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An Optimal Scheduling and Planning of Campus Microgrid Based on Demand Response and Battery Lifetime

Muhammad Shahzad Pansota[1], Haseeb Javed[1], H.A. Muqeet[2], Hamza Ali Khan[1], Naveed Ahmed[1], Muhammad Usama Nadeem[1], Syed Usman Faheem Ahmed[1], Ali Sarfraz[1]

[1]Department of Electrical Engineering, Muhammad Nawaz Sharif University of Engineering and Technology, Multan, Pakistan.
[2] Department of Electrical Engineering Technology, Punjab Tianjin University of Technology Lahore, Punjab, 54770, Pakistan.
Corresponding author: Haseeb Javed(e-mail: haseebjaved1996@yahoo.com).

Abstract- **Existing electricity supply systems face several challenges, including increasing energy prices with greenhouse gas (GHG) emissions and fossil fuel depletion. These issues have a significant impact on all power system stakeholders, including customers/prosumers, utilities, and microgrid operators. Renewable energy incorporation and different energy managing strategies such as demand-side management (DSM), demand response (DR), and others may help to overcome these limitations. This article presents a new energy management (EMS) system for a university campus microgrid with onsite solar PV and ESS that operates in a grid exchange scenario. The suggested EMS not only lowers power consumption costs by prolonging storage life; however, it also guarantees grid stability through limiting and shifting loads using price-based and incentive-based demand response methods. ESS is utilized as a stand-by energy reserve to maintain the microgrid system stability and to assist the utility network in the event of a power outage. The given model is implemented in MATLAB using quadratic approach. The results show that utilizing EMS in a hybrid DR scheme reduces operating costs and peak load on the grid more than using it in a price-based DR scheme employing RTP, with savings of 65.7 percent and 70.1 percent in case (i) RTP-based price DR, and case (ii) a hybrid approach among price-based DR and incentive-based DR, respectively. According to the findings, the suggested EMS decreases the prosumer's operating cost and increasing self-consumption, minimizes peak load from the national grid, and encourages campus stakeholders and energy controllers to engage in large-scale ESS installations and distributed generation (DG).**

Index Terms-- **Demand response, energy storage system, prosumer microgrid, campus microgrid, renewable energy resources.**

I. INTRODUCTION

One of the major problems in the smart grid area is an intelligent energy management (EMS) system for especially end-customers. The smart power system consists of the interconnectivity of microgrids, therefore power exchange between them has an ability to lower microgrid operational costs and minimize the load-shedding problem by employing various programmes [1].

Virtual power plants are one of many power projects, that includes demand-side management, energy storage system (ESS), and demand response involvement in the electricity market [2]. Other advantages of a microgrid include ESS, a safe and secure power supply, a dependable system that enhances the revenue of active users through participation in the electrical market, and the ability to operate in both grid and islanded connected modes [3], [4].

Microgrids employ a variety of renewable energy resources, such as solar PV, biomass, wind turbines, and geothermal. Energy storage systems, on the other hand, provide a reliable and steady energy supply in peak consumption hours [5]. Many uses for energy storage systems, such as batteries, exist in resource management of energy, such as in isolated microgrids [6], back-up energy for essential loads [7]. The lifespan of storage is determined by a variety of operational ageing variables such as ambient temperature, terminal voltages, internal resistance, and depth of discharge [8].

Prosumers are grid-connected consumers who may sell their excess energy to the grid or other nearby consumers [9]. Renewable energy resources are incorporated into the conventional grid is also an increasing trend in developing and emerging countries [10] to provide a cost-effective energy supply. Pakistan is likewise an emerging country with a significant energy shortage of 32% [11], which is a serious concern for policymakers. The power outage is likewise a concerning incident that has lasted for roughly 6-8 hrs. and is a regional issue [12]. Institution microgrids especially campus microgrids, are also an evolving component of the electrical system with a variety of client types, including residential, office buildings, and commercial [13].

On the suggested issue, there are several literature reports and research. However, the writers in [14] examined the university microgrid at Aligarh (AMU). For different distributed generating applications, the HOMER pro software-based solution was offered. The authors provided PV-storage scheduling utilizing a mixed integer programming-based solution to an actual university microgrid in [15]. The unpredictability of DGs and load, on the other hand, was overlooked. The authors of [16] conducted an economic study of a grid-connected system in the case of Pakistan. The rate of return and net present (NPV) values was estimated, but the energy storage was not.

The price and cost structure is provided in [17] for prosumers of community microgrid. When compared to energy trading without optimal scheduling, Solar PV microgrid prosumers benefitted from the proposed strategy since it reduced costs and increased profits. Moreover, the energy storage technology was not thoroughly studied. The Korean university campus microgrid was designed in [18] to see if it was financially feasible. MDSTool was used to solve the suggested model, which took into account a variety of economic considerations. In [19], the study examine the cost / benefit analysis of rooftop Solar which is isolated and separated both with PV-storage systems for 369 US households, taking into account the feed-in tariff (FIT). The research indicated that while the PV-only system was effective at the time, it lacked self-sufficiency that was the most important criteria in participating in the power market. Only PV-storage systems with retail energy prices over $0.4 per kWh but feed-in tariffs less than $0.05/kWh were found to be feasible. In [20], a PSO (Partial Swarm Optimization) based two-stage optimal scheduling method for cost reduction was described. The function of the ESS in microgrid operating was investigated through a variety of scenarios. In comparison to other resources, the results revealed that ESS plays a considerable role in cost-effective operation.

