Optimisation of battery-integrated diesel generator hybrid systems using ON/OFF operating strategy

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PRESENTATION OUTLINE

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- Introduction,
- Proposed hybrid system components,
- Optimization model and proposed algorithm,
- Case study,
- Simulation results and discussions,
- Conclusion.

INTRODUCTION

Challenges in rural electrification

- The lack of reliable electrical power supply.
- The high cost of AC grid extension and rough topography.
- High initial cost of the system.

Diesel generator in rural electrification

- Low initial capital costs and generate electricity on demand.
- Easily transportable, modular, and have a high power-to-weight ratio.
- Can also be integrated with other power sources and energy storage in hybrid system.

However, due to the long running times and the highly non-linearity in the daily load demand profiles, DGs are usually operated inefficiently resulting in higher operation cost of energy produced.

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Advantages of hybrid systems

The most important feature of hybrid systems is to generate energy at any time by using each available energy sources (with back-up and storage system).

Problems in operation:

- The non-linearity of the DG fuel consumption curve,
- The dissimilarity of the load demand pattern,
- The battery operation limits.

Aim of the study: The present study focuses on minimizing the cost function subject to the load energy requirements as well as to the diesel generator and the battery operational constraints during a **24** hour period.

PROPOSED HYBRID SYSTEM COMPONENTS

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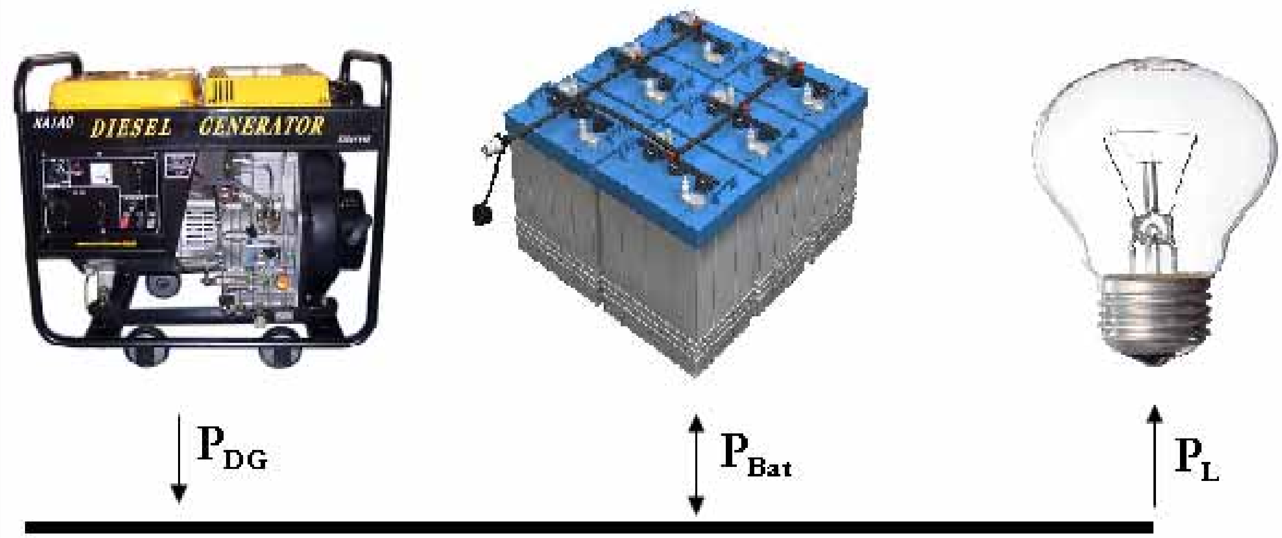


Hybrid system layout (power flow)

OPTIMIZATION MODEL AND PROPOSED ALGORITHM

Objective function

$$\min C_f \times \sum_{j=1}^{N} (aP_{DG-rated}^2 + bP_{DG-rated} + c) \times S_{(j)}$$

