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An Efficient Technique-Based Distributed Energy Management for Hybrid MG System: A Hybrid SBLA-CGO Technique

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Abstract

This manuscript presents an optimal energy management on microgrid (MG) connected to the grid that chooses the energy scheduling based on the proposed method. The present method is the joint implementation of the Side-Blotched Lizard Algorithm (SBLA) and the Chaos Game Optimization Algorithm (CGO) and hence it is named as SBLA-CGO method. Here, the MG system contains a photovoltaic system (PV), wind turbine (WT), battery storage (BS) and fuel cell (FC). Constantly, the necessary load demand of MG system connected to the grid is measured with SBLA method. The CGO increases the perfect match of MG with the expected load requirement. Moreover, renewable energy forecasting errors are evaluated twice by MG energy management for minimizing the control. Through the operation of MG schedule of several RES to decrease the electricity cost using the first method. Balancing the energy flow and minimize the effects of prediction errors according to the rule presented as planned power reference is second method. The main aim of the present method is evaluated with connection of fuel cost, the variation of energy per hour of the electrical grid, the cost of operation and maintenance of MG system connected to the network. According to RES, the energy demand and

SOC of the storage elements are the conditions. Renewable energy system units use batteries as energy sources to allow them to operate continuously on stable and sustainable power generation. The analysis of the present method is analyzed by comparing with the other systems. The results of the comparison assess the strength of the present system and confirm their potential for solving the issues.

Keywords: *Micro grid, optimal energy management, forecasting errors, renewable energy sources, operation and maintenance cost, batteries*

1. Introduction

The power production around the world is represented as thrusts of economic enhancement (Hossain et al., 2019). Consequently, the generation of electricity in formulated nations carries a great weight over formulated energy. Energy efficiency on RES is generated by the daily enlargement of energy use, the consumable idea of fossil fuels and expansion of global situation (Dong and Chen 2018; Roslan et al. 2019). At current stage, the wind and solar energy system evaluates remarkable work for energy production (Nasr et al. 2019; Yan et al. 2019; Bui et al. 2019). Several connections have gained based on the correct reason in the HRES. Additionally, the embedded method produces a hybrid system for missing networks like distant islands (Mansour-lakouraj and Shahabi 2019; Xing et al. 2019). It is essential to regard variable MGs the future distribution networks will involve a novel SG concept, that are available to work smartly below all earth considerations (Ding et al. 2019; Han et al. 2018). Various automatic control methods and a unique network of top-of-the-line converters / inverters are explored for ensuring that MG systems are used properly. For necessitate the high-bandwidth communication system based on conventional drop-based controllers, centralized and master-slave controllers are developed (Hua et al. 2019; Wakui et al. 2019; De Angelis et al. 2012; Jafari et al. 2019). They

have inherent detention, like powerless transient execution, unavailability of viability and no black boot ability (Choi and Kim 2016). Fuzzy logic controller control approaches (Yin et al. 2019), various level control strategies (Teleke et al. 2010), slider mode and neuro-fuzzy control (Riffonneau et al. 2011; Penangsang et al. 2016) were implemented for overcoming the above obstacles. The current prompted by huge signal interference, like engine start or sc loss, which can trickle out the DER unit or destruct electronic power ingredients (Huang and Liu 2011).

This manuscript presents optimal energy management on microgrid (MG) connected with grid, that chooses energy scheduling based on the proposed method. The present method is the joint implementation of Side-Blotched Lizard Algorithm (SBLA) and Chaos Game Optimization Algorithm (CGO) and hence it is named as SBLA-CGO method. Here, the MG system contains a photovoltaic system (PV), wind turbine (WT), battery storage (BS) and fuel cell (FC). The rest of the manuscript is given beneath: Section 2 looks at current investigative operation and background of research work. Section 3 describes that optimal power configuration management with MG integrated system. Section 4 portrays that SBLA-CGO control approach through optimal energy management. Section 5 describes that simulation result and conversation of the proposed and existing systems. At last, section 6 concludes the manuscript.

2. Recent Research Works: A Brief Review

Based on optimal energy management in grid-connected microgrid several research works have presented in the literatures using different methods. Some of them are described here.

