ELEC4712: HOSTING CAPACITY MANAGEMENT

THE UNIVERSITY OF SYDNEY

THESIS PROGRESS REPORT

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CONTENTS

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NOMANCLATURE

H	set of time slot h
N	set of prosumers n
τ_h	Time of tariff at time slot h
$p_{h,n}^{inf}$	Load demand of prosumer n at time slot h
$p_{h,n}^{ev}$	EV (flexible) demand of prosumer n at time slot h
e_n^{ev}	EV battery state of charge of prosumer n
E_{min}^{ev}	EV minimum state of charge
P^{max}	Transfomer Thermal Limit
$p_{h,n}^{max}$	Power limit for prosumer n at time slot h

ABSTRACT

This is the abstract.

Chapter 1 Introduction

1.1 Motivation and Background

With increasing penetration of Electric Vehicles (EVs), distribution transformers face potential thermal overload risks. This project tackles the problem of scheduling EV charging in a way that: • Respects transformer thermal capacity limits (Upper Level), • Allows flexible EV charging while satisfying household energy demand (Lower Level).

1.2 Summary

This project explores Host Capacity Management by transforming a bilevel optimization problem into a single-level optimization problem. The original formulation considers an upper-level decision maker managing transformer capacity and a lower-level model representing the flexible charging behavior of electric vehicle (EV) users. The bilevel model is reformulated into a single-level problem using Karush-Kuhn-Tucker (KKT) conditions.

CHAPTER 2 LITERATURE REVIEW

Generic Demand - [1]
Capacity Firming - [2]

CHAPTER 3 ASSUMPTIONS

3.1 UPPER LEVEL

Simplifed to only consider transformer Thermal limit.

3.2 LOWER LEVEL

• Model: Each household has: • Inflexible load (e.g. lighting, appliances), • Flexible EV charging with no power export and no on-site generation (e.g. PV), • EVs can only import energy for charging, • Time of Use Tariff Applied

CHAPTER 4 MODELLING

4.1 LOWER LEVEL

$$
\begin{aligned}
\underset{p_h^{ev}}{\text{MIN}} \quad & \sum_{h \in H} \tau_h (p_h^{inf} + p_h^{ev}) \\
\text{subject to} \quad & \\
& E_{min}^{ev} - e^{ev} - \sum_{h \in H} p_h^{ev} \leq 0 \\
& p_h^{inf} + p_h^{ev} - p_h^{max} \leq 0 \quad \forall h \in H \\
& - p_h^{ev} \leq 0 \quad \forall h \in H
\end{aligned}
$$

Lagrange:

$$
\begin{aligned}
\mathcal{L}(p_h^{ev}, \lambda) = & \sum_{h \in H} \tau_h (p_h^{inf} + p_h^{ev}) \\
& + \lambda^1 \left(E_{min}^{ev} - e^{ev} - \sum_{h \in H} p_h^{ev} \right) \\
& + \sum_{h \in H} \lambda_h^2 \left(-p_h^{ev} \right) \\
& + \sum_{h \in H} \lambda_h^3 \left(p_h^{inf} + p_h^{ev} - p_h^{max} \right)
\end{aligned}
$$

$$
\begin{aligned}
\text{Stationarity:} \quad & \frac{\partial \mathcal{L}}{\partial p_h^{ev}} = \tau_h - \lambda^1 - \lambda_h^2 + \lambda_h^3 = 0 \quad \forall h \in H \\
\text{Primal feasibility:} \quad & E_{min}^{ev} - e^{ev} - \sum_{h \in H} p_h^{ev} \leq 0 \\
& - p_h^{ev} \leq 0 \quad \forall h \in H \\
& p_h^{inf} + p_h^{ev} - p_h^{max} \leq 0 \quad \forall h \in H \\
\text{Dual feasibility:} \quad & \lambda^1 \geq 0 \\
& \lambda_h^2 \geq 0 \quad \forall h \in H \\
& \lambda_h^3 \geq 0 \quad \forall h \in H \\
\text{Complementary slackness:} \quad & \lambda^1 \left(E_{min}^{ev} - e^{ev} - \sum_{h \in H} p_h^{ev} \right) = 0 \\
& \lambda_h^2 \left(-p_h^{ev} \right) = 0 \quad \forall h \in H \\
& \lambda_h^3 \left(p_h^{inf} + p_h^{ev} - p_h^{max} \right) = 0 \quad \forall h \in H
\end{aligned}
$$

