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Controlling power fluctuations in grid-connected hybrid PV system with energy management using hierarchical fuzzy logic

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Abstract: This paper presents a novel approach for energy management in grid-connected hybrid PV system using hierarchical fuzzy logic control. The proposed method exploits limited control data available into a hierarchical structure where each layer is specialised for controlling different system parameters. The energy management is controlled by secondary control, which has access to demand and supply whereas primary control restores busbar voltages as per requirement taking local conditions into account. Joint action between primary and secondary controllers reconfigures the system to operate with minimal power flow in tie line and maximum energy storage utilisation while maintaining optimal state of charge. To demonstrate the effectiveness of the proposed method, different case studies are performed under various operating conditions and results show the system can maintain optimal power flow and effectively utilise batteries. This leads to longer battery life, reduced energy costs, and reliable power supply in different supply and loading situations.

Keywords: energy management; fuzzy logic control; FLC; hierarchal control system; hybrid system; renewable energy; sustainable energy.

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1 Introduction

The entire world is driven by conventional energy sources like natural gas, coal, diesel, and so on. Most of the energy is provided by fossil fuels. Nowadays, electricity demand increases with an increase in population. Combustion of fossil fuel produces harmful gases like NO_x , CO_x , and SO_x which are not good for human beings. The primary driver of global warming is the combustion of fossil fuels, which primarily generates CO_2 resulting in the greenhouse effect (Alankrita et al., 2022; Omar and Hamdan 2024). Therefore, it is crucial to reduce CO_2 and other harmful gases to protect the environment and mitigate the effects of global warming. However, due to the limitations of conventional energy sources, there is a global shift towards renewable energy sources (RES). RES offers a sustainable alternative to meet the increasing energy demand while protecting the environment. Solar, biomass, wind, geothermal, and hydro-based energy sources are considered renewable and can be used as a substitute for fossil fuels to generate electricity while reducing environmental impact (Kumar et al., 2023). Solar energy is a significant contributor to clean energy production (Negi et al., 2024). The amount of solar energy that reaches the earth's landmass is 200 times greater than the total annual commercial energy consumed by humans (Badr et al., 2024; Prajapat et al., 2023).

RES offers numerous advantages over traditional energy sources. However, the intermittent supply of renewable energy is a significant challenge. To address this issue, hybrid RES has been developed which utilises two or more RESs, with a supplementary source energy storage system (ESS) to regulate power fluctuations (Alankrita and Srivastava, 2020b; Abdelghany et al., 2024). Hybrid systems are characterised by their high share of renewable energy, decentralised structure, and flexible operation with the use of local energy. The flexibility of hybrid systems enables multiple combinations, which can lead to highly efficient solutions for power generation, improved reliability, and overall energy efficiency. This system can operate as a standalone system or grid-connected system (Alankrita and Srivastava, 2020a). To coordinate different

generation and energy storage units, energy management systems (EMS) are widely proposed in a hybrid system.

A computer-aided system designed for electric utility operators, an EMS facilitates ongoing monitoring, control, and optimisation of the system's operations. Its primary objective is to decrease operational expenses in transmission and distribution systems, resulting in reduced power bills for consumers by minimising losses (Alankrita et al., 2020b; Fagundes et al., 2024). It also minimises overall maintenance and running costs through direct monitoring and control of energy sources (Ge et al., 2023; Gholampour et al., 2024; Liu et al., 2023; Wang et al., 2023). This system is also used to increase the reliability and stability of the system (Zhao et al., 2024; Alankrita et al., 2020a). Multiple controllers are proposed for EMS out of which the fuzzy logic controller is preferred over traditional controllers as it is better suited for complex problems that do not require knowledge of underlying dynamics (Rodriguez et al., 2024). Fuzzy logic control (FLC) systems are frequently used in situations where an exact mathematical model is unknown, and an approximate solution is sufficient. A fuzzy logic controller's fundamental idea is to harness human intelligence and proficiency to develop a control system that steers a problem-solving process (Al Smadi et al., 2024). The input relationship of the problem is described by a collection of fuzzy control rules that employ verbal parameters (Xie and Jin, 2024; Sharma et al., 2023). The primary structure of the fuzzy control inference system comprises IF-THEN rules (Ali et al., 2023). Designing a fuzzy controller involves using linguistic variables and fuzzy inference rules (Panneerselvam et al., 2024; Hesamian et al., 2024).

This work proposes an EMS control for a grid-connected hybrid photovoltaic (PV) system. System dynamics are approximated by FLC and a hierarchal control structure is used to control various parameters in different layers. The main contributions of this article can be summarised as follows:

- 1 A novel EMS is proposed for power flow control in a grid-connected hybrid PV system based on a hierarchical control structure that decomposes the distributed state of system into different layers, each controlling different parameters.
- 2 The secondary controller is used to feed forward state of the system into the primary controller leading to faster controlling action.
- 3 Tie line power flow is minimal and there is maximum utilisation of ESS.
- 4 The proposed method is evaluated through simulations under a range of operating conditions, which include variations in generation and grid power dynamics.