In ref. [21] the author proposed a concept for lowering operational costs by purchasing electricity from the utility. For efficient microgrid resource management, the cost of battery storage and energy losses were also minimized. The authors of [22] created a PV-storage G scheduling system that took battery operating and degradation costs into consideration. The model decreased the cost of energy, the penalty for exceeding peak demand, and the cost of battery deterioration. The SOC controlling cost was decreased by (36,286,371 -to- 34,354,996) KRW using flexible assignment method (FAM) by RTCS2. The authors of [23] used linear programming in MATLAB to create a power system load reduction model for household applications that considered utility availability into account. Various load-shedding situations were investigated; However, It has been demonstrated that load shedding for 8 hours may give energy supply up to 1000kWh for a typical 1200W home. Furthermore, the researchers discovered that a load-shedding scenario with 4 hours decreases monthly peak energy consumption expenses by 16%.

The battery storage modelling for DISCO profitability expansion was given by Yu Zheng [24]. For cost reduction and bidding strategy, the Conic relaxation and Natural Aggregation (NA) techniques were used. In day-ahead (DA) energy market, the incorporation of BESS lowered the electricity cost by 448.4$ to 433.6$. Using a binary backtrack method, the authors planned several µGs to construct a virtual power plant (VPP) in [25]. (BBSA). When contrasted to binary particle swarm optimization (PSO), the suggested model had a considerably superior fitness function. It was discovered that operational costs and power losses might be reduced while dependability was improved. The recommended approach improved the profits from (187926.86 -to- 222246.62 RM).

With the use of incentive-based DR (Demand Response), Dahraie [26] created a dual-stage probabilistic method for continuous demand and supply, taking into account the frequency security providing cost, which was minimized by (835.5$ -to- 773.7$). Demand Response is a growing field of study that may be described as shifting consumer electric energy consumption patterns affected by increased in electricity unit prices in order to decrease system peak demands and instabilities. Customer involvement in the electrical market also contributes to network reliability [27].

Incentive-based and price-based demand response are the two kinds of demand response. In addition, the price is split into three categories: critical peak pricing (CPP), real-time pricing (RTP), and time of use (TOU) [28]. [29] Examined at community energy exchange in multiple microgrids setting with regard to demand response. Pakistan has a huge potential for solar Energy, which may help in alleviating the country's current electricity deficit [30]. Wind power's potential, on the other hand, cannot be underestimated, but it is restricted to a few geographical areas [31]. Passive consumers become prosumers in an intelligent microgrid system, selling excess electricity to the national power system or neighboring contractual customers. In the current literature, many kinds of microgrid concepts are introduced to increase resilience and save operational costs. Figure 1 depicts a comprehensive

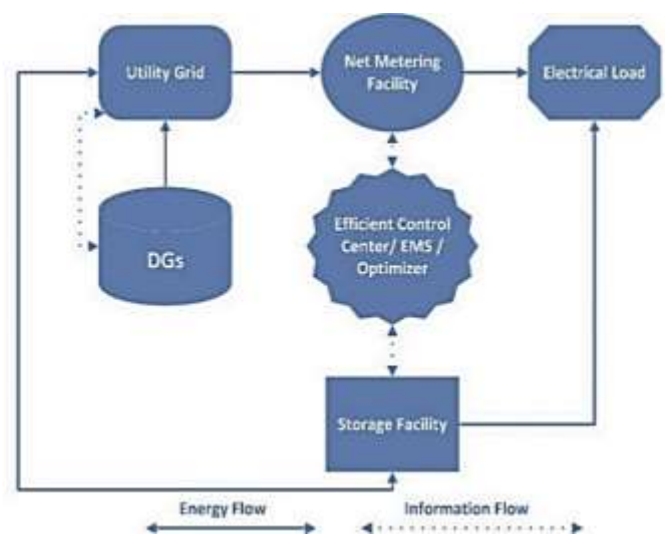

FIGURE 1: General architecture of the system

suggested microgrid system model that speculates on the campus electricity flow among the microgrid.

According to a literature review, campus energy management has a number of challenges, including lowering energy consumption costs and maximizing utility grid profit. As a result, a resilient smart microgrid [23] might be a viable alternative for underdeveloped nations. As previously said, Pakistan has a huge amount of potential for solar energy as well as other renewable energy (RERs) in Asia [32]. In 2016, net metering was introduced, transforming the passive consumer into an active prosumer. An institution based microgrid was designed for optimum energy exchange among university campus buildings and the electrical grid in this research. Although prior work addressed microgrids in the context of uncertainty, it overlooked battery life, which is a critical aspect. Our suggested system takes into account a combination incentive-based/price-based demand response, as well as ESS lifetime.

A. MAIN CONTRIBUTION

Another aspect of our work that may be summarized is:

1) Developed a nonlinear model for the utility grid integrated with the PV and storage systems with ESS degradation cost for the prosumer microgrid community.

2) Cost estimation was done using price-based and incentive demand responses to analyze the proposed system.

3) Grid outage and Grid support-based modes are also taken into account for load-shedding conditions to study the effect on system operation cost.

The remaining portions of the paper are as follows: The suggested system model is presented in Section III. The problem formulation and outcomes of day-ahead scheduling are presented in Sections IV and V, respectively, while the conclusion of this article is summarized in Section VI.

III. PROPOSED SYSTEM MODEL

In developing economies, integrating renewable energy into the national grid is a new field. Pakistan has a lot of solar PV capacity, but it has to be well organized in order to boost the green and clean energy production. The architecture of the proposed system with flowchart for the given model is shown in Figure 2. The main campus of UET Taxila, which is located in Punjab and has longitude and latitude of 72.840 and 33.70 correspondingly, was chosen as the test environment. The scheduler receives solar irradiance and various loads from campus as input data. This scheduler sends out decision signals after making the best use of the available resources.

