Smart Charging Strategies for Electric Vehicles

E-mobility NSR Seminar
30th March 2012

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Agenda

1. Introduction

2. Current EV Charging Issues
   - From customers point of view
   - From power network point of view

3. Requirement for Smart Charging

4. Smart Charging Controller Design
   - Basic Structure
   - Simulation Results

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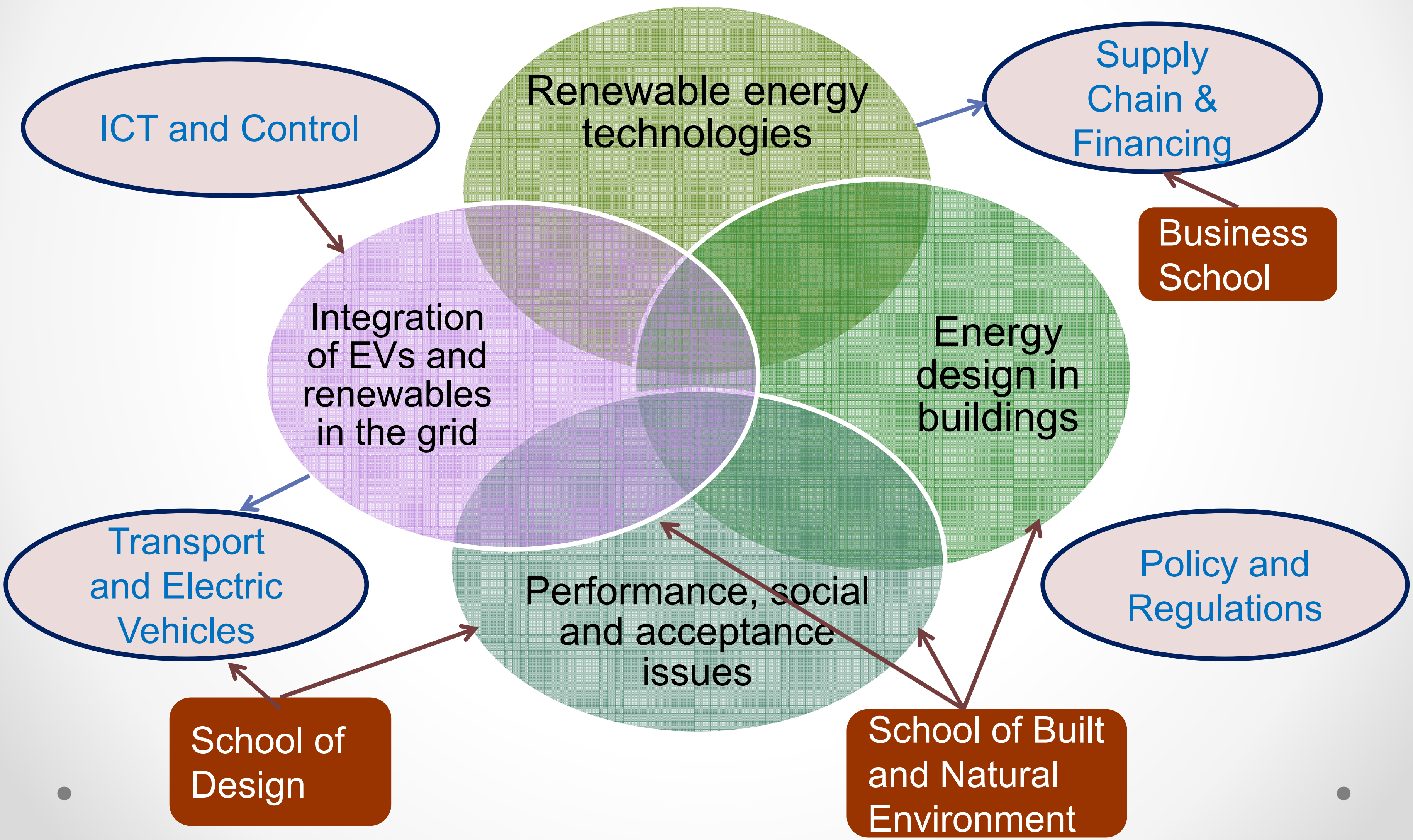
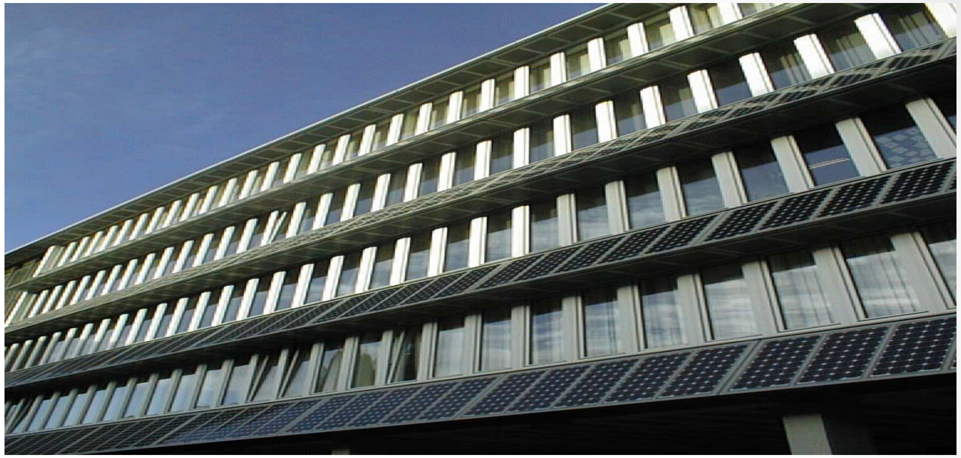
School of Computing, Engineering and Information Sciences

