An Optimal Energy Management System for Electric Vehicles using Firefly Optimization Algorithm based Dynamic EDF Scheduling

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Abstract—Mitigation of global warming gases from burning gasoline for transportation in vehicles is one of the biggest and most complex issues the world has ever faced. In an intention to eradicate the environmental crisis caused due to global warming, electric vehicles were been introduced that are powered by electric motor which works on the energy stored in a battery pack. Inspired by the research on power management in electric vehicles, this paper focuses on the development of an energy management system for electric vehicles (EMSEV) to optimally balance the energy from battery pack. The proposed methodology uses firefly optimization algorithm to optimize the power consumption of the devices like electric motor, power steering, air conditioner, power window, automatic door locks, radio, speaker, horn, wiper, GPS, internal and external lights etc., from the battery in electric vehicles. Depending upon the distance to cover and the battery availability, the devices are made to switch down automatically through dynamic EDF scheduling. CAN protocol is used for effective communication between the devices and the controller. Simulation results are obtained using MATLAB.

Keyword - Energy management system (EMS), electric Vehicles (EV), Dynamic EDF scheduling, Firefly optimization algorithm.

I. INTRODUCTION

Majority of 1 billion passenger vehicles worldwide are powered by fuel that is obtained from crude oil. By 2020 this number will have increased to 1.2 billion. In India, about 90 lakh liters of petrol and 4 lakh 50 thousand liters of diesel is consumed annually to meet the country’s transportation needs [1]. Energy derived from fossil fuels is the leading cause of greenhouse gas emissions which leads to serious impact on people and ecosystem around the globe. Automobiles are one of the major causes for global warming that has a devastating impact on the planet’s environment [1]. Henceforth, Electric vehicles have gained much interest in the decades from automobile manufacturers and many researchers due to its efficacy in energy saving and emission reduction. In an intention to mitigate the emission of global warming gases which will have a drastic change in the environment in the next 40 years, electric vehicles are being stationed as the next biggest rebellion in today’s automobile technology.

Electric vehicles contribute much to the nation in reducing the impact of global warming. The real importance of energy is realized only if it gets reduced. Therefore there is a requirement of energy management system for battery in electric vehicles so to make an optimal and wise use of energy from the battery. An EV’S excellent energy economy comes not only from it extended energy storage, but also from the energy management control strategy. In general, the energy management system aims in minimizing the power consumption while operating within the system without compromising the driving compatibility. Battery plays a very predominant role in EV, as it has a large impact on the acceleration of the vehicle and functioning of the devices like electric motor, power steering, air conditioner, power window, automatic door locks, radio, speaker, horn, wiper, GPS etc., Therefore there is a requirement for energy management system in electric vehicles, so as to optimally balance the battery pack for the functioning of the devices in the vehicle.

II. RELATED WORK

Today, the need for energy management system has become crucial in electric vehicles as they are powered exclusively by electricity [2]. Improving energy management in EV will result in benefits such as reducing power consumption, lowering vehicle running cost, minimizing noise pollution, increasing life span of the battery, optimizing the power of battery, improving driving performance and ease of use [3]. In the literature, various EMSs are been developed for electric vehicles. They are classified into “rule based” and "optimization based" [4]. In [5], authors have used particle swarm optimization technique to optimize the power within the battery depending upon the speed of the vehicle, temperature and the time to reach the destination.

In [6], authors have proposed a novel trip oriented energy consumption preplanned method using driving pattern based dynamic programming.. In [7], authors of this paper have proposed real time energy management system for plug in hybrid electric vehicles using fuzzy logic and MPPT algorithm. By knowing the arrival and departure time of the vehicle and the state of charge available when the vehicle arrives the charging park, it is charged accordingly.

