EVOCATION AND EXPEDIENT OF AN ASSEMBLE OF ROOFTOP SOLAR PV AND VEHICLE TO GRID TECHNOLOGY: ON PERSPECTIVE OF BANGLADESH

Abu Hena MD Shatil and MD Rakib Ahsan

Abstract**—**Demand response systems have become a big draw for reducing peak demand in the electrical power sector as a smart grid enabler. The household consumer will add significantly to the capacity for peak-hour energy demand mitigation. The aim of this paper is to discuss the energy usage of a single household with multiple properties, including household appliances, an electric vehicle (EV), and a battery energy storage device (BESS). A rooftop solar photovoltaic (PV) generation system on a small scale is also a component of a smart household. The BESS and PV are used to charge household equipment, and any excess electricity produced can be pumped back into the grid. The optimization problem of intelligent home energy management is formulated as a mixed integer linear programming problem (MILP). The load serving body registers the energy user for real-time price-based demand response programs (LSE). The simulation results demonstrated the LSE's major contribution to achieving usage cost gains and minimizing peak to average ratios. An algorithm has been proposed to reduce the conversion losses. Eventually then, the whole system analyzed by MATLAB software.

Keywords**—**Demand response, home energy management system, electric vehicle, solar photovoltaic, battery system, real time pricing

I. INTRODUCTION

A grid-linked rooftop power generating system is a worthy system, which generates electrical power from the sunlight along with the help of PV system. Furthermore, a Vehicle to Grid (V2G) technology is also added here to charge the vehicle, and after using, there is a scope to deliver the rest of the energy to the grid. Like, V2G system-generated electric power from PV system will be used and rest of the energy will be sold to the national grid, if extra energy needed then it will be collected from the gird [1]. That means it will work as two-way system and the net meter will calculate the maximum and minimum energy about balancing purpose. Here used a maximum power point tracker (MPPT) to track maximum solar energy. A 2.5 kW transformer less inverter (grid-tied) has been used here along with the duel state buck-boost converter. Finally, the economic and environmental aspects of the whole project sound good due to renewable energy [2].

II. SYSTEM DESCRIPTION

The whole system is designed depending on two phases. First, the PV plate absorbed the light energy and converted it into electrical energy; after that, the inverter inverted it DC to AC. After disconnecting the AC switch, the current entered into the distribution panel. Then the system delivered the power to customer load (household demand); after that maximum measuring energy, the net meter delivered the rest of the energy to the National grid with the help of a step-up transformer. In the second phase, when the customer load needs energy, after measuring by net meter, it will be collected from the National grid by stepping down by the same transformer [3].

Furthermore, there is also a sub-phase, which is Vehicle to Grid (V2G) technology, which is linked with a net meter. This technology is also the same as the first phase. In a particular area, if there is a good number of hybrid Vehicles, then all of them can connect with the net meter to balance the energy demand [4]. With the help of Fig. 1, the whole system has been shown.

