Central University of Technology, Free State

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

K. Kusakana

Department of Electrical, Electronics and Computer Engineering

Central University of Technology, Free State. Bloemfontein, South Africa

PRESENTATION OUTLINE

- 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.

Central University of Technology, Free State

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,

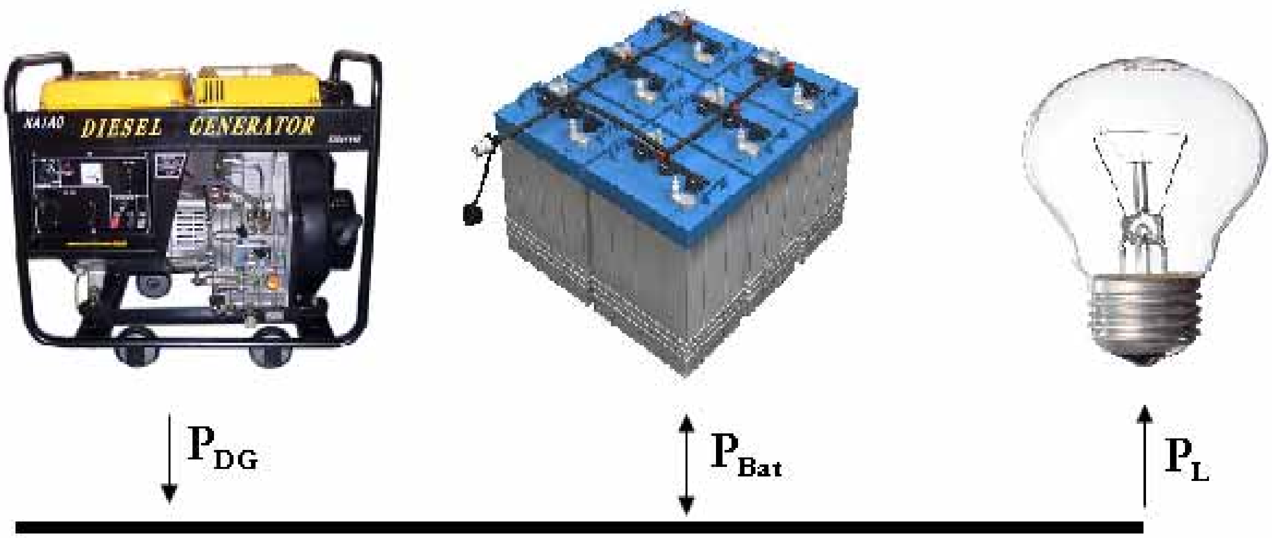
• The dissimilarity of the load demand pattern,

• 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.

Central University of Technology, Free State

PROPOSED HYBRID SYSTEM COMPONENTS



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:

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

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

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

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

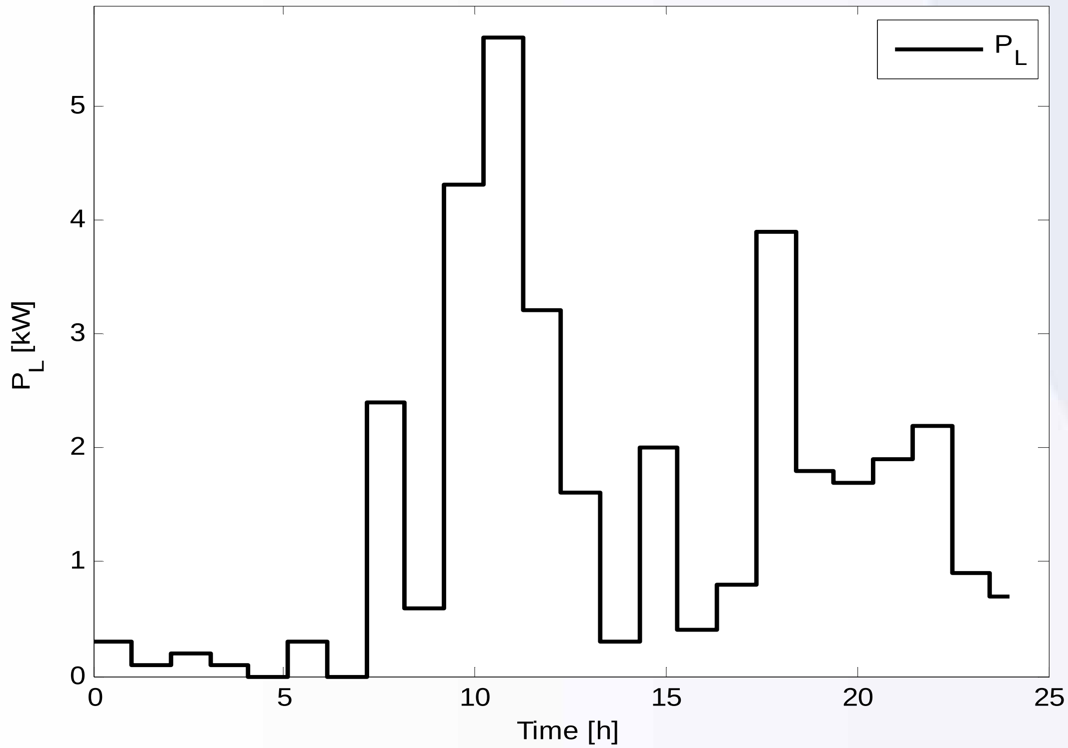
Central University of Technology, Free State