In this paper, an optimal energy management system for electric vehicles is been proposed which is achieved by dynamic scheduling. Depending upon the availability of battery power, the devices are made to switch OFF automatically based on the allocated priority. Through this process, the battery power is made used efficiently and optimally. The contribution can be summarized as follows:

1).To optimize the power consumed by the devices in an electric vehicle, by keeping track on the power consumed by the devices using firefly algorithm.

2). Dynamic EDF scheduling is used to schedule the task, to automatically switch off the lower priority devices depending upon the battery availability and the distance to cover, so as to make an optimal use power from the battery

III. ENERGY MANAGEMENT SYSTEM

There is a necessity of battery power for the operation of all the components in an electric vehicle as it solely depends on battery. This paper focuses on how to manage the energy from the battery and to make use optimally. EMS in electric vehicles is achieved through dynamic EDF scheduling. Firefly optimization algorithm incorporating the dynamic EDF scheduling is used in achieving the objective of this thesis.

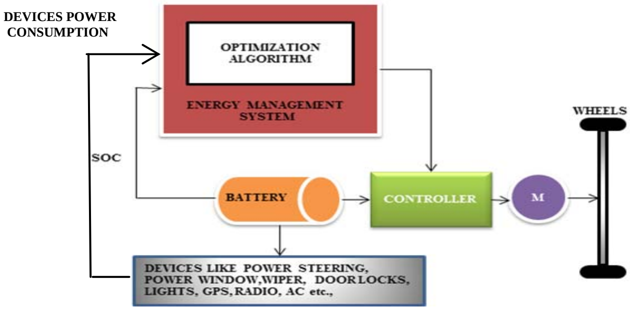

Fig.1. Energy management system.

The ultimate source for the functioning of the devices is the battery. Obviously there will be a reduction in the battery power as these devices consume power when the vehicle is in motion. To bring an efficient EM in electric vehicles there is a necessity on the foreknowledge on the power consumption of the devices. State of charge (SOC) in the battery is to be known as it is also one of the input to the controller to make decision on what all devices shall made ON using scheduling.

1) BATTERY

Battery is used for powering an electric vehicle. Performance of the vehicle gets reduced, if the battery is completely drained off without charge. Figure 2 shows the devices that draw power from the battery. Although battery monitoring system is available in EV, they just monitor the status of energy in the battery and not optimize the power consumption. This project aims in optimizing the power that is consumed from battery for the operation of entire devices in the vehicle.

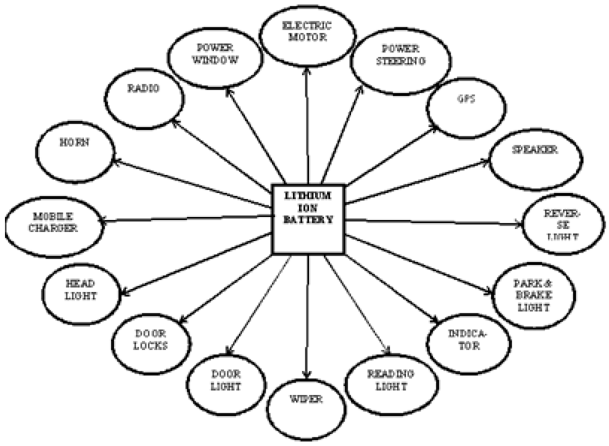

Fig.2. Devices that draw power from battery in an electric vehicle.

The state of charge in the battery is obtained by knowing the current and voltage reading of the devices in the vehicle. The state of charge in the battery is estimated through the following relationship:

$$SOE(t) = SOE(t0)\int_{t0}^{t}(P_e + P_d)dt$$

Where P_e is the instantaneous power delivered from the battery to the electric motor and P_d is the power drawn by the devices in the vehicle which is shown in table 1. "t" represents the time period that the devices are functioning.

2) POWER CONSUMING DEVICES

Since battery electric vehicles are powered by electric motor that runs on the energy stored in a battery for vehicle propulsion, almost all the devices in an electric vehicle depends on battery power for its operation as it does not indulge the concept of internal combustion engine. Figure 3 shows the diagrammatic representation on the various devices that consume power from the battery for its operation in an electric vehicle. A model is made assuming to be car and the components that are marked in the figure is concentrated in scheduling.

