Load Factor Optimization with Different Algorithm

Mazharul Sharker, Anika Tun Naziba, Manika Tun Nafisa, and Abu Hena MD Shatil

Abstract—The energy is obtained to the primary and secondary substations during high demand, using dynamic weight-based load. The shifting algorithms minimize demand by shifting the load, maximizing utilization and enhancing load factor efficiency by distributing loads over various time frames. Maintaining stable demand and increasing users' consumption is a cost-effective way of increasing output while maximizing the usage of electricity. The load factor would improve in both cases and, thus, reduce the average unit cost per kWh. The main factors in establishing the theory of optimal energy usage are high energy use and the depletion of established energy resources. The existing algebraic theory model approach is incapable of properly optimizing the load factor for a large distribution network, resulting in excessive load energy consumption. To solve this issue, this article proposes many load factor optimization methods. The trend of the grid's load curve is studied in order to achieve the grid's optimum load factor management under various situations. The simulation findings indicate that the Genetic Algorithm approach performs better in terms of control performance and accuracy while optimizing load factors.

Keywords—Load factor, bisection algorithm, cubic algorithm, genetic algorithm, PSO algorithm, average power, peak power.

I. Introduction

DIFFERENT types of rotating transmission components in the transmission system accomplish load or torque transmission. Tooth pairs, which are taken into consideration here, are one of the potential methods of load transmission. In general cases, on teeth and teeth surfaces that are currently in mesh Gear meshing during load transmission, distinguished by non-uniform distribution of load [1-3]. It seems that it is

M. Sarker is with the Department of Electrical and Electronic Engineering, American International University Bangladesh, Dhaka (e-mail: *darkhorsegins7@gmail.com*).
A. T. Naziba is with the Department of Electrical and Electronic Engineering, American International University Bangladesh, Dhaka (e-mail: *anikanaziba9@gmail.com*).
M. T. Nafisa is with the Department of Electrical and Electronic Engineering, American International University Bangladesh, Dhaka (e-mail: *nafisamanika@gmail.com*).
A. H. M. Shatil is with the Department of Electrical and Electronic Engineering, American International University Bangladesh, Dhaka (e-mail: *abu.shatil@aiub.edu*).

very important in this field to optimize the methods of energy consumption and production, especially in the plants and factories, electrical energy, household sector and also the fact where also involved in the same issues. In order to make easy about the procedure of the fact, there are a lot of researchers prefer to use of the way called linear assumptions, but this fact can be discussed as a linear or non-linear optimization issue [4-5].

II. Calculation Different Load Parameters

A. Load Factor

Here, Daily Load factor is given below,

Daily Load Factor = Total kWh in 24 hours/(Peak Load in kW×24 Hours)

Similarly, Weekly, Monthly and Yearly Load Factors can be obtained.

For example, daily consumption is 18000 kWh and peak demand is 50 kW, then daily Load Factor is can be calculated as follows:

Load Factor = 18000 kWh/(50 kW×30×24 h) = 0.5 or 50%

Here, the 50% Load Factor shows that the daily consumption was 50% of the total energy available for use at peak demand of 50 kW.
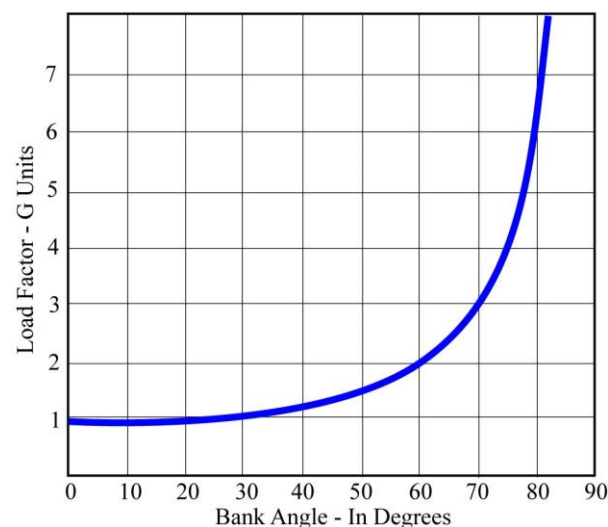

Fig. 1. Graph of load factor chart

B. Load Demand

The load factor is determined by dividing the number of kilowatt-hours (kWh) used during a given period by the kilowatt-hours (kWh) spent by the device with the greatest or maximum demand in kilowatts (kW) and the number of hours consumed by the device during that time [7-10]. The majority of industrial and residential electricity tariffs are made up of three fundamental facts:

- A total kWh charge for the consumed
- A power factor charge
- A maximum kW demand charge

In many of countries in this world, there are a lot of tariff variations for the industrial and household sector, such as low voltage, medium and high voltage tariffs also the period that is used to about these three types of voltage [2]. Usually, between 18 hours and 22 hours is the peak hour for these tariffs, while it is noticed that the off-peak duration is in between 22 hours and 6 hours. There are also a casual periods of in between 6 hours to 18 hours [6].
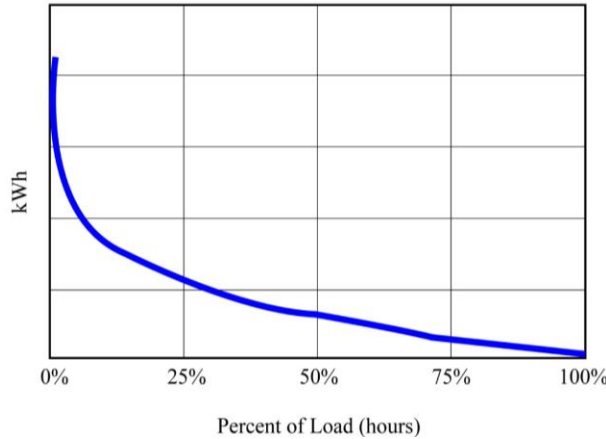

Fig. 2. Load duration curve

C. Load Parameter

The annual energy consumption or the annual purchase of energy is proportional to the duration of the load and the curve is shown in Fig. 2, and the load curves (shown in Fig. 3) are directly dependent on the load factor [1, 3, 14].

The parameters of this model are defined as follows:

P = Total Power Consumption Variable

$H_{(P)}$ = Time Utilization Function for Load Duration Curve (LDC)

P_{max} = Maximum Peak Consumed Power for LDC

P_{min} = Minimum Peak Consumed Power for LDC

h_m = Number of Hours for a Specified Period (e.g., for a year this will be 8760)

In accordance with the above curve $H_{(P)}$ will be as follows generally:

$$H_{(P)} = \begin{cases} h_m & \text{if } 0 < P < P_{min} \\ h_{0\,(P)} & \text{if } P_{min} < P < P_{max} \\ 0 & \text{if } P > P_{max} \end{cases} \tag{1}$$
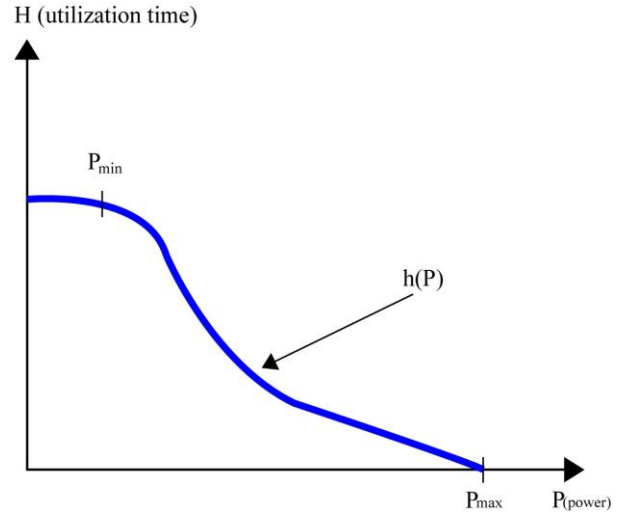

Fig. 3. Time utilization versus maximum peak power consumption for load duration curve

If assume that the utilization time is h_t and the result is:

$$P_{max} \cdot h_t = E_t \tag{2}$$

Also,

$$E_t = \int_0^{P_{max}} H_{(P)} dp \tag{3}$$

,which means the total consumed energy or the area is under the LDC curve.