An intelligent system for EMS based on Recurrent Neural Network (RNN) method with Ant-Lion Optimizer (ALO) was introduced by K. Roy et al. (2019) to obtain energy scheduling in MG. The main intention of the proposed method was used to diminish the cost of electricity generation by scheduling daily and in real time. Through the use of RNN, the demand response

(DR) was assessed and extra codes were also evaluated. To calculate the generation, storage and receptive load offers, the ALO system was introduced to rectify the economic dispatch problems. A distributed energy management system of MG community was presented by G. Liu et al. (2019). In all repetitions, the central controller MG aligns the DER and ESS programming at MG level. Optimization occurs while the disturbed power of entire buses approaches zero. The dynamic thermal model house was interconnected with the HEMS to control heating, ventilation and air conditioning system through clients. Y. Liu et al. have established a safe distributed phrase energy management (S-DTEM) strategy of multiple interrelated MGs (Liu et al. 2019). Every MG was maintained through a distributed MG ESS that only converts the commercial quantity and price information with other MGs for preserving the privacy of information. While every MG involves a buyer, S-DTEM will change the energy selling price and working period for reducing their local cost by trading energy with MGs / main stage. This method could reduce the cost of integrated MGs. With quadratic barrier functions, the finite time integration of S-DTEM could analyze certain difficult operating conditions. An intentional MG-EMS can penalize the prohibition of maximum function; the misbehavior detection mechanism was also developed by the finite-time convergence property. X. Yang et al. have described a bilayer game theoretic method (Yang et al. 2019) for IEM of multi-MG (MMG). The maximum layer of the method has maintained the energy trade and consumption behavior of every MG; the cost model was intended based on economic factors and the will of the users. The minimized segment executes at high frequency and regulates the MG operations for reducing the larger and actual segments. Also, the supply and demand variables and the output events could be managed correctly and the energy trading behind the MGs may gain directly devoid of disturbance. J. Zeng et al. have developed a completely distributed operating method of MEMS with maximum

penetration and demand for renewable energy (Zeng et al. 2018). The iterative best method-response algorithm was developed for choosing the Nash equilibrium game. Finally, to validate the effective and validity MG method was evaluated.

2.1. Background of Research Work

A review of current investigation operation illustrates that, energy management of hybrid RES devices for MG. At energy management system, the power generator persistence is a great challenge. The energy source management is established using energy supervision system and committed to solve the energy sources of RES and cost factors included in the problem. Additionally, there are several methods that are used: fuzzy, neuro-fuzzy and optimization methods on MG energy management system. Through fuzzy logic controller provides best outcomes hence it does not categorize fuzzy system theory unique nature. On contrary, it has been evaluated that PSO has a better optimal search capacity. Moreover, the PSO algorithm, there are random variations in velocity equation, thus varying the better value from unstably. Also, a RES control method is primarily evaluated for tracking the power requirement and control the DC bus voltage. Finally, the integrated MG system is evaluated to defeated this challenge and offer a hopeful solution. Several work-based methods are established at bibliography to remedy this issue; these demerits and troubles have encouraged this investigation work.

3. Energy Management Configurations with MG Connected System

This section introduces the energy management system with the MG system connected. EMS is used to assess and verify the MG power management is evaluated on grid-connected mode for the purpose of performance. The MG may be organized through corresponding classifications subsequent to the control tasks have been performed. Below the grid mode during MG task, load

demand should be met at entire time. To gain the main goal, the MGs goal may be set and imagined using optimization method. The main objective is to establish with the production of wind / solar energy, Fc and battery. Resources are energy storage devices and unassignable / assignable resources. The control factors considered the dynamic power and operating position of ESS and transmitting units to determine energy management tasks. Moreover, a power equilibrium condition, the power of the controllable units and optimal start-up time of the transmitting units are evaluated.

Fig 1: Architecture of MG with proposed method

The working state and the ready intensity of the controllable units are specified at provided time. Meanwhile, due to any anticipated misinformation, and improving voltage and power flow, the proposed method considers power and evaluates power variations from non-dispatchable units. Considering the power requirements cost through penalty function is the main objective (v et al. 2019). In this way, The architecture of MG with proposed method in figure 1, when the goal of MGs is to be reduced and increased revenues the optimal operation is established. Dispatchable units can work continuously and visible at the most higher rate of demand. When the ESS achieved at the point it's upper/brings down energy levels and afterward the control method thinks regarding the variety attitudes of non-dispatchable source control.