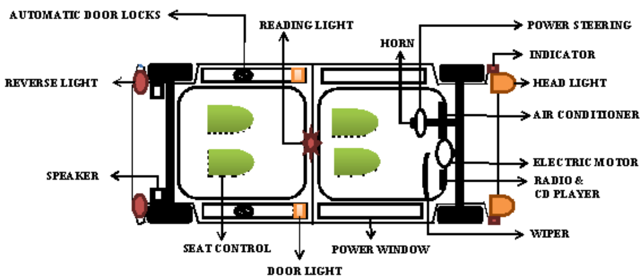

Fig.3. Components in electric vehicle

IV. PROPOSED METHODOLOGY

1) SYSTEM DESIGN

The system module consists of a number of devices that draw power from the battery. Based on the consumption of the devices, they are scheduled using dynamic EDF scheduling. Depending upon the battery availability and the distance to cover, scheduling is carried in such a way to switch off the devices accordingly. Energy optimization is carried out using fire fly algorithm which helps in optimizing the energy consumed by the devices from the battery. The prior knowledge about the amount of power drawn by the devices helps in finding the amount of energy that is persisted within the battery. The optimization algorithm is thus used so as to track the energy consumed by each device from the battery and also to optimize it accordingly using dynamic EDF scheduling. The overall system design is shown in figure4.

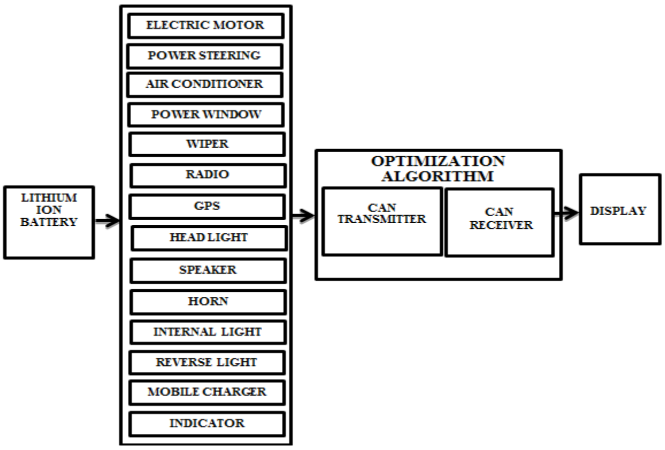

Fig.4. Overall system block diagram

2) FIRE FLYOPTIMIZATION ALGORITHM

The fireflies are a unique kind of species which produce short and rhythmic flashes. The flashing light is produced by a process of bioluminescence [10]. Using such flashes they attract their mating partners. Light Intensity "I" of a firefly for a particular location "X" can be denoted as:

$$I(x)\alpha f(x) ----(I)$$

Attractiveness (β) is judged by other fireflies. The light intensity I(r) varies according to inverse square law.

$$I(r) = \frac{Is}{r^2} ----(II)$$

Where "Is" denotes the intensity at source and r denotes the distance. The light intensity I decrease as the square of the distance r increases. The idealized behavior of the flashing characteristics of fireflies are:

1. Fireflies are unisexual.
2. Less bright firefly starts moving toward the brighter one. If none is brighter, it moves randomly.
3. Brightness of the firefly denotes the objective function.

The optimization of energy in electric vehicles is carried out using the firefly algorithm in a sequence as shown in the flowchart in fig 5.