4.2 BI-LEVEL REFORMULATION WITH KKT

$$\underset{p_{h,n}^{max}}{\text{MAX}} \quad p_{h,n}^{max}$$

subject to

$$\sum_{n \in N} p_{h,n}^{max} - P^{max} \leq 0 \quad \forall h \in H$$

(Stationarity)

$$\tau_h - \lambda_n^1 - \lambda_{h,n}^2 + \lambda_{h,n}^2 = 0 \quad \forall h \in H, \forall n \in N$$

(Primal Feasibility)

$$E_{min}^{ev} - e_n^{ev} - \sum_{h \in H} p_{h,n}^{ev} \leq 0 \quad \forall n \in N$$

$$-p_{h,n}^{ev} \leq 0 \quad \forall h \in H, \forall n \in N$$

$$p_{h,n}^{inf} + p_{h,n}^{ev} - p_{h,n}^{max} \leq 0 \quad \forall h \in H, \forall n \in N$$

(Dual Feasibility)

$$\lambda_n^1 \geq 0 \quad \forall n \in N$$

$$\lambda_{h,n}^2 \geq 0 \quad \forall h \in H, \forall n \in N$$

$$\lambda_{h,n}^3 \geq 0 \quad \forall h \in H, \forall n \in N$$

(Complementary Slackness)

$$\lambda_n^1 \left(E_{min}^{ev} - e_n^{ev} - \sum_{h \in H} p_{h,n}^{ev} \right) = 0 \quad \forall n \in N$$

$$\lambda_{h,n}^2 \left(-p_h^{ev}\right) = 0 \quad \forall h \in H, \forall n \in N$$

$$\lambda_{h,n}^3 \left(p_{h,n}^{inf} + p_{h,n}^{ev} - p_{h,n}^{max}\right) = 0 \quad \forall h \in H, \forall n \in N$$

(Big M reformulation for Complementary Slackness)

$$\lambda_n^1 \leq M z_n^1 \quad \forall n \in N$$

$$E_{min}^{ev} - e_n^{ev} - \sum_{h \in H} p_{h,n}^{ev} \leq M(1 - z_n^1) \quad \forall n \in N$$

$$\lambda_{h,n}^2 \leq M z_{h,n}^2 \quad \forall h \in H, \forall n \in N$$

$$-p_{h,n}^{ev} \leq M(1 - z_{h,n}^2) \quad \forall h \in H, \forall n \in N$$

$$\lambda_{h,n}^3 \leq M z_{h,n}^3 \quad \forall h \in H, \forall n \in N$$

$$p_{h,n}^{inf} + p_{h,n}^{ev} - p_{h,n}^{max} \leq M(1 - z_{h,n}^3) \quad \forall h \in H, \forall n \in N$$

$$z_n^1 \in \{0,1\}, \quad z_{h,n}^2 \in \{0,1\}, \quad z_{h,n}^3 \in \{0,1\} \quad \forall h \in H, \forall n \in N$$

CHAPTER 5 ANALYSIS

CHAPTER 6 CONCLUSION

CHAPTER A ADDITIONAL FIGURES

CHAPTER B CODES

BIBLIOGRAPHY

[1] S. Riaz, H. Marzooghi, G. Verbič, A. C. Chapman, and D. J. Hill, "Generic demand model considering the impact of prosumers for future grid scenario analysis," *IEEE Transactions on Smart Grid*, vol. 10, no. 1, pp. 819–829, 2019.

[2] M. Aldaadi, M. Pantoš, S. Riaz, A. C. Chapman, and G. Verbič, "A novel production cost model for provision of capacity firming by prosumer batteries," *Energy*, vol. 321, p. 135221, 2025.