At upcoming time steps the necessary increase/reductions for future time steps is stable. The power of transmissible / non-transmissible resource units and ESS is coordinated premature. By choosing the most optimal control group of controllable units, assuming the market prices, the prediction power of non-transmissible units load level, the proposed method is improving the revenues in a provided time horizon. Using the proposed method, the cost of fuel for dispatchable resources is described as energy management problems.

3.1. Problem Formulation

The mathematical modelling of renewable sources like WT, PV, FC and Battery are articulated as follows,

3.1.1. Modelling of Photovoltaic (PV)

In RES one of the sources is PV, it can able to occupy the sunlight and directly transform the sunlight into electricity. Based on the solar radiation, output power produced by PV is expressed as follows,

$$p_{PV} = \eta_{PV} \times n \times p_{MPV} \times \frac{g^t}{g_{sc}} \quad (1)$$

Fig 2: Equivalent circuit of PV

From the above equation, the efficiency of comparative units of PV is denoted as η_{PV} , the PV array of output power is expressed as p_{PV} , under standard condition the rated power of PV is expressed as p_{MPV} , the maximum size of PV panels is represented as n , and the faculty of global irradiance of tilted plane is expressed as gt . The equivalent circuit of PV is a figure 2.

3.1.2. Modelling of Wind Turbine (WT)

The WT output power is evaluated through power curve shown at below equation.

$$P_{Wind}(T) = \begin{cases} 0 & v < v_D, v > v_{Co} \\ P_{WG} \left(\frac{v - v_{Ei}}{v_{Rated}} \right)^3 & v_{Ci} \leq v_{Ci} \leq v \leq v_{Rated} \\ P_{Rated} & v_{Rated} \leq v \leq v_{Co} \end{cases} \quad (2)$$

From the above equation (2), the optimum unit of wind power expressed as p_{WG} , then the wind speed, minimum wind speed, cut out and cut in wind speed is expressed as v_{Rated} , v_{cut} and v_{Ci} .

3.1.3. Modelling of Battery Energy Storage System (BESS)

Depending on weather conditions, the energy production of RES is evaluated. To defend the frequency and system voltage for saving the excess power the BESS is employed and the MG system load changes or power production of Res is less means the BESS will provide the power

to the load. The variation of PV and WT was smoothening by the BESS. Compared to the MG system, the load is low while the power is produced by RES then for succeeding usages the extra power will save in BESS. Related to the earlier SOC, generated power of RES and specified overall loads of the system, the energy saved in the BESS at time t which is expressed from below,

$$e_{Bat}(T) = e_{Bat}(T-1) + \left(\frac{e_{RES}(T) - e_{Load}(T)}{\eta_{Dc} / \eta_{Ac}} \right) \times \eta_{Charge} \quad (3)$$

here the efficiency of battery charging is expressed as η_{Charge} , based on RES, the overall energy produced is represented as $e_{RES}(T)$, in the MG system, and the overall provided energy is expressed as e_{Load} .

3.1.4. Constraints

The overall power produced from the DER, the energy saved at BESS and energy exchanged through the grid will fulfill the overall demand for MG. At time t output constraints of DER convey the generated power of each DER which will be in upper and lower bounds of production of power for all kinds of DER. The constraints of DER is described as follows,

$$p_{DER}^{Min} \leq p_{DER}(T) \leq p_{DER}^{Max} \quad (4)$$

The increased and decreased suitable saving ability of BESS in energy storage is expressed as follows,

$$e_{BESS}^{Min} \leq e_{BESS}(T) \leq e_{BESS}^{Max} \quad (5)$$

$$e_{BESS}^{Min} = (1 - DOD) \times e_{BESS}^{Max} \quad (6)$$

From the above equation, the DOD is expressed as the Depth of battery discharge. The overall produced power by DER, energy storage in BESS and the interchanged energy at all time by grid will be fulfill the overall demand of MG.