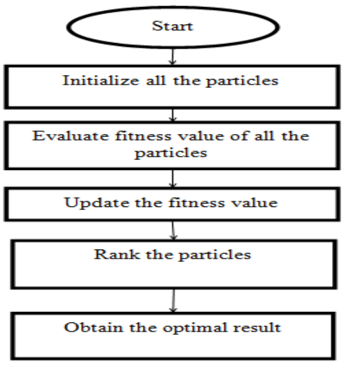

Fig.5. Flowchart of firefly algorithm

2.1) INITIALIZE ALL THE PARTICLES

The devices in an electric vehicle are initialized in such a fashion as shown in table 1by allocating identifier for each devices ranging from 1 to 15. Optimization and scheduling are performed with respect to these values as initialized. The devices like Electric motor, power steering, door locks, horn, head light and wiper are allocated with priority 1 as they are mandatory whenever the vehicle is functioning. Head light and wiper are also mandatory during night. Similarly, devices like AC, GPS, power window, indicator and reverse lights are allocated with priority 2 as these are less required compared to the priority 1 devices. Finally, devices like radio, speaker, mobile charger, and reading light are allocated with priority 3 as these devices are not such important when the battery power is decreased. People can stay without the lower priority devices as the user gives preference in reaching the destination than to be reached sophisticatedly when he has struck in a situation where only a quantum of energy can be used to reach the destination. Table 3 shows the list of devices along with the priority allocation for each device.

TABLE I. Initialization of the devices with their corresponding current and voltage values along with priority allocation.

UNIT NO	DEVICES	POWER (W)	VOLT (V)	I (Amps)	DEVICE PRIORITY
01	'Electric motor '	15	4.5	3.33	1
02	'Power steering'	15	3.5	4.2	1
03	'Door locks'	13	1.3	10.0	1
04	'Horn'	12	0.6	20.0	1
05	'Head light'	18	1.2	15.0	1
06	'Wiper'	20	2.0	10.0	1
07	'AC'	25	2.1	11.8	2
08	'Radio'	20	2.0	11.0	3
09	'GPS'	10	12.0	8.3	2
10	'Speaker'	20	2.0	11.0	3
11	'Power window'	15	1.5	11.0	2
12	'Mobile charger'	0.01	5.0	0.4	3
13	'Reading light'	10	5.2	2.1	3
14	'Indicator'	18	1.8	10.0	2
15	'Reverse light'	18	1.8	10.0	2

INITIALIZATION OF 3 MODES OF OPERATION

Three different conditions such as day, night and raining condition are initialized by allocating modes like 0, 1, 2 for each mode. Table 4 shows the modes allocated for each condition.

Day condition: (mode 0)

- During day time there is a necessity that devices like electric motor, power steering, door locks and horn is mandatory.

Night condition: (mode 1)

- Devices like electric motor, power steering, door locks, horn and head light are mandatory during night time.

Raining condition: (mode 2)

- Devices like electric motor, power steering, door locks, horn, head light and wiper are mandatory during the time of rain.

INITIALIZATION OF CONSTRAINTS

The distance to cover, maximum energy in the battery, and availability of energy in the battery are initialized. For example: Assume, the distance to reach the destination is of 50 Km, the motor runs at the speed of 100 Km/ hour, maximum storable energy in the battery is 1000 watts, available energy in the battery is 100 watts. The values that are mentioned keep varying as the distance and battery availability varies. Depending upon the availability of battery and distance to cover, dynamic scheduling is performed.

2.2) EVALUATE FITNESS VALUE OF ALL THE PARTICLES

To obtain the fitness value, the number of agents and the number of iterations are given as 10. Using 3 different conditions the fitness value is gained.

MODE 1: DAY

In step 1, three modes of operation is been initialized namely day, night and raining conditions. Devices such as electric motor, power steering, door locks and horn are mandatory during day time. Apart from these 4 devices the remaining are switched ON according to the availability of battery power. It has been programmed that wiper and head light are supposed to be in OFF state at day time. Remaining all the devices are set be ON. Depending upon the availability of battery power, the loop checks whether the first priority devices shall be in ON state. If still more power is available in the battery then it gives preference to the second priority devices. Similarly it gives next preference to the third priority devices if the battery power is still available. Therefore the loop executes and comes out with the result on what all devices shall be in ON and OFF states respectively. Similarly the scheduling takes place for night and rain modes respectively.