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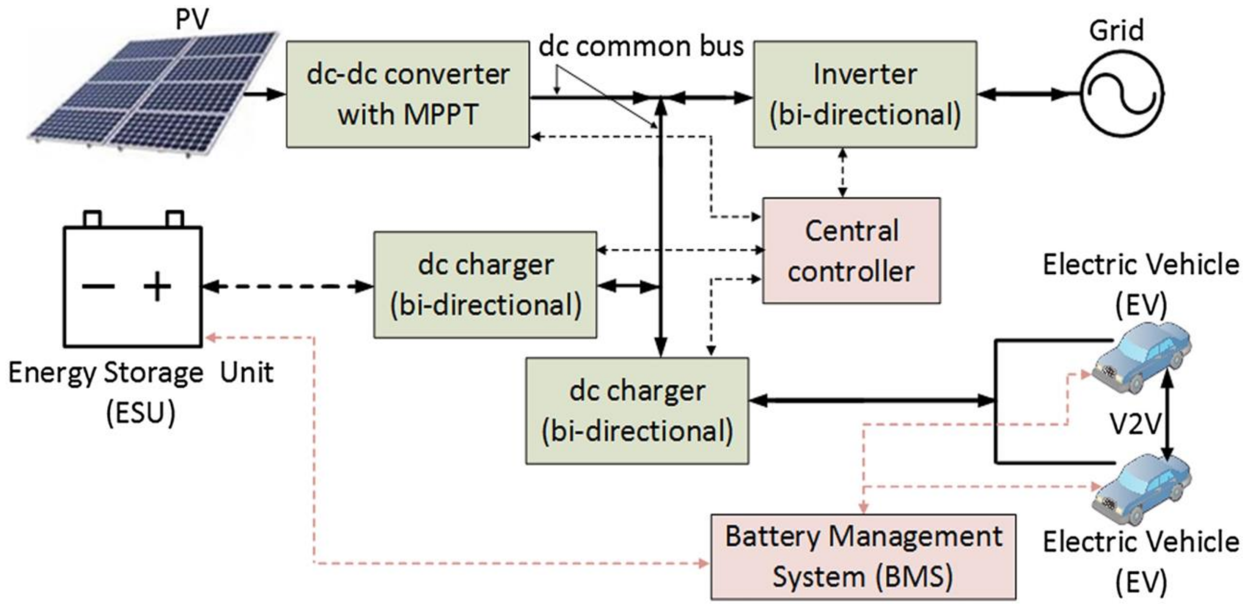

Fig. 1. A Proposed block diagram of a grid-tied rooftop solar pv system and V2G technology [5]