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:

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

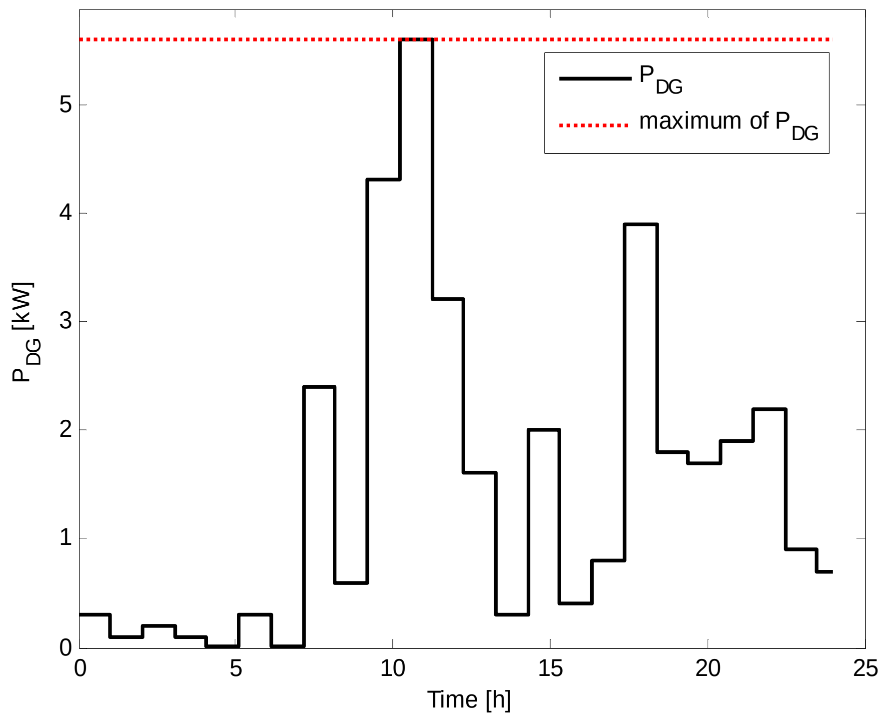
CASE STUDY 1: HOUSEHOLD

Simulation data



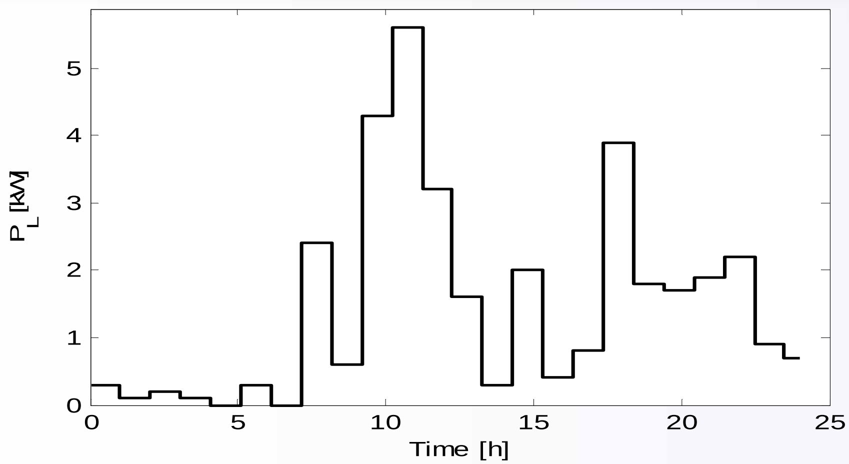
Item	**Household**
Sampling time (Δt)	15 min
Battery nominal capacity	5.6kWh
Battery maximum SOC	95%
Battery minimum SOC	40%
Battery efficiency	85%
DG rated power	5.6kW
Diesel fuel price	1.4$/l
a (L/h.kW^2)	0.246
b (L/h.kW)	0.0815
c (L/h)	0.4333