2.3) UPDATE THE FITNESS VALUE

The fitness value is thus obtained for each agents and iterations. The power values of the devices that are in ON state are added for all the agents in 10 iterations.

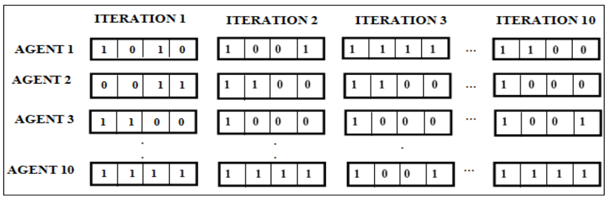

Fig.6.Relationship between iteration and agent.

2.4) RANK THE PARTICLES

In firefly algorithm the best value is obtained by comparing the parameters among each other so that the final best value is thus obtained. The X value is obtained for each agent in all iteration. The reduced power value is taken as the best value. For each iteration there exists a best value (minimum power consumption agent). All the iterations are compared each other. First iterations is compared with the next iteration. The best value is compared with the next iteration. Similarly, the process continues till 10 iterations until the best value is obtained. Finally the best value is thus found and updated.

3) CAN CONTROL SYSTEM DESIGN

To create CAN communication certain procedure has to be followed to transmit and receive the data accordingly which is shown in figure 7 and 8. The power consumed by the devices in the vehicle is being sent to the controller to monitor and to manage the energy consumed by the devices. Optimization of the energy is made possible through dynamic EDF scheduling in firefly algorithm. Table II shows the syntax for enabling CAN transmission and reception in Matlab.

TABLE II. Syntax for creating CAN communication

STEPS	SYNTAX
Create a can channel	canch = canChannel('Vendor name' , 'device name', channel number);
Configure channel properties	get(txCh) for transmitter and get(rxCh) for receiver
Start configured channel	Start(txch1)
Build the message	messageout = canMessage(ID number, extended / standard, datalength);
Pack message with data	pack(message, value, startbit, signalsize)
Transmit the message	transmit(canch, message)
Receive the message	message = receive(canch, messagesrequested)
Unpack the message	value = unpack(message, startbit, signalsize, byteorder, datatype)
Disconnecting channels	stop (TxCh, RxCh);

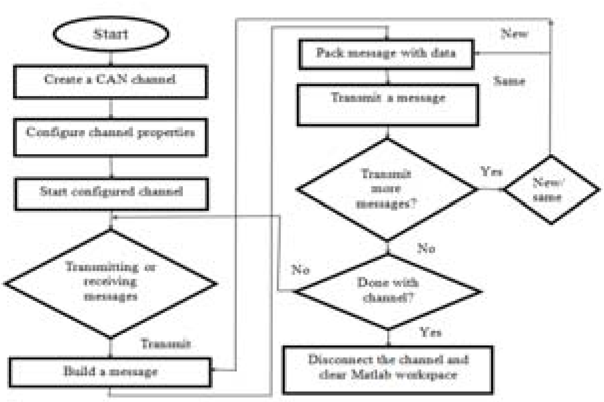

Fig.7.Flowchart for transmission of data through CAN protocol

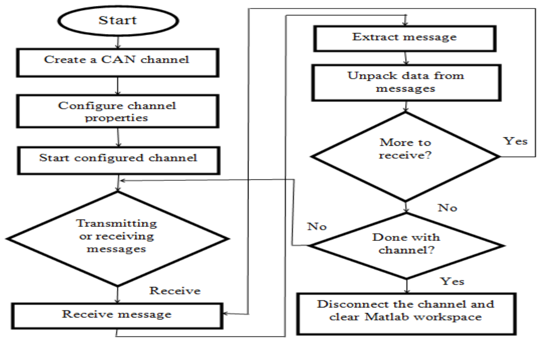

Fig.8.Flowchart for reception of data through CAN protocol

V. RESULTS AND DISCUSSION

The results are obtained as per the conditions which are specified for device scheduling. Based upon the initialization strategy, the devices are made to schedule themselves accordingly. The conditions like initialization of the devices with its identifier, initialization on the power consumption of the devices with its corresponding priority, initialization of the three different modes (day night and rain) are discussed in section 4. Based on these constraints the algorithm and scheduling is designed.