Subject to:

$$P_{DG-rated} S_{(j)} + P_{Bat(j)} = P_{L(j)} \qquad (1 \le j \le N)$$

$$-P_{Bat}^{rated} \le P_{Bat(j)} \le P_{Bat}^{rated} \quad (1 \le j \le N)$$

$$SOC^{\min} \le SOC_{(j)} \le SOC^{\max}$$

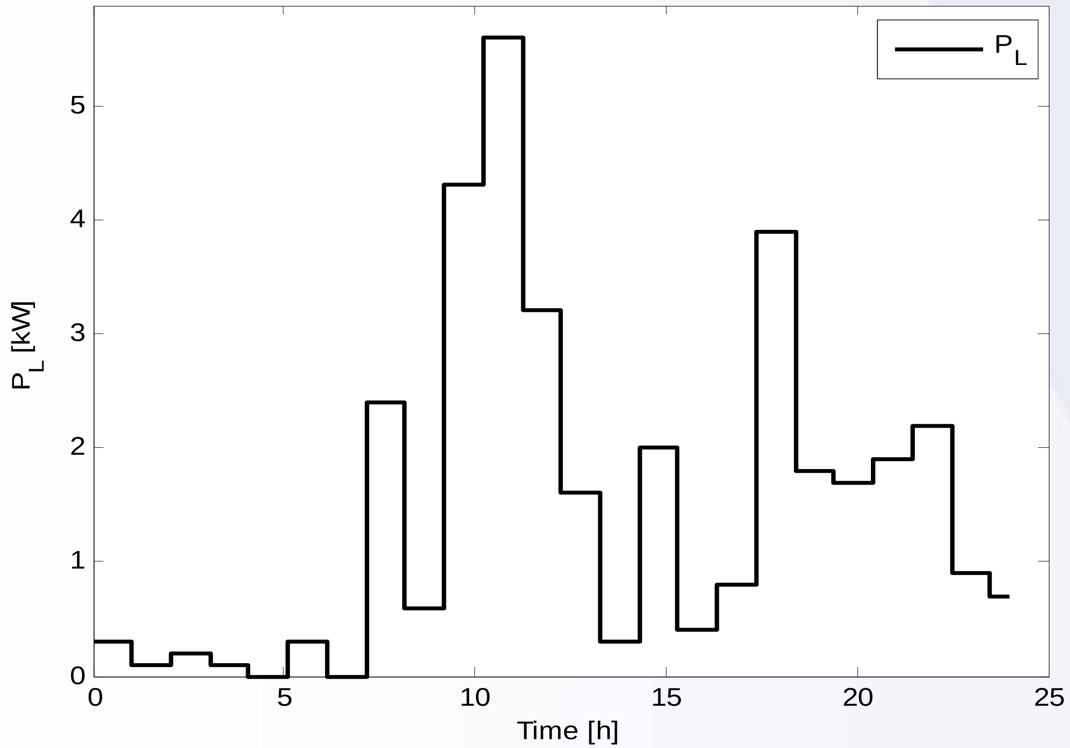
$$SOC^{\min} \le SOC_{(0)} - \Delta t \frac{\eta_{Bat}}{E_{nom}} \sum_{j=1}^{N} P_{Bat(j)} \le SOC^{\max}$$

The objective function has been modeled as a function of the switch controlling the DG and the variable battery output power. This mixed-integer optimization problem can be solved using "*Intlinprog*" function from MATLAB Optimization toolbox. This function solves problems in the form:

$$\min_{x} f(x) \quad \text{subject to:} \quad \begin{cases} x(\text{int}\,con) \\ A.x \le b \\ A_{eq}.x = b_{eq} \\ l_b \le x \le u_b \end{cases}$$