Merging the equation (2) and (3) results the following equation:

$$h_t = \frac{E_t}{P_{max}} = \frac{1}{P_{max}} \int_0^{P_{max}} H_{(P)} dp \tag{4}$$

Analysing this equation shows that h_t equals the average of the function, $h_{(P)}$. Now assuming that 'a' is a parameter that represents the energy demand charges and 'b' represents the energy costs and for utilization time 'h_t' the interest of the consumed power (k_0) will be:

$$k_0 = aP_{max} + bE_t = P_{max}(a + bh_t) \tag{5}$$

Also the average price per KWh will be:

$$v(h_i) = k_m = \frac{P_{max}(a + bh_t)}{E_t} = \frac{a + bh_t}{h_t} \tag{6}$$

$$k = \frac{a}{h_t} + b$$

As the function $H_{(P)}$ does not exist in the current LDC, it is necessary to approximate it using numerical analysis models. This is accomplished by considering the linear curve shown in the following picture. The load

factor is defined as the ratio of load during a certain period of time to the highest demand, which is the peak load demand during that period. In other words, load factor is the ratio of electricity used during a certain time period to the highest load experienced during that time period [15, 16].
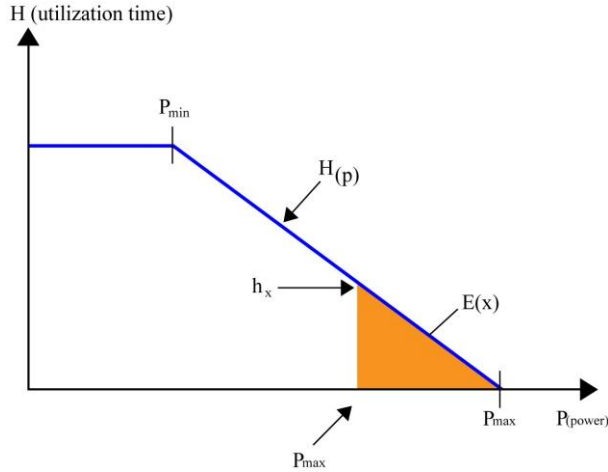

Fig. 4.   Utilization Time Versus Power Curve

Here the load factor equation,
Load Factor = (Average energy)/(Maximum energy)
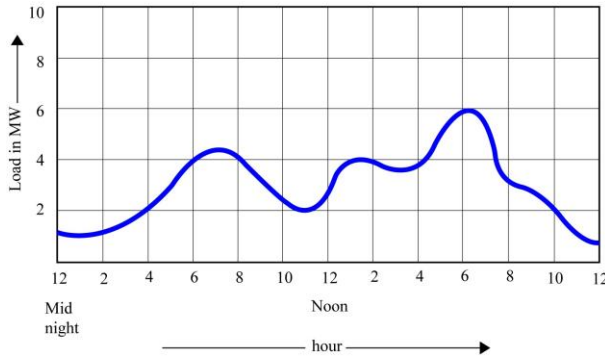Load Factor = (Energy produced in the particular time)/(Maximum Load×Hours of Operation)

Fig. 5.   Load on Different Time Period

III.   DIFFERENT ALGORITHMS

A.   Algorithm for Bisection Method

Step 1: Given P_{max}, P_{min}, ε, and Δx
Step 2: Compute $\alpha = (P_{max}+P_{min})/2$, $f(a)$ and $f(\alpha)$
If $f'(a) f'(\alpha) < 0$
    then $b = \alpha$
    else $a = \alpha$
If $|a - b| > \varepsilon$
    then go to Step 2
    else go to Step 3
Step 3: Converged. Print $x^* = a$, $f(x^*) = f(a)$

B.   Algorithm for Cubic Polynomial Fit

Step 1: Given x, ε, and Δx
Step 2: Compute $\alpha = (P_{max}+P_{min})/2$, $f'(a)$ and $f'(\alpha)$
If $f'(a) f'(\alpha) < 0$
    then $b = \alpha$
    else $a = \alpha$
Step 3: Repeat Step 2 until $f'(a) f'(\alpha) < 0$
Step 4: Using $f(a), f'(a), f(b), f'(b)$, compute μ, z, and w
Step 5: Compute x
If $f\_(x) < \_$ go to Step 6
If $f\_(a)\_f\_(x) < 0$
    then $b = x$
    else $a = x$
    go to Step 4
Step 6: Converged. Print $x^* = x, f(x^*) = f(x)$

where,

$$\mu = \frac{f'(x_2)+w-z}{f'(x_2)-f'(x_1)+2w} \qquad (7)$$

$$z = \frac{3\{f(x_2)-f(x_1)\}}{x_2-x_1} + f'(x_1) + f'(x_2) \qquad (8)$$

$$w = \frac{x_2-x_1}{|x_2-x_1|} + \sqrt{z^2} - \sqrt{f'(x_1) + f'(x_2)} \qquad (9)$$