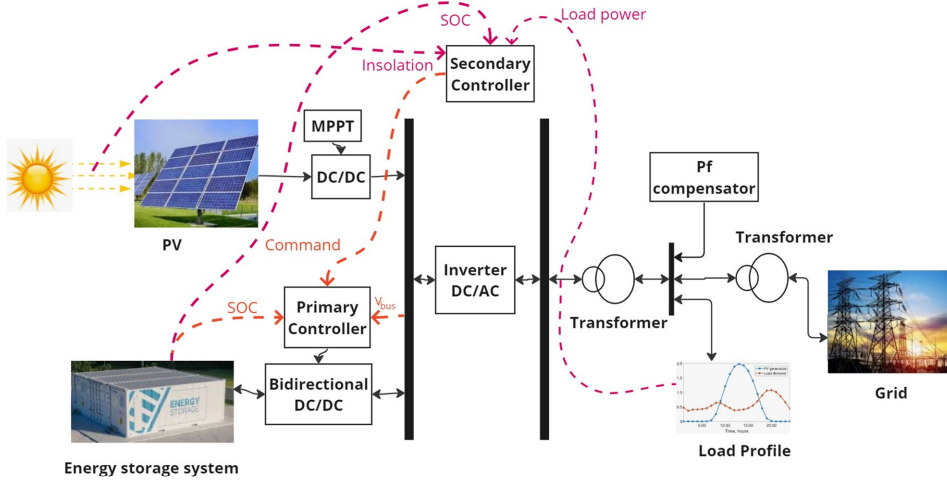
The subsequent section describes energy management by the ESS and the corresponding controller. In Section 3, a comprehensive analysis of the outcomes is presented, along with the details of the simulation setup. Finally, a conclusion and future work is provided.

2 EMS and control

The hybrid system in this work consists of a PV array and ESS connected to a common DC busbar. DC power is converted into grid-quality AC power by an inverter, which is fed into a load and tie line connected to the grid. The block diagram of the system is illustrated in Figure 1. To ensure that load demand is always met and any surplus is

efficiently utilised, an ESS is designed. The main components of ESS include lithium-ion batteries (which typically have a lifespan of 8–10 years), a bidirectional DC-DC converter, and a primary controller. Power flow in ESS is controlled by the primary controller based on fuzzy logic based on secondary controller commands and local conditions which include the battery's state of charge (SOC) and busbar voltages.

Figure 1 Block diagram of hybrid PV system connected with grid and load (see online version for colours)



2.1 Fuzzy logic for battery control

The power supply between the load, grid, and DC bus bar is regulated by the charge and discharge rates of an ESS. The primary controller at the battery expects three inputs, namely:

- 1 Difference between reference and actual busbar voltage (from here on, this is referred to as an error in busbar) which is representative of a mismatch between supply and demand.
- 2 Battery's SOC.
- 3 Command signal from the secondary controller.

These input membership functions for the primary controller are given in Tables 2 and 4. It can be seen that the controller can accept bus voltage deviation of ± 100 V and a full range of SOC. The membership function for output is given in Table 4 for the duty cycle between 0 and 1.

Table 1 outlines a set of rules for the Mamdani fuzzy inference system, demonstrating that the primary controller at the battery considers all three inputs. It then executes the optimal control action to reduce error. The output of this controller is a duty cycle which is fed into the DC-DC converter. Figure 2 shows how secondary control feeds commands to primary controller hierarchal layers.

Table 1 Fuzzy inference rule for battery control at the primary controller

<i>Load power demand</i>	<i>State of charge</i>	<i>Secondary command</i>	<i>Duty cycle</i>
EH	L	C	NCD
EH	N	C	NCD
EH	H	C	NCD
EH	L	D	VSD
EH	N	D	FD
EH	H	D	VFD
VH	L	C	FC
VH	L	D	VSD
H	N	C	NCD
H	L	C	VSC
H	N	D	FD
H	L	D	NCD
L	L	C	VFC
L	H	C	NCD
L	L	D	NCD
L	H	D	SD