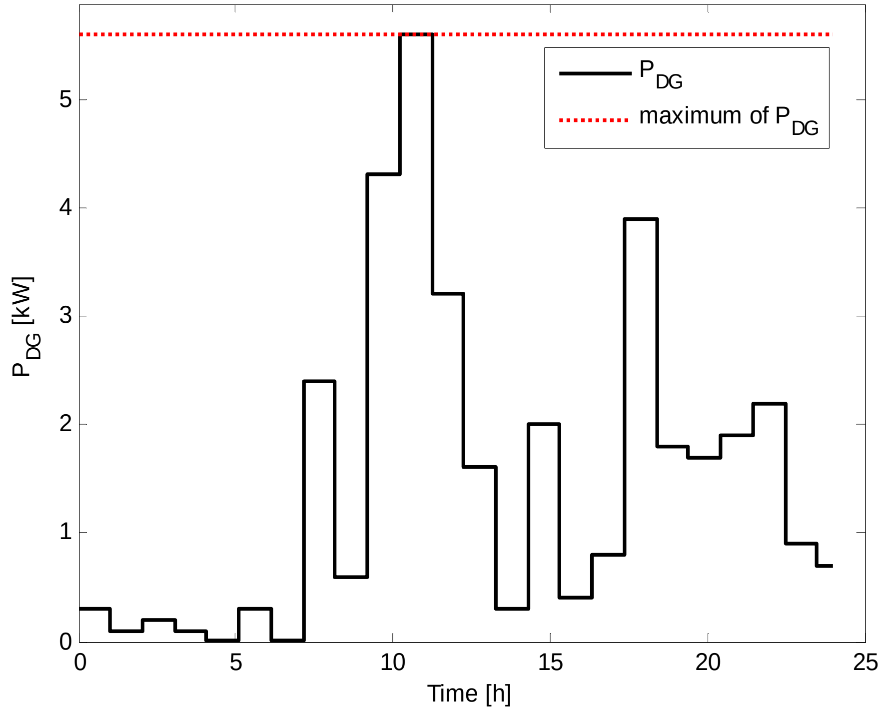
CASE STUDY 1: HOUSEHOLD

Simulation data

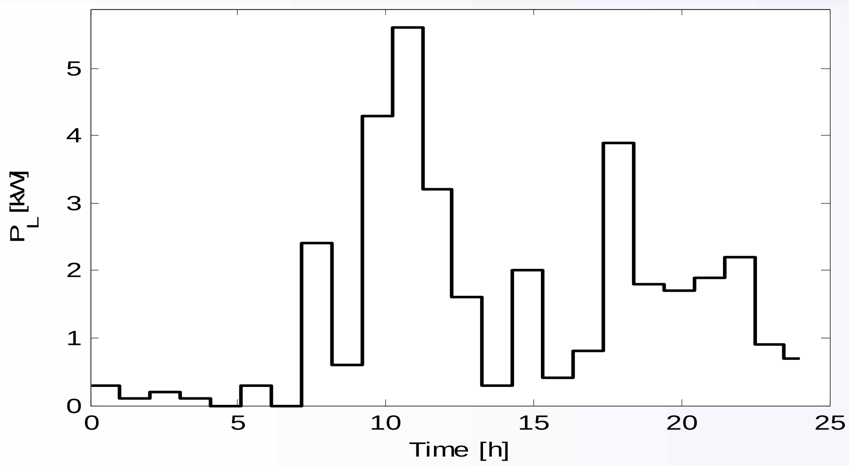


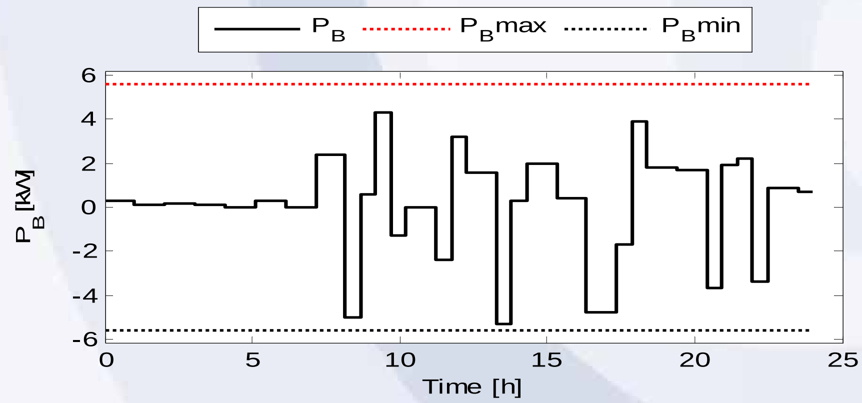
Item	Household
Sampling time (Δt)	15 min
Battery nominal capacity	5.6kWh
Battery maximum SOC	95%
Battery minimum SOC	40%
Battery efficiency	85%
DG rated power	5.6kW
Diesel fuel price	1.4$/l
a (L/h.kW^2)	0.246
b (L/h.kW)	0.0815
c (L/h)	0.4333

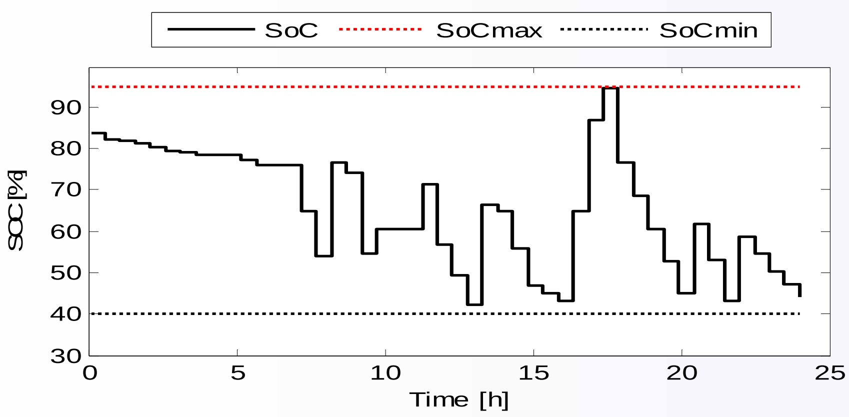
Simulation results and discussion (DG only)

