

Real-Time Adaptive Energy Management in Renewable Energy Community: Reducing the Challenge of Forecasting and Prior Knowledge Dependencies

Ateeq Ur Rehman¹, Sandra Corasaniti^{1*}, Paolo Coppa¹, and Yasir Abbas Khan²

¹. Department of Industrial Engineering, University of Rome Tor Vergata, , 00133 Rome, Italy,

². United States-Pakistan Center for Advanced Studies, University of Engineering & Technology, Peshawar 25000, Pakistan

*Corresponding Author: Sandra Corasaniti (sandra.corasaniti@uniroma2.it)

INTRODUCTION & AIM

- Traditional energy management models focus on demand, costs, and renewables, which may results less effective in dynamic circumstances.
- This paper presents a real-time Lyapunov optimization paradigm that eliminates the need for prior forecasting and functions adaptively under uncertainty.
- Do appliances energy management considering heating ventilation and air conditioning (HVAC), electric vehicle (EV), and energy storage system (ESS)

METHOD

- Lyapunov optimization-based energy controller
 - Input: Solar irradiance, temp, energy prices, user occupancy, demand
 - Output: Appliance scheduling, HVAC, EV, ESS decisions

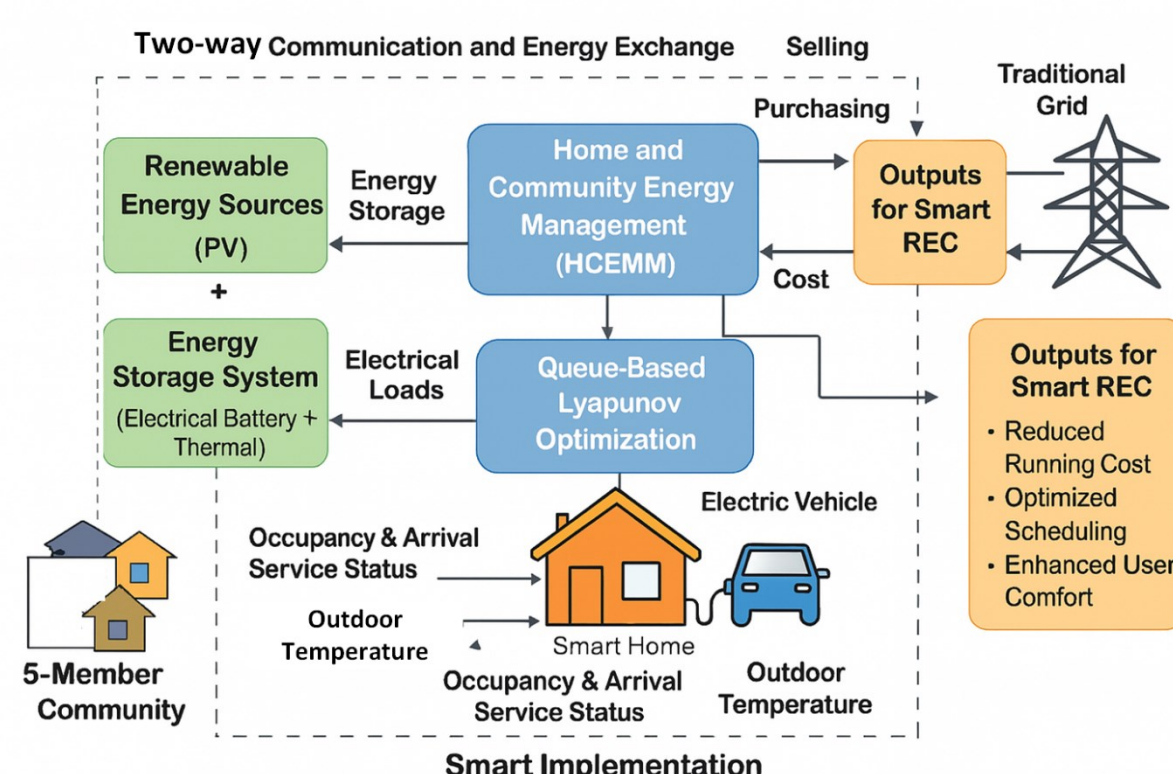


Fig. 1: System model architecture

- Developed the home & community energy management model (HCEMM), which includes PV, ESS, HVAC, and EV scheduling.
- The system constraints (comfort, EV delay, and battery limits) were stabilized using queue-based Lyapunov optimization.
- Decisions are made slot by slot based on real-time data (prices, irradiance, and demand).