Table 2 Fuzzy membership function for error voltage at busbar

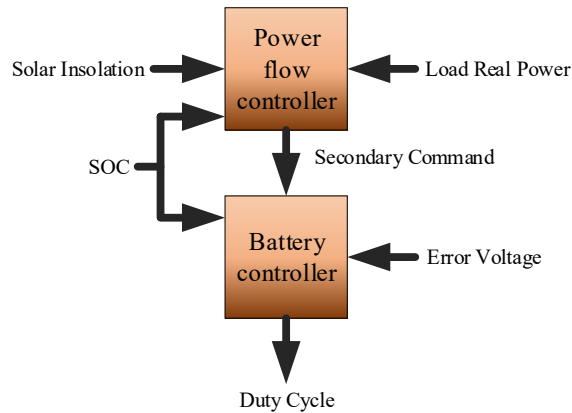
<i>Demand</i>	<i>Standard deviation of Gaussian curve</i>	<i>Centre of Gaussian curve</i>
EH	51.230	−100.0
VH	41.200	−50.8
H	40.200	−20.9
N	10.230	0.0
L	41.230	20.0
VL	41.230	50.0
EL	51.230	100.0

Table 3 Membership function for duty cycle

<i>Discharge/charge rate</i>	<i>Standard deviation of Gaussian curve</i>	<i>Centre of Gaussian curve</i>
Discharge very fast	0.00828	0.020
Discharge fast	0.05308	0.125
Discharge slow	0.05308	0.250
Discharge very slow	0.05308	0.375
No charge/discharge	0.10620	0.512
Charge very slow	0.05308	0.625
Charge slow	0.05308	0.750
Charge fast	0.04056	0.875
Charge very fast	0.04056	0.980

Table 4 Membership function for the battery's SOC

SOC	Standard deviation of Gaussian curve	Centre of Gaussian curve
L	12.75	20
N	20.00	50
H	12.75	80

Figure 2 Block diagram of hierarchal controllers (see online version for colours)

2.2 Fuzzy logic for power flow (secondary control)

The secondary level controller is used for energy management. It ensures optimal power flow between PV, ESS, load, and grid (via tie line). Inputs to the secondary controller are:

- 1 PV insolation
- 2 battery's SOC
- 3 load demand.

Outputs of the secondary controller a command signal (hereby referred to as a secondary command) to the battery storage controller to either charge, discharge, or no change (neither charge nor discharge). Although the battery's SOC is not strictly required at secondary control as the primary controller already has access to it, this information does help the secondary controller to consider the current power reserve while computing power flow requirements. The secondary controller serves as a feed-forward mechanism for power imbalances. Without this controller, the mismatch between supply and demand would take longer to reflect in the primary controller as these power imbalances would need to be transformed into busbar voltage imbalances before the primary controller could take any corrective actions.

Table 1 classifies three inputs: load power demand (LPD), SOC and secondary command (SC). Load power demand can be given as: extremely high (EH), very high (VH), high (H) and low (L). SOC are categorised in low (L), high (H), normal (N). Secondary commands are given as: charge (C), discharge (D). Resulting duty cycle is

given as: no charge or discharge (NCD), very slow discharge (VSD), slow discharge (SD), fast discharge (FD), very fast discharge(VFD), fast charge(FC), very slow charge (VSC) and very fast charge (VFC). In Table 2, input parameter demand is categorised as extremely high (EH), very high (VH), high (H), normal (N), low (L) and very low (VL).

Table 5 lists fuzzy inference rules for power flow control. These rules are based on the available reserve power on the battery and the requirement of the load. In case of high demand, an attempt is made to extract power from the battery only when the PV array is not generating sufficient power, once the PV array generates sufficient power, any undue power pressure on the battery is relieved. This ensures the longevity of the battery and reduces aging.

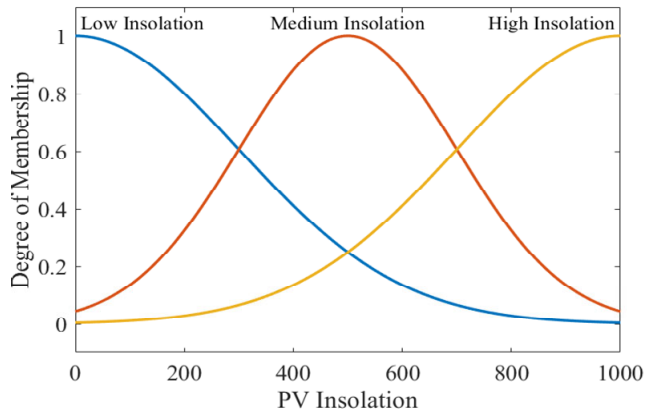
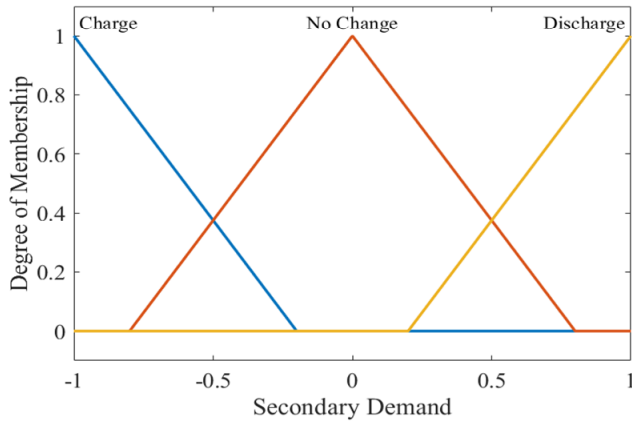
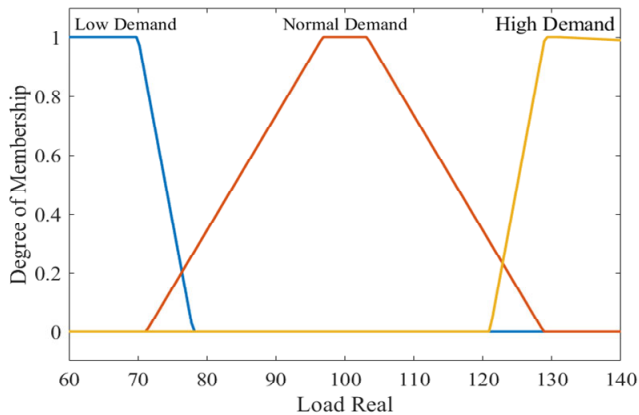
Table 5 Fuzzy inference rule for power flow control

