6TH International Conference and Workshop on Engineering and Technology Research (ICWETR) LAUFET 2025: 370-379

Forecast Uncertainty Energy Management of Grid-Connected Microgrid Using Nash Bargaining Solution

[1]Oladejo I. O., [2]Adetutu R. A. and [3]Adepoju G. A.

[1]Department of Electrical Engineering, The Polytechnic, Ibadan, Nigeria.
[2]Department of Technical Education, Oyo State College of Education, Lanlate, Nigeria
[3]Department of Electronic and Electrical Engineering, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

https://www.laujet.com/

Keywords:
Cooperative game theory,
Micro-grid,
Nash bargaining solution,
Uncertainty,
Energy management

Corresponding Author:
gaadepoju@lautech.edu.ng
+23487037298582

ABSTRACT

This paper reviews the Micro-grid (MG) concept, emphasizing its role in managing uncertainties in power systems. Load fluctuations and renewable energy sources integration pose challenges in MG operation and scheduling, necessitating effective uncertainty management. MGs integrate renewable energy sources, storage systems, and dispatchable resources to ensure a stable power supply. Efficient energy management is essential to balance intermittent generation and demand. A case study of six sites with varying energy consumption patterns, utilizing solar PV and battery storage, illustrates the modeling process. Cooperative Game Theory (CGT), based on Nash Bargaining Solution (NBS), is applied to model high uncertainty levels among MG participants and the results obtained are optimized using Particle swarm optimization to achieve optimal results. This approach enhances profitability, minimizes reliance on the upstream network, and reduces generator operations. It also enables fair energy sharing among participants, improving economic outcomes. Performance evaluation demonstrates that NBS increases profits compared to non-cooperative strategies.

INTRODUCTION

Uncertainty in MG networks arises due to the intermittent nature of renewable energy sources (RESs). Conventional power systems employ long-term, medium-term, and short-term scheduling, but accurate decision-making is critical for MG operations (Merrill and Wood, 1991). However, there is a need to ensure accurate decision-making for this scheduling. By 2030, RESs are projected to contribute up to 36% of the energy mix, increasing uncertainty in power system planning (Oladejo and Folly, 2019). Two main factors cause uncertainty in power systems, namely, technical and economic factors. Technical uncertainties involve generator failures, transmission line outages, and demand fluctuations, affecting operational decisions. Economic uncertainties stem from energy prices, environmental policies, and economic growth, impacting system efficiency. Effective uncertainty management ensures stable power system operations (Oladejo, 2019).

MGs integrate RESs and function as a single controllable unit, comprising distributed energy resources (DERs), distributed energy storage systems (DESSs), and loads. The energy mix includes non-dispatchable sources like solar PV and wind turbines, supplemented by dispatchable sources such as diesel generators. Storage units, including batteries and fuel cells, enhance energy availability over 24 hours. MGs operate in two modes: grid-connected and islanded modes, the MG meets local demand without external support, while grid-connected mode allows energy exchange with the main grid. An efficient Energy Management System (EMS) is essential for optimizing power generation, ensuring stability, and minimizing operational costs. According to IEC 61970, EMS is a computer system that ensures a secure energy supply at minimal cost (Zia *et al*, 2018). MG EMS follows similar principles, structuring the problem as an optimization challenge constrained by operational requirements. Forecasting uncertainties complicates EMS scheduling, particularly in MGs with high-RES penetration. Optimal scheduling must account for forecast errors, adding complexity to MG management. EMS in MGs requires uncertainty modeling to enhance decision-making and resource utilization.

Several studies have examined EMS in MGs. Zia *et al*. (2018) reviews decision-making strategies and problem-solving methods in MG EMS, but does not fully address uncertainties. Shayeghi *et al*. (2019)discusses various uncertainty modeling approaches alongside objective function formulation and constraints. Simulation results highlight key performance metrics. In Kumar and Saravanan, (2017)Uncertainty modeling techniques for MGs are explored, focusing on renewable energy fluctuations and load variations. Hong and Apolinario (2021) presents simulation tools and unit commitment models, while Soroudi and Amraee (2013) classifies uncertainty management methods, analyzing their strengths and limitations (Oladejo, 2019; Hemmati *et al*, 2020). This paper presents an uncertainty-aware EMS based on the NBS to ensure equitable profit sharing. It facilitates a fair agreement among MG participants, ensuring each one gains a reasonable benefit from cooperation. Additionally, participants can collaborate and share surplus energy, reducing reliance on costly grid electricity.