RESULTS & DISCUSSION

Cost savings:

- Single home: -19.2% (from \$642 to \$518/month).
- 5-home REC: -27.6% (from \$516 to \$374/month).
- Comfort index: 94.8-97.2% was maintained.
- We achieved adaptive load shifting, peak shaving, and grid-friendly operating.

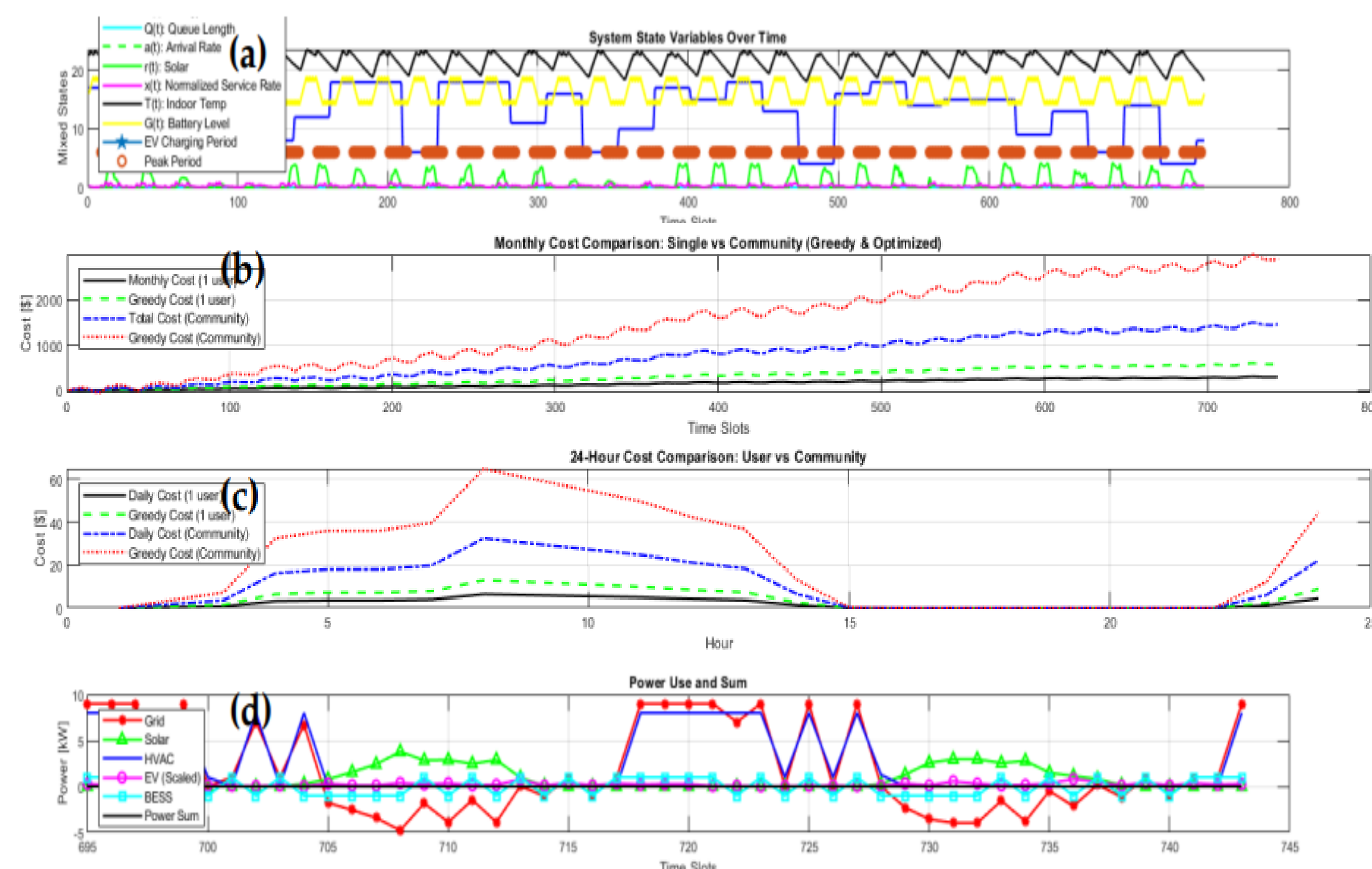


Fig. 2: System dynamics, a) state variables b) monthly total vs greedy cost, c) daily total vs greedy costs, d) power allocation to and from grid, solar, HVAC, EV, and ESS

CONCLUSION

- Lyapunov-based scheduling ensures less costs, consistent comfort, and scalability for smart renewable communities without requiring forecasts.

FUTURE WORK / REFERENCES

- Incorporate reinforcement learning to promote adaptable user behavior.
- Expand testing to include varied climates and demand response programs.