<i>PV insolation</i>	<i>SOC</i>	<i>Load demand</i>	<i>Secondary command</i>
L	L	H	No change
L	H	L	Discharge
L	M	L	Discharge
L	M	H	Discharge
M	L	H	No Charge
M	H	L	No Charge
M	M	L	No change
M	M	H	discharge
H	L	H	No change
H	H	L	No change
H	M	L	Charge
H	M	H	Discharge

Membership function plots for the input Power flow controller are given in Figure 3 and Figure 4. Output of power flow control is shown in Figure 5. It is negative whenever it requires a battery storage system to get charged and positive if it requires a battery storage system to get discharged. The magnitude of this output value indicates the rate of charging or discharging required.

3 Simulation results

The proposed system is designed and simulated in a MATLAB/Simulink environment. Different case studies are performed to assess the viability of the system. The DC power at the bus bar is converted by an inverter into AC power which is then supplied to load and grid. The inverter's phase angle is adjusted to control the power flow in the tie line. Reactive power demand is supplied by reactive support. The energy demand is represented as a fixed load of 100 kW and variability in the system is imposed by variation in PV generation. Additional power is drawn from ESS and tie line as per as energy requirement.

Figure 3 Membership function plot for PV insolation (see online version for colours)**Figure 4** Membership function plot for power required (secondary command) (see online version for colours)**Figure 5** Membership function plot for load read power (see online version for colours)

3.1 Simulation results

The system specifications for simulation are detailed in Table 6.

Table 6 Ratings

Parameter	Ratings
PV array	Current _{maximum power point} = 7.35 A, Voltage _{maximum power point} = 29 V Parallel modules = 50, series modules = 10, PV Array peak power = 102.57 kW
DC-DC boost converter	$C_{sh} = 100 \mu\text{F}$, $L_s = 50 \text{ mH}$, $R = 1 \text{ m}\Omega$, $L = 10 \text{ mH}$, switching frequency = 15 kHz
Transformer	200/440 kV, 150 kVA, 50 Hz
Reactive support	Active power = 0.5 kW, reactive power = 15 kVAR
Battery	Rated capacity = 300 Ah, nominal voltage = 48 V
Grid	100 MVA, 33 kV, 50 Hz
Maximum tie-line power	$\pm 20 \text{ kW}$
Load	100 kW

3.2 Results and analysis

Three test scenarios are being considered based on the battery's SOC at different levels. The PV generation varies according to solar insolation, as depicted in Figure 6. Additionally, the PV output power profile is illustrated in Figure 7.

3.2.1 Case 1: Low SOC (< 20%)

Battery cannot supply power to load if demand is high and power production from the PV array is low, if SOC is below 20%. As indicated in Table 5, the secondary controller does not issue any power change command to the battery controller under these conditions. In this scenario, the local system state takes precedence over global requirements. To meet the high demand, tie line provides additional power as depicted in Figure 9. As illustrated in Figure 8, the load power demand is fulfilled within 2 to 4 seconds. However, there is a shortfall in power from 0–2 seconds and 4–5 seconds, since the grid can only supply a maximum of 20 kW, which falls short of meeting the load demand.