The battery energy storage bank and AC loads make up the system. Critical with non-critical loads are two types of loads that can be classified. In certain circumstances, the control system

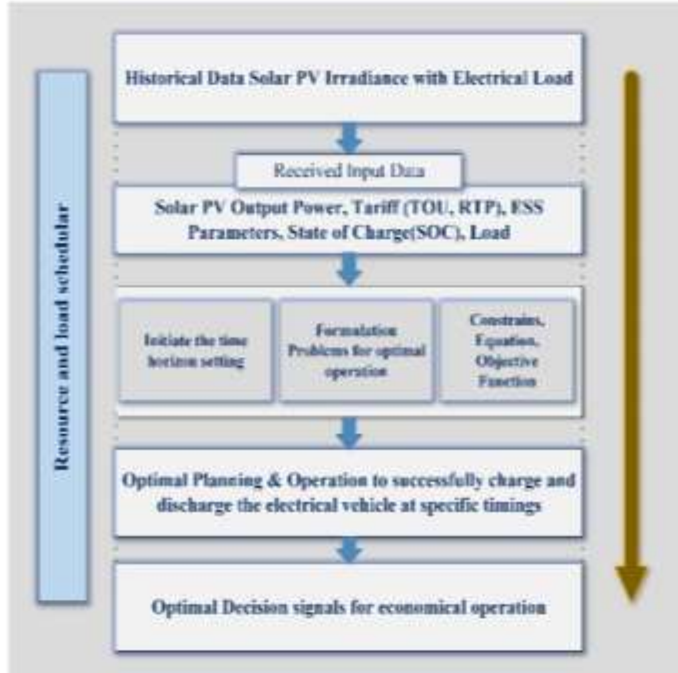

FIGURE 2: Flowchart of proposed optimal operation of system

actively controls the ESS. The storage battery system receives power exclusively during off-peak hours or from solar panels, and it is discharged during peak hours. The suggested campus microgrid includes a resource scheduler for an optimal energy exchange operation and administration, and Tab. I lists the suggested model's fundamental characteristics.

The data signals from the system are received by this scheduler, which then creates a final decision signal. Based on According to the price variation, the decision signal effectively runs the PV-energy storage system. The desire to share energy is influenced by the Feed-in-Tariff (FIT). We considered that the prices of trading and acquiring energy are similar, which encourages prosumers to sell their excess energy in the electrical grid. The suggested scheduler's precise layered structure is demonstrated in Fig. 2 together with its functionalities.

TABLE I: Proposed techno-economic system parameters

Parameters	Value	Parameters	Value
$\mathbf{P^{PV}_{rated}}$	1000kW	C^{ES}	800kWh
$\mathbf{P^{G}_{(t,max)}}$	750kW	$P^{G}_{(t,min)}$	-750kWh
$\mathbf{P^{S}_{(t)}}$	800kW	$P^{bat}_{(t,min)}$	-800kWh
$\mathbf{SOE_{(max)}}$	90%	$SOE_{(min)}$	10%
$\mathbf{SOE_0}$	50%	1$	164PKR