3.2. Formulations of Objective Function

The main purpose of the work is to reduce the annualized cost of system. The overall cost of the system comprises: replacement cost, overall capital cost, operating cost, power purchasing cost and maintenance cost. In the capital cost the updating cost is also occurred. The cost minimization of the objective function is shown below,

$$\min(c) = [n_{PV}c_{PV} + n_{WT}c_{WT} + p_{FC}c_{FC} + p_{ESS}c_{ESS} - c_{GS} + c_{GP}] \quad (7)$$

here the annualized cost of system is expressed as c , the annual cost of the PV, WT and Fc is represented as c_{PV}, c_{WT}, c_{FC} . The overall cost of electricity is expressed as c_{GS}, c_{GP} . The annualized cost of each element is the capital, operational and replacement cost.

3.2.1. Annualized Cost

The cost of capital of the element comprises the cost of installation and purchase. The annualized cost of all elements like PV, WT and FC which s expressed as follows,

$$c_{C(Cap)}^{AT} = c_{(Cap)}^{AT} CRF(\alpha, \beta) \quad (8)$$

From the above equation, the initial capital cost of WT is expressed as $c_{C(Cap)}^{WT}$.the interest rate is represented as α and the years of life is expressed as β . The measurement of CRF is described as follows,

$$CRF(\alpha, \beta) = \frac{\alpha(1+\alpha)^\beta}{(1+\alpha)^{\beta-1}} \quad (9)$$

Fig 3: Energy Management System with HRES

3.2.2. Annual Replacement Cost

Replacing the WT final life is denoted as annual replacement cost. The overall replacement cost is expressed as follows,

$$c_{c(Rep)}^{AT} = c_{Rep}^{AT} CRF(\alpha, \beta) \frac{1}{(1 + \alpha)^Y} \quad (10)$$

4. Proposed Approach of SBLA-CGO Based on Energy Management System

Based on proposed method is presented in this paper. The present method is the joint implementation of both the Side-Blotched Lizard Algorithm and Chaos Game Optimization and hence it is named as SBLA-CGO method. Here, the MG system contains a Photo-Voltaic (PV) system, Wind Turbine (WT), Battery Storage (BS) and Fuel cell (FC). The required load requirement of grid associated MG system is measured using SBLA method. The exact combination of MG is increased with the load demand condition forecasted using CGO. The energy management system with HIREs is a figure 3. A step-by-step process of the proposed method

4.1. Load demands using SBLA

Step 1: Initialization

The input parameters like PV, WT, FC and battery

Step 2: Random Generation

After the process of initialization arbitrarily create the distributed solutions along lower and upper bounds.

$$\begin{aligned} P[i] \times \text{point } s[j] &= Rand \times (ul - ll) + ll \\ i &= 1, 2, \Lambda, N; j = 1, 2, \Lambda, d \end{aligned} \quad (11)$$

Step 3: Fitness Function

Utilize the below functionality to establish cost reduction.

$$fit = \min [C] \quad (12)$$

Step 4: Subpopulation

Produce the frequencies of subpopulation and for deflect the depletion of morph a less number of population is maintained.

Step 5: Population Changes

Based on the fitness function if the initial population is produced and then the subpopulation colors are dispatched. In the population changes it has many subpopulations which are described as follows,

- ***Delete Function***

If the population of morph interchanged as negative then the algorithm cells delete the function of lizard.

- ***Transform Function***

When the changes in the population of the color with the described population has a positive change and the one affected by it has a negative one the methods conducts the transform lizard function.

- **Add Function**

In one population if there is a positive change in the population index or one is affected and it did not have negative change means the algorithm will add a population function.

Step 6: Termination

After completing the above process the population will give best position and to enhance more values the iterative process will repeat.

4.2. Chaos Game Optimization for MG System

Step 1: The preliminary location of applicant's solution or the previous eligible points on search space is specified in terms of random process of selection approach

Step 2: Previous points are measured to the fitness values of the previous applicant's solution based on self-similarity.

Step 3: Global best process: In this process the maximum stage of qualification is evaluated.

Fig 4: Flowchart of Proposed SBLA-CGO

Step 4: The mean group is evaluated at the search point for the qualification point based on the random process.

Step 5: In the search space for the qualification point with three vertices a transitory triangle is evaluated.

Step 6: The fitness values of the new candidate solution are measured depends on self-compatibility problems.

Step 7: The early qualifying points with poor fitness values equivalent with poor self-similarity levels are replaced through novel seeds.

Step 8: The termination criteria is evaluated.