Figure 6 PV insolation level (see online version for colours)

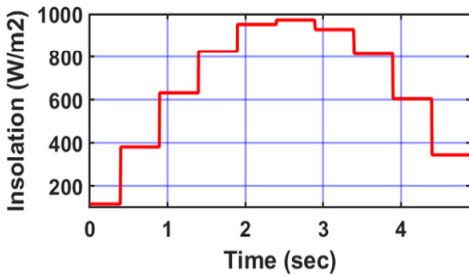
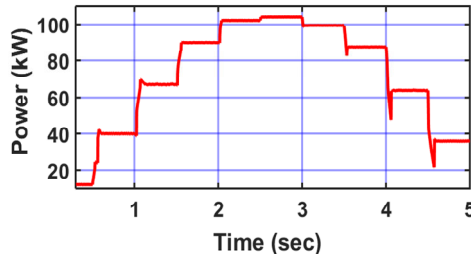
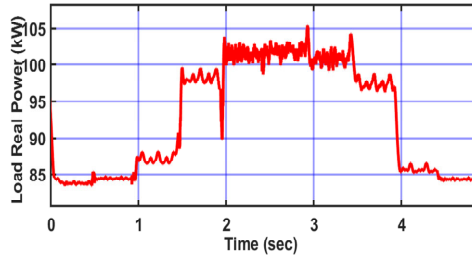
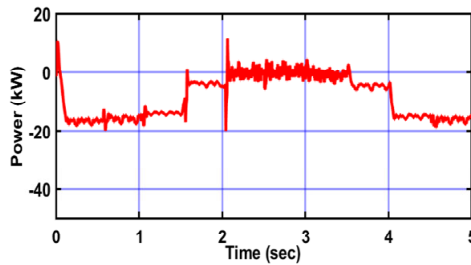
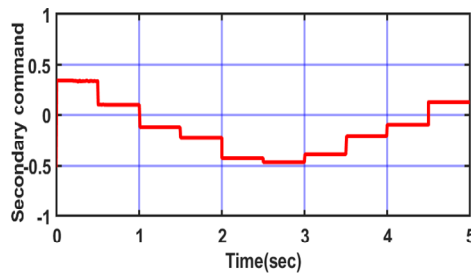


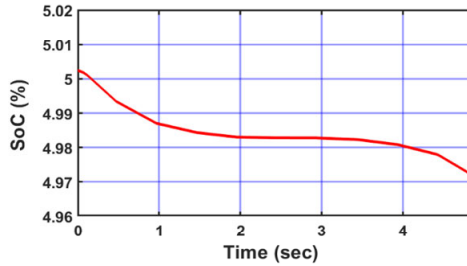
Figure 7 Power generated by PV system (see online version for colours)**Figure 8** Load real power (see online version for colours)**Figure 9** Power drawn from tie line (see online version for colours)**Figure 10** Secondary command (see online version for colours)

Once the PV array generates sufficient power and load demand is lower, surplus power is used to charge the battery but in the current case, power generated by PV is deficit for time $0 < t < 2$ and $3.5 < t < 5$. Rate of discharging/charging depends on load demand, PV array supply, and requirement as specified by the power flow controller. From Figure 10,

it is seen that even though the power flow controller requests discharge from the battery, the requested discharge is not as large as in cases of high or normal SOC.

Power is drawn from the grid as there is a power deficit at load and ESS as well as supply, both are weak. From Figure 11, it can be seen that the battery's SOC profile remains flat as at no point there have been a surplus supply to charge batteries and discharge did not happen even during excess power demand.

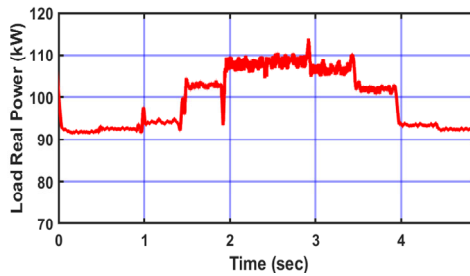
Figure 11 Battery SOC (see online version for colours)



3.2.2 Case 2: High SOC ($> 80\%$)

When battery SOC is high, the battery can supply the required power demand as needed. The batteries are set to charge when the power demand is low and the power supply is high, indicating that there is surplus power available for charging the battery. According to Table 5, under these conditions, the secondary controller does not issue any change commands to the ESS; hence, the battery does not charge even if surplus power is available.

Figure 12 Load real power (see online version for colours)



During the initial and final time frame viz $0 < t < 2$ and $3.5 < t < 5$, when supply is low, ESS supplies power to correct the bus bar voltage. Battery storage system supplies required power and load demand remains within specified limits as seen in Figure 12. From Figure 15, it is seen that except time $2 < t < 3.5$ when solar power is abundant, the battery is mostly in discharging mode. When PV power is sufficient, any extra power generated is supplied to the grid as seen in time $3 < t < 4$, and tie line power is positive as given in Figure 13. Power is supplied to the grid because the battery's SOC is high. In secondary command (Figure 14), the peak magnitude of discharging is higher than in cases where SOC is low or normal. Compared to case 1, no power is drawn from the tie

line even when demand exceeds generation. But also there is no charging of batteries during surplus power.