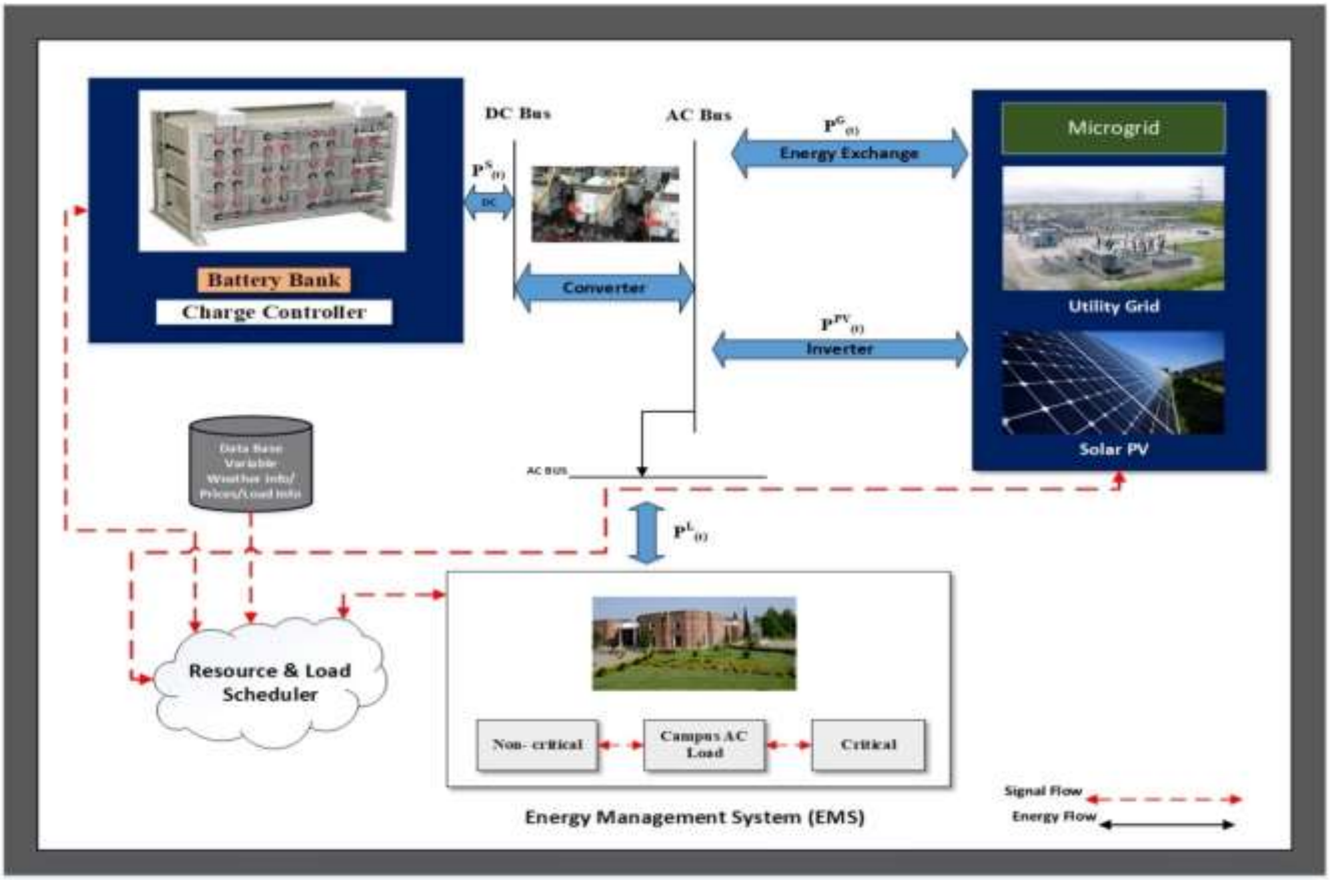

FIGURE 1: Proposed architectural model of the system

IV. DAY-AHEAD SCHEDULING PROBLEM FORMULATION

A mathematical expression of day-ahead planning is described here in the sections. A stochastic model is examined for a proposed model with an optimal solution and an objective function.

A. OBJECTIVE FUNCTION

A non-linear objective function is modelled and solved through quadratic programming to optimize the suggested model in expression (1).

$$\boldsymbol{min} \sum_{t=1}^{t=24} \{ \left(\boldsymbol{P}^{\boldsymbol{G}}_{(t)} \boldsymbol{K}^{\boldsymbol{b}}_{(t)} - \boldsymbol{P}^{\boldsymbol{G}}_{(t)} \boldsymbol{Q}^{\boldsymbol{s}}_{(t)} \right) + \boldsymbol{j}.(\boldsymbol{SOE}_{(t)} - \boldsymbol{SOE}_{(t-1)})^2 \} \quad (1)$$

$\boldsymbol{P}^{\boldsymbol{G}}_{(t)}$ represents energy exchanging power only with grid, whereas $\boldsymbol{K}^{\boldsymbol{b}}_{(t)}$, $\boldsymbol{Q}^{\boldsymbol{s}}_{(t)}$ represents unit pricing trading rates or Buy/Sell rates while $\boldsymbol{SOE}_{(t)}$is the battery storage energy level expressed as a percentage of its actual capacity, and $\boldsymbol{j}$ is a weighting factor used throughout the process. The weighting factor is set at 0.5, which is used to determine the cost of battery degradation.

B. POWER EQUALITY EQUATION

The following Eq. depicts the exchange of energy with the power grid (2).

$$\boldsymbol{P}^{\boldsymbol{G}}_{(t)} + \boldsymbol{P}^{\boldsymbol{S}}_{(t)} = \boldsymbol{P}^{\boldsymbol{L}}_{(t)} + \boldsymbol{P}^{\boldsymbol{C}}_{(t)} + \boldsymbol{P}^{\boldsymbol{PV}}_{(t)} \quad (2)$$

The power output of storage is given by $\boldsymbol{P}^{\boldsymbol{S}}_{(t)}$ and the utility system must be equivalent by adding all the available power in the right-hand side, where it is denoted by contracted power $\boldsymbol{P}^{\boldsymbol{L}}_{(t)}$, prosumer load, $\boldsymbol{P}^{\boldsymbol{C}}_{(t)}$, and $\boldsymbol{P}^{\boldsymbol{PV}}_{(t)}$denotes the power output of solar PV. The charging/ discharging of the BESS system are represented thru the positively and negatively storage power output, respectively.

C. PROSUMER CONSTRAINTS OF PROPOSED MODEL

The utility system can buy extra energy from prosumers, especially during contracted hours. Grid supportive mode is also used for peak load reduction in emergency situations.

$$\boldsymbol{Net}_{\boldsymbol{e}} = \sum_{t=1}^{24} \boldsymbol{P}^{\boldsymbol{G}}_{(t)} \times \boldsymbol{t} \quad (3)$$

Eqs. (3) show overall energy trading among grids, whereas Eqs. (4)-(5) show energy import and export. The grid power limit is measured in kw given in (6).

$$\boldsymbol{Net}_{\ (e,exp)} = \sum_{t=1}^{24} \boldsymbol{P}^{\boldsymbol{G}}_{(t)} \times \boldsymbol{t} \quad \forall \ \boldsymbol{P}^{\boldsymbol{G}}_{(t)} > \boldsymbol{0} \quad (4)$$

$$\boldsymbol{Net}_{(e,\text{imp})} = \sum_{t=1}^{24} \boldsymbol{P_{(t)}^{G}} \times \boldsymbol{t} \quad \forall\ \boldsymbol{P_{(t)}^{G}} < \boldsymbol{0} \quad (5)$$

$$\boldsymbol{P_{(min)}^{G}} < \boldsymbol{P_{(t)}^{G}} < \boldsymbol{P_{(max)}^{G}} \quad (6)$$

Due to the short length of entire transmission system, just active power was considered here and line losses were ignored.

D. BATTERY STORAGE CONSTRAINTS

For uninterrupted performance, energy storage has certain upper and lower limitations. Because the battery's life is influenced by a variety of circumstances, as previously stated, its power output is regulated by the limitations given in equation (7) and (8) to avoid unexpected charging / discharging.

$$\frac{SOE_{(t-1)} - SOE_{(\max)}}{100}\ BCap^{S} \leq P_{(t)}^{S} \quad (7)$$

The manufacturer specifies the battery capacity $\boldsymbol{BCap^{S}}$. The standby position and the charging/ discharging state are the most common battery modes.

$$\boldsymbol{P_{(t)}^{S}} \leq \frac{\boldsymbol{SOE_{(t-1)} - SOE_{(max)}}}{\boldsymbol{100}}\ \boldsymbol{BCap^{S}} \quad (8)$$

Eq. (9) determines the battery present state of energy (SOE), whereas Eq. (10) controls the beginning and end of operations for day-ahead energy participation. Apart from the various advantages of this supposition, the energy prosumer can engage in the exchange services, particularly the energy management (EMS) system, starting the next day.