ROLE OF COOPERATIVE GAME THEORY IN MANAGING UNCERTAINTY IN MICROGRID

MG uncertainty analysis identifies uncertain factors and assesses their impact on MG operations. This process helps in risk mitigation and system reliability. CGT provides a structured approach for decision-making, resource allocation, and risk-sharing among MG participants (Oladejo and Folly 2019). By applying CGT models, such as NBS and coalition formulation games, effective strategies can be developed to manage uncertainty. Key uncertainties in MGs include fluctuations in renewable energy generation, demand variations, and equipment failures (Luo *et al*, 2022). CGT facilitates cooperation among participants, enhancing resource allocation and risk management. By fostering collaboration, CGT strengthens MG stability and efficiency, ensuring uncertainties are addressed collectively.

The benefits of CGT in MG management include risk-sharing, optimized resource allocation, and improved decision-making under uncertainty. It ensures fair distribution of costs and benefits while maximizing efficiency in energy scheduling. However, challenges such as complex modeling and the need for accurate data must be considered. Despite these limitations, CGT enhances MG performance, making it a promising approach for managing uncertainties and improving overall system stability (Zhou and Lund, 2023).

PROBLEM FORMULATION

Uncertainty scheduling in modern power systems, particularly MGs, involves managing distributed generation, storage units, and controllable/uncontrollable loads. The complexity arises from the high integration of renewable energy sources like solar PV and their probabilistic characteristics. The primary objective is to maximize participant profit by optimizing resource utilization while minimizing annual costs.

$$\max f x. = \pi_s\left(P_{rs} - P^{L}{}_{rgs}\right) \tag{1}$$

Where $\max f x$ is the profit maximization of all the participants, P_{rs} is the profit of the participants on the site and $P^{L}{}_{rgs}$ is the lower profit (i.e, status quo profit) of the participants in the site.

$$P_{rs} = I_s - AC_s \quad (2)$$

where I_s is the income of the MG, AC_s is the annual cost of MG.
The total income of the participant is calculated as follows (Oladejo, 2019)

$$I_s = TSC_s + SC \cdot PSE \quad (3)$$

where TSC_s is the transfer selling price, SC represents the sell coefficient and is a constant (it is used to evaluate marketability of a product, which represents the ratio of market price to the original price), and PSE is the price of selling energy to the upstream network, given as

$$PSE = \sum c^e w_p T_t E_{tps} \quad (4)$$

where c^e represents the price of electricity exported to the upstream network, w_p represents the weight of the day p, T_t denotes duration at time t and E_{tps} indicates exported electricity to the upstream network.

$$TSC_s = \sum W_p\, T_t\, E_{ss'}\, y_{tpss'} \quad (5)$$

where $E_{ss'}$ is the transfer price of electricity between sites s and s' and y_{tpss}' represents the electricity transfer on a certain day and time. The total annual MG cost (AC_s) when connected to the upstream network includes annualized Capital Cost (ACCs), operation and maintenance cost (OMC).

$$AC_s = ACC_s + OMC_s + ARC_s + TBS_s + GBC_s \quad (6)$$

where ACC_s is calculated as follows

$ACC_s = Ccap \cdot CRF(i, y)$,where Ccap is the capital cost (US$) and CRF (i, y) is the capital recovery factor (i represents a 12% interest rate and y is the annualized project lifetime). The calculation aspect of CRF is as follows (Oladejo, 2019). The interest rate i typically ranges from 0.04 (4%) to 0.20 (20%) per year, depending on the project risk profile and market conditions, while the annualized project y can range from 1 to 50 years or more, depending on the project's lifespan.

$$CRF = \frac{(1+i)^y}{(1+i)^y - 1} \quad (7)$$

The second and third terms of (6) indicate annual operation and maintenance cost (OMC) and annual replacement cost calculated in (8) and (9), respectively

$$AOM = Ccap\, \frac{(1-\lambda)}{y} \quad (8)$$

where, λ is the component reliability.