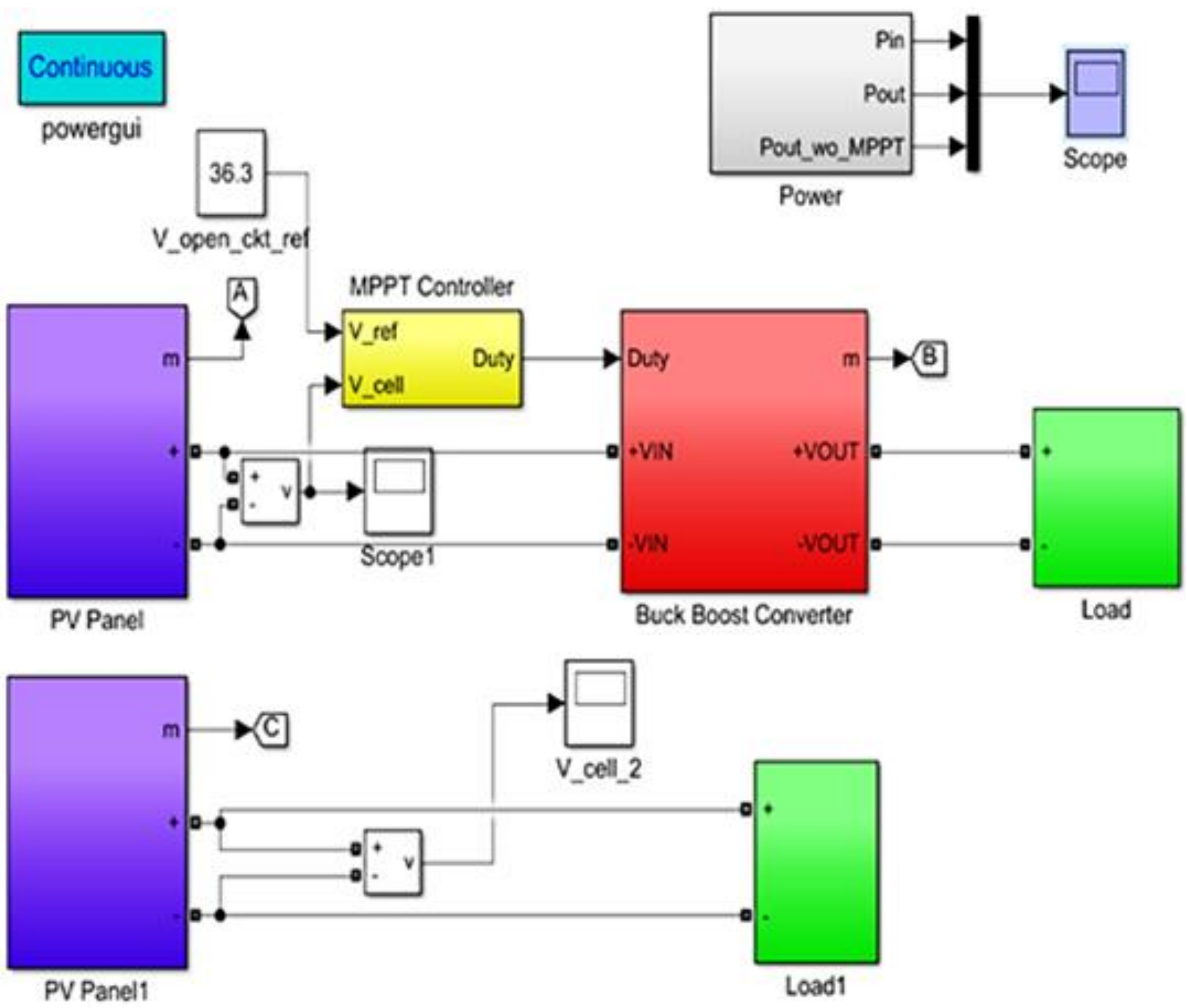

Fig. 2. MPPT Simulink diagram [6]

III. MPPT TECHNOLOGIES

Maximum Power Point Tracker is an inevitable element in the Solar PV system. Maximum Power Point Technologies conducted in grid-connected inverters, an essential part of the system, maintain the output efficiency as high as possible . Among different version of MPPT system here used efficient one applicable in various kinds of the environment—considered 16 panels and each solar panel able to delivered 250-W power. To place 16 panels, here needed 280 square feet roof space. The entire operation individual panel gave 30.7 V (V_{mp}) voltage and 8.15 A (I_{mp}) current at the maximum power point. Reportedly, the total sum of maximum output power disclosed as (30.7×8×8.15 = 2000 Watts). On the contrary, without, MPPT the output power disclosed output power is 1200 Watts. Thus, with the aid of MPPT, the power increased up to 1.8-1.9 kW. So, the load is going to absorbed 1900 W approximately.

Figure 2 shows the mechanism of the whole MPPT technology, done by MATLAB.

Fig. 3 shows the basic and inner algorithm of the whole system based on voltage where the intersecting point is the subtracting part to find if there is any kind of error. In addition, if there is an error, the value will be 0.

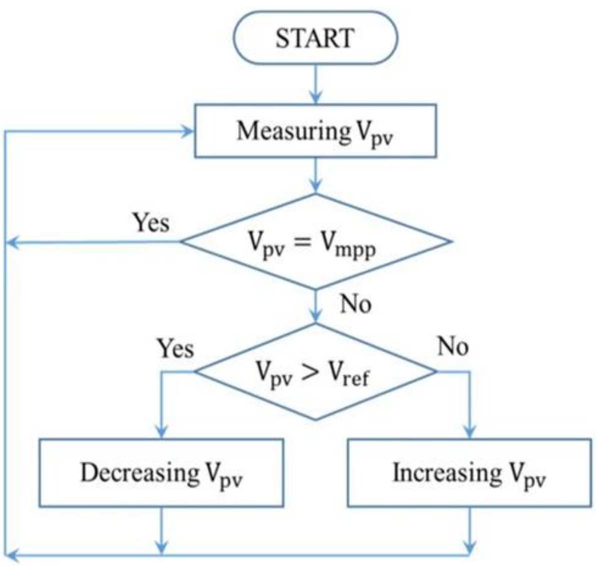

Fig. 3. Algorithm depending on voltage based [7]