5.1) Result of optimization algorithm for day time

The devices like electric motor power steering door locks and horn are the devices that are mandatory during the day time. Except these four devices remaining all the devices are scheduled depending upon the distance to travel and the battery availability. The scheduling for these devices is made for all the ten iterations and agents respectively. The best value (lowest power consumption) is chosen by comparing all the 10 iteration values. The iteration takes place in a manner as shown below.

Table III shows the conditions on the distance to cover and the battery availability.

TABLE III. Conditions for day mode

CONDITION NO.	CONDITION
1	➢ Distance to cover = 100, Battery availability = 273
2	➢ Distance to cover = 50, Battery availability = 73

The first condition is **Distance to cover = 100, Battery availability = 250.** As per the constraints stated in section B, the scheduling takes place accordingly. Devices like electric motor, power steering, door locks and horn made to be ON always as these devices are essential during day time. Remaining all the devices get scheduled based on the following condition (rand.* high (j) – (low (j) + low (j)). This condition is checked for each agent in all the ten iterations and the best value is thus chosen through the loop that is created to compare the devices power consumption among the iterations.

$(rand.*high(j)-(low(j)+low(j)))$ Where high (j) = highest power consumption value in the agent.
Low (j) = lowest power consumption value in the agent.

OUTPUT FOR DAY MODE

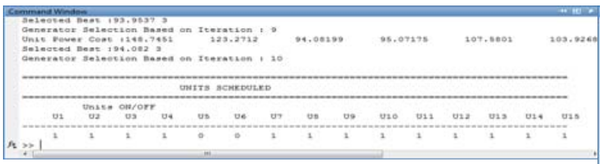

Fig.9. Result of first condition for day mode

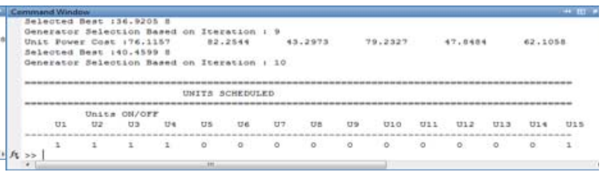

Fig.10. Result of second condition for day mode

5.2) Result of optimization algorithm for raining mode

The devices like electric motor power steering, door locks, horn, head light and wiper are the devices that are mandatory during the time of rain. Except these six devices remaining all the devices are scheduled depending upon the distance to travel and the battery availability. The scheduling for these devices is made for all the ten iterations and agents respectively. The best value (lowest power consumption) is chosen by comparing all the 10 iteration values. Table IV shows the conditions on the distance to cover and the battery availability. Based on these conditions the scheduling takes place for every device.

TABLE IV. Conditions for raining mode

CONDITION NO.	CONDITION
1	➢ The distance to cover = 100, Battery availability = 273
2	➢ The distance to cover = 50, Battery availability = 73

Based on the conditions as stated above in table IV, the scheduling output for the first condition is shown in the figure 11. The first condition is **Distance to cover = 100, Battery availability = 273.** As per the constraints stated above the scheduling takes place accordingly. The best value is thus chosen through the loop that is created to compare the devices power consumption among the iterations.