$$ARC = (Crep) SFF(i, y_{rep}) \quad (9)$$

where Crep is the battery replacement cost (in US$), yrep is the lifetime of the battery, and SFF is the sinking fund factor, which is calculated as follows

$$SFF = \frac{1}{(1+i)^{Yrep} - 1} \quad (10)$$

The fourth term of (7) is the MG transfer buying cost. This is given in Zhang, *et al*., (2013) as follows.

$$TBS_s = \sum w_p T_t E_{s's} y_{tps's} \tag{11}$$

where, $E_{s's}$ represents the electricity price transfer between sites s' and s and $y_{tps's}$ is the quantity of electricity transferred. The fifth term of (6) represents Grid Buying Cost (GBC) and is calculated as follows

$$GBC = \sum c^i w_p T_t I_{tps} \tag{12}$$

where c^i represents the exported electricity price to the upstream network and I_{tps} represents the quantity of electricity imported from the upstream network.

Constraints

a) Power Balanced Constraints: The total sum of the power generated by non-dispatchable system i.e, solar PV and dispatchable source, i.e., battery unit and power exchange with the grid is equal to the power demanded in grid-connected mode, which is expressed as follows

$$P_{Lgs}(t) = P_{PVs}(t) + P_{Bs}(t) + P_{grid}(t) \tag{13}$$

where, $P_{Lgs}(t)$ represents the load power demand at time t, $P_{PVs}(t)$ is the output power of solar PV at time t, and $P_{grid}(t)$ is the power exchange with the upstream network at time t.

b) Battery Power Output: The use of upper and lower limits is equivalent to the charge/discharge of battery storage units

$$P_B \min(t) \leq P_B(t) \leq P_B max(t) \tag{14}$$

where, $P_B \min(t)$ and $P_B max(t)$ indicate the minimum power discharged and maximum power charged by the battery units, respectively.

c) Electricity Demand Constraints: Electricity Demand Constraints: Quantity of electricity demand L_{tpgs} is given as

$$\sum_{s'} y_{tps's} - \sum_{s'} y_{tpss'} + I_{tjs} - E_{tps} + P_{B_S}(t) + P_{pv_s}(t) = L_{tpgs} \tag{15}$$

where transfer electricity from other sites is $y_{tps's}$, transfer of energy to other sites is $y_{tpss'}$, I_{tps} is the energy imported from the grid. The exported energy to the grid is E_{tps}.The battery energy is $P_{B_S}(t)$and and solar PV power is $P_{pv_s}(t)$.

d) Transfer price level

Generally, there are discrete transfer price levels, that is, k discrete. Therefore, between the two sites price $E_{ss.}$The decision variable $X_{ss'k}$ and the parameter $E_{ss'k}$, which can be summed up over the levels of transfer price

$$E_{ss'} = \sum_k E_{ss'k} X_{ss'k} \qquad \forall s, s' \tag{16}$$

By using one transfer price at a certain time.

$$\sum_k X_{ss'k} \leq 1 \qquad \forall s, s' \tag{17}$$

For each pair of sites and between two transfer directions, the electricity transfer prices are the same. There is an equal transfer price for each site in two directions of transfer.

$$X_{ss'k} = X_{s'sk} \qquad \forall s, s' \tag{18}$$

e) Grid power limits constraint

Limitation in grid power is given as:

$$P_{grid}^{min} \leq P_{grid_s}(t) \leq P_{grid}^{max} \tag{19}$$

where the minimum power is P_{grid}^{min} and peak power is P_{grid}^{max}

UNCERTAINTY MODELLING AND FORECAST GENERATION SCHEDULING IN MICRO-GRID

In MG operation, uncertainty primarily stems from RE penetration. Solar PVs are the most commonly used RES, but their power generation varies due to solar irradiation fluctuations, making uncertainty modeling essential. Another major uncertainty factor is daily load variation, influenced by consumer behavior, time of day, and weather conditions.