C.   Genetic Algorithm Flow Chart

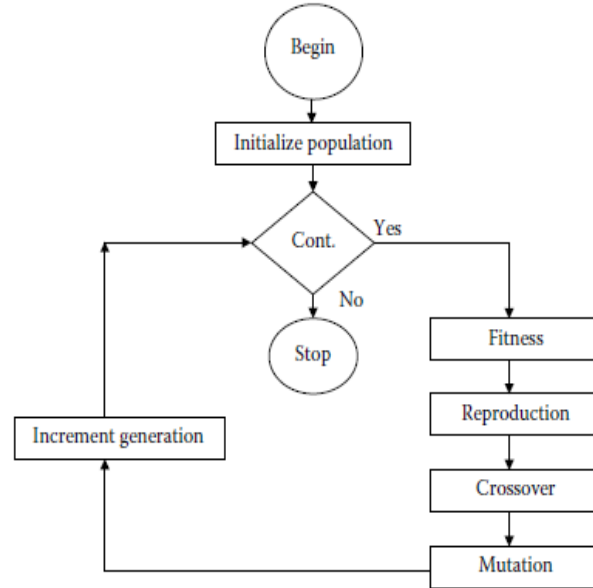The flow chart of the Genetic Algorithm is given in Fig. 6.

Fig. 6. Flow chart of the Genetic Algorithm

D.   Algorithm for Particle Swarm Optimization

Step 1: Initialize $i$max, $w1$, $\phi1$, $\phi2$, n (population size), x_i,min, and x_i,max.
Step 2: Initialize the starting position and velocities of the variables as
$x_i,k = x_i,\text{min} + (x_i,\text{max} - x_i,\text{min})u_i$ $k = 1 \cdots n$, $v_i,k = 0$

30

Step 3: Compute $p_i,k = f(x_i,k)$ $k = 1 \cdots n$

Step 4: Compute $pbest_{i,k} = p_{i,k}$ and $gbest_i =$ minimum ($pbest_{i,k}$)

The location of $pbestk$ and $gbest$ is given by $pxik$ and gix.

Step 5: Update velocity

$$v_{i+1},k = w_1vi,k + \phi_1(px_{ik} - x_{i,k})u_i + \phi_2(g_{ix} - x_{i,k})u_i$$

Step 6: Update position $x_{i+1},k = x_{i,k} + v_{i+1,k}$

Step 7: Update fitness $p_{i+1,k} = f(x_{i+1,k})$

Step 8: If $p_{i+1,k} < pbest_{i,k}$

then $pbest_{i+1,k} = p_{i+1,k}$

Step 9: Update $gbest_{i+1} =$ minimum($pbest_{i+1,k}$)

Step 10: If $i < i_{max}$

then increment i and go to Step 5,

else stop.

IV. METHODOLOGY

The Binary search method or the Dichotomy method or also the interval halving method is known as the bisection method. For continuous functions the bisection method is based on the Bolzano's theorem. The value of g for which the plot is crossing the x-axis is the root of the equation $f(g) = 0$.

Based on the cubic content of a building the calculating of the cube method is a single rate estimation method. For household activities, the cost per cubic meter method is exact. It means to resolve the current critical floor area method that does not take into consideration potential differences in the height of the store [7-10].

Let us consider Average Power of a system which varies to 650 or 750 MW.

Peak Power of Machine is 1000 MW

Load Factor = ?

The method is,

LF = (Average Power/Peak Power)×100%

Values taken are,

$a = 62.5$

$b = 70$

Function is,

$f(x) = (x/1000) * 100;$

The result of bisection and cubic method is given below:

TABLE I
PEAK POWER OF LOAD FACTOR USING BISECTION AND CUBIC METHODS

List of Variable	Bisection Method	Cubic Method
Peak Power	1000 MW	1000 MW
Load Factor	6.999	7

These two techniques are used to determine the system's minimal load factor. A greater load factor is preferable, while a low load factor indicates that power usage is wasteful when compared to peak demand management. Consumers may continue to consume the same amount of power month after month while lowering their average cost per unit (kWh) by decreasing peak demand, since load factor reflects real energy usage against peak demand [11-15].

V. RESULT ANALYSIS AND DISCUSSIONS

Optimization terminated average change in the fitness value less than option.