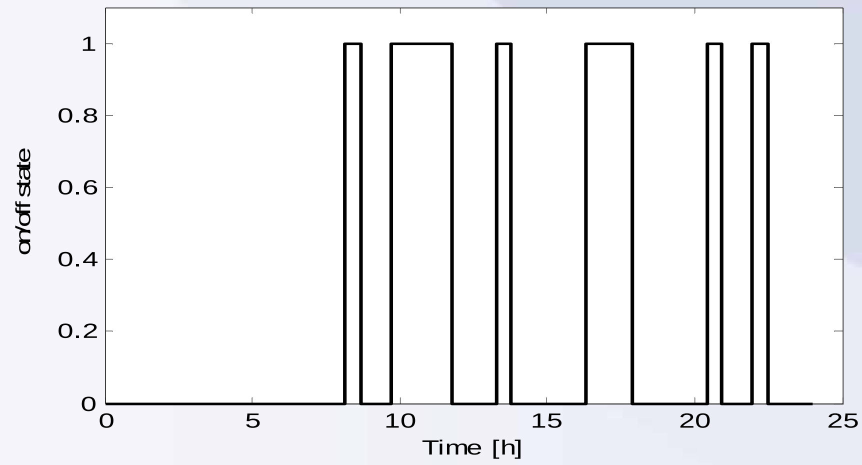


Simulation results and discussion (DG + Battery)