Figure 13 Power drawn from tie line (see online version for colours)

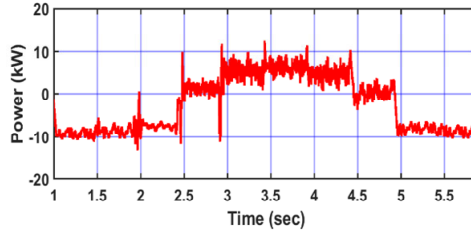


Figure 14 Secondary command (see online version for colours)

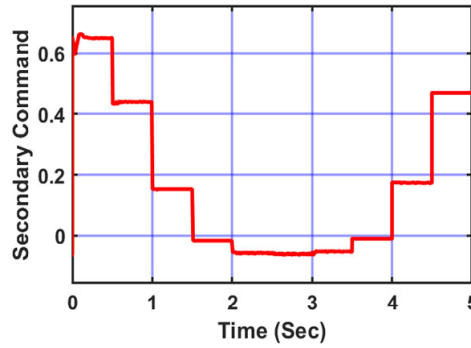
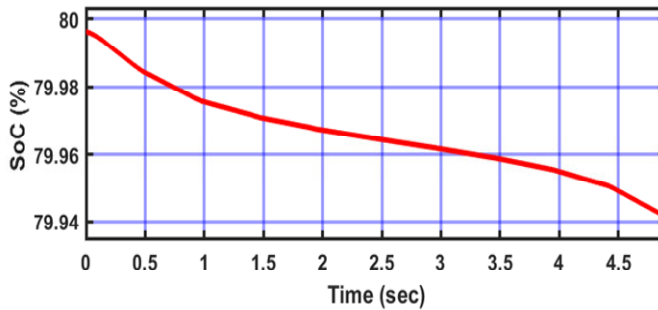


Figure 15 Battery SOC (see online version for colours)



3.2.3 Case 3: Normal SOC ($80\% > SOC > 20\%$)

When battery SOC is normal, the battery can supply power if demand is high and power production from the PV array is low. Any command from the power flow controller to charge/supply power from the battery storage system is taken into account apart from the power needed to correct the bus bar voltage. Extra power is not needed to be drawn from the grid as long as PV and ESS can meet the load demand.

During the initial and final time frames viz $0 < t < 2$ and $3.5 < t < 5$, when supply is low, the ESS supplies the power. It not only corrects the busbar voltage, but extra input

from the secondary controller makes the system more proactive as such change would have otherwise taken some time to propagate as a change(error) in busbar voltage. Battery quickly supplies power and load demand remains within specified limits as seen in Figure 16. The secondary command alternates between charging and discharging, in accordance with the battery's SOC, as illustrated in Figure 18. From Figure 19, it is seen that except time $2 < t < 3.5$ when PV generation is abundant, the battery is mostly in discharging mode. Power is drawn from the tie line for a small time frame between $0 < t < 1.5$ and $4 < t < 5$ when PV and battery power are not sufficient as given in Figure 17. As compared to both cases 1 and 2, no power transfer occurs in tie line as batteries absorb or provide power as demanded by the load.

Figure 16 Load real power (see online version for colours)

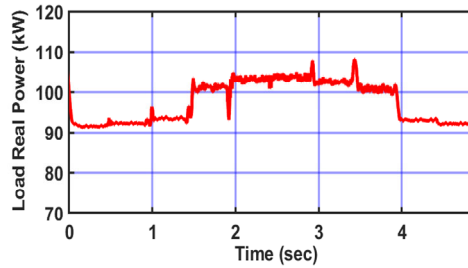


Figure 17 Power drawn from tie line (see online version for colours)

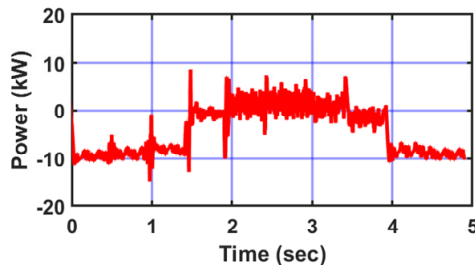


Figure 18 Secondary command (see online version for colours)

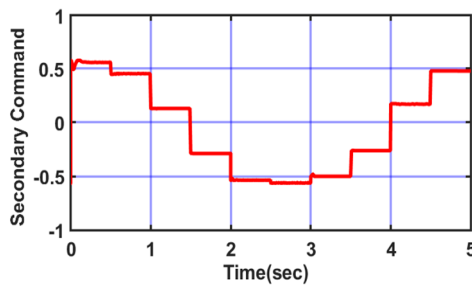
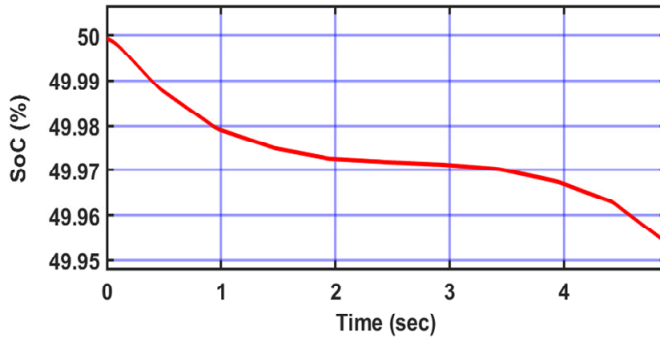