OUTPUT FOR RAINING MODE

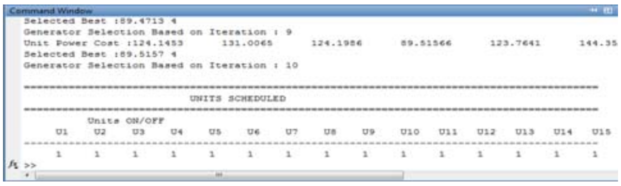

Fig.11. Result of first condition for raining mode

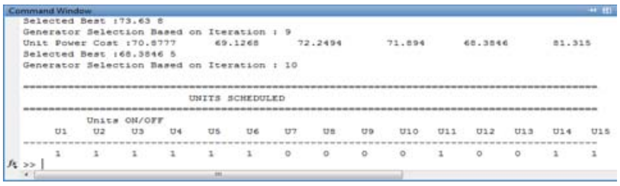

Fig.12. Result of second condition for raining mode

5.3) Result of optimization algorithm for night time

The devices like electric motor power steering, door locks, horn and head light are the devices that are mandatory during night time. Except these five devices remaining all the devices are scheduled depending upon the distance to travel and the battery availability. The scheduling for these devices is made for all the ten iterations and agents respectively. The best value (lowest power consumption) is chosen by comparing all the 10 iteration values.

TABLE V. Conditions for night mode

CONDITION NO.	CONDITION
1	➢ The distance to cover = 100, Battery availability = 250
2	➢ The distance to cover = 350, Battery availability = 350

Based on the conditions as stated above in table V, the scheduling output for the first condition is shown in the figure 13. The first condition is **Distance to cover = 100, Battery availability = 250.** As per the constraints stated above the scheduling takes place accordingly. The best value is thus chosen through the loop that is created to compare the devices power consumption among the iterations.

OUTPUT FOR NIGHT MODE

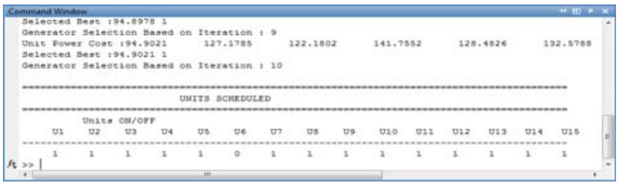

Fig.13. Result of third condition for night mode

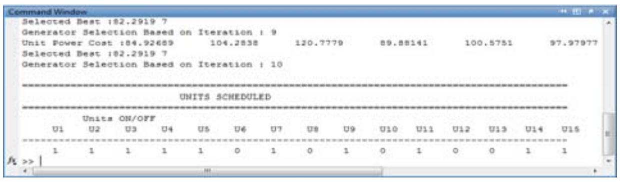

Fig.14. Result of third condition for night mode

5.4) Result of CAN controlled optimization

Figure 15 shows the transfer of the power consumption specification for each device as initialized. A virtual CAN communication is developed and the power consumption of the devices are transmitted and the optimized results are obtained via CAN channel.

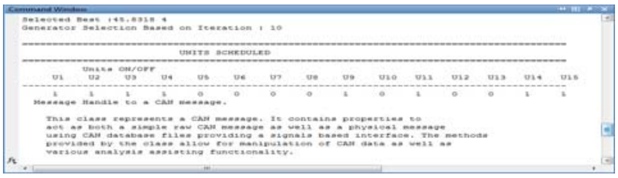

Fig.15. Output for CAN communication

VI. CONCLUSION

Thus an optimal energy management system for electric vehicles is been proposed to optimize the power consumption of the devices from the battery. The objective is achieved by dynamic EDF scheduling using firefly algorithm. Depending upon the availability of battery power and the distance to cover, the devices are made to switch OFF automatically based on the allocated priority. Through this process, the battery power is made used efficiently and optimally. It also relieves the user from the problem that he faces after the battery gets drained half way through his journey. CAN protocol is used for effective communication between the devices and the controller. Simulation results on scheduling the devices to optimize the battery power and development of controller area network channel for communicating the power consumption of the devices are thus obtained using MATLAB.

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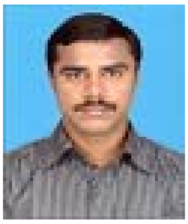

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