$$\boldsymbol{SOE_{t}} = \boldsymbol{SOE_{t-1}} - \frac{\boldsymbol{100.P_{(t)}^{S}}}{\boldsymbol{BCap^{S}}} \quad (9)$$

$$\boldsymbol{SOE_{24}} = \boldsymbol{SOE_{0}} \quad (10)$$

A fixed amount of electricity may be charged and discharged from the battery system in a single step, as represented in expression (11) as a power gradient, which prevents the ESS power output from being entirely charged and discharged. The solar PV output is computed in Eq. (12)-(13), while the limitations are provided in equations (12,13,14).

$$-\Delta \boldsymbol{P_{(t)}^{S}} \leq \left(\boldsymbol{P_{(t)}^{S}} - \boldsymbol{P_{(t+1)}^{S}}\right) \leq \Delta \boldsymbol{P_{(t)}^{S}} \quad (11)$$

$$\boldsymbol{P_{(min)}^{S}} \leq \boldsymbol{P_{(t)}^{S}} \leq \boldsymbol{P_{(max)}^{S}} \quad (12)$$

$$\boldsymbol{SOE_{(min)}} \leq \boldsymbol{SOE_{(t)}} \leq \boldsymbol{SOE_{(max)}} \quad (13)$$

$$\boldsymbol{P_{(t)}^{PV}} = \boldsymbol{\gamma_{PV} \beta_{PV} I} \quad (14)$$

Where γ_{PV} denotes the efficiency or performance of the deployed solar panels, β_{PV} denotes the covered rooftop solar PV area (m^2), and I denote the solar irradiance patterns (kW/m^2).

E. CONSTRAINTS OF DEMAND RESPONSE (DR)

Demand response (DR) is an energy management method based on smart grids that includes customers in the energy market to minimize peak load demand as efficiently as possible. It is important to consider this for system dependability.

A. DEMAND RESPONSE INCENTIVE-BASED (IBDR)

Energy retail prices fluctuate throughout the day in actual pricing time, affecting client usage costs. In this work, the optimum load curtailment is used to assess 0% and 20% DR, utilizing the equation (15). When the IBDR is enforced at 20%, the 20% flexibility range is utilized to transfer demand load from (peak-to-off-peak) hours, and the $DR_{(t)}$ represents the load demand pattern. IBDR is not considered while using the 0% as stated in instance 1 from the expectations, i.e., 0 percent and 20%.

$$\Delta DR_{(t)} = \sum_{t=1}^{t=24} DR_{(t)} \quad (15)$$

$$\Delta DR_{(min)} \leq \Delta DR_{(t)} \leq \Delta DR_{(max)} \quad (16)$$

Where equation (16) shows to manage the load restriction in the usual range by (20%).

B. DEMAND RESPONSE (PRICE-BASED)

Demand response program have three different kinds of pricing tariffs i.e., i) Real time pricing ii) Time of use and iii) Critical peak (CPP) pricing. The 1st pricing scheme (RTP) is taken into account in our given analysis.

F. PROPOSED SOLUTION METHODOLOGY

This proposed method is a non-linear function that is linearly constrained. To solve the proposed model, quadratic programming (QP) is used. This approach achieves an accurate solution with some additional characteristics. The Eq. gives the generic equation for QP (17).

$$f(x) = C^{T}x + \frac{1}{2} * x^{T}Dx \quad (17)$$

$$A_{1}x = B \quad (18)$$

$$A_{2}x \leq C,\ x \geq 0 \quad (19)$$

In equation (19), the constants A_2 and C are vectors of the in-equality constraint, whereas A_1 and B in equation (18), there are independent vectors with separate linear-equality requirements. The suggested system is solved in MATLAB using the solvers.

V. RESULTS & DISCUSSION

The best way to use both dispatchable and non-dispatchable electrical energy resources is to schedule reserves optimally. A campus load was collected from the power grid and then used to create the model shown above. As illustrated in Fig. 4, the prosumer energy consumption, that is a regular load demand in the winter season, is used for study. The month of December is considered the winter season's peak consuming month. A regular day from this season's peak load is used in the analysis to account for the worst-case situation. Choosing the worst-case scenario for the cost analysis allows for precise budget decisions. Using the peak consumption load demand, we are estimating the savings. When the campus load is lower, the majority of the surplus solar PV-generated power is exported to the power grid, resulting in greater savings. Price and Incentives-based demand response strategies are investigated. Figure 6 depicts the present campus's rapidly increasing energy consumption costs.

The primary goal of this research was to investigate both the RTP and IBDR. The grid power exchange is focused on the problem model formulation expressed in formulations (1)- (16).