a) Solar PV power

Solar PV power output depends on solar radiation and air temperature, both of which follow a normal distribution in terms of mean (μ) and standard deviation (σ) of forecasted irradiation is expressed in (Hemmati *et al*, 2020) as follows

$$F(G_{ING}, T_r) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(\frac{-((G_{ING}, T_r) - (\mu))^2}{2 \times \sigma^2}\right) \tag{20}$$

The solar PV output power generated is calculated as

$$P_{PV} = P_{STC} \times \frac{G_{ING}}{G_{STC}} \times (1 + K(T_c - T_r) \tag{21}$$

Where P_{PV} is the output PV power generated, G_{ING} represents irradiation in hours (hr), G_{STC} denotes standard irradiation, T_r and T_c are the cell and air temperature, respectively. K and P_{STC} are the maximum temperature coefficient and PV rated power, respectively (Hemmati *et al*, 2020).

b) Load modelling: Load modeling is complex due to multiple connected appliances such as air conditioners, heaters, and refrigerators. The load variations also depend on many factors such as the time of day and weather conditions. Load models can be classified into two types: static and dynamic models (Oladejo and Folly 2019). In a static model, the modelling is always achieved in terms of the magnitude and frequency of the bus at that time. The paper makes use of the dynamic model, which represents load behavior over time, taking into account the dynamic characteristics of the load as indicated in Table 1.

Table 1: Annual Demand Profile of each Participant (Oladejo, 2019)

	School	Hotel	Restaurant	Fire station	Residential building	Hospital	Total
Annual electricity demand (kW)	49859	66028.5	90082	37631.5	68036	75004.5	456641.5
Electricity peak demand (kW)	10.7	11.6	17.7	6.8	18.6	7.2	0

Case study

The proposed MG has six participants' sites having solar PV units of 20kW and a battery storage source of 20kWh in each site. Considering the uncertainty in modelling solar PV and load demand, the value of these parameters is forecast as a maximum of 100 kW in summer and 60 kW in winter. Electricity demand for both winter and summer is shown in Table 2. The differences in peak electricity demand for each participant make it possible for electricity to be transferred to other participants. Excess energy will be transferred to the participant in need of energy from the participants having surplus.

Table 2: Electricity Demand for Both Winter and Summer Seasons (Day 1 for winter and Day 2 for summer)

Day	Period (hr)	School (kW)	Hotel (kW)	Restaurant (kW)	Fire Station (kW)	Residential Building (kW)	Hospital (kW)
Daytime 1	P_1	2.11	2.31	8.91	2.11	3.71	2.19
Daytime 1	P_2	2.11	9.29	3.51	3.29	5.61	4.49
Daytime 1	P_3	10.7	11.61	8.91	6.79	7.51	7.31
Daytime 1	P_4	10.69	11.61	17.71	6.79	7.51	7.30
Daytime 1	P_5	10.7	11.61	8.89	6.81	7.51	7.3
Daytime 1	P_6	4.30	9.31	17.69	4.11	18.60	5.41
Daytime 1	P_7	2.11	2.29	8.90	2.11	3.71	3.01
Daytime 2	P_1	2.11	2.29	8.91	2.10	3.71	3.01
Daytime 2	P_2	2.10	9.31	3.49	3.31	5.60	4.50
Daytime 2	P_3	10.71	11.61	8.89	6.81	7.49	7.31
Daytime 2	P_4	10.7	11.6	17.7	6.8	7.5	7.3
Daytime 2	P_5	10.7	11.6	8.9	6.8	7.5	7.3
Daytime 2	P_6	4.3	9.3	17.7	4.1	18.6	5.4
Daytime 2	P_7	2.1	2.3	8.9	2.1	3.7	3.0