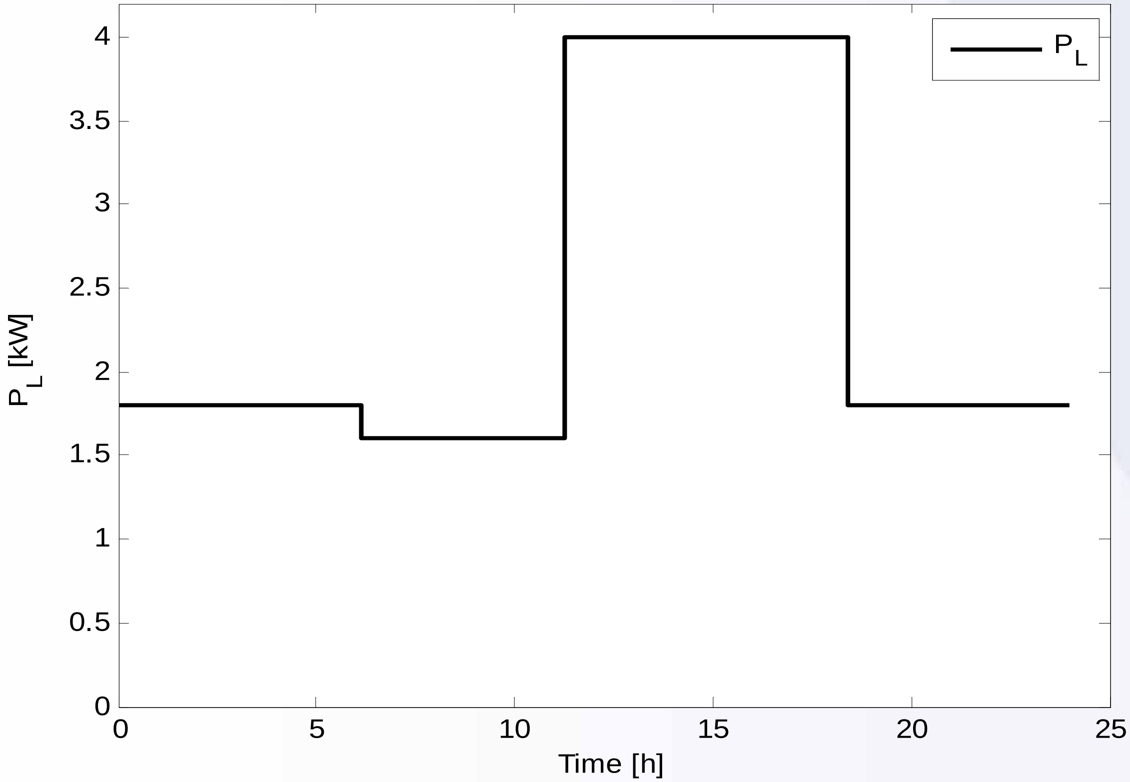






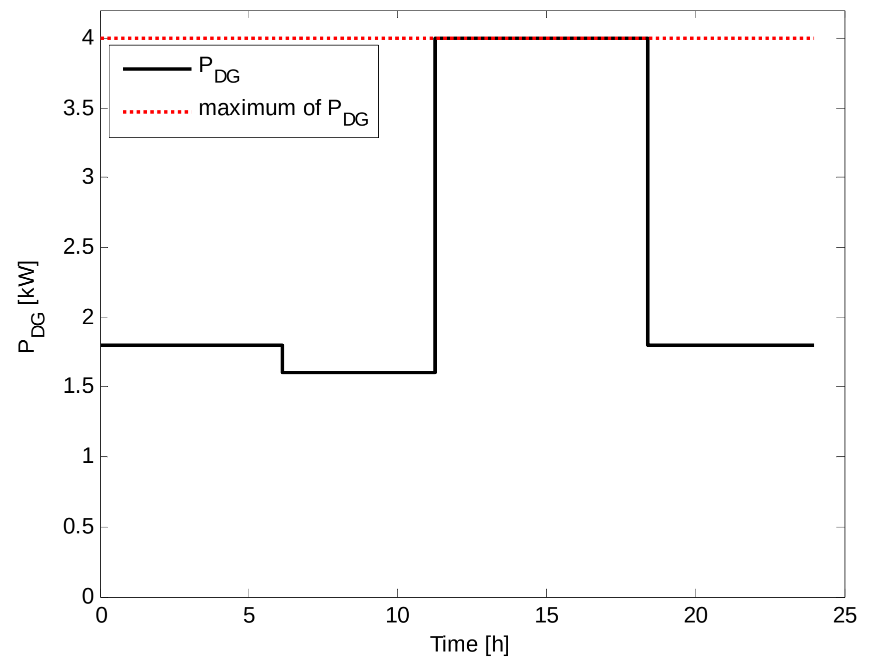
CASE STUDY 2: BTS

Simulation data



Item	BTS
Sampling time (Δt)	15 min
Battery nominal capacity	5.6kWh
Battery maximum SOC	95%
Battery minimum SOC	40%
Battery efficiency	85%
DG rated power	4kW
Diesel fuel price	1.4$/l
a (L/h.kW^2)	-0.0113
b (L/h.kW)	0.3527
c (L/h)	1.1531

Simulation results and discussion (DG only)