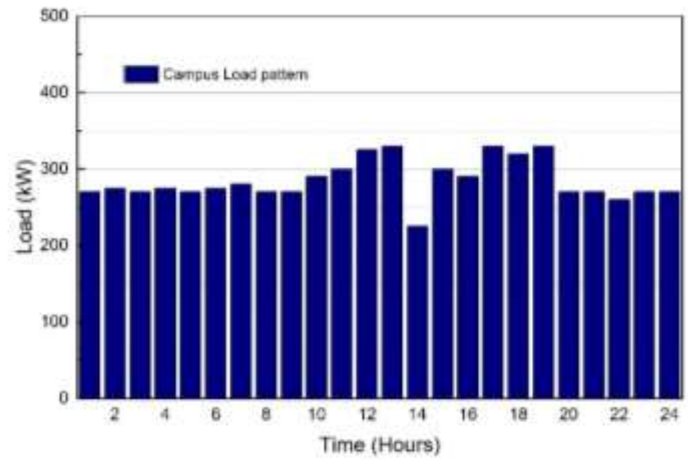

FIGURE 2: Energy demand of Prosumer

A. CASE STUDY

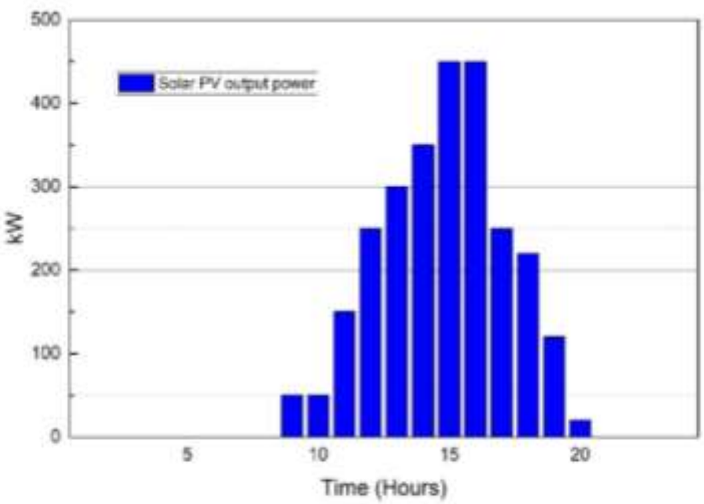

FIGURE 3: Solar PV output power

Two examples are examined in this case study to assess the consequences of various circumstances. Because grid outages are a concern in developing nations like Pakistan, they are included in this scenario along with grid assistance. We'll assume that energy is exchanged with the network at almost the same price per unit. Figures 5 show the solar PV generated energy and prosumer power consumption, respectively. Table II specifics of all case studies, as well as the subcases of both techniques. In case scenario 1, we'll examine price-based DR, whereas in case 2, we'll examine hybrid DR.

Air conditioners, lights, fans, and computers are among the AC loads. Additionally, there are two types of loads: critical and non-critical. Critical loads that cannot be slowed down and must be carried out.

A. CASE (1): ANALYSIS OF DEMAND RESPONSE PRICE-BASED

In this scenario, a (price-based) demand response analysis is used to study impacts on different scenarios for the prosumer microgrid community's operational costs.

Case (1, a): First case scenario has the grid connection which are used to meet all of the energy demands. To supply energy and run all of the campus's loads, there is only one source of energy. In this case, the overall operational cost is 2422.2$, that will be used as baseline.

Case (1, b): Second case scenario comprised of solar PV, diesel generator, and energy storage systems that are used without any scheduling. The cost is calculated in this case $1349.9. In this instance, the costs of installation and repair are not covered.

TABLE II: Case profile with multiple studies

(Case 1): Demand Response Price-Based Analysis		**(Case 2): Demand Response Hybrid Analysis**	
Case (1, a)	Grid available mode	Case (2, a)	Grid available mode
Case (1, b)	Operation cost without scheduling	Case (2, b)	Operation cost without scheduling
Case (1, c)	Grid outage mode	Case (2, c)	Grid outage mode
Case (1, d)	Grid Support mode	Case (2, d)	Grid Support mode
Case (1, e)	Proposed scheduling mode considering storage degradation cost	Case (2, e)	Proposed scheduling mode considering storage degradation cost
Case (1, f)	Proposed scheduling without consideration of degradation cost	Case (2, f)	Proposed scheduling without consideration of degradation cost

Scenario (1, c): In third case scenario, the grid's scheduled outage is examined as illustrated in Figure 9. The system operations cost for the whole day is $1354.3. Solar PV and BESS is compensated for the planned outage. Solar PV is a viable option here, and is selected with ESS which helps to maintain the efficiency of the system. The red line represents the charging / discharging power capacity of ESS.

Case (1, d): The grid in this case scenario issued a signal to the client to assist with grid support. As a result, the client operates as a power importer towards the utility system via an aggregator. The operation costs in this case are $1332.4, as shown in Figure 10.

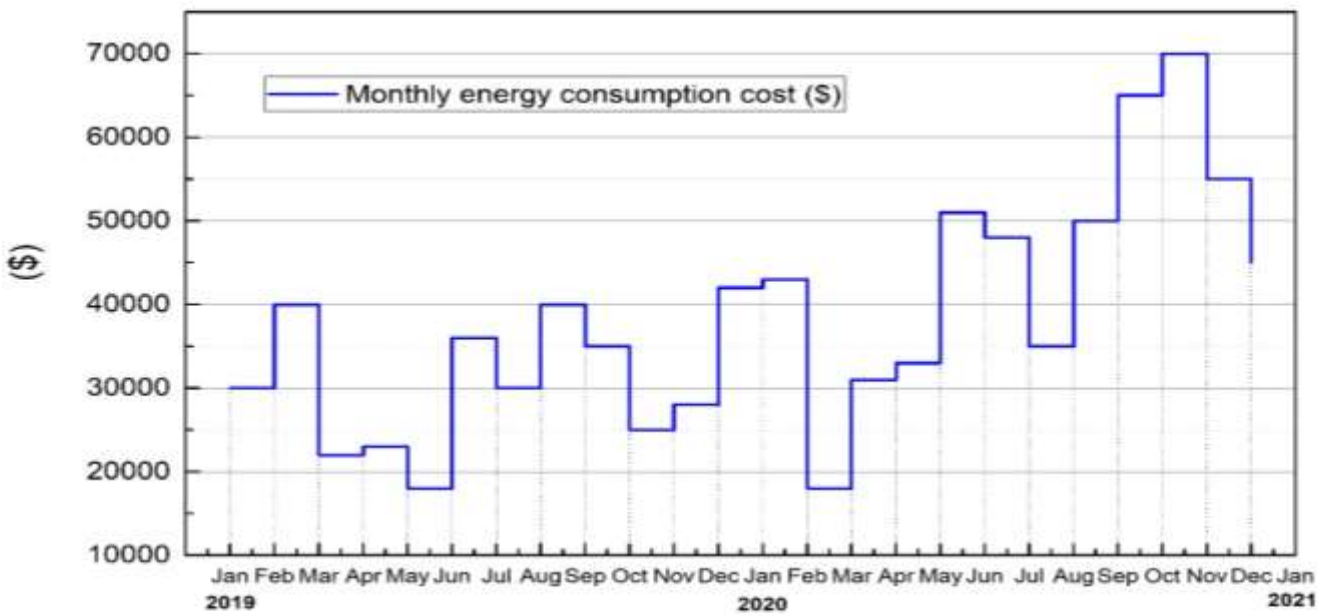

FIGURE 6: Existing campus monthly energy cost (bill)