IV. METHODOLGY

The proposed article examined the Dhaka area through a case report. As the supply of electric vehicles at the office is more dependent on office hours than it is at the suburban level during the day. This paper advocated using rooftop solar PV to charge electric vehicles and meet electric load requirements in commercial buildings. It not only alleviates the grid's unnecessary load in the evening, but also maximizes solar PV output usage by charging EVs and commercial loads during the sun's availability time. Solar energy is used from 6 a.m. to 6 p.m. However, the industrial site's EV is accessible from 9 a.m. to 5 p.m. Thus, solar PV energy can be pumped into the grid or used to charge the battery when solar PV is not available on-site. To optimize solar PV utilization while minimizing grid acquisition or battery demand, the EV charging pattern is compared to solar availability. The EV charging pattern is determined by the amount of solar energy available [8-10].

V. MATHEMATICAL MODELLING

A smart household consumer is run in this paper using a variety of supporting technology provided by the electricity grid. The energy consumer is equipped with an Automatic Load Controller Unit (ALCU) in this place. This ALCU is equipped with a smart meter and an adaptive controller. The ALCU enables bidirectional coordination between the load-serving agent and the household customer. It is certain that energy users need real-time pricing details so that they can plan their appliances according to their comfort level by instructing the controller. The load-serving business that delivers power to the household customer is mindful of their previous day's energy use [11, 12].

The user's home is equipped with a variety of appliances. Appliances have unique characteristics based on their intended use. P^{NS_app}, P^{TS}, P^{TS_cont}, P^{PS} denotes the amount of energy used by non-shiftable, time-shiftable, time-shiftable continuous run, and power-shiftable appliances. So the total load will be,

$$P^{TOTAL} = P^{NS\_app} + P^{TS} + P^{TS\_cont} + P^{PS} \quad (1)$$

This segment illustrates the statistical simulation of various assets deployed in a smart home. The integration of an electric car, a photovoltaic system, and a battery system into a smart home energy storage system demonstrates economic and comfort benefits. The service of household equipment is included in the overall H hours; each hour is denoted by the letter h.

A. EV (Electric Vehicle)

EVs are used in this section for charging and discharging purposes. Charging an EV is accomplished by the use of energy from the grid. Discharging occurs where a car is not accessible at the residence. Equations may be used to model the mathematical understanding of EV.

$$P^{ev,C} = n^{ev} \times \hat{P}\text{ev}* \quad \forall h \in [Ha, Hd] \quad (2)$$

$$P^{ev,D} = \frac{\hat{P}\text{ev}*}{n^{ev}} \quad \forall h \in [Ha, Hd] \quad (3)$$

Where $P^{ev,C}$ and $P^{ev,D}$ signify the electric vehicle's battery's charging and discharging power for a one-hour slot, respectively. $\hat{P}ev*$ denotes the rated capacity of the EV battery. n^{ev} represents the efficiency of both charging and discharging. Ha, Hd denote the vehicle's arrival and departure times.

$$E^{ev,ini} + E^{ev,C} \leq E^{ev,max} \qquad \forall h \in [Ha, Hd] \quad (4)$$

$$E^{ev,ini} - E^{ev,D} \geq E^{ev,min} \qquad \forall h \in [Ha, Hd] \quad (5)$$

$$E^{ev,min} \leq E^{ev,ini} \leq E^{ev,max} \qquad \forall h \in [Ha, Hd] \quad (6)$$

$E^{ev,ini}$ denotes the EV battery's initial state of capacity. The maximum and minimum allowed energy capacities of an electric vehicle battery are denoted by the terms $E^{ev,max}$ and $E^{ev,min}$. $E^{ev,C}$ and $E^{ev,D}$ reflect the energy used by an electric vehicle during the charging and discharging processes, respectively. Additionally, it is possible to use EV after discharge by merely applying equation (6), where the lower limit must be increased from $E^{ev,min}$ to $E^{ev,req}$ (minimum required SOC) with a constraint that $E^{ev,req} \geq E^{ev,min}$

B. Case Study

To evaluate the suggested approach's capabilities, various scenarios have been used. The following section contains the statistical explanations for the situations.