Figure 19 Battery SOC (see online version for colours)

4 Conclusions

This paper presents a hierarchal strategy for power flow control and energy management of a hybrid PV system. The proposed system is based on multilevel FLC for tracking local disturbance of the busbar at the primary level and global disturbance of power at the secondary level. In case of mismatch between supply and demand, the secondary controller issues corrective action commands that are processed by the primary controller. Taking into account local states such as the battery's SOC and bus voltage, the primary controller issues necessary commands to the ESS for power adjustment. The proposed method combines local and distributed states to generate optimal action for power flow control.

Different case studies were performed and the simulation results shows that:

- 1 Load power demand is met by either ESS or grid based on the battery's SOC.
- 2 Additional power is used to charge ESS. In case of high SOC, excess power is delivered to the tie line. The cost associated with power injected to tie line can be recovered.
- 3 The battery's SOC is maintained at an optimal operating range, enhancing its longevity.
- 4 Tie line is utilised only in case of contingences thus decreasing overall power cost and maintenance of tie line.

The proposed method achieves superior performance for energy management by reducing energy costs and increasing effective utilisation of available ESS and grid power. Performance of the system provides improvement over similar control strategies in hybrid PV systems (Alankrita et al., 2022) owing to hierarchal control strategy leading to faster response and lower power fluctuations.

For future work, the integration of additional RES such as Wind Turbines could be explored, and the feasibility of the proposed system in a microgrid setting could be assessed. Further control strategies, including adaptive droop control, backstepping control, and reinforcement learning-based control, could be examined for the design of secondary and tertiary controllers.

References

- Abdelghany, M.B., Al-Durra, A. and Gao, F. (2024) 'A coordinated optimal operation of a grid-connected wind-solar microgrid incorporating hybrid energy storage management systems', in *IEEE Transactions on Sustainable Energy*, January, Vol. 15, No. 1, pp.39–51, DOI: 10.1109/TSTE.2023.3263540.
- Al Smadi, T., Handam, A., Gaeid, K. S., Al-Smadi, A. and Al-Husban, Y. (2024) 'Artificial intelligent control of energy management PV system', *Results in Control and Optimization*, Vol. 14, No. 1, p.100343.
- Alankrita and Srivastava, S.K. (2020a) 'Analysis of constant real power flow injection from PV system to power grid', in *2020 International Conference on Electrical and Electronics Engineering (ICE3)*, IEEE, February, pp.396–401.
- Alankrita and Srivastava, S.K. (2020b) 'Application of artificial intelligence in renewable energy', in *2020 International Conference on Computational Performance Evaluation (ComPE)*, IEEE, July, pp.327–331.
- Alankrita, A., Srivastava, S.K., Pandey, A.K. and Gupta, S.K. (2020a) 'Analysis of hybrid PV-fuel cell system for load power flow control', in *2020 International Conference on Power Electronics & IoT Applications in Renewable Energy and its Control (PARC)*, IEEE, February, pp.267–271.
- Alankrita, Srivastava, S.K., Gupta, S.K. and Pandey, A.K. (2020b) 'Assessment of technical parameters of renewable energy system: an overview', in *2020 International Conference on Computational Performance Evaluation (ComPE)*, IEEE, July, pp.107–112.
- Alankrita, Pati, A., Adhikary, N., Mishra, S.K., Appasani, B. and Ustun, T.S. (2022) 'Fuzzy logic based energy management for grid-connected hybrid PV system', *Energy Reports*, Vol. 8, pp.751–758.
- Ali, M., Ahmad, M., Koondhar, M.A., Akram, M.S., Verma, A. and Khan, B. (2023) 'Maximum power point tracking for grid-connected photovoltaic system using adaptive fuzzy logic controller', *Computers and Electrical Engineering*, Vol. 110, No. 6, p.108879.
- Badr, M.A., Khalil, A.A.I., Khalil, M.M., Hafez, A.I. and Mostafa, E.M. (2024) 'Effect of weathering conditions on the durability of solar energy mirrors that heat the HTF oil in El-Kureimat solar energy power plant', *International Journal of Power and Energy Conversion*, Vol. 15, No. 2, pp.99–121.
- Fagundes, T.A., Fuzato, G.H.F., Magossi, R.F.Q., Silva, L.J.R., Vasquez, J.C., Guerrero, J.M. and Machado, R.Q. (2024) 'A modified redundancy-based energy management system for microgrids: an SoC enhancement approach', *IEEE Transactions on Industrial Electronics*, Vol. 71, No. 1, pp.1–10.
- Ge, Y., Hu, H., Chen, J., Wang, K. and He, Z. (2023) 'Hierarchical energy management of networked flexible traction substations for efficient RBE and PV energy utilization within ERs', in *IEEE Transactions on Sustainable Energy*, July, Vol. 14, No. 3, pp.1397–1410, DOI: 10.1109/TSTE.2022.3233531.
- Gholampour, K., Adabi, J., Gholinezhad, H. and Inegbedion, O. (2024) 'Optimal hierarchical energy management system with plug-and-play capability for neighborhood home microgrids', in *IEEE Transactions on Industrial Electronics*, August, Vol. 71, No. 8, pp.9067–9076, DOI: 10.1109/TIE.2023.3319729.
- Hesamian, G., Johannssen, A. and Chukhrova, N. (2024) 'Fuzzy nonlinear regression modeling with radial basis function networks', in *IEEE Transactions on Fuzzy Systems*, April, Vol. 32, No. 4, pp.1733–1742, DOI: 10.1109/TFUZZ.2023.3332918.
- Kumar, C.M.S., Singh, S., Gupta, M.K., Nimdeo, Y.M., Raushan, R., Deorankar, A.V., Kumar, T.A., Rout, P.K., Chanotiya, C.S., Pakhale, V.D. and Nannaware, A.D. (2023) 'Solar energy: a promising renewable source for meeting energy demand in Indian agriculture applications', *Sustainable Energy Technologies and Assessments*, Vol. 55, No. 1, p.102905.