Case (1, e): In the fifth case scenario, a price-based DR scheduling is used to maximize the use of resources available. The contractual neighbors of prosumer energy are likewise provided from 4.00pm to 6:00pm for two hours, as shown in Fig. 11. When compared to base scenario case 3, the entire cost dropped by 65.3 percent, as indicated in Table.

Case (1, f): In the proposed scheduling case scenario, the cost of storage degradation is ignored, and the cost savings are noticeable when compared to case 1. (e). The cost has minimized from $840 to $754. It has an impact on the battery storage system's lifetime if the storage deterioration cost is ignored.

B. CASE (2): ANALYSIS OF HYBRID DEMAND RESPONSE

In the Hybrid based analysis, the customer adjusts their load to off-peak periods and receives a financial incentive from the national grid. During high-cost peak time periods, a 20% load reduction is possible, this instance is a combination of price and incentive-based demand response. Figures 7 and 8 show IBDR's real-time pricing scheme and load pattern.

Case (2, a): In the base case, just one energy source accessible is the grid, which yielded a result of $2290.5. The difference between scenario 1(a) and scenario 2(b) is considerable, reducing from 2442.6 to 2290.5, a 6 % decline reduction.

Case (2, b): With the rooftop solar panels and ESS, the overall operational cost is decreased to $1017.8 in comparison to scenario 2(a). The output power of rooftop Solar and ESS was used at random, with no regard for any schedule restrictions.

Case (2, c): Costs were decreased from $1332 to $809.2 in grid support mode. The grid is supported by the stored output power for 2 hours, from 10:00 to 11:00. Until the request is completed, the energy status changes to discharging mode.

Case (2, d): An optimal scheduled grid-outage owing to an energy shortage happens at the same time every day between 10:00 and 11:00 a.m. Due to load restriction during these hours, the cost was decreased from $1354.3 to $1137.5.

Case (2, e): In this case, the scheduler included the available resources, particularly the loads, to generate a controlled signal that assured optimal performance. When compared to the basic example, the cost in this scenario was reduced by 70.6 percent, from $2290.5 to $673.2. Correspondingly, Fig. 12 depicts the entire process with set parameters, with the results provided in Table 3.

Case (2, f): In this proposed scheduling case scenario, when calculating the influence on operating expenses, the cost of storage degradation is ignored. The price dropped from 673$ to 594$.

C. DISCUSSION

According to the results of the aforementioned research, both the price-based DR and incentive-based DR methods benefit customers in the energy market. The research is being done for the Pakistani environment, which is still emerging. The integration of renewables with the existing national grid, with the best optimal planning and scheduling of available resources, was investigated, and a substantial reduction in scheduled usage was discovered. As a result, for a seamless and cost-effective operation, a microgrid scheduler is necessary.

In Tab. IV, the recent work is analyzed and compared to this literature. The suggested hybrid DR based scheduling, the effects of solar Energy and ESS are estimated, and the results are provided in the Tab. III. The recommended scheduling has reduced carbon emissions by more than 5,000 kg per day.

TABLE III: Both Cases Results

Cases	(a)	(b)	(c)	(d)	(e)	(f)	Savings Calculated ($)	Economic Benefits (%)	GHG Reduction (Carbon) in (kg/Day)		
Case 1	2422.6	1349.9	1354.3	1332.4	840.3	754.25	1582.2	65.7	Total Load (kWh/day)	Energy generated by Solar PV (kWh/day)	GHG reduction Observed (kg/day)
Case 2	2290.5	1017.8	1137.5	809.2	673.2	594.23	1617.2	70.6	16996	9515	5709

TABLE IV: Proposed Method Comparison with the Existing Work

Ref.	Year	Application	Technique	Remarks	Savings
[25]	2017	IEEE-14 bus system	BBSA	Reliability, Power losses	18.26%
[22]	2018	Campus µG	MILP	ESS Degradation Cost, Peak Demand	5.32%
[24]	2018	IEEE-15 bus system	NA and Conic Technique	Financial Feasibility	3.3%
[26]	2018	Residential Level	MILP	Frequency regulation	7%
[32]	2019	Residential µG	LP	Grid outage	16%
Proposed Model	2021	Campus µG	QP	Self-Consumption, Demand response & ESS Degradation	65.7%, 70.1%