Scenario 1: In this situation, the household device with photovoltaic energy generation and smart charging for electric vehicles is considered. There is no electricity returned to the grid; only appliance consumption and EV charging are performed.

Scenario 2: This scenario includes photovoltaic power injection, smart charging for electric vehicles, and BESS charging/discharging. Additional energy produced by the appliance and EV can be fed back into the grid.

Scenario 3: This scenario assesses solar energy generation, electric vehicle charging/discharging, and BESS charging/discharging.

VI. Simulation and Analysis

A single smart household device with 21 appliances is designed for the simulation. To analyze user behaviour, the functional data from appliances is analyzed. The load modeling of household appliances is based on historical data from [14]. As shown in Fig. 1, user appliance load data is created based on previously stored data. The household owner is fitted with a Toyota Prius (plug in hybrid) electric vehicle with a 16 kWh battery and a 2 kWh battery system. Consideration is provided to small-scale photovoltaic (PV) systems capable of producing 2 kW of electricity for the home.

ALCU's built-in controller makes the scheduling call. The customer is permitted to object to the suggested schedule but may face a penalty. In (14) the optimization problem is expressed as mixed integer linear programming (MILP). The MILP load scheduling optimization problem is solved using CVX version 2.0 beta [16] on the MATLAB platform.

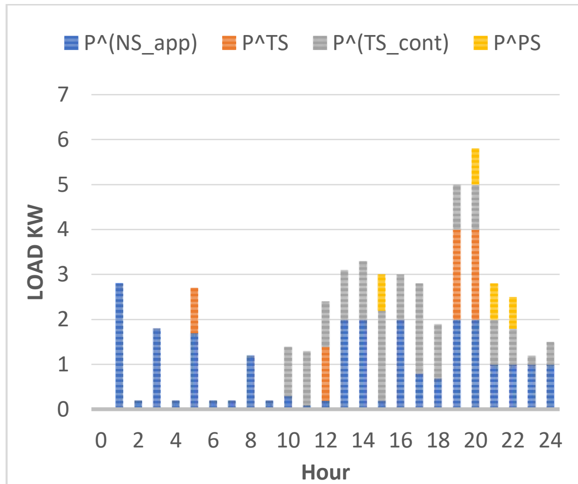

Fig. 4. Smart household appliance unshceduled load

Certain conclusions have been made in order to enforce the current SHEM load scheduling. Each consumer with an ALCU is believed to have a built-in smart meter. For the initial operation of an EV, the vehicle's arrival time is between 6 and 9 pm, and the vehicle's departure time is between 8 and 10 a.m. Additionally, it is believed that when the car is returned to the house, 60% of the EV battery's capacity has been depleted.

VII. Results Discussion

The simulation was conducted in a variety of ways to demonstrate the capability of enabling technology such as rooftop solar, electric vehicles, and building energy management systems (BESS) in smart homes. The EV is a high-energy-consumption load in today's power grid. It is necessary to work prudently with this load in order to avoid causing disruption to the power grid. The intelligent charging operation of an EV is capable of determining the most optimal time slot for charging action. In a smart charging operation, EVs are charged during off-peak hours, also known as low-price hours.

Smart charging of EVs benefits the grid while still saving the customer money on their electricity bill by charging at off-peak hours. Additionally, the current scheduling reduces the peak-to-average ratio (PAR) of overall consumption, which is particularly beneficial in order to preserve the electricity demand-supply ratio. For the purpose of analyzing the alternative solution, the following scenarios are considered.