TABLE II
GENETIC ALGORITHM SOLVER SIMULATION PROPERTIES

Genetic Algorithm Solver Simulation Properties	First Iteration	Second Iteration	Third Iteration
Stopped in	1021	1021	1021
Final Time of Process	129 sec	131 sec	114 sec
Convergence	yes	yes	yes
Stopping criteria	Stall Generations	Stall Generations	Stall Generations
Stall generation	910	913	914
Stall Time	19 sec	20 sec	20 sec

(a)

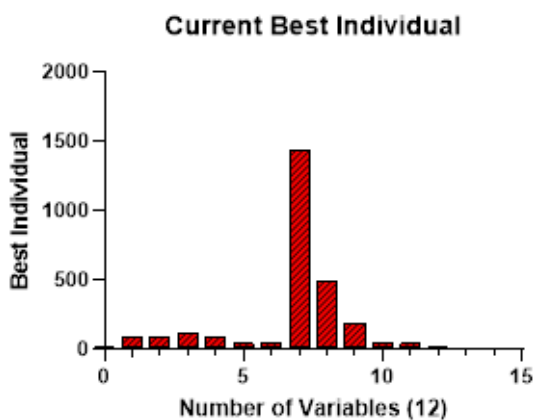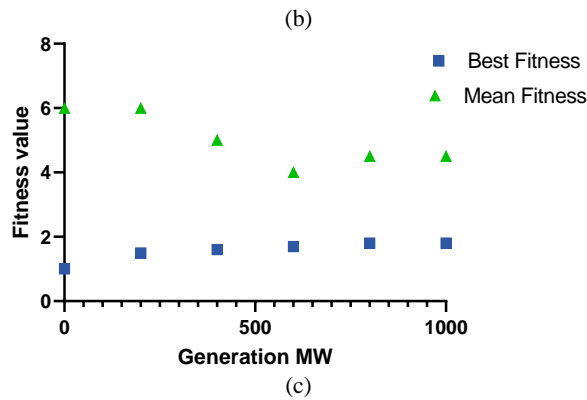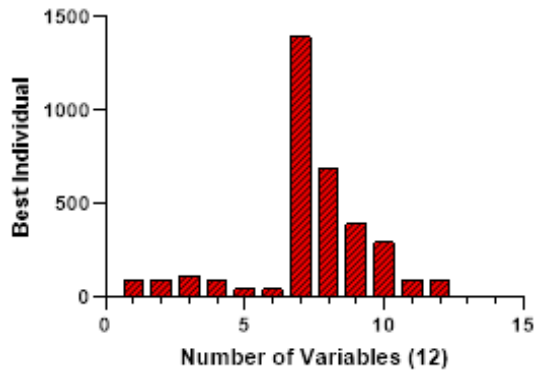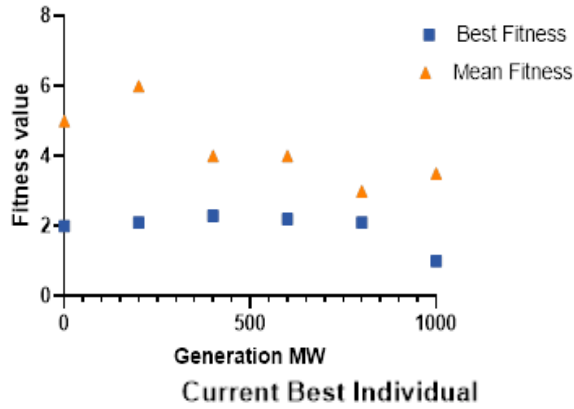**Current Best Individual**

(b)

(c)