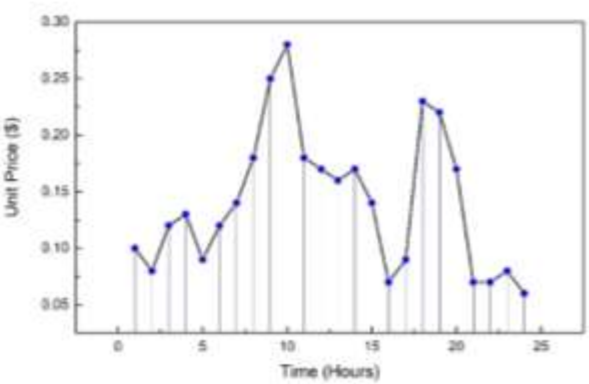

FIGURE 7: Real-time pricing with respect to time

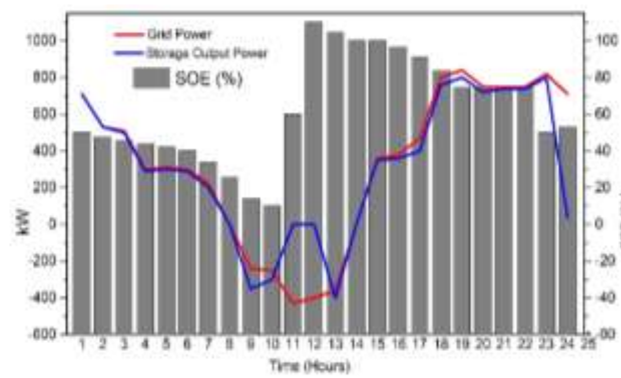

FIGURE 9: Case (1, c): Grid outage only for 2 hours

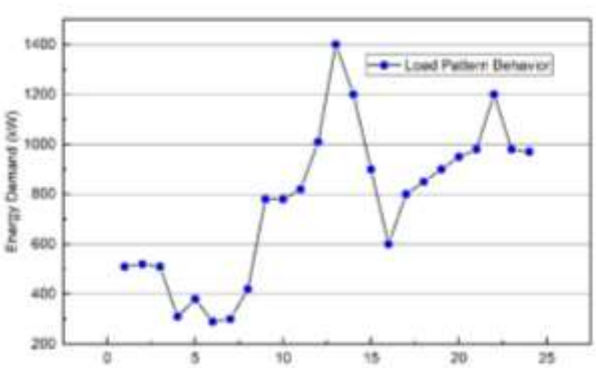

FIGURE 8: Load pattern behavior (20% IBDR)

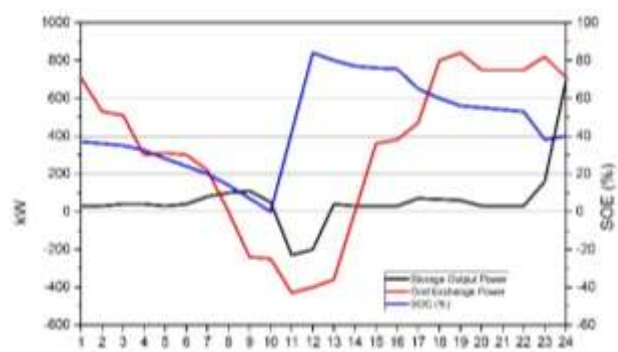

FIGURE 10: Case (1, d): Grid support Scenario

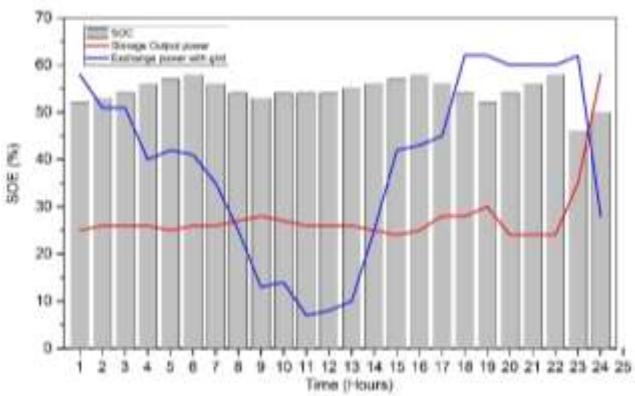

FIGURE 11: Case (1, e): Proposed optimal scheduling mode

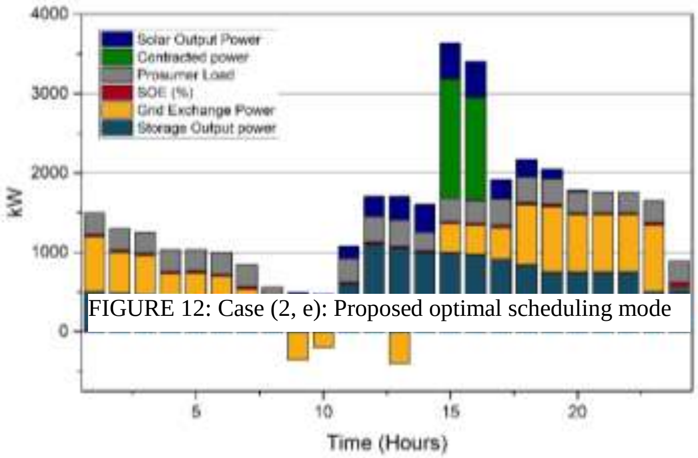

FIGURE 12: Case (2, e): Proposed optimal scheduling mode

VI. CONCLUSION

The suggested EMS model additionally takes into account the impacts of ESS deterioration and DR methods. Because ESS behavior is non-linear, a non-linear problem is implemented in MATLAB by quadratic programming. In addition, the prosumer contracts for a certain amount of fixed electricity with the utility and a neighboring consumer for a specified period. The suggested EMS not only saves money on energy by prolonging storage life, but it also assures grid stability using DR systems. Two different types of DR schemes were investigated: (i) RTP-based price DR, and (ii) a hybrid approach among price-based DR and incentive-based DR The results show that utilizing EMS in a hybrid DR scheme reduces operating costs and peak load on the grid more than using it in a price-based DR scheme employing RTP, with savings of 65.7 percent and 70.1 percent in Case (1) and Case (2), respectively. In addition, the grid outage is taken into account while analyzing the islanded mode of a microgrid. The microgrid has been shown to be able to run its essential loads on the ESS for a short period of time until the utility grid is normally restored. The power manager of the campus microgrid is in charge of selecting a critical load with caution. Future extensions of the research might include various types of DGs, including as wind, biomass, and fuel cells, as well as mobile ESSs as electric cars (EVs) in the campus parking lot. In the future, stochastic methods might be used to integrate random grid presence, DGs, SOCs of mobile ESSs, EV arrival and departure, and so on.

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