- Liu, X., Zhao, T., Deng, H., Wang, P., Liu, J. and Blaabjerg, F. (2023) 'Microgrid energy management with energy storage systems: a review', in *CSEE Journal of Power and Energy Systems*, March, Vol. 9, No. 2, pp.483–504, DOI: 10.17775/CSEEJPES.2022.04290.
- Negi, P., Pal, Y. and Gopinathan, L. (2024) 'Performance analysis of grid-connected photovoltaic systems using grey wolf optimisation and genetic algorithm', *International Journal of Power and Energy Conversion*, Vol. 15, No. 2, pp.122–146.
- Omar, M.A. and Hamdan, A. (2024) 'Control strategy of battery inverter for voltage profile improvement in low voltage networks with high PV penetration level', *International Journal of Power and Energy Conversion*, Vol. 15, No. 1, pp.25–41.
- Panneerselvam, G., Rahmani, A. and Mani, P. (2024) 'Fuzzy event-triggered control for grid-connected PMSM model with stochastic disturbances', in *IEEE Transactions on Fuzzy Systems*, April, Vol. 32, No. 4, pp.1630–1640, DOI: 10.1109/TFUZZ.2023.3330420.
- Prajapat, G.P., Tanwar, S.S. and Dubey, R.K. (2023) 'A multivariate regression model of solar photovoltaic and its validation through ANN', *International Journal of Power and Energy Conversion*, Vol. 14, No. 4, pp.359–375.
- Rodriguez, M., Arcos-Aviles, D. and Guinjoan, F. (2024) 'Simple fuzzy logic-based energy management for power exchange in isolated multi-microgrid systems: a case study in a remote community in the Amazon region of Ecuador', *Applied Energy*, Vol. 357, No. 5, p.122522.
- Sharma, S., Chauhan, B.K. and Saxena, N.K. (2023) 'Grid connected fuzzy logic control-based MPPT techniques for hybrid photovoltaic wind with battery system', *International Journal of Power and Energy Conversion*, Vol. 14, Nos. 2–3, pp.280–309.
- Wang, Y., Hu, J. and Liu, N. (2023) 'Energy management in integrated energy system using energy-carbon integrated pricing method', in *IEEE Transactions on Sustainable Energy*, October, Vol. 14, No. 4, pp.1992–2005, DOI: 10.1109/TSTE.2023.3295573.
- Xie, Z. and Jin, L. (2024) 'A fuzzy neural controller for model-free control of redundant manipulators with unknown kinematic parameters', in *IEEE Transactions on Fuzzy Systems*, March, Vol. 32, No. 3, pp.1589–1601, DOI: 10.1109/TFUZZ.2023.3328545.
- Zhao, Z., Xu, J., Guo, J., Ni, Q., Chen, B. and Lai, L.L. (2024) 'Robust energy management for multi-microgrids based on distributed dynamic tube model predictive control', in *IEEE Transactions on Smart Grid*, January, Vol. 15, No. 1, pp.203–217, DOI: 10.1109/TSG.2023.3290191.