Our Research and Partnership



New and Renewable Energy at CEIS



40 kW PV System, Northumberland Building

6 kW QR5 VWT

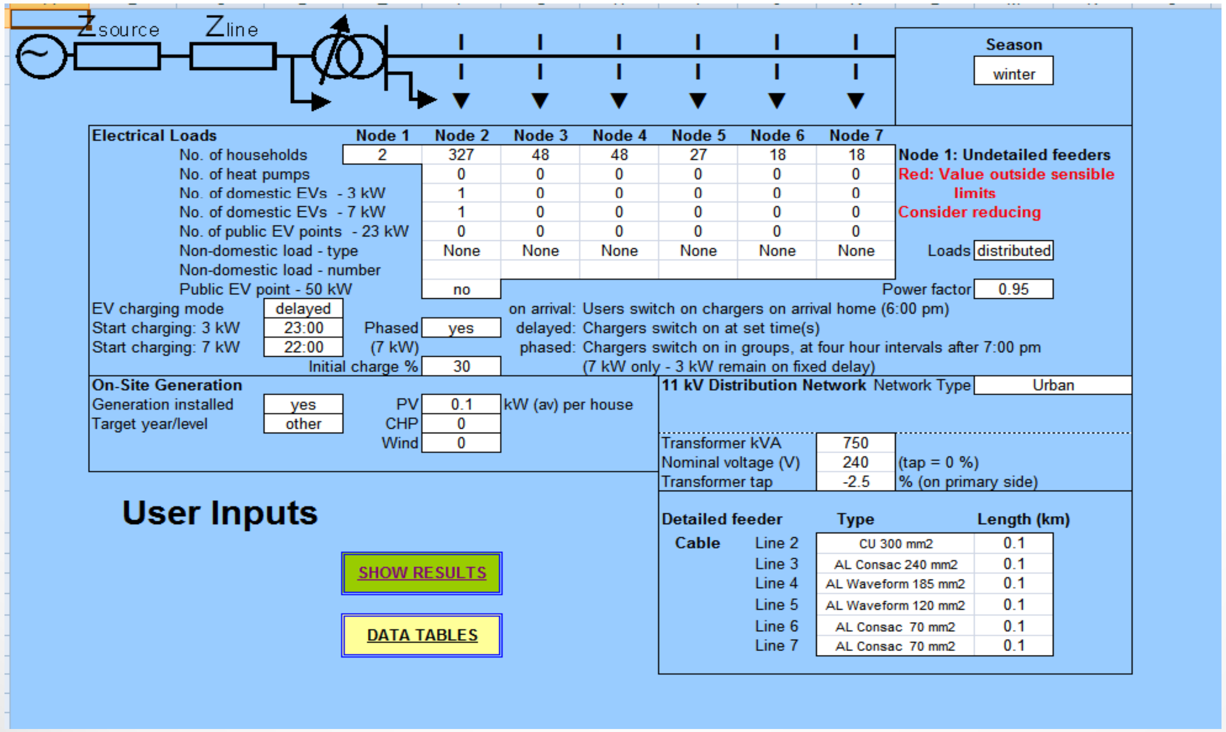
1.5 kW HWT and 1 kW PV system

Up to 300A 10V
battery test unit

Plans for further development in Pandon Building in 2012 (cost £115,000)

Recent Projects

- e-mobility NSR project: Smart grid solutions
- Electric Vehicle Infrastructure – Smart Grids and EV Infrastructure Regional Impact: **Development of a Modelling Tool to Evaluate Likely Impact of Electric Vehicles on the Electrical Supply Infrastructure.**
    - Jointly with the School of Built and Natural Environment.
    - Funded by: Zero Carbon Futures (ONE)



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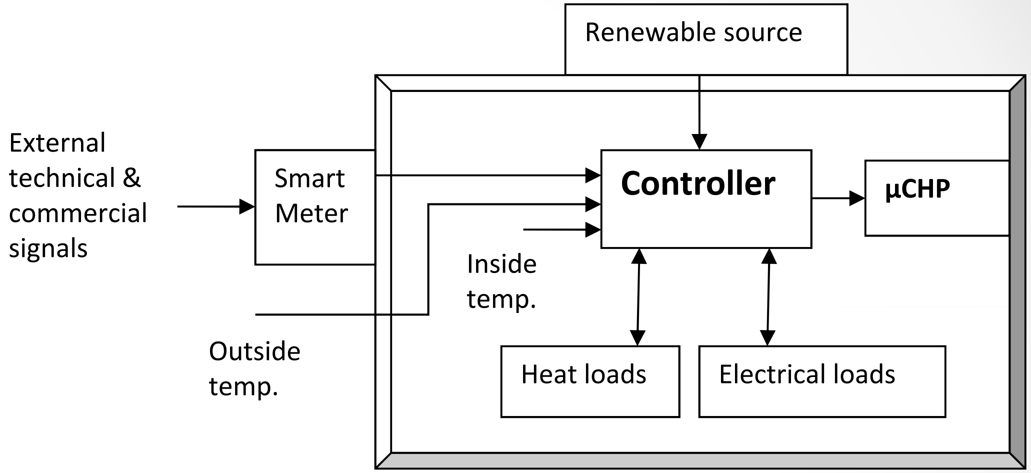
Development of Smart controllers for Dynamic Energy Management

Partly funded by Narec