5. Result and Discussion

The simulation consequences of proposed and other method are evaluated on this section. To reduce the overall cost creation and enlarge PV and WT usage. The proposed system is utilized for optimal operation of the MG. The flowchart of proposed SBLA-CFO is a figure 4. A demand response of MG is assessed from the SBLA application. Moreover, the production cost of MG is reduced by using the CGO method. The proposed method is assessed on MATLAB / Simulink operating system. The analysis of SBLA-CGO system is assessed and compared with other systems like SSA, EFA and CFA. Fig 5 portrays that performance analysis of annual solar irradiance, WT, and load. In subplot (a) shows the analysis of annual solar irradiance. Here the PV flows from 600 to 1000 W/m² at 0 to 9000h time interval. In subplot (b) shows the analysis of annual wind speed. Here the wind speed flows from 0m/s to 15m/s at the time period of 0 to 9000h. In subplot (c) shows the analysis of annual load. Here the load power flows from 0.4kW to 0.8kW at 0 to 9000h time interval. Fig 6 portrays that analysis of CO₂ emission. Here the CO₂ flow maximum from 0 to 6m-kg at scenario 1 and it minimized at scenario 3 and again it

increased at scenario 6. Fig 7 portrays that analysis of energy cost emission. Here the energy cost flows maximum from 0 to 6 m-kg at scenario 1 and it minimized at scenario 3 and again it increased at scenario 6. Fig 8 shows that PV and WT output power units. In subplot (a) shows that output power units of PV. Here the PV flows from 600 to 1000 W/m² at 0 to 9000h time interval. Subplot (b) shows the output power units of WT. Here the WT flows from 0m/s to 15m/s at 0 to 9000h time interval. Fig 9 portrays that output power of fuel cell. Here the fuel cell flows from 600 to 1000 W/m² at 0 to 9000h time interval. Fig 10 shows the variation of energy in battery. Here the battery flows from 0 to 900kWh at 0h and it reduced at 2000 up to 0 to 400kWh time interval. Fig 11 shows the grid connected system of solar energy and purchased energy. Here the solar energy flows from 0 to 900kWh at 0h and it reduced of 2000 up to 0 to 400kWh time interval. Here the purchased energy flows from 0 to 900kW at 0h and it reduced at 2000 up to 0 to 400kW time interval. Fig 12 shows the production of electricity for one day with RES like PV, WT, sell, buy, battery and electrical demand.

Fig 5: Performance of (a) annual solar irradiance (b) annual wind speed (c) annual load

Fig 6: Analysis of Co2 emission

Fig 7: Analysis of energy cost

Fig 8: Output power units of (a) PV (b) WT

Fig 9: Output power of fuel cell

Fig 10: Variation of energy in battery

Fig 11: Grid connected system of (a) Solar energy (b) Purchased energy

Fig 12: Production of electricity for one day with RES

Fig 13: SOC of BESS for one day

Fig 14: Annual emission of Co2

Fig 15: Amount of Fuel Consumption

Fig 16: Peak of load at dissimilar years

Fig 17: Various types of DER units of (a) PV (b) WT (c) Battery

Fig 18: Various types of DER units for fuel cell

Fig 19: Consumption of fuel cell

Fig 20: Comparison of Co2 emission with SBLA-CGO and existing method

Fig 21: Comparison of COE with SBLA-CGO and existing method

Fig 22: SOC of BESS comparison of SBLA-CGO and existing system

Fig 23: Amount of fuel consumption comparison

Fig 24: Fuel cost comparison of SBLA-CGO and existing system

Fig 25: Fitness of proposed method

Fig 26: Fitness of existing GA method

Fig 27: Fitness comparison of SBLA-CGO and existing system

Fig 12 shows that production of electricity for one day with RES. The RES like wind, PV, diesel generator, sell, buy, battery and electrical demand. Fig 13 shows the SOC of BESS for one day. Here the BESS flows from the SOC of 20% to 100% then it reduced up to 20%. Fig 14 shows the annual emission of Co2 for only diesel generator, optimization without battery bank and optimization with battery bank are presented. Here the emission of only diesel generator flows from the maximum emission of 750kg. The emission of optimization without battery bank flows from the maximum emission of 400kg and the emission of optimization with battery bank flows from the maximum emission of 310kg. Fig 15 shows the annual amount of fuel consumption with BESS and without BESS. The annual fuel consumption with BESS ranges from 0 to 1.5 fuel consumption and annual fuel consumption without BESS ranges from 0 to 1.9 fuel consumption. Fig 16 shows the Peak of load at different years. Here the load flows from 1 to 1.7 p.u and at 1.7 p.u the load remains constant at the time period of 10 to 20 years. Fig 17 shows the various types of DER unit of PV, WT and battery. In subplot (a) the several kinds of DER units of PV is presented. PV flows from maximum range of 1002kW. In subplot (b) several kinds of DER units of WT is presented. The WT flows from maximum range of 1002kW. In subplot (c) several kinds of DER units of battery is presented. The battery flows from maximum range of 1002kW.

Fig 18 shows the various types of DER unit of fuel cell is presented. The fuel cell flows from maximum range of 1002kW. Fig 19 shows the consumption of fuel cell. Here the fuel cell of optimal size and only diesel generator is presented. Figure 20 illustrates that comparison of CO₂ emissions with the proposed and existing system. Figure 21 shows the comparison of COE through proposed and existing method. Figure 22 shows a comparison of proposed and existing system. Figure 23 shows the amount of fuel consumption compared to the proposed and existing method. Fig 24 portrays that fuel cost comparison of proposed and existing method. Fig 25 portrays that fitness of proposed system. Fig 26 illustrates that fitness of existing GA system. Fig 27 explains that fitness comparison of proposed and existing system.

Table 1: Statistic investigation of proposed and existing systems

Solution	Mean	Median	SD
SBLA-CGO	1.0946	1.0160	0.1505
SSA	1.3383	1.2569	0.1334
EPA	1.4855	1.3873	0.1493
GA	1.5784	1.4892	0.5883

Table 1 illustrates that statistic investigation of proposed and existing method based on mean, median and standard deviation (SD).

6. Conclusion

In this paper presents the optimal energy management of PV-WT, FC and ESS hybrid energy systems connected to grid using the SBLA-CGO method. The paper evaluates the modelling of the system and the distribution of MG with less effort using proposed SBLA-CGO system. The proposed method finds MG as suggested through load requirement with less fuel cost,

replacement and operation cost. The proposed system assesses for dissimilar load requirement values and describes the MG function related with total annual costs. The efficiency of the proposed system is evaluated using comparison research through other methods like SSA, EFA and GA. The comparison results evaluates that the present method is deeply trained across the other method in the system.

Declaration Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Compliance with Ethical Standards

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Authorship contributions

Mr. T. Logeswaran: *Conceptualization, Methodology, Writing- Original draft preparation.*

Mr. Francis H Shajin: *Supervision*

Mr. Paulthurai Rajesh: *Writing- Reviewing and Editing*

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Figures

Figure 1

Architecture of MG with proposed method

Figure 2

Equivalent circuit of PV

Figure 3

Energy Management System with HRES

Figure 4

Flowchart of Proposed SBLA-CGO

Figure 5

Performance of (a) annual solar irradiance (b) annual wind speed (c) annual load

Figure 6

Analysis of Co2 emission

Figure 7

Analysis of energy cost

(a)

(b)

Figure 8

Output power units of (a) PV (b) WT

Figure 9

Output power of fuel cell

Figure 10

Variation of energy in battery

Figure 11

Grid connected system of (a) Solar energy (b) Purchased energy

Figure 12

Production of electricity for one day with RES

Figure 13

SOC of BESS for one day

Figure 14

Annual emission of Co2

Figure 15

Amount of Fuel Consumption

Figure 16

Peak of load at dissimilar years

(a)

(b)

(c)

Figure 17

Various types of DER units of (a) PV (b) WT (c) Battery

Figure 18

Various types of DER units for fuel cell

Figure 19

Consumption of fuel cell

Figure 20

Comparison of Co2 emission with SBLA-CGO and existing method

Figure 21

Comparison of COE with SBLA-CGO and existing method

Figure 22

SOC of BESS comparison of SBLA-CGO and existing system

Figure 23

Amount of fuel consumption comparison

Figure 24

Fuel cost comparison of SBLA-CGO and existing system

Figure 25

Fitness of proposed method

Figure 26

Fitness of existing GA method

Figure 27

Fitness comparison of SBLA-CGO and existing system