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DESIGN AND OPTIMIZATION OF RENEWABLE ENERGY (RE)-BASED MICROGRID USING GENETIC ALGORITHM

by

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Department of Electrical and Electronic Engineering
INTERNATIONAL ISLAMIC UNIVERSITY CHITTAGONG

DECEMBER 2020

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A thesis/project
submitted as partial fulfilment of the requirement for the degree of

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DECEMBER 2020

CERTIFICATE OF APPROVAL

The thesis designated "Design and Optimization of Renewable Energy (RE)-based Microgrid Using Genetic Algorithm" presented by **Md. Mofij Uddin**, having Matric ID. **ET 161063** and **Md. Faisal Hossen Bablo**, having Matric ID. **ET 161058** of session **Spring-2020**, to the Department of Electrical and Electronic Engineering (EEE), International Islamic University Chittagong (IIUC), has been acknowledged as acceptable in halfway satisfaction of the necessities for the degree of Bachelor of Science in Engineering and recognized for the assessment held on **31st December 2020**.

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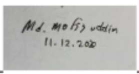
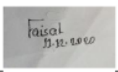
DECLARATION

It is thus pronounced that this work has been finished by us and no part of the work contained in this thesis/project has been submitted somewhere else for the honour of any degree or certificate.

___________

Md. Mofij Uddin

_________________

Md. Faisal Hossen Bablo

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For the sake of Allah, the Most Charitable and the Most Kind.

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Authors

ABSTRACT

Renewable energy systems are proving to be efficient and environmentally sustainable ways of producing electricity. Day by day, using RE-based microgrid systems have been causing more to notice give power to disengaged or energy-lacking locales. To set up a microgrid system, optimization is required for cost and reliability analysis. Genetic algorithm is one of the most trending optimization techniques. In most off-grid areas, as an alternative to electricity provided by diesel generators, they are not environment friendly and very costly. This thesis presents a RE-based microgrid system and reduce diesel generator uses and capacity to satisfy the electrical load demand of a rural area in Saint Martin, Bangladesh. For optimizations, a recently proposed genetic algorithm is applied in this thesis. We use local weather data for calculating. The wind generation, photovoltaic generation, and load are modeled by historical hourly wind speed, solar irradiance, and temperature data. System optimization would be based on the sizing of the modules and the operating strategy. Programming of genetic algorithms is used to test all conditions to minimize the total net present expense for optimal configuration. To verify the proposed technique's strength, the results are compared with the results obtained from the particle swarm optimization (PSO) algorithm. The GA optimization technique provides efficient results. It is noticeable from the findings that the proposed system can maintain a steady power flow with the same optimum configuration also reduce the emission of CO_2. The annualized system cost (ASC) from the proposed system's GA algorithm is a total of \$34576.7(USD). It's seen that the PSO-based system emission of CO_2 6.76 ton and GA-based system emission of CO_2 4.11 ton. A comparison reveals that our proposed system reduces the cost 72.95 times and reduces the emission of CO_2 2348.14 times by only using DG-based system.

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LIST OF ABBREVIATIONS

GA	Genetic Algorithm
PSO	Particle Swarm Optimization
LP	Linear programming
DG	Diesel Generator
VSI	Voltage Source Inverters
HCC	Hysteresis Current Control
RER	Renewable energy resources
DER	Distributed Energy Resources

CHAPTER 1
INTRODUCTION

1.1 Introduction

In Bangladesh, the national grid line is not currently reaching a large number of remote regions so that the microgrid-based renewable energy system is the only way to provide electricity to this remote region. Hybrid energy systems, especially photovoltaic (PV) solar energy, which rely on renewable energy are now widely used. Their efficiency was demonstrated if they are used in power supply to different places, especially with small isolated loads. Its usage will reduce the effects of greenhouse gasses and emissions of CO_2, NO, NO_2, and SO_2, where other emissions can also be minimized. Its key benefits are low maintenance costs and low pollutant emissions [1-5]. Generators with diesel or petrol normally supply power to the off-grid site. It is frequently only accessible for certain hours of the night. Renewable energy applications at the location are solar energy panels, wind turbines and small hydro turbines, via photovoltaic energy (PV). The system is initially a single source system. But a single source of renewable energy is generally over dimensioned to satisfy demand [6]. The energy efficiency of PV output is however poor while the cost of electricity per kWh is high. This resulted in a large rise in wind power production. Many studies focus on the performance and ideal size of wind-based systems [7-9]. Hybrid energy systems focused on stand-alone solar wind have been analyzed for cost effectiveness in different research projects [10-11]. An independent solar wind power system's most significant inconvenience is its power supply reliance because wind and solar resources are intermittent. In the case of an individual hybrid system, diesel generators or power storage devices such as batteries or ultra-capacitors can usually provide back-up. There are enough solar and wind resources available in rural areas. Electric power needs in these areas can also be met by smart use of these resources. Moreover the energy produced must be stored in a large battery bank for the hybrid renewable energy system [12]. Different factors such as system expense, renewable energy size and capability play a significant role in such hybrid systems. Due to the intermittent nature of renewable energy sources, an optimum flow of power between the different components of the combined system is required. The hybrid system's significant challenges are two main parameters, such as energy pricing and device reliability. The best choice of components should be an integrated system, thus ensuring that the system is reliable [13].

1.2 Background

A model of or abstraction from biological growth based on Charles Darwin's theory of natural selection is developed as the genetic algorithm (GA), which John Holland and his collaborator developed in the 1960s and 1970s. The first time Holland was used for adaptive and artificial systems was crossover, recombination, mutation and choices [14]. In recent years, a new trend has been observed, with researchers commonly applying these evolutionary algorithms to the optimal dimensioning of the hybrid energy system. Very little work is found to the best of the writers' awareness, where the optimization of hybrid PV-wind-DG and the energy storage system has been explored. For rural areas of India, a PV-biomass-wind hybrid system has been suggested. With the assistance of the standard software tool hybrid optimization model for electric renewables, the authors performed economic analysis and part selection (HOMER) [15]. [16] The purpose of this research is to explain the comparative efficacy of different energy resource planning optimization algorithms in rural microgrids. Three optimization techniques were evaluated for the least cost optimization using artificial data for the standardized Indian rural village system. The three optimization algorithms are GA, PSO and LP. The findings of the comparative analysis tend to suggest that while LP algorithm provide less efficient, PSO is the most effective one. Between these two algorithms, GA maintains a mean location. It is proposed that these three optimization algorithms should be used to pass additional energy resource behaviour before generalizing the comparative effectiveness of these optimization algorithms. To solve the optimum configuration, the microgrid consisting of the PV panels, wind turbine and CHP device, also the battery is studied, after that a Genetic Algorithm technique is controlled. In the light of the fact that the day is recognized as the optimum length, compare the dispatch systems before and after optimization, the cheaper electricity can be provided to consumers [17]. In order to meet the electrical demand of an island, an autonomous hybrid PV-wind-DG with a battery system is proposed in this report.

1.3 Problem Statement

We know that the off-grid area has no electricity without supply additional sources like DG, Renewable energy, etc. But there is a problem that RE needs much space and needs to be a targeted area where the weather is perfect. On the other hand, no conventional energy like DG source produces lots of CO_2 so that rural and coastal area maybe hamper for this. To eliminate this thing we use Optimum RE and DG source using an algorithm so that we can reduce the CO_2 and mitigate load demand and reduced costs on this area. Different research practices were carried out using traditional methods, such as graphical construction method, iterative method, trade off method and linear programming [18-20]. The issue with traditional approaches is that in local minima, they frequently lock so that several meta-heuristic evolutionary algorithms used. We use GA and PSO and it's have been introduced in various hybrid systems to resolve these vulnerabilities.

1.4 Motivation

Many algorithms worked on to optimized a microgrid with different techniques. The previous literature shows that for performance analysis, researchers have used either software tools or traditional optimization approaches. Software tools, however, have some significant drawbacks, such as black box coding, minimization of single functions, and need more processing time compared to current optimization techniques. In hybrid systems, however several works have been found where various researchers have proposed various traditional and evolutionary algorithms to achieve the optimum size of the components used in hybrid systems. Where GA is the trending optimization techniques for field of all industry. It also has strong convergence accuracy and the ability, like other evolutionary algorithms, to provide optimal performance [21]. Many past optimization technique used by HOMER but GA is the new thing in my research area so that's the main motivation for this thesis work.

1.5 Objectives

1) Selection of site according to the balanced system.

2) To build up a mathematical model of an autonomous system also the least levelized cost of energy (LCOE).

3) Minimizing CO_2 emissions and comparing PSO-based optimization results and GA-based optimization results.

4) To minimize the emission of CO_2 and cost between proposed model vs. using only conventional DG-based system.

1.6 Thesis Outline

The thesis consists of 6 chapters and is structured as follows:

Chapter 1 Concentrates on the background of the hybrid renewable energy optimization, significant drawbacks of the different optimization techniques. The objectives are defined out for the thesis work carried out. Also, motivation has been discussed briefly.

Chapter 2 Provides insight into microgrid and GA related Literature review. Classification of microgrid and GA type, application and advantages different optimization technique in literature are also discussed.

Chapter 3 Model of a microgrid discussed with a diagram for better understanding. A design of algorithm, mathematical expression etc. are also discussed.

Chapter 4 Complete design of a GA is discussed and showed with flowchart briefly. For design the GA, design mathematical expression and flowchart are examined.

Chapter 5 Results of the optimization with CO_2 emission are discussed. Finally, the results of the proposed model are shown through Matlab GA optimization graph and table of the expenses and LOCE etc.

Chapter 6 The study carried out in this thesis ends with the potential scope of the work of the proposed optimization techniques.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Microgrid describes a short-range, near-consumer power system. A microgrid system is normally characterized as a low or medium voltage distribution arrangement that includes multiple distributed generations (DGs), storage devices, and controllable loads. A microgrid plays a vital part in the usage of environmentally friendly services, such as PV models and wind turbines [22]. The microgrids are equipped for running both the focal utility network (lattice associated structure) or can work without the mediation of a utility framework (protected or segregated mode) without forfeiting the proficiency of the force. DGs dependent on environmentally friendly power sources, for example, sun based and wind can be handily consolidated into a microgrid to ensure a massive rise in interest in the availability of electricity. This are the key advantages of building micrograids in a distribution network. According to the most advanced near Indian summary, the transmission of grid problems to the delivery system alone is 20-40% [23]. A microgrid can ready to direct both in lattice associated or autonomous (islanded) structures. Islanding structure happens once the microgrid is isolated from the utility matrix when a primary change in the central utility lattice [24-25]. The microgrid can safeguard the ensured yield by controlling the customary voltage and recurrence guideline of the framework associated appropriated dynamo [26].

2.2 Microgrid Architecture

Fundamental microgrid engineering appears in **Fig. 2.1**. The plan involves a social event of extended feeders, which may be a certain bit of a scattering system or a structure's electrical structure. There is a single reason for the relationship between the microgrid and the service called the purpose of basic coupling. A few feeders, (Feeders A-C) have delicate burdens, which admission neighborhood age. The non-basic burden feeders don't allow any neighborhood age. Feeders A-C can island from the lattice utilizing the static switch that can isolate lesser than one cycle. In this engineering, four micro sources at different hubs 8, 11, 16, and 22 control the activity by utilizing just neighborhood voltages and flows estimations of a microgrid. At whatever point there is a matter with the principle service flexibly, the inactive switch opens confining the delicate burdens from the force framework. When the microgrid is in matrix associated, all-out force from the neighbourhood age can be coordinated to the non-delicate burdens.

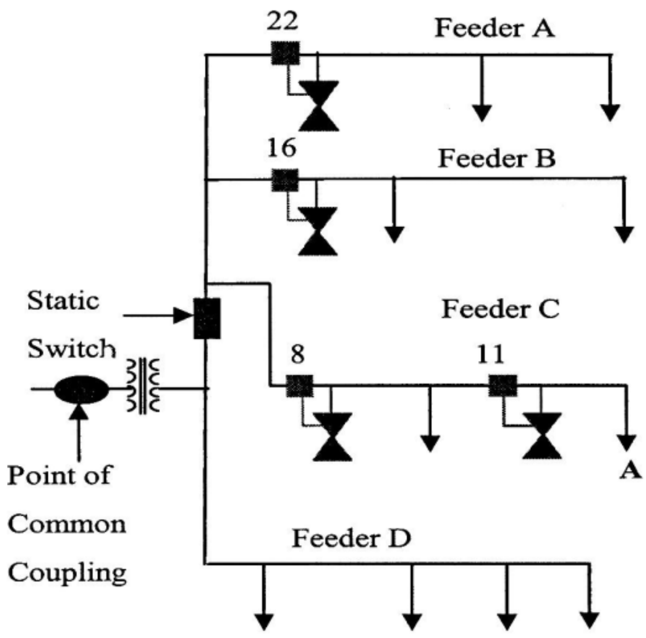


Fig. 2.1 Microgrid Architecture Diagram [27].

The execution of sustainable power into existing force frameworks is the main test. In addition to its heaps and a few small secluded era structures associated with it, the microgrid organization can be defined as a low voltage organization (e. g., a small urban city, a strip mall, or a mechanical park) [28]. Application territories of this organization including business markets, modern zones, complex shopping centers, grounds conditions, military offices, off-network activities, network/utility settings, and so on [29]. The requirement for DG is to expand the administration dependability and decrease the requirement for group of people yet to come development or lattice fortification [30]. On the off chance that there is an issue that exists in the primary utility lattice, at that point the DG must be incapacitated. Subsequently, it is desirable to work the microgrid in islanding mode till the issue in the primary utility framework is illuminated. On the off chance that the deficiency happens inside the microgrid in islanding mode, at that point it will get closure [31]. The sustainable power sources, for example, wind, photovoltaic, hydro, and energy components are regularly interconnected by methods for modulation of pulse diameter inverters of the voltage source which has nonlinear qualities of voltage versus current that produces high exchanging recurrence. Along these lines, a nonlinear regulator hysteresis current control (HCC) is utilized for a 3-stage framework associated VSI framework which repays current blunder with dynamic reaction. The nature of intensity is improved by this regulator [32].

2.3 Models of Operation

Two different models are available. Example: (i) Connected to the grid model, (ii) Autonomous microgrid model

2.3.1 Connected to the grid:

Just in **Fig. 2.2** connected to the grid model is shown. The utility grid is running and the static switch is closed in this model. The power grid provides all of the radial feeders.

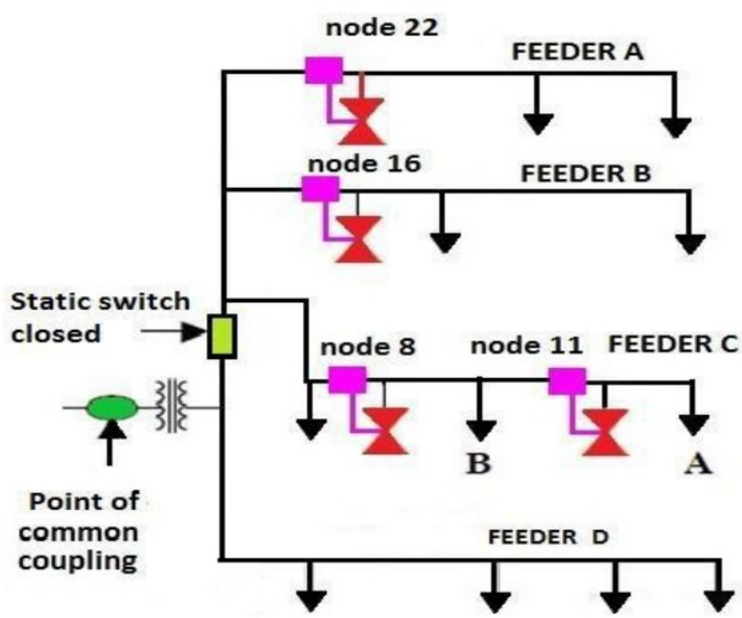


Fig. 2.2 Operation of connected to the grid model. [33]

2.3.2 Autonomous model:

It's in **Fig. 2.3** Autonomous model is shown. There is no electricity on the power grid and the inactive switch is available. Micro-sources are supplied to all feeders A, B, C and feeder D is gone.

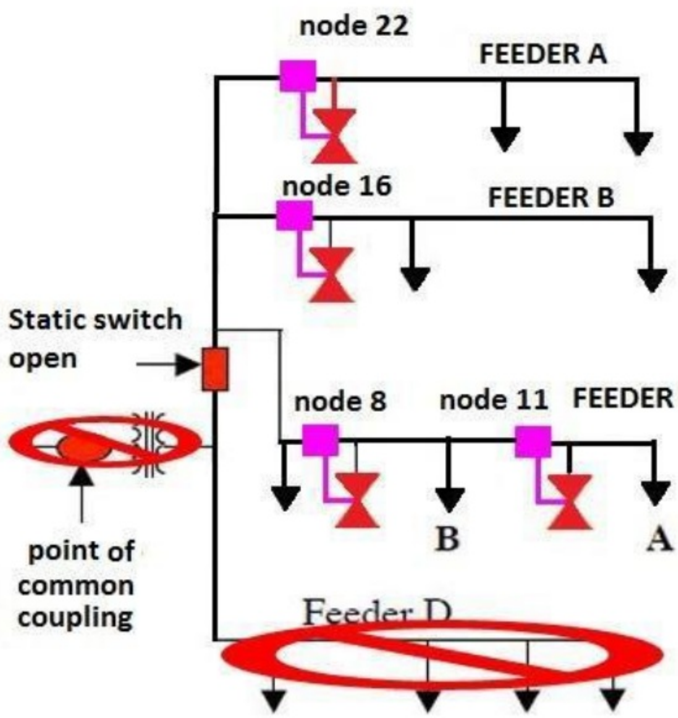


Fig. 2.3 Operation of autonomous model. [33]

2.4 Reasons to link the Microgrid to the main grid

2.4.1 Availability:

The large availability of power grids serves as an extra source to micro-grids. The usage of renewable energy resources (RER) is the charming options as providing loads by the utility grid itself [34].

2.4.2 Stability/operations:

The direct interaction between ac microgrids and a high power grid enables continuous operation when that power grid operates on the microgrid as a "hard" supply. Applying green sources of power, such the combination minimizes the necessity for an energy storage operation. A grid connection minimizes the expense in economic generation [35].

2.4.3 Economics:

Microgrids are typically designed with additional capability regarding the local load. This extra electricity can be returned to the grid to achieve a certain strategic advantage. Interconnection with the grid permits minimizing the operational costs of fuel using the microgrid at night or low peaks that reduce the cost of energy. The requirement for a decrease in CO_2 emissions and commercial probability throws huge difficulties in the extension of microgrid [36].

2.5 Advantages of Microgrid

Microgrid has huge effective advantages that have cited below:
Optimizes the latest generation and transmission capacity. It integrates more renewable energies and makes DERs to be more commonly infiltrated and energy storage solutions used. It decreases carbon footsteps and improves energy production, energy protection, managerial performance and overall competitiveness of services. It provides two-way connectivity with customers by helping them to control their use of electricity [37].
Market-based dispatch arrangement in a microgrid has extra advanced focus sectors including:

(i) Responsibilities on a regular basis and in real time.

(ii) Unit engagement and industrial dispatch with additional unique transmission safety limitations.

(iii) Investigations and equality to secure clearness and firmness.

(iv) Intercept of high-range arrangement that is topical and multi-regional in nature.

(v) Combination of power sources spread and sources of demand response.

(vi)Effective generation and storage method to store energy and decreasing carbon discharges.

(vii) Combining technological progress to manage reactive power movement using SVC [38].

2.6 Classification of Microgrid

An overall arrangement of microgrid has appeared in the **Fig. 2.4**

Usually, the microgrid consists of a static transmission switch (STS), circulating simple loads, non-critical loads, and several DER units with various intensity hardware interfaces [39]. Microgrids are grouped into three sorts dependent on the kind of flexibility and their areas. (i) Utility interface microgrids, (ii) Business and modern microgrids, and (iii) Distant microgrids [40].

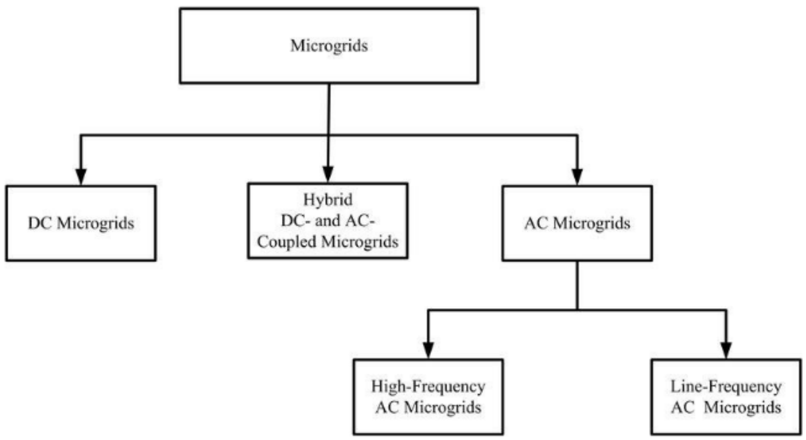


Fig. 2.4 Classification of microgrid. [41]

2.6.1 DC Microgrids:

DC microgrid is generally utilized in the use of media transmission frameworks [42], electric vehicles [43], and shipboard force frameworks [44].Escalated utilization of electronic burdens in business structures and in places of business This DC arrangement is introduced for business power framework with delicate electronic burdens [45].

2.6.2 AC Microgrids

HFAC Microgrids:

Utilized in the utilizations of airplane framework and military uses of 1-stage 400Hz [46].

HF AC conveyed power frameworks are restricted to neighbourhoods, the misfortunes are significantly expanding with the separation. So it is material for little territories [47]. It can control both dynamic and responsive force streams from/to the microgrid. HF air conditioning microgrid will operate with higher recurrence (400 Hz or 500 Hz).

LFAC Microgrids:

Generally utilized in many exploration regions, far off towns, and in test fields. Operational and control procedures of LFAC microgrids in DER units. A force and energy the executive's system go under the arrangement of LFAC microgrids.

2.6.3 Microgrids hybrid DC and AC-Coupled:

The DC component is used by cross-breed DC and AC-coupled microgrids to associate disseminated energy storage frameworks like battery, control devices, and also bidirectional AC-DC converter-related flywheels and other DC renewable resources. For example, PV frameworks linked by DC-DC Boost converters and simple turbines (gas and wind) linked by rectifiers are DC fuel sources. The architecture of the mixture microgrid with DC and AC joining was implemented in [48–50]. Utilizing power converters, separable monitoring of DC and AC sections of a microgrid is carried out by [51].

2.7 Genetic Algorithms

GA has a place in the class of transforming calculations and also its success has been driven by the characteristic genetic growth period. Darwin [52] contributed the first study on routine progression in which he claimed that characteristic populations progress as suggested by the usual decision interval focused on the "natural selection"law. Holland [53] led the introductory study on GA in 1975, which was then greatly extended through Goldberg [54]. Giraffes use their long necks to consume the higher portions of the plants from the leaves. Giraffes have also progressed with ages of long tails, contrary to the criterion with natural selection. A Product is used to reflect this regular period of hereditary progression on the theory of evolution to obtain answers to problems built. GA's brilliance lays with its evolving environment; i. e., according to the changing environment, it can modify its own. The following region clarifies the critical functioning of GA.

2.8 GA's Basic Components

The essential working component of GA is the quality, a gathering of which comprises a chromosome. The chromosomes contain the present status information coded as paired digits 0 or 1 which is particularly put away in quality. This structure speaks to an applicant's answer for the issue in thought. GA chips away at these coded types of information as opposed to taking a shot at real information components. The chromosomes join to shape a populace which thus plans an age. GA is an iterative developmental cycle that plans an age after every emphasis. **Fig. 2.5** speaks to the schematic portrayal of the connection of these components.

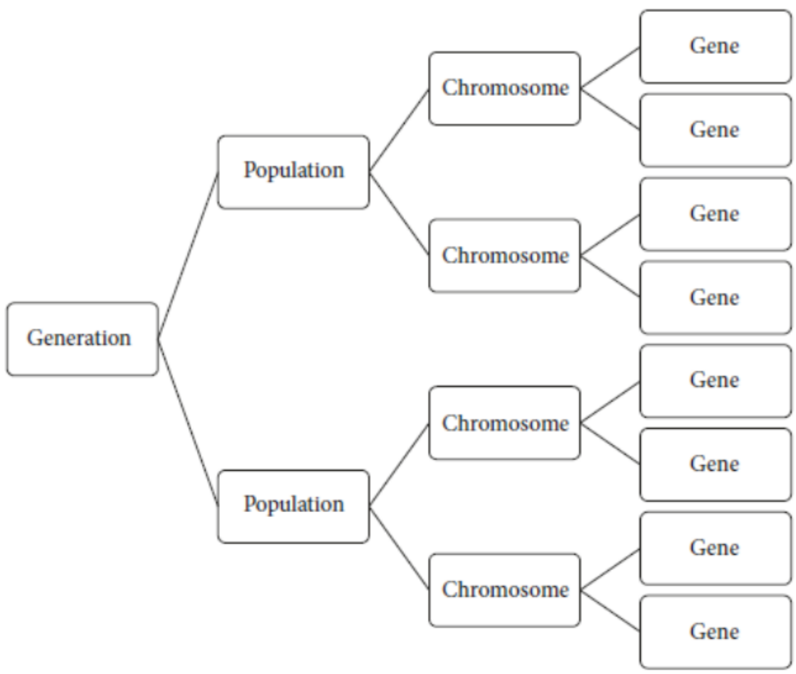


Fig. 2.5 GA's Basic Components. [55]

2.9 Operators of Genetics

To reach another age, each age is revealed to natural administrators. The new age is hypothetically in a way that is better than the past age, as the new age is produced in the wake of actualizing the guideline of "natural selection" and accordingly it replaces the more established age. During this cycle, either the entire populace can be changed or just the most exceedingly awful chromosome can be supplanted [56]. Clearly, these are two outrageous techniques and a few procedures for the new populace can be defined.

The cycles are guided such that they fulfill a wellness standard and they are rehashed to acquire a satisfactory age. Hereditary managers are accustomed to the perfection of variability in the measuring. In the corresponding method, regular GA administrators become added.

2.9.1 Selecting:

The selector administrator is used to pick genes inside an age-dependent period. The chromosomes fulfilling the wellness measures are probably going to be chosen in each more up to date age. For the most part, utilized determination models are as per the following:

(i) Option Slots panel: a chance of a gene decision is clear according to its well-being as tested by a wellness standard. In this way a chromosome with higher wellness will have a greater likelihood to be chosen; be that as it may, lower health genes could also be chosen.

(ii) Level evaluation for fitness: the whole approach ties the comparative well-being of singular genes, holding an age for having in all configuration of the gene. That technique becomes basically often used to keep up variety within a population.

(iii) Choice of Tournament: the bunch of genes is haphazardly picked but only the luckiest genes are picked of additional action. That strategy seems totally arbitrary.

(iv)Arrogance: each core of such a approach is that a set number of luckiest genes are retained and also the majority of citizens is generated using either of the chosen option strategies. Subsequently this strategy not just guarantees that the best arrangements stay in the populace yet in addition guarantees the expansion of the populace by choosing chromosomes from the whole arrangement space.

2.9.2 Iteration:

To produce two offspring that contain the individuality of the parental gene, the crossover administrator is added to the characteristics of the homologous chromosome. All such offspring get a better chance of stamina than their people, since they are strong as compared to their people. Consider the following parent chromosomes that both have 4 characteristics. At the third quality (at point bolts), hybrid can be added to these chromosomes to obtain two descendants shown in **Fig. 2.6**. This solution is regarded as a single-point hybrid. Several modified hybrid techniques that will be differentiated in this review have been suggested in writing.

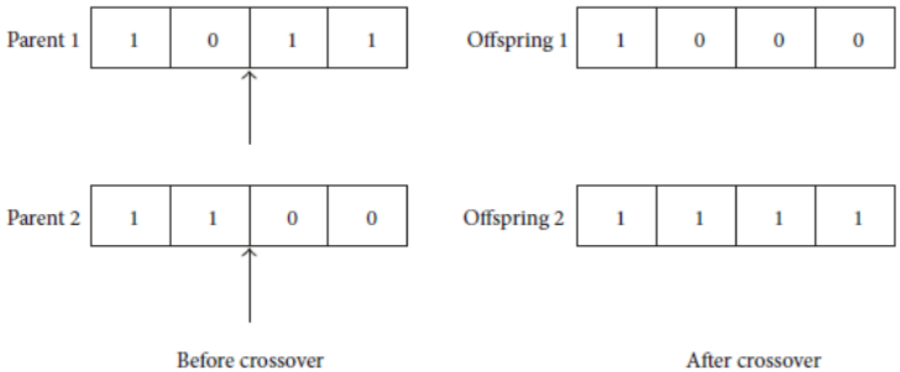


Fig. 2.6 A customary crossover. [55]

2.9.3 Genetic changes:

A solitary gene is added to the mutation administrator to modify quality in its separate region. Quality 1011 can be translated to 1111 since quality is flipped from 0 to 1 in region 2. To modify any data in a chosen gene or differentiate the arrangement room for further investigation, the transition administrator is used. Several changed strategies of reform have been suggested in writing that would be acknowledged with this study.

2.10 Applications

2.10.1 Learning Device:

In inherited qualities dependent on AI, which is an evolving area, the GA is used. Each GAs for three variables are central to AI. It functions in isolated spaces right off the bat, where slope-based approaches can not be implemented. This may be used to search for rule sets, systems of neural institutions, machines for cell computerization, and some other. This could therefore be used, though stochastic high scaling and progression estimates could also be complied with. There are also reinforced learning strategies [57]. The basic factor, health, has been used to evaluate the success of the teaching method. In the end, GA requires a populace, and frequently whatever one necessity is certainly not a solitary person, be that as it may, a network. Preparing in multi-specialist structures is an ideal case of this [58].

2.10.2 Production Images:

The GA can be used various specialized image processing exercises and measurements with the same weighty pixel resolution. One of it's crucial challenges in the field of image handling is image division. To unravel this challenge, a good number of efficient strategies are possible. The motive for such an approach is to divide the computerized image into various parts based on genetic or applied similarity, on the other hand. Its motivation is to explore the execution of GA in the division of pictures [59].

2.10.3 Vehicle routing problems:

Different delicate time periods, numerous terminals, and heterogeneous armada issues are too settled through the GA. Vehicle steering issues are comprising of an assortment of shoppers, each requiring a similar measure of the items to be moved. The vehicle is conveyed from a solitary distribution center will gracefully the items required and re-visitations of the distribution center. This vessel could have a clear weight and can also be reduced to that same separation voyage it may convey. Just one vehicle is permitted to visit each purchaser. The elective spectrum of circulation courses that conform with these models which have low and high costs is a challenge. In fact, it is often seen as similarly related to reducing the total separation covered or reducing the amount of vehicles used, as opposed to reducing the total separation for this number of units [60].

2.10.4 Problems of Optimization:

The GA may be most broadly utilized within improved difficulties wherever we can have to augment rather than again decrease a given target work an incentive through a given arrangement of conditions. Such a procedure will take care of an issue identified with enhancement. The advancement raises issues of limiting or streamlining factors with a few factors that are ordinarily dependent upon reasonableness and disparities limitations. This assumes an essential function in research, promoting, what's more, fabricating activities. A few difficulties of mechanical designing engineering are perplexing and difficult to conquer utilizing customary enhancement calculations. Over the past years, GA has pulled in huge regard for its ability as a creative enhancement system. Contingent upon their ease of use, simplicity of movement, least determinations, and concurrent and worldwide perspective, GA has been normally applied to an assortment of issues [61].

2.10.5 Economics:

The GA can likewise be utilized to depict different monetary frameworks, for example, the spider web framework, the goal of game hypothesis advancement, resource valuing, and so on A few financial analysts have begun to utilize GAs to fix regular inadequacies of traditional financial models while holding an advantageous numerical formation. This advancement like GA takes place in a way that can replicate the dynamics of actual dynamic problems. In addition, it reduces the need for a fixed structure of the approach problem and can thus determine between replacement improvements [62].

2.10.6 Neural Networks:

GA, especially recursive neural organizations, also serves to rehearse AI. GA seems to be a meta-heuristic approach affected by the usual option method that has a role in the broader growth enhancement enterprise. The GA becomes typically also used deliver top-notch measurement and decision making options by concentrating on bio-enlivened practices such as choosing, transition, and hybrid activities. This calculation is a dependable way to deal with transformative streamlining dependent on natural ideas. The populace of strings portraying possible answers for issues is created [63].

2.10.7 Parallelization:

The GA appears to have excellent synchronous usefulness and ends up being a very fruitful approach to tackle such issues, just as giving a decent report territory. This method would be a phase of population-based analytical enhancement that can be used to better plan neural organization frameworks. However, if numerous individuals making up the populace, the runtime of the calculation is in every case extremely huge. Parallelism processing is a system that can hypothetically be utilized to handle this issue. Through the examination investigates the execution of an equal GA for the quest for ideal determinations of fake neural organizations framework. The Palatalization is refined utilizing the Interposes correspondence Structure, wherein sub-populaces are shared among processors during choice, transformation, and hybrid [64].

2.10.8 Scheduling applications:

A timetable at booking issues ordinarily incorporates opposing needs dependent on the cost of the individual and the expense of the administrator. Buyers will in general invest less energy pausing, changing, and driving by open vehicles. Experts are interested in taking in cash from decreased car operating costs and offering a base number of vehicles. Shoppers are engaged in lower crowing, as far as the essence of administration is included, while vendors are engaged in increasing wages and consequently have high lead levels. Holding up a lot of energy plays a key role to fixing booking problems. Clients are keen on coordinating administrations with sensible holding up times, while administrators will in general offer fewer types of assistance [65]. The GA is utilized to unravel different planning issues, for example, schedules, etc.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter illustrates the work flow of the study with proposed model, mathematical equation with proper explanation for better understanding in the section 3.2 and 3.3 respectively.

3.2 Microgrid

The microgrid's key model is seen in **Fig. 3.1**. There are two busses in this figure, one is AC and the other is DC. The AC bus is connected to the wind turbine, the DG, and the consumer load. The DC bus is connected to the Solar PV panels, the battery bank, and the dumb load.

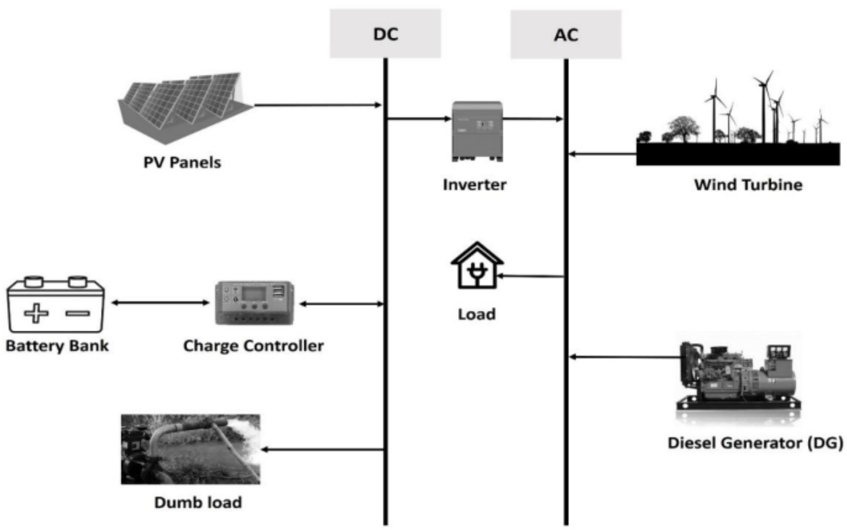


Fig. 3.1 Various components of the microgrid.

The system is most reliable for the off-grid system so that in Saint Martin, Chottogram, Bangladesh doesn't reach the national grid line so that it's helpful to optimize the solar PV, wind turbine, and battery bank to reduce the cost and efficiently worked all the system in **Fig. 3.1**. Now we show more mathematical data for all the systems below.

3.2.1 Solar photovoltaic panel

The solar PV panels power output varied on the data of the solar radiation. The equation will be

$$P_{pv} = P_{rated} \times H / H_{ref} \times [1 + C_t (T_{amb} + (0.0256 \times H) - T_{reff})] \tag{3.1}$$

where P_{rated} is the rated power under reference condition, H is the solar radiation (W/m2), H_{ref} is the 1 Kw/m^2 , T_{ref} is 25°C, C_t is 3.9 ×10^{-3} and T_{amb} is the ambient Temperature.

3.2.2 Wind Power Generation

The power generated by a wind turbine given by this formula:

$$P_{wind\text{-}out} = 0.5 \times \rho \times A \times V^3 \times C_p \tag{3.2}$$

where ρ is the air density (Kgm^{-3}), A is the solar Swept area (m^2), V is the wind Velocity (ms^{-1}) and $P_{wind\text{-}out}$ is the output of the wind power generation.

3.2.3 Battery bank

To store energy from the PV panels we use battery banks & it's discharging when a sufficient amount of power does not have in the consumer and Its Charging when fulfilling the load demand and extra power stored in the battery bank.

$$\frac{SOC(t)}{SOC(t-1)} = \int_{T-1}^{T} \frac{P_b(t)\eta_{batt}}{V_{bus}} dt \tag{3.3}$$

where V_{bus} the voltage of the bus is, $P_b(t)$ is the battery's input/output power and η_{batt} is the round trip efficiency of the battery. If $P_b(t)$is positive, the battery is charging, else it is discharging. Further, the round trip efficiency of a battery is defined as follows,

$$\eta_{batt} = \sqrt{\eta_{batt}^{c}\,\eta_{batt}^{d}} \tag{3.4}$$

where η_{batt}^{c} and η_{batt}^{d} are charging and discharging efficiency of the battery respectively [66]. The battery bank's round trip efficiency is considered to be 92.2%. It is often believed that the efficiencies of charging and discharging are different and are considered to be 85% and 100 %, respectively. The battery bank cannot discharge beyond a minimum limit which is called SOC_{min}. All batteries are connected in series to the DC bus bar, and below is the calculation of the number of batteries connected in series.

$$N_{batt}^{series} = \frac{V_{bus}}{V_{batt}} \quad (3.5)$$

The operation of battery charging and discharging are described more on the operation part.

3.2.4 Diesel Generator

We use diesel generators if other systems' production is getting off and if any natural disaster happened in the coastal area. As a backup, we use two diesel generators that are running to mitigate the load demand.

We use yearly fuel consumption by this equation:

$$D_f(t) = a.D_P(t) + b.D_r \quad (3.6)$$

where D_f (t) fuel consumption (L/Hr), D_p is the generated power (kW) and D_r is the rated power of the DG, and a,b is the constant parameter (L/kW) and it depends upon the kinds of diesel generator.

We use two 30kW diesel generator.

3.2.5 Inverter

We need to use an inverter in the DC to AC bus line to convert the DC to AC. Based on peak load demand, the converter size is selected ($P_{load}^{m}(t)$).

The rating of the inverter (P_{inv}) is determined as follows,

$$P_{inv}(t) = \frac{P_{load}^{m}(t)}{\eta_{inv}} \quad (3.7)$$

3.3 Problem Framework

The major goal of this analysis is to develop an off-grid energy system that is cost-effective and efficient. The main decision variables are the rating and sizing of solar PV panels, wind turbines, battery banks and DG. We use Genetic algorithm (GA) to solve this problem and later we use particle swarm optimization (PSO) for comparison.

CHAPTER 4

DESIGN AND INPUT DATA

4.1 Introduction

This chapter illustrates the essential parameters for GA design in section 4.2, flow chart of genetic algorithms of this proposed model in section 4.2.1, parameter taking in section 4.3 and Input data in section 4.4.

4.2 Genetic Algorithm (GA)

A genetic algorithm is a search heuristic, influenced by Charles Darwin's theory of natural evolution. This algorithm demonstrates the natural selection process in which the fittest individuals are selected for reproduction to produce offspring of the next generation [67]. In a genetic algorithm, five steps are considered.

1. Initial populations
2. Fitness value
3. Selecting
4. Crossover
5. Mutation

We have used Matlab to code the GA, then we find the system's optimum value.

4.2.1 Objective Function

The key aim of this research is to minimize the overall ASC of the proposed method while retaining the optimum flow of energy. Four key decision criteria have been chosen for optimum design, i.e., the number of wind turbines, solar PV panels, batteries, and DG rating. It is found that the outcome with the least ASC is an optimal one, thus following all other constraints and parameters. The objective function considered is the overall expense of the device, consisting of

(i) The overall cost of capital
(ii) The cost of replacement and
(iii) The components' maintenance & operating costs.

The following function is said to be the main objective function to be minimized subject to constraints,

$$f_{ASC} = f(N_{solar}C_{solar} + N_{wind}C_{wind} + N_{battery}C_{battery} + P_{dg}C_{dg} + P_{inv}C_{inv}) \quad (4.1)$$

where $C_{solar}, C_{wind}, C_{battery}$ and C_{inv}, are the cost of solar PV panel (per kW), wind turbine (per wind plant cost), battery (per unit) and inverter (per kW) respectively. On the other hand N_{solar}, N_{wind} and $N_{battery}$ are the number of solar PV panels, wind turbines and battery units respectively. P_{dg} & P_{inv} are the power rating of diesel generator (DG) and inverter respectively.

Total annual system cost are described by these equations,

$$C_{solar} = C_{solar}^{cap} + C_{solar}^{rep} + C_{solar}^{maintain} - C_{solar}^{salvage} \quad (4.2)$$

$$C_{wind} = C_{wind}^{cap} + C_{wind}^{rep} + C_{wind}^{maintain} - C_{wind}^{salvage} \quad (4.3)$$

$$C_{batt} = C_{batt}^{cap} + C_{batt}^{rep} + C_{batt}^{maintain} - C_{batt}^{salvage} \quad (4.4)$$

$$C_{inv} = C_{inv}^{cap} + C_{inv}^{rep} + C_{inv}^{maintain} - C_{inv}^{salvage} \quad (4.5)$$

$$\boldsymbol{C_{dg} = C_{dg}^{cap} + C_{dg}^{rep} + C_{dg}^{maintain} + C_{dg}^{fuel} - C_{dg}^{salvage}} \quad (4.6)$$

where capital cost ($\boldsymbol{C_{cap}}$), replacement cost ($\boldsymbol{C_{rep}}$), annual maintenance cost ($\boldsymbol{C_{maintain}}$), fuel cost ($\boldsymbol{C_{fuel}}$) and salvage cost ($\boldsymbol{C_{salvage}}$).

We also analysis the cost using capacity recovery factor (CRF) in each components cost,

$$\boldsymbol{CRF(i, P) = \frac{i(i+1)^P}{(i+1)^P - 1}} \quad (4.7)$$

where the lifetime in years is P and the annual interest rate is i.

The objective function minimized following the several constraints,

$$\boldsymbol{1 \leq N_{sol} \leq N_{sol}^{max}} \quad (4.8)$$

$$\mathbf{1} \leq \boldsymbol{N_{wt}} \leq \boldsymbol{N_{wt}^{max}} \tag{4.9}$$

$$\mathbf{1} \leq \boldsymbol{N_{batt}} \leq \boldsymbol{N_{batt}^{max}} \tag{4.10}$$

$$\mathbf{1} \leq \boldsymbol{P_{dg}} \leq \boldsymbol{P_{dg}^{max}} \tag{4.11}$$

where N_{sol}^{max} the maximum number of solar PV is panels, $N_{batt}^{max}$is the maximum number of batteries, N_{wt}^{max} is the maximum number of wind turbines and P_{dg}^{max} is the maximum rating of DG.

Flowchart of genetic algorithms of the microgrid model **Fig. 4.1** is given below:

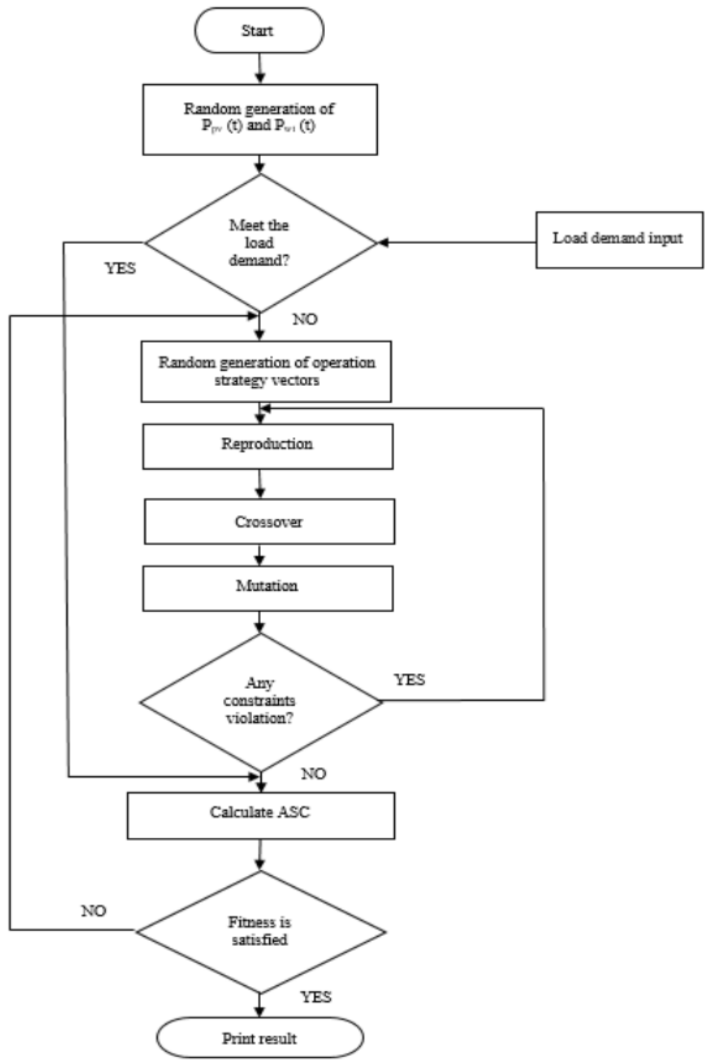


Fig. 4.1 Flowchart of genetic algorithms of this proposed model

In this flowchart, first, the algorithms will arbitrarily select a set of vectors for the model size of the microgrid. The power derived from these components is compared with the parameters of the hourly load. If the power supplied by the system will fulfill the load requirements, it is possible to calculate the ASC. If the extracted power is insufficient to fulfill the load criteria, the operation strategy shall take effect. The technique vector of the operation is chosen randomly. The expense of each device shall be measured. For every size, the lowest operating strategy cost would be added to the ASC. Then test the fitness and the solution to the problem will be the one with the lowest ASC if the fitness is met.

4.3 Parameter of taking Genetic Algorithm:

We customize the main parameter of GA's design manually by Matlab. We take,

Population Size: 100

Crossover Fraction: 0.8

Reproducibility: twister

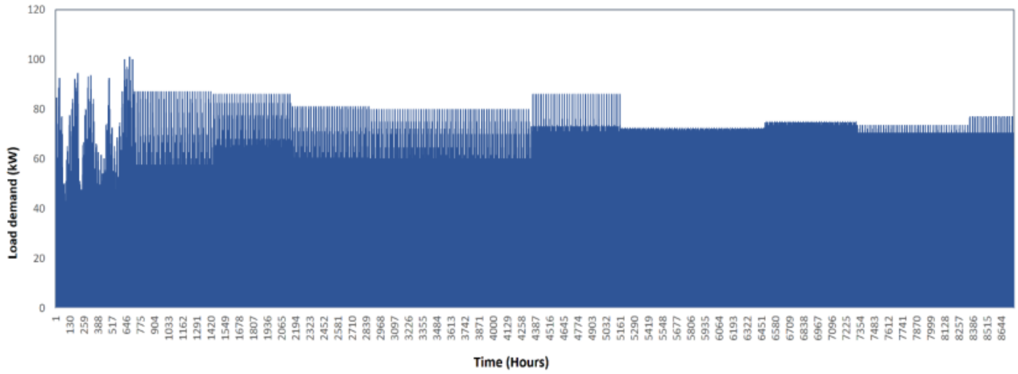
Number of variables: 03

Lower bound: 1 1 1 (Minimum 1 wind plant, 1 solar plan, 1 battery unit)

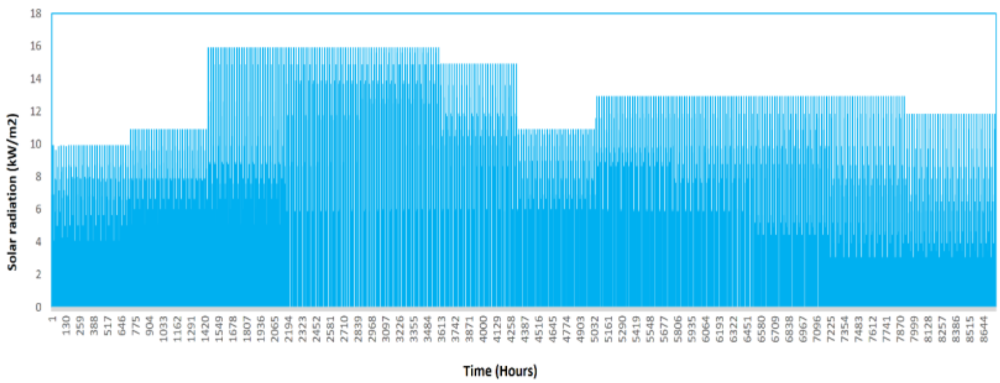
Upper bound: 1 400 150 (Maximum 1 wind plant, 400 solar plan, 150 battery unit; According to our geographical area).

4.4 Input Data:

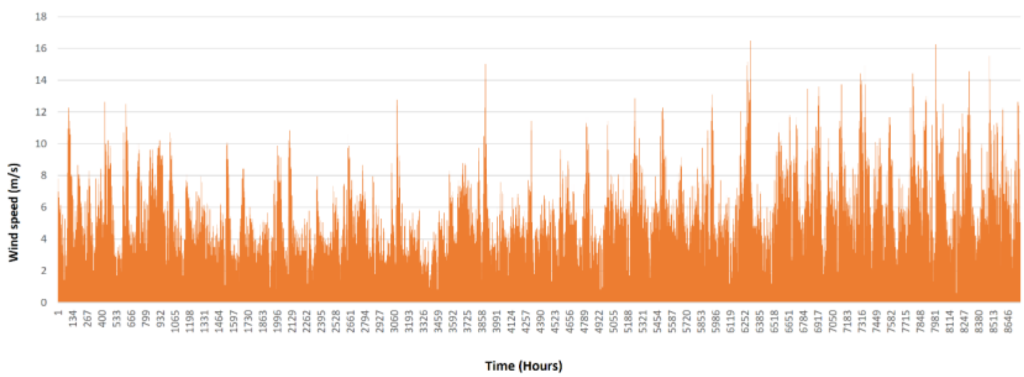
The methodology developed in this work was used to plan a small stand-alone PV-wind-diesel generator-battery banking system, as shown in **Fig. 3.1**, to meet the energy requirement. A small island in the Bay of Bengal, Bangladesh. Case study field It is located at 20 ° 36′47″N latitude and 92 ° 19′36″E longitude. The device is basically configured for household loads of a small microgrid with a peak load requirement of 102 kW. The area is found to have the strongest supply of solar and wind energy during the year.



(a)



(b)



(c)

Fig. 4.2 (a) Daily load profile (kW). (b) Solar radiation (kW/m2). (c) Wind Speed (m/s) for a year.

Table 4.1: Technical and economic data of the components used in proposed System.

Component	Parameter	Value	Unit
Wind turbine	Rated power (P_{wr})	50	kW
	Cut in speed (V_{cin})	3.5	m/s
	Cut out speed (V_{co})	20	m/s
	Rated wind speed (V_{rat})	9.5	m/s
	Capital cost (per plant)	176756.25	$
	Replacement cost (per plant)	60848	$
	O & M cost (per year)	15000	$/yr
	Rotor Swept area	227.0	m^2
	Survival wind speed:	50.0	m/s
	Life time	20	years
Solar PV	Rated power (P_{sr})	1.05	kW
	Derating factor (f_{loss})	80	%
	Capital cost (per module)	972.48	$
	Replacement cost (per module)	972.48	$
	O & M cost (per kW)	10	$/yr
	Life time	20	years
Battery	Nominal capacity (C_b(Ah))	150	Ah
	Nominal voltage (V_{batt})	12	V
	Max charging current (I_{max})	18	A
	Minimum state of charge (SOC_{min})	30	%
	Maximum state of charge (SOC_{max})	100	%
	Round trip efficiency (g_{batt})	92	%
	Capital cost (per unit)	129.42	$
	Replacement cost (per unit)	53.7	$
	O & M cost (per unit)	5	$/yr
	Life time	5	years
Diesel Generator	Rated power (P_{dg})	30	kW
	Fuel consumption	251	g/kw.h
	Fuel cost(diesel)	0.77	$/litre
	Capital cost (per unit)	3,161.00	$/unit
	Replacement cost (per kW)	3,161.00	$/unit
	Life time	20	years
Inverter	Rated power	10-100	kW
	Inverter efficiency	≥95	%
	Capital Cost(per inverter)	850.00	$/kW
	Replacement cost (per inverter)	850.00	$/kW
	O & M cost (per inverter)	12	$/yr
	Life time	20	years
Other	Interest rate (i)	4.879	%
	Project life (N)	20	years

CHAPTER 5
RESULTS AND DISCUSSION

5.1 Introduction

This chapter illustrates the Matlab GA optimization graph in section 5.2, chart of the Energy, CO_2 analysis proposed model in section 5.2.1, graphs of operational analysis in Matlab in section 5.2.2.

5.2 Matlab Results

After iteration, need wind plant: 1 Solar plan: 16 & Battery unit: 77 to the optimal microgrid system satisfies the load demand.

Fig. 5.1 is the Matlab graph of fitness function according to cycle number. Where X-axis indicate the cycle number and Y-axis indicate the value of fitness function.

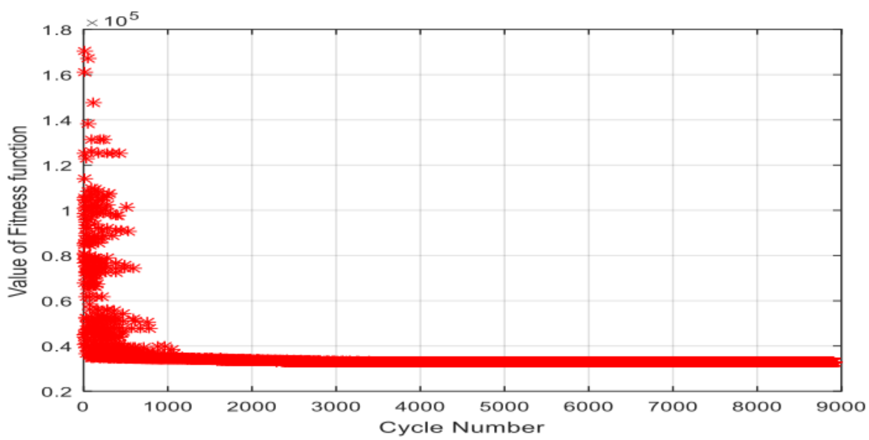


Fig. 5.1 Value of fitness function according to cycle number

Table 5.1: Break down the ASC from the GA algorithm for the proposed system.

Component($/yr)	Total($/yr)
PV	2922
Diesel Generator	2922
Wind turbines	24206
Batteries	3238.7
Inverter	1288
Total	34576.7

Table 5.2: Energy analysis by GA and PSO algorithm.

	GA (kWh/yr)	PSO (kWh/yr)
Solar Energy	700260	690380
Wind Energy	171160	171160
Battery in	228150	227820
Battery out	205820	205530
Excess electricity	275180	265710

Table 5.3: Total CO_2 Emission comparison.

	GA	PSO
Total CO_2 Emission(ton)	4.10577894	6.760475

Table 5.4: Comparison analysis with proposed system vs. only using DG based system.

	Proposed system	Only using DG system
Total Cost($)	$34576.7	$2522358
Total CO_2 Emission(ton)	4.10577894	9640.936523

Table 5.1 demonstrate break down the ASC from the proposed system's GA algorithm where different components (PV, wind turbine, diesel generator, batteries, inverter) are included. Here, we discussed the per year cost for various parts. **Table 5.2** demonstrate energy analysis by GA and PSO algorithm, here genetic algorithm generates higher solar energy than particle swarm optimization. **Table 5.3** indicates the total CO_2 emission comparison between GA and PSO. Here, the genetic algorithm highly reduces CO_2 emission than particle swarm optimization, which is environment friendly. **Table 5.4** demonstrate comparison analysis with the proposed system vs. only using DG based system. It is noticeable that the proposed system cost is low, and CO_2 emission is less than only using a DG-based system.

5.2.1 Chart of the Energy, CO_2 analysis

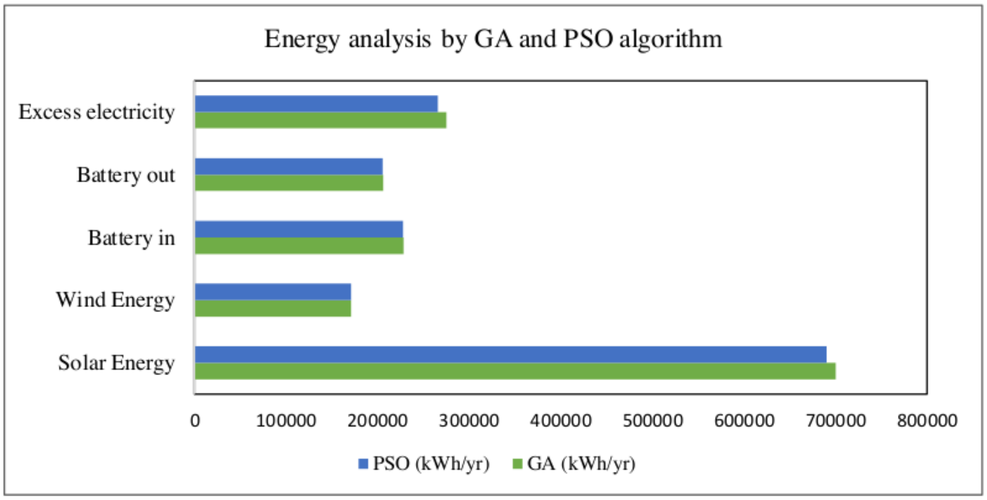


Fig. 5.2 Energy analysis by GA and PSO algorithm

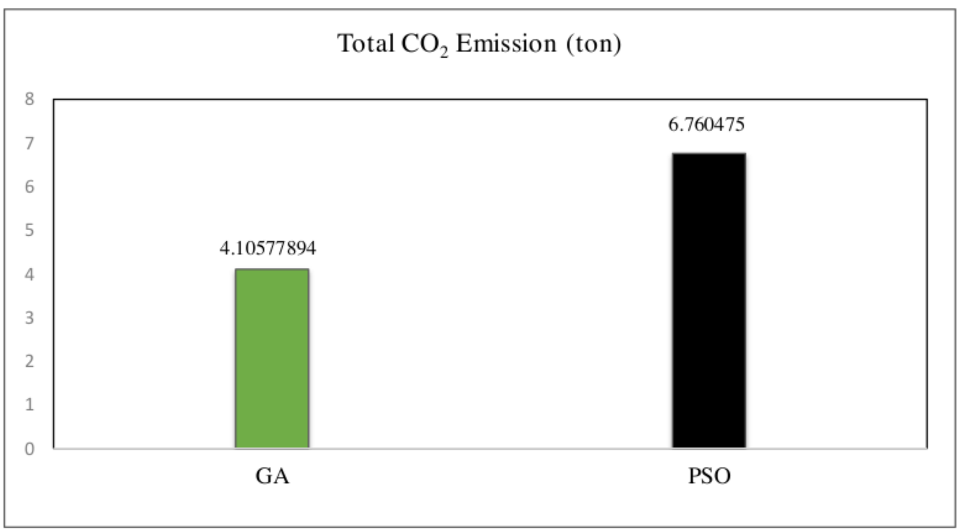


Fig. 5.3 Total CO_2 emission analysis with GA vs. PSO algorithm

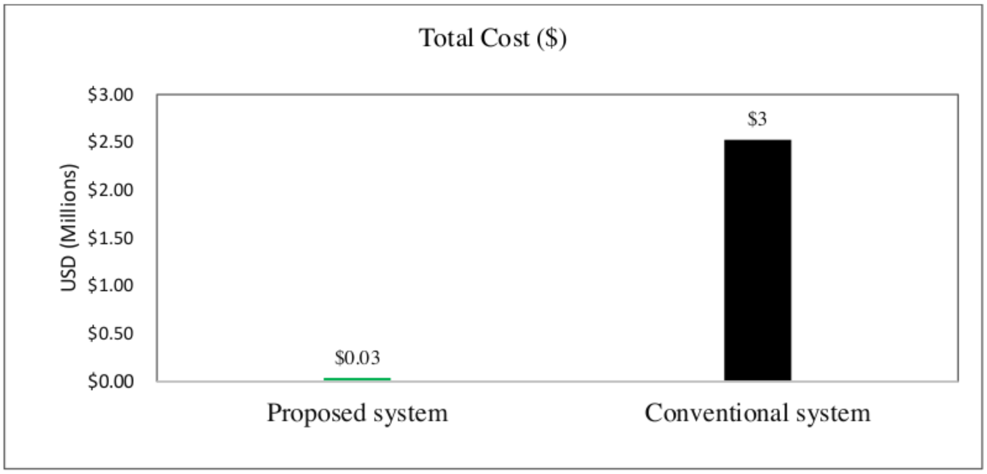


Fig. 5.4 Total cost analysis with proposed system vs. only using DG-based system

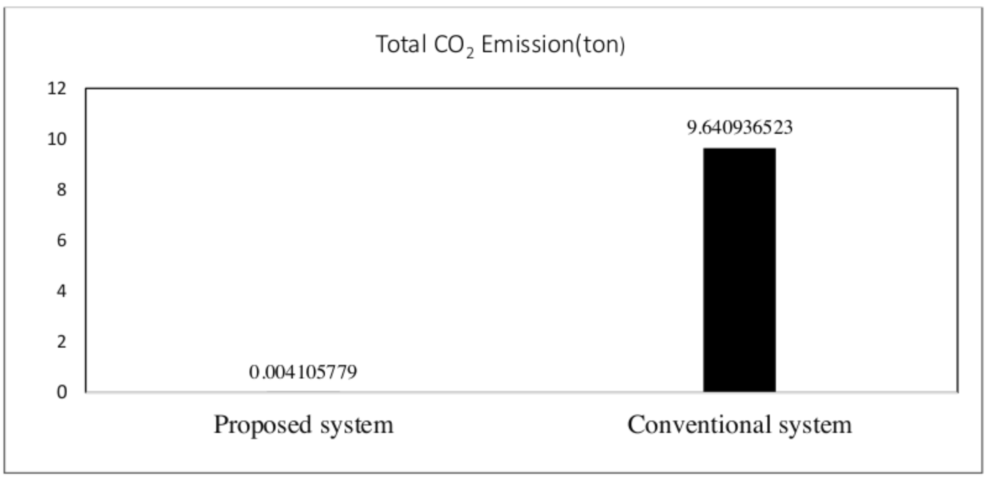


Fig. 5.5 Total CO_2 emission analysis with proposed system vs. only using DG based system

Fig. 5.2 demonstrates the GA and PSO algorithm's energy analysis, where solar energy, wind energy, and battery are included. **Fig. 5.3** shows the total CO_2 emission analysis with GA vs. PSO algorithm and it's clear that GA provides good results. **Fig. 5.4** shows the total cost analysis with the proposed system vs. only using DG-based system, where our proposed system cost too lower than only using DG-based system. **Fig. 5.5** shows the total CO_2 emission analysis with the proposed system vs. only using the DG-based system, where the conventional system is not environment friendly.

5.2.2 Graphs of operational analysis in Matlab

The proposed system satisfies the overall energy demand only with solar, wind and battery capacity. **Fig. 5.6** shows the energy balance for the third week of September. It may be said that solar and wind power was compliant with the available solar and wind resources and handled load demand without the use of a diesel generator. **Fig. 5.7** shows the battery charge and solar power view for the third week of September, where the X-axis denoted is hour and Y-axis is the energy (kWh).

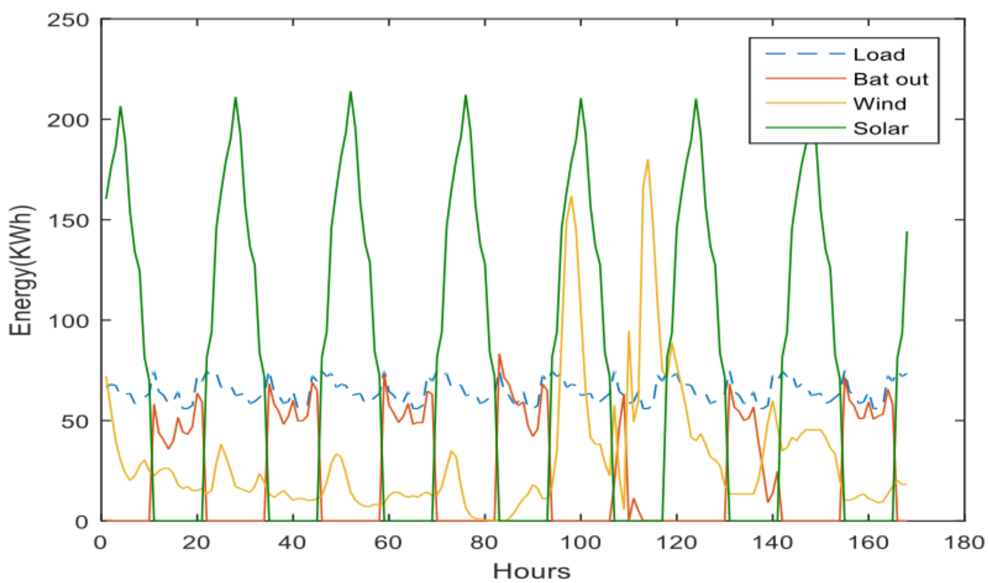


Fig. 5.6 The energy level of the third week of September.

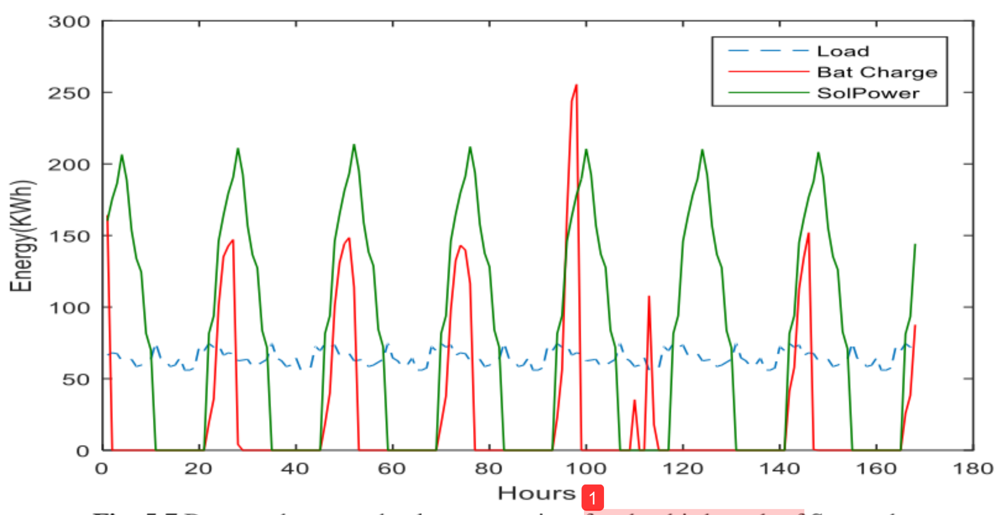


Fig. 5.7 Battery charge and solar power view for the third week of September.

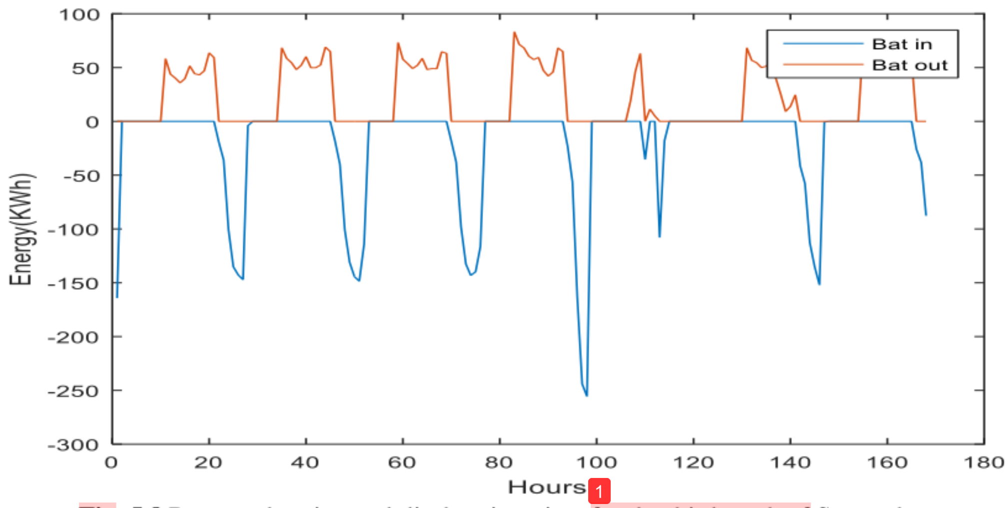


Fig. 5.8 Battery charging and discharging view for the third week of September.

Fig 5.8 shows the battery charging and discharging view for the third week of September. If the energy is sufficient to charge above the charging rate, it can be used as dumped energy. If the discharging of electricity is greater than the discharging of batteries, the DG can be used as a power. Also **Fig. 5.9** shows the battery charging and discharging view for a year.

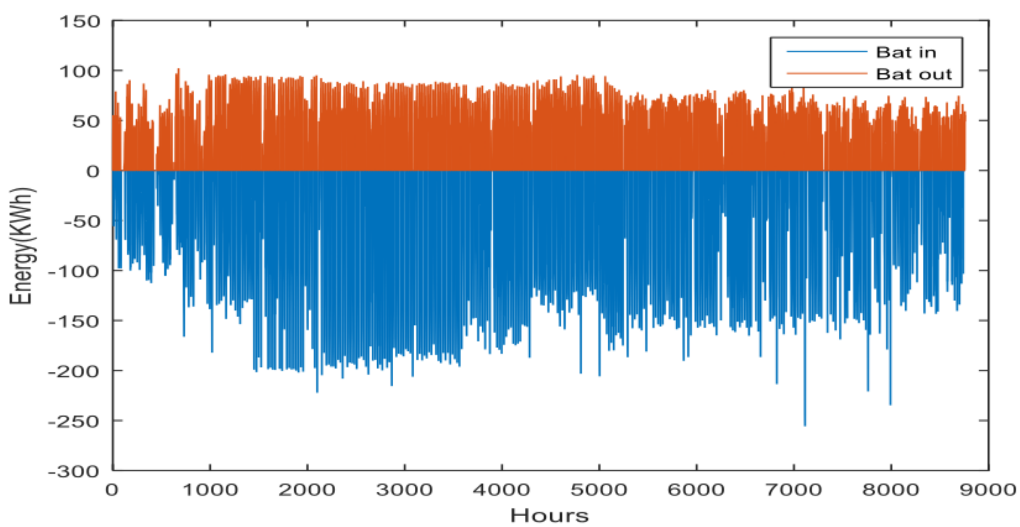


Fig. 5.9 Battery charging and discharging view for a year.

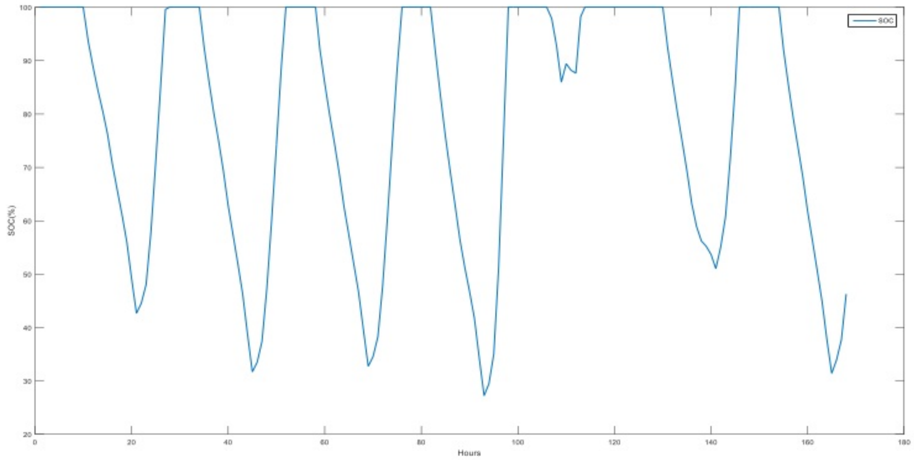


Fig. 5.10 SOC of battery for the third week of September.

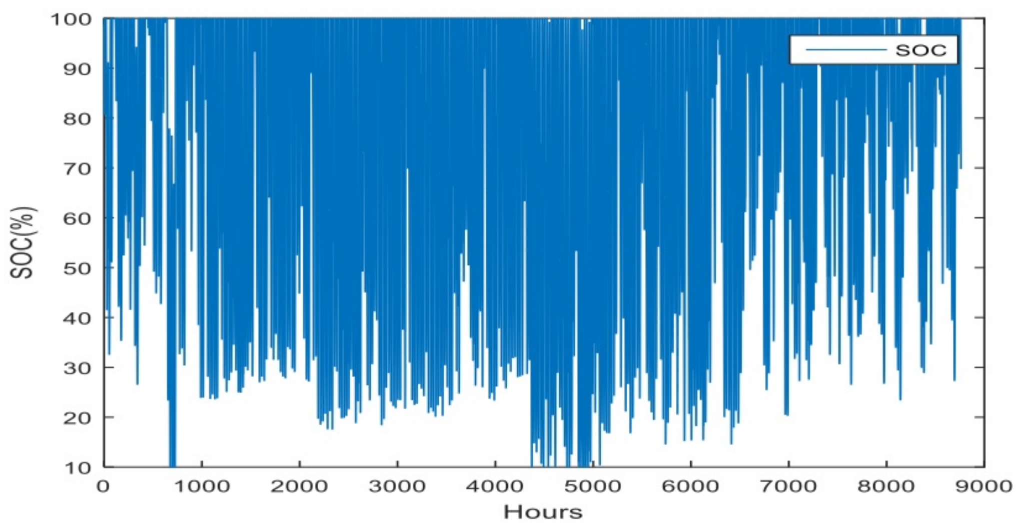


Fig. 5.11 Battery SOC view for a year.

Fig. 5.10 displays SOC battery in September for the third week. It indicates that the SOC battery is still inside the predefined limit. **Fig. 5.11** shows the battery SOC view for a year. It also reveals that most of the time the SOC battery is fine, except for a few instances.

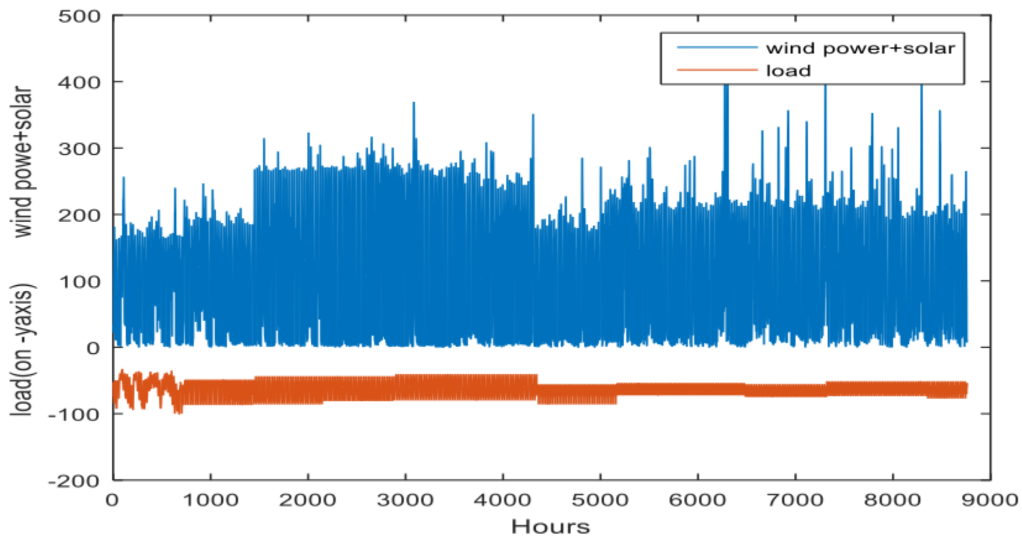


Fig. 5.12 Renewable energy source and load demand view for a year.

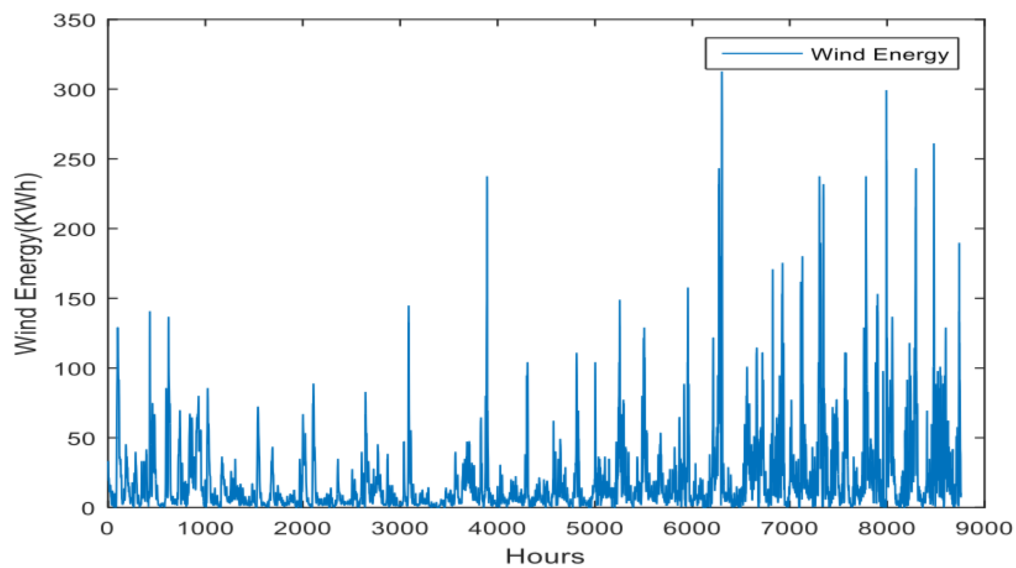


Fig. 5.13 Produce wind energy for a year.

Fig. 5.12 shows the renewable energy source and load demand view for a year, where X-axis indicate the solar and wind energy for a year and -Y-axis indicate the load demand. Also in **Fig. 5.13** shows the produce wind energy for a year. In this graph maximum wind energy is 302 kWh.

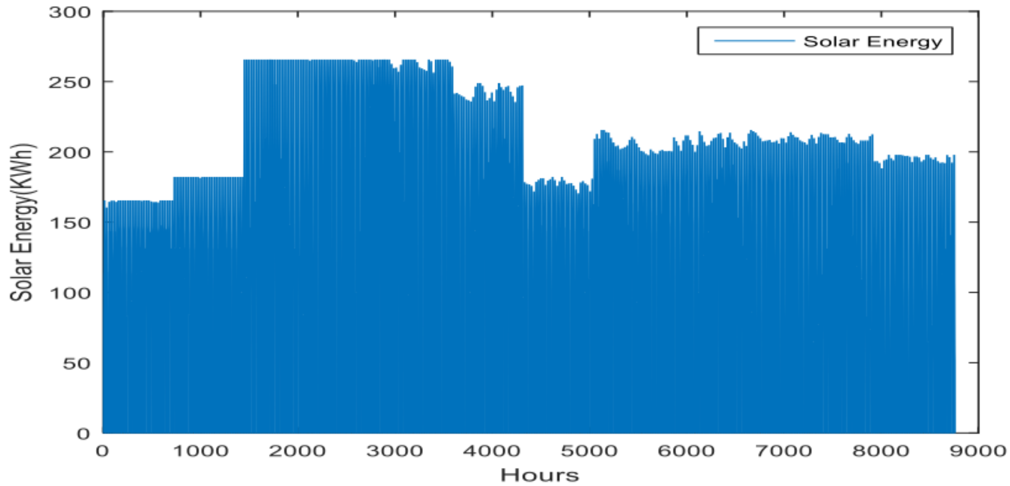


Fig. 5.14 Produce solar energy for a year.

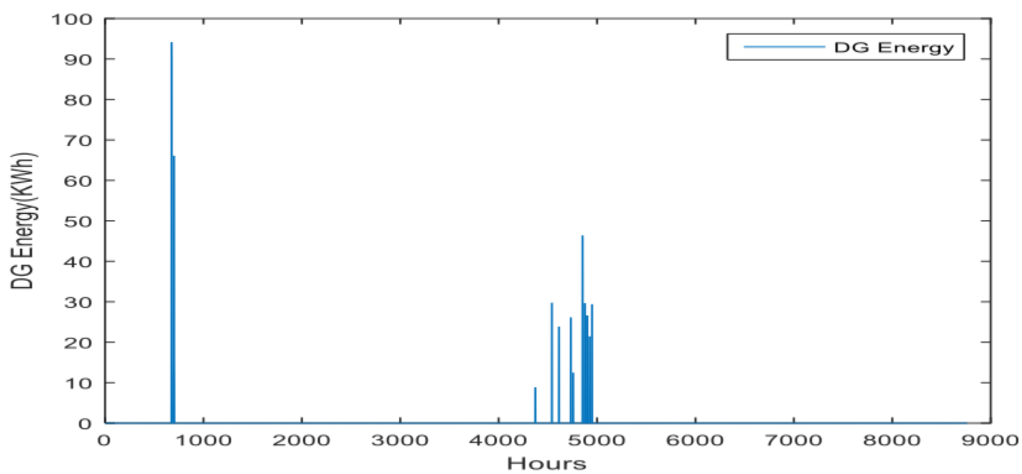


Fig. 5.15 Produce DG energy for a year.

Fig. 5.14 shows the produce solar energy for a year. It indicates that due to the improved availability of solar resources, enough solar energy is produced. **Fig. 5.15** shows the produce DG energy for a year. It is obvious that less time is needed for DG power because only batteries, solar and wind meet the total load requirement. **Fig. 5.16** It has been observed that the LCOE declines significantly as the inverter performance improves.

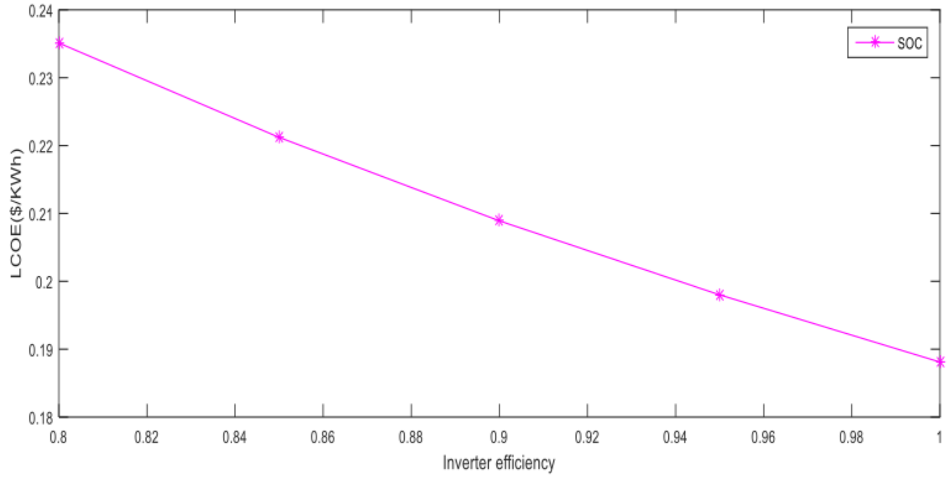


Fig. 5.16 LCOE vs. Inverter efficiency

CHAPTER 6

CONCLUSION

6.1 Introduction

Renewable energy-based microgrid systems are efficient and environmentally sustainable ways of producing electricity. Using the genetic algorithm optimization technique provides cost-efficient results also reduces the greenhouse effects in this thesis. There is also an opportunity for future improvements to the proposed work.

6.2 Conclusion

This microgrid system is the best for a more reliable, economical, and effective source of electricity for the off-grid location. The preliminary results show that with a collection of manufacturer data, the algorithms manage to optimize the strategy for size and operation for a simple daily load. The study design a PV, wind, battery, diesel microgrid system in Saint Martin Island. It has been shown that the use of our proposed model decreases the use of DG and fulfil the electricity from renewable energy sources. The system with 1.05 kW of 16 PV plan and a 30 kW of 1 diesel generator, 50 kW of 1 wind turbine, and 77 numbers of batteries (nominal capacity 150 Ah, nominal voltage 12V each) gives the most economically feasible solution. The ASC from the proposed system's GA algorithm is a total of $34576.7(USD). The primary objective of the study is to optimize power output while reducing total costs using the GA. The load requirements for a mix of renewables are met in this proposed system. This proposed system considerably lowers CO_2 emissions, which decreases global warming, a matter of headache worldwide. We also compare with PSO, and it's seen that PSO-based system emission of CO_2 is 6.76 ton and GA-based system emission of CO_2 is 4.11 ton. A comparison reveals that our proposed system reduces the cost 72.95 times and reduces the emission of CO_2 2348.14 times by only using DG-based system. According to our system design by hourly data, there is some limitation when collecting data in our country but our input mostly relatable according to our geographical area. The study concludes that the optimal microgrid system satisfies the demand for load satisfactorily without violating any constraints.

6.3 Future Work

On the basis of our analysis, we address some of the possible dynamic fields that will carry this approach to the next level. These are:

1. Operation can be done by changing parameters.
2. Implement such a methodology in other remote areas in our country.
3. Using Biomass or Wave energy system in the methodology
4. Using various metaheuristics algorithm.

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