Current Best Individual
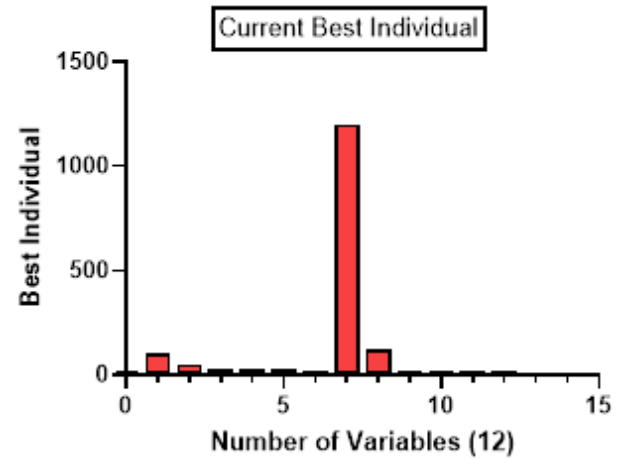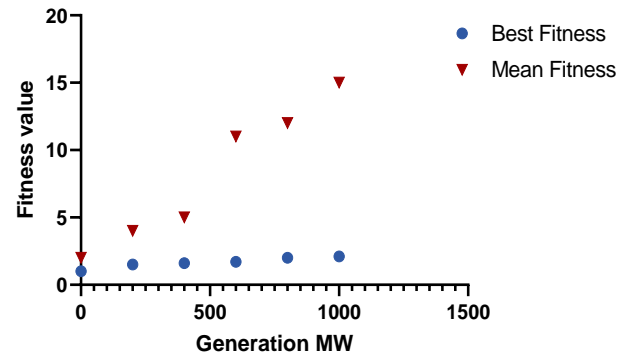
Fig. 7. Convergence for Genetic Algorithm in generations at
(a) Best fitness: 2.451e-005, Mean fitness: 0.001077
(b) Best fitness: 3.242e-007, Mean fitness: 0.0061845
(c) Best fitness: 5.7493e-007, Mean fitness: 0.0020403

TABLE III
OPTIMIZED PEAK POWER AND LOAD FACTOR OUTPUT USING
GENETIC ALGORITHM AND PSO ALGORITHM

List of Variables	Genetic Algorithm	PSO Algorithm
Peak Power	1000 MW	1000 MW
Load Factor	6.936460463	6.209722447

As far as time-of-use prices are concerned, the load factor must be measured differently. There are separate On-Peak and Off-Peak periods for TOU prices that must be separately measured. The only modifications here are:

• Understanding how many hours are on-peak and the kilowatt-hours used during this time during the billing period.

• During the billing period, the off-peak hours and the kWh used during that time.

It is also possible to determine the maximum load factor of a system with the help of the bisection method and the cubic method.

Now the similarities between algorithms are given in Table IV.

TABLE IV
SIMILARITY BETWEEN ALGORITHMS

List of Algorithms	Number of function evaluations to find optimum load factor	Sluggishness towards converging optimum point %
Bisection	58	25%
Cubic Polynomial Fit	52	26%
Genetic Algorithm	38	2%
Particle Swarm	40	8%

It is always desirable to have a higher low load factor. For any consumer, commercial or industrial, reducing their peak demand would be the first step in improving the load factor and, as a result, reducing the amount of the energy bill.

Another method to increase the load factor is to analyze past energy bills and identify high consumption times, such as summer. Make required adjustments to ensure that all high-wattage cooling equipment is not operating concurrently but is planned for optimal peak use distribution [16].

VI. CONCLUSION

Within four algorithm comparing in Table IV, Bisection and Cubic polynomial shows sluggishness towards the optimum value. When it comes near to convergence, they start to fluctuate. The same can be assumed true near the vicinity of the optimum point. However, if the initial starting point is far away from

the optimum, the search direction may not always be descent. Often a restart is required with a different starting point to avoid this difficulty. Though the PSO method is known for converging in a single iteration for a quadratic function, the Genetic Algorithm (GA) method does not show sluggishness in reaching the optimum point. Compared to the number of function evaluation, bisection and cubic method required large time to complete the function. PSO and Genetic Algorithm required almost similar number of steps to reach convergence. If the starting search point is near to the optimum convergence point, PSO may require less time than GA. With less number of evaluations and less sluggishness value, GA is complete solution for load factor optimization.

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Mazharul Sharker finished his MSc in Electrical and Electronic Engineering (EEE) from American International University Bangladesh (AIUB). His areas of interests are renewable energy, power systems, and energy system.

Anika Tun Naziba finished her MSc in Electrical and Electronic Engineering (EEE) from American International University Bangladesh (AIUB). Her areas of interests are renewable energy and power electronics.

Manika Tun Nafisa finished her MSc in Electrical and Electronic Engineering (EEE) from American International University Bangladesh (AIUB). Her areas of interests are renewable energy and power system management.

Abu Hena MD Shatil is an Assistant Professor of the Department of Electrical and Electronic Engineering (EEE) at American International University Bangladesh (AIUB). His work focuses specifically on the Energy modelling and their impact on society. He obtained his Postgraduate degree in Electrical Energy Systems from Cardiff University, UK.