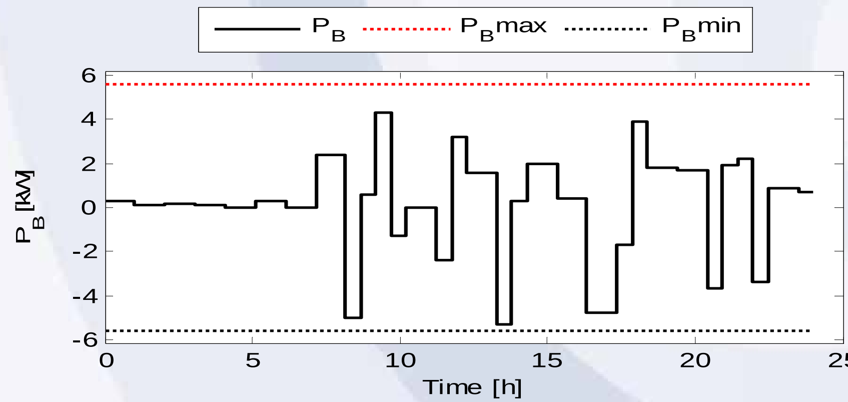
Simulation results and discussion (DG only)

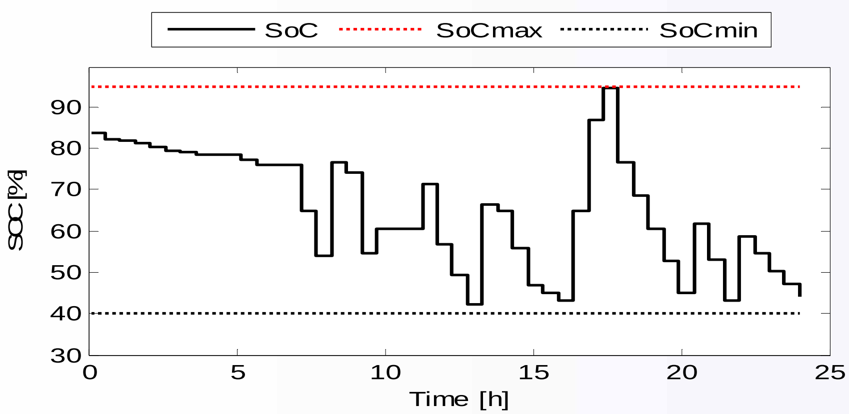


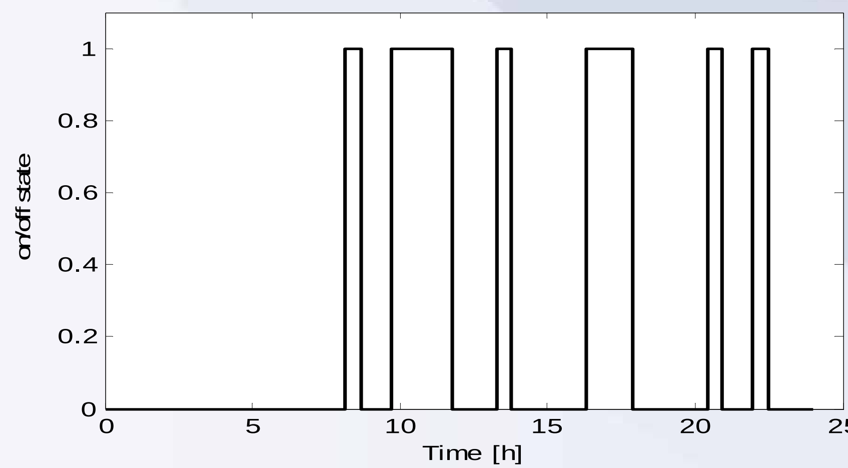
Central University of Technology, Free State

Simulation results and discussion (DG + Battery)