Generation Scheduling in Managing the Uncertainty for MG Participants

MG participants such as schools, hospitals, and fire stations experience peak power demand during the day, while restaurants peak during lunch and dinner, and residential buildings in the morning. These variations allow participants to cooperate and benefit from MG operations. Hourly demand schedules are shown in Table 2, while Table 3 presents forecast scheduling, including electricity generation, profit/loss (excess/deficit), and power exchange. Simulation results indicate that restaurants have the highest energy consumption, particularly in the morning and night. Since participants have different energy usage patterns, demand persists throughout the day. Table 3 (column 1) highlights periods of high solar radiation (7 – 17 hours), during which most batteries charge and later hibernate to extend their lifespan. No solar generation occurs between 1–6 hours and 19–24 hours, requiring battery discharge to meet demand. The proposed technique determines power exchanges between the MG and the upstream network. Table 3's second-to-last and last columns show electricity imported from and exported to the upstream network. Using CGT, participants first satisfy their demand, transfer excess energy to other participants, and then sell surplus to the grid. As solar radiation peaks during the day, most sites meet their demand, and excess energy is exported. Since solar power is absent during some hours, energy must be purchased from the upstream network. Table 3's last column details imported energy during 1–6 hours and 19–24 hours when local generation is insufficient.

Table 3: Forecast Uncertainty Scheduling of the Participants

Time (Hrs)	School (kW)		Hotel (kW)		Restaurant (kW)		Fire Station (kW)		Residential Building (kW)		Hospital (kW)		Import (kW)	Export (kW)
	Own Gen	E/D	Own Gen	E/D	Own Gen	E/D	Own Gen	E/D	Own Gen	E/D	Own Gen	E/D		
1	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
2	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
3	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
4	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
5	2.4	0.3	2.3	0	2.4	-6.5	2.3	0.2	2.2	-1.5	2.3	-0.7	8.2	0
6	2.7	0.6	2.5	0.2	2.8	-6.1	2.6	0.5	2.8	-0.9	3.1	0.1	5.6	0
7	5.5	3.4	5.3	-4	5.6	2.1	5.3	2	5.5	-0.1	5.4	0.9	0	4.3
8	7.7	5.6	7.2	-2.1	7.8	4.3	6.5	3.2	7.3	1.7	6.3	1.8	0	14.5
9	10.2	-0.5	9	-2.6	9.5	0.6	7.9	1.1	10.5	3	7.8	0.5	0	2.1
10	11.7	1	10.9	-0.7	11.4	2.5	8.4	1.6	11.5	4	8.5	1.2	0	10.5
11	12.8	2.1	12.1	0.5	12.6	3.7	9.5	2.7	12.6	5.1	9.6	2.3	0	16.4
12	13	2.3	12.8	1.2	13.1	-4.6	10	3.2	13	5.5	10	2.7	0	10.3
13	15	4.3	14.8	3.2	15	6.1	10	3.2	15	7.5	10	2.7	0	27
14	14.8	4.1	14.8	3.2	15	6.1	9.8	3	14.6	7.1	9.7	2.4	0	25.9
15	14.3	3.6	13.9	2.3	14.5	5.6	9.3	2.5	14.2	6.7	9.1	1.8	0	22.5
16	12.9	2.2	12.4	0.8	13.1	4.2	8.5	1.7	12.8	5.3	8.7	1.4	0	15.6
17	10.7	0	10.2	-1.4	10.8	1.9	7.1	0.3	10.6	3.1	7.2	-0.1	0	3.8
18	7.7	3.4	7.7	-1.6	7.8	-9.9	5.6	1.5	7.5	0	5.7	-1.6	8.2	0
19	5	0.7	4.8	-4.5	5.2	-12.5	3.6	-0.5	4.9	-13.7	3.4	- 2	32.5	0
20	3.5	-0.8	3.2	-6.1	3.7	-14	2.9	-1.2	3.6	-15	3	- 2.4	39.5	0
21	2.8	-1.5	2.5	-6.8	2.9	-14.8	2.2	-1.9	2.7	-15.9	2.3	- 3.1	44	0
22	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
23	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0
24	2.1	0	2.1	-0.2	2.1	-6.8	2	-0.1	2.1	-1.6	2	-1	9.7	0

Given that: own gen = Participant's generation, E/D =Excess/deficit, Dem = demand, Negative sign under E/D column represents deficit. Deficit energy implies an energy shortfall and excess energy is the energy surplus.