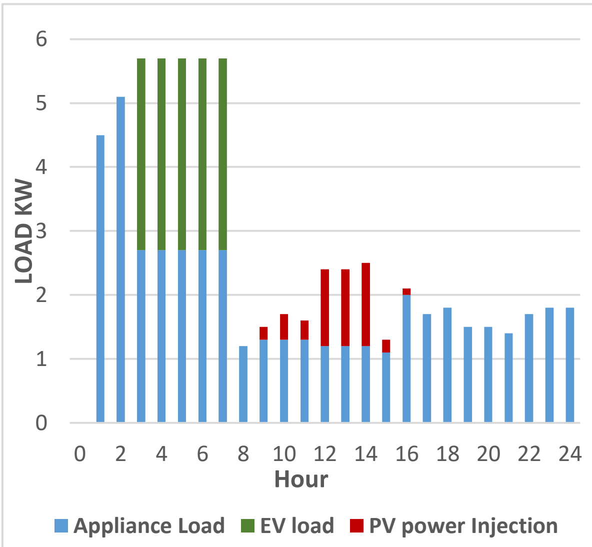

Fig. 5. Load schedueling for scenario 1

1) Scenario 1

The household consumer facilitates load scheduling of home appliances in the presence of smart charging for electric vehicles and solar photovoltaic generation in this scenario. After successfully implementing the planned load scheduling strategy, the expected load discovered is depicted in Fig. 5 It illustrates how the user's appliance load is supplied by the grid and self-generated photovoltaic energy. Since solar energy is only usable during daylight hours, it should be used during daylight hours. The impact of smart charging on EVs can be summarized by the fact that the EV load is planned during night hours, which results in significant cost savings for the consumer. Prior to applying scheduling, the cost of buying electricity from the grid is 203.78 BDT, while the cost achieved in this case is 146.64 BDT. By using smart billing, the customer receives 57.13 BDT in savings. By using smart charging, the peak to average time is reduced from 3.14 to 2.19. The operator would pay a tax of 6.8 BDT for refusing to accept the controller plan.

2) Scenario 2

This scenario includes household properties such as electric vehicles, photovoltaic generation, and BESS. The service of the EV is allowed for smart charging, and BESS is permitted to be used for both charging and discharging. Essentially, this scenario adds BESS charging and discharging to scenario 1. Chargers for EVs and BESS are used at low-cost hours. Fig. 6 illustrates the simulation effects for the planned load scheduling. As shown in Fig. 6, EV and BESS charging occurs at off-peak hours between 11 p.m. and 10 am.

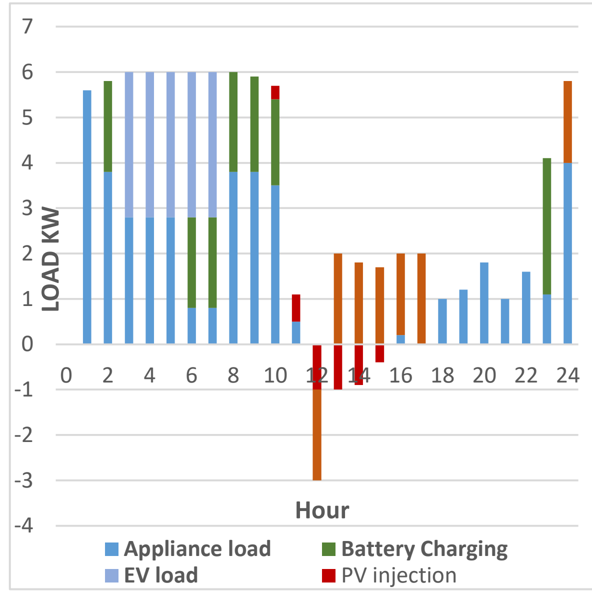

Fig. 6. Load schedueling for scenario 2

The positive portion of BESS discharge is used to power household appliances. When the grid's load for EVs and home appliances is smaller than the overall power required at the residence, the excess power will be pumped back into the grid. The positive portion of the BESS charging load is used by home appliances, while the negative portion is fed out to the grid. EVs are only valid for smart charging purposes in this place. The load scheduling cost is 127.36, which is the cost to the customer for use. By using BESS charging/discharging, the customer gains a net value of 76.41.

3) Scenario 3

Discharging of EVs is also allowed in this scenario. The EV should be discharged at peak hours to meet the user's load. Fig. 7 illustrates the implications of load scheduling using EV and BESS charging and discharging. At 2 am, the EV will provide approximately 3.3 kW of load to the appliance and battery. Since the battery needs 2 kW of electricity, 2 kW can be dedicated to BESS and the remaining 2 kW can be used for appliance use. About 1 and 9 pm, BESS discharging is used to supply the appliances' load, and excess load can be fed back into the grid. The excess energy produced at home through photovoltaic (PV) panels is also fed back into the grid. By using this strategy, the customer saved 116.72 BDT and gained 87.06 BDT in net value. The peak to average ratio is decreased to approximately 2.05.

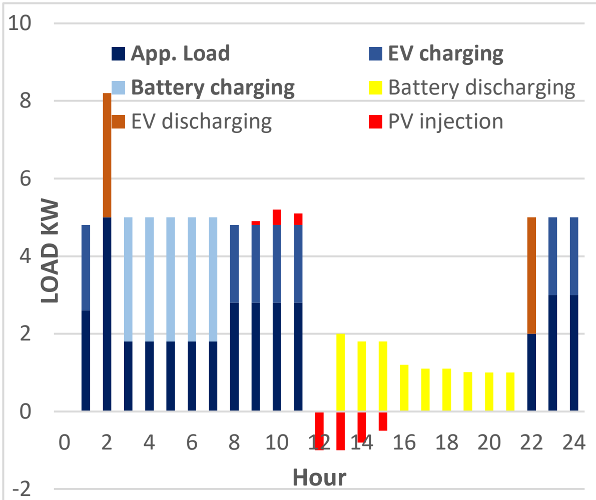

Fig. 7. Load schedeuling for scenario 3

By comparing the load scheduling in each situation, it is clear that the majority of energy is returned to the grid in scenario 3 due to EV and BESS discharge. However, in scenario 3, electricity is returned to the grid as a result of BESS discharge and PV surplus. It can be deduced that scenario 1 costs more than scenarios 2 and 3. The third example results in the greatest decrease in power costs, at 87.06 BDT. The peak to average ratio is reduced by 29.99%, 29.29%, and 34.40%, respectively, for scenarios 1, 2, and 3. PV, EV, and BESS together have a value to the customer of 87.06 BDT. The penalty is the amount of damage incurred by the customer as a result of deviating from a set schedule. The suggested load management is deemed advantageous by both users and energy suppliers.

VIII. CONCLUSION

This article discusses load scheduling in a smart household with home properties such as an electric car, a battery pack, and small-scale photovoltaic generation. The suggested methodology is primarily concerned with analyzing the application of supporting technologies such as EV and BESS to the service of the home and grid. Three distinct examples are used to analyze the proposed optimization problem as a MILP. In scenario 3, bidirectional energy transactions between the grid and the home are used in the presence of home properties. It utilizes the surplus energy produced after home use can be fed back into the grid, resulting in additional savings. It is more realistic where the consumer comfort is modeled using a waiting parameter with a penalty. The simulation findings demonstrate the efficacy of the suggested scheduling solution in scenario 3 in terms of decreased customer bill payment and decreased peak demand. The realistic application of such home energy scheduling techniques will improve the electrical power system's stability. This work can be applied to a multi-household user system, allowing for fruitful analysis of the function of the waiting parameter.

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