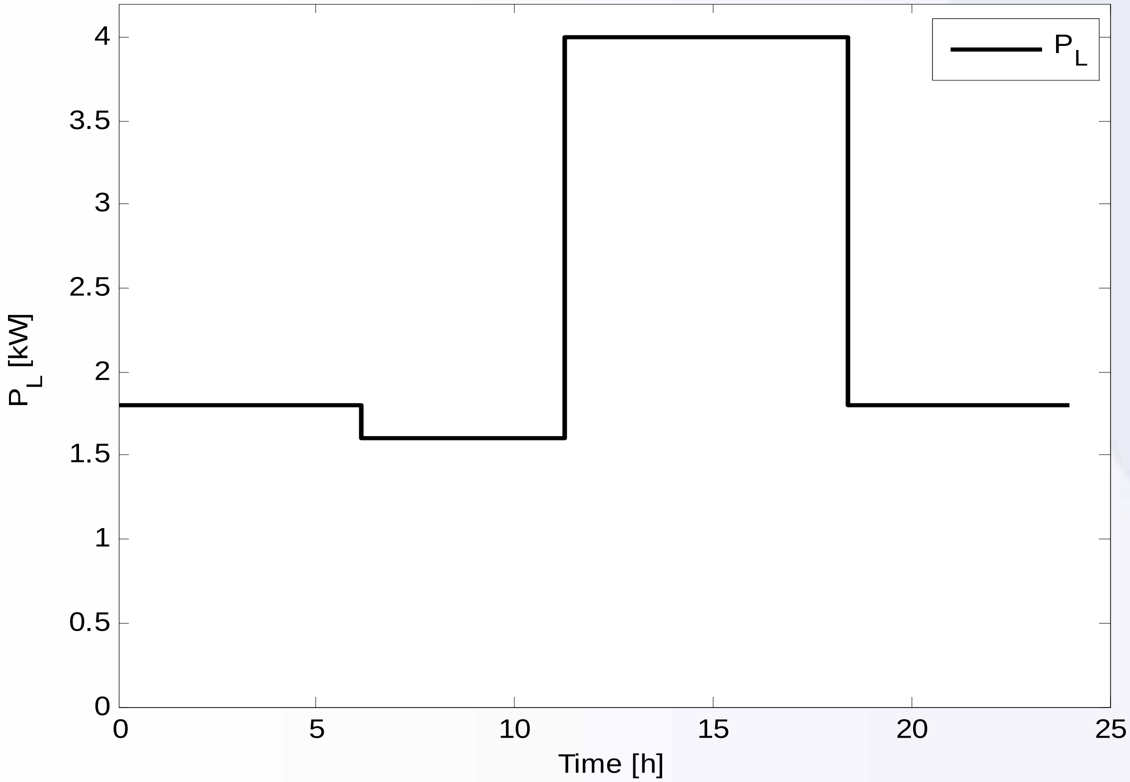






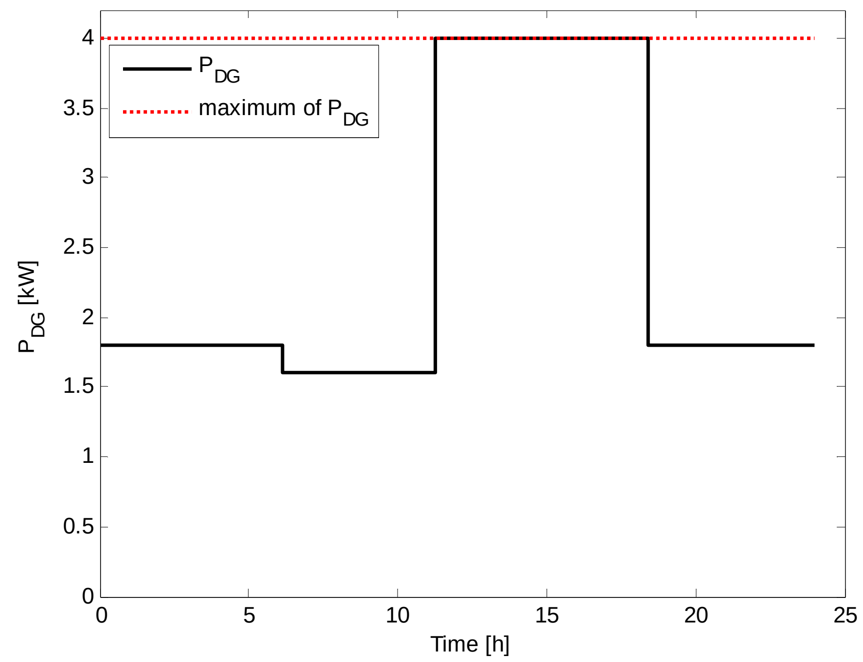
CASE STUDY 2: BTS

Simulation data

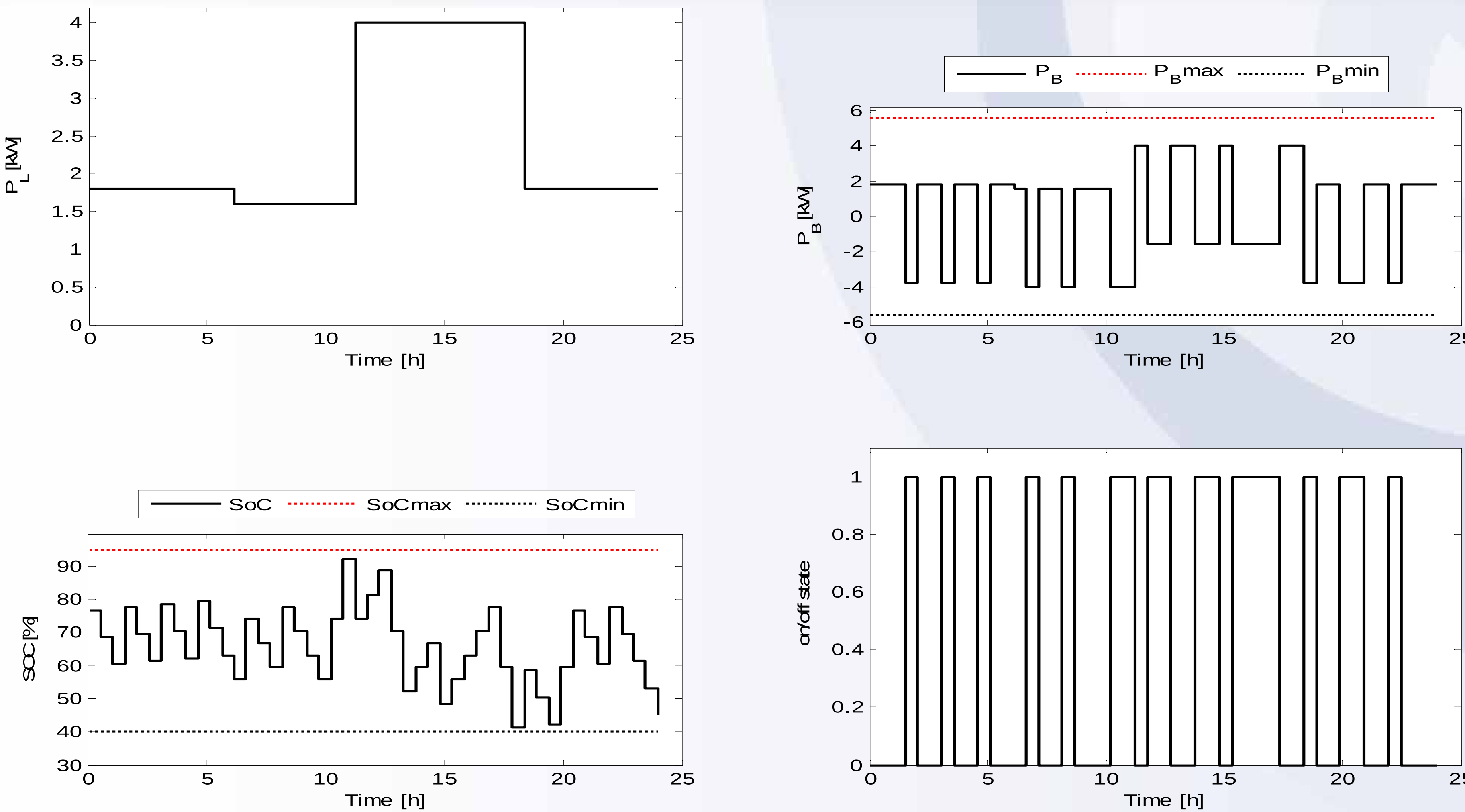


Item	**BTS**
Sampling time (Δt)	15 min
Battery nominal capacity	5.6kWh
Battery maximum SOC	95%
Battery minimum SOC	40%
Battery efficiency	85%
DG rated power	4kW
Diesel fuel price	1.4$/l
a (L/h.kW^2)	-0.0113
b (L/h.kW)	0.3527
c (L/h)	1.1531

Simulation results and discussion (DG only)



Simulation results and discussion



Central University of Technology, Free State

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.

Central University of Technology, Free State

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.

Thank you for your attention