the nano-grid performance. According to the simulation's findings, Hydro power power plants produced the most efficient amount of electricity. To optimise the utilisation of locally available renewable energy, the study findings must be maintained through the development of a nano-grid control strategy.

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