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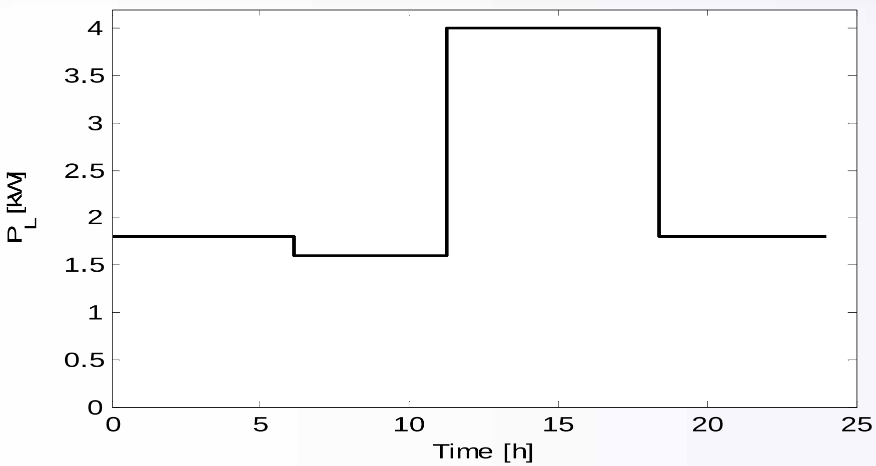
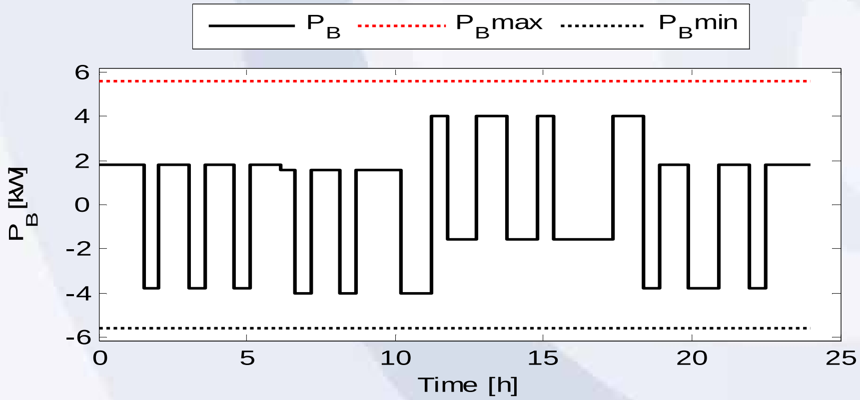
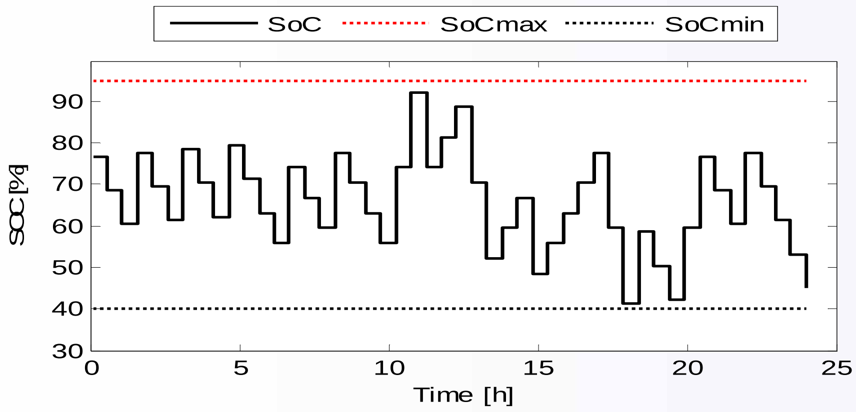
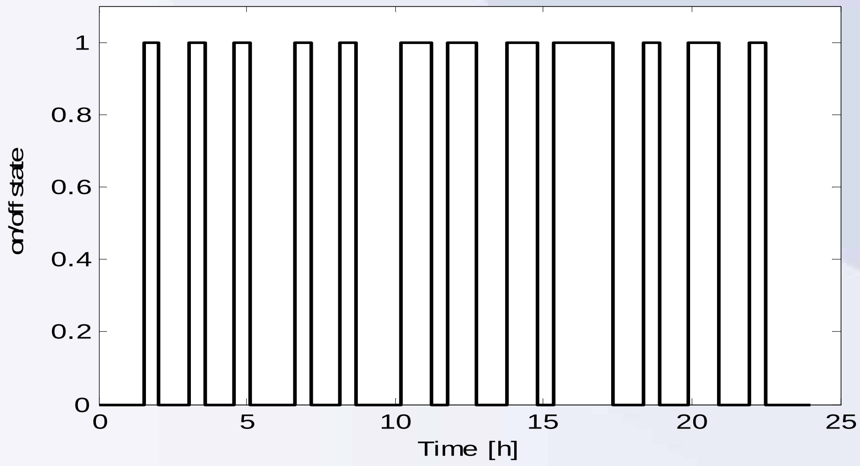
Simulation results and discussion









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Daily fuel cost savings

	Household		BTS Load	
	Consumption (L)	Cost ($)	Consumption (L)	Cost ($)
DG only	19.13L	26.8$	28.00L	39.20$
Hybrid system	17.83L	25.0$	25.80L	36.12$
Savings	1.30L	2.52$	2.20L	3.08$

CONCLUSION

A model to optimize the daily operation of battery-integrated diesel generator hybrid systems has been developed. This work considers the non-linearity of the load demand as well as diesel fuel consumption resulting in non-uniform daily operational costs.

The developed optimal operation control model can also be used to:

- Analyze the operation costs achieved by using different manufacturers' DG in the architecture of the proposed hybrid system.
- Analyze the impact of the battery operation limits (settings) on the system operation cost.

For future work, the **CONTINUOUS** operation control of the DG should also be studied and the results compared with the ON/OFF control.

The impact of excessive charging/discharging cycles of the battery as well as starting (ON/OFF) of the DG on the system life cycle cost have to be analysed.

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Thank you for your attention