Transfer of electricity among the MG participants

The algorithm used has an electricity agreed transfer price fixed at 0.0039 kWh (Zhang, *et al*., 2013). The optimal results of the electricity transferred between the two sites are as shown in Table 3. In the interval (1 to 4 hours and 20 to 24 hours), solar power is absent and hence, electricity transfer becomes impossible and energy deficit cannot be tackled by a battery alone. However, at intervals (7- to 10-hour, 12-hour and 17-to 18-hour) transfer of electricity among MG participants is very high. Table 4 shows the annual electricity transfer among the MG participants. To satisfy the participants of MG, a total amount of 75,153kW of electricity was purchased from the upstream network, which is calculated to be 16.48% of the electricity demand in a year. The energy sources from the participants, i.e., the solar PV with battery storage unit, provide the MG a total amount of 381.48kW of electricity annually and about 55,808.5kW of electricity is sold to the upstream network. Annually, the total sum of 8,541 kW of electricity is transferred among the MG participants, which is 1.9% of the electricity demand annually.

Table 4: The Annual Amount of Electricity Transferred Between Sites

Site		Amount of Electricity Transferred (kW)
From	**To**	
School	Hospital	255.5
School	Restaurant	1241
School	Hotel	2007.5
School	Residential Building	328.5
Fire Station	Residential Building	73
Fire Station	Hotel	255.5
Fire Station	School	182.5
Fire Station	Restaurant	730
Restaurant	Hotel	730
Residential Building	Restaurant	1679
Residential Building	Hotel	949
Hospital	Residential Building	36.5
Hotel	Residential Building	73
Total		8541

SIMULATION AND RESULTS

The study presents simulations involving MG participants. The optimization problem is solved using MATLAB and executed on an HP laptop with 4GB of RAM and an Intel Pentium processor. CGT effectiveness is evaluated using NBS. Table 5 shows the study comparison of total cost when MG connects to the upstream network. Two scenarios are considered, trading electricity with the grid and purchasing from the grid. In Case Study 1, participants achieve a 5.2% cost reduction when managing production independently. However, cooperation leads to a 6.4% profit increase. The CGT approach provides a 7.3% improvement, making it more advantageous. In Case Study 2, electricity is imported from the grid, and no profit is recorded under both independent and cooperative strategies, aligning with prior research. Cooperative strategies reduce expenses compared to independent methods.

Table 5: Comparison of Total Costs and Overall Revenue

Case study	Types of MG operation	Participant's strategy	Overall Expenses $	Income $	Overall profits $
1	Purchasing and sales of electricity to the upstream network	Independent	178,006	186,710	8,704
		Cooperative	156,118	165,457	9,339
2	Purchase of electricity from the upstream network	Independent	183,371	183,371	0
		Cooperative	181,802	181,802	0

Allocation of Individual Profit in MG

Figure 2 compares profits under cooperation and independent operation. The restaurant achieves the highest profit, while the fire station has the lowest. Without cooperation, the fire station earns $25,441, increasing to $26,656 (2.42%) with cooperation. The restaurant's profit rises from $28,558 to $29,005 (+1.6%) with cooperation. These results indicate that CGT with NBS enhances profitability compared to independent strategies.

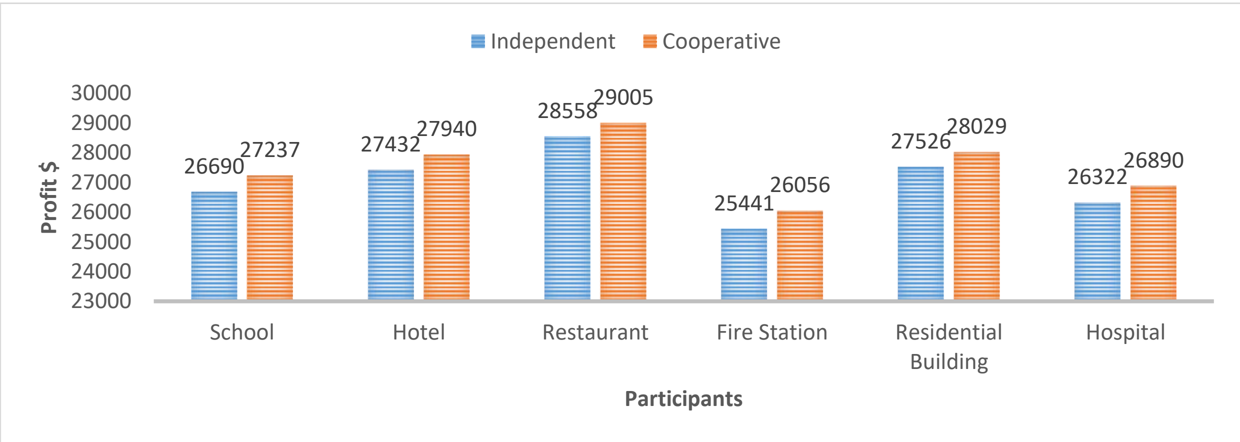

Figure 2: Participants' Profit under Independent and Cooperative

CONCLUSION

This study examines managing uncertainties in a grid-connected MG, addressing operational and scheduling challenges due to fluctuating load demand and renewable energy integration. Six participant sites, each with a dispatchable unit and solar PV, are analyzed. CGT with NBS is applied to optimize generation scheduling and maximize participant profits despite uncertainty in demand and renewable energy output. Instead of purchasing expensive grid electricity, participants transfer excess energy among themselves. Results indicate that the CGT approach yields higher profits than independent methods. Simulations confirm that cooperative strategies reduce overall expenses while increasing income. Energy transfer due to cooperation accounts for 1.9% of annual demand. Cooperative energy management leads to improved economic outcomes, as participants share resources and transfer energy instead of relying on costly grid imports.

REFERENCES

Hemmati, M., Mohammed-Ivatloo, B., and Soroudi, A. (2020). Uncertainty Management in Power System Operation Decision Making. *Electrical Engineering System Science> Systems and Control, arXiv: 1911.10358*.

Hong, Y. Y., and Apolinario, G. E. (2021). Uncertainty in unit commitment in power systems: A Review of Models. Methods and Applications. *Energies, 14*(6658).

Kumar, K. P., and Saravanan, B. (2017). Recent Techniques to Model Uncertainties in Power Generation from Renewable Energy Sources and Loads in Micro-grids: A Review. *Renew. Sustain. Energy Rev., 71*, 348-358.

Luo, J., Li, H., and Wang, S. (2022). A[i] Quantitative Reliability Assessment and Risk Quantification Mehod Micro-gids Considering Supply and Demand UNcertainities. *Applied Energy*.

Merrill, H. M., and Wood, A. J. (1991). Risk and uncertainty in power system planning. *International Journal of Electrical Power and Energy Systems, 13*, 81-90.

Oladejo, I. O. (2019). Energy Management of Micro-grid using Cooperative Game Theory. Cape Town, South Africa: University Of Cape Town.

Oladejo, I. O., and Folly, K. A. (2019). Management of Grid-Connected Micro-grid using Game Theory Approach. *South Africa University Power Engineering Conference/Robotic and Mechatronics/Pattern Recognition Association of South Africa(SAUPEC/ROBMech/PRASA).* Boemfontein, South Africa.

Shayeghi, H., Shahryari, E., Moradzadeh, M., and Siano, P. A. (2019). A Survey on Micro-grid Energy Management Considering Flexible Energy Sources. *Energies, 12*(2156).

Soroudi, A., and Amraee, T. (2013). Decision making under uncertainty in energy systems: state of the art. *Renewable and Sustainable Energy Reviews, 28*, 376-384.

Zhang, D., Samsatli, N. J., Hawkes, A. D., Brett, D. J., Shah, N., and Papageorgiou, L. G. (2013). Fair Electricity Transfer Price and Unit Capacity Selection for Micro-grid. *Elsevier, Energy Economy, 36*, 581-593.

Zhou, Y., and Lund, P. D. (2023). Peer-to-Peer Energy Trading of Renewable Energy in Smart Communities - Trading Pricing Models, Decision-Making and Agent-based Collaboration. *Renewable Energy*.

Zia, M. F., Elbouchikhi, E., and Bembouzid, M. (2018). Micro-grids energy management systems: A critical review on methods, solutions and prospects. *Appl. Energy, 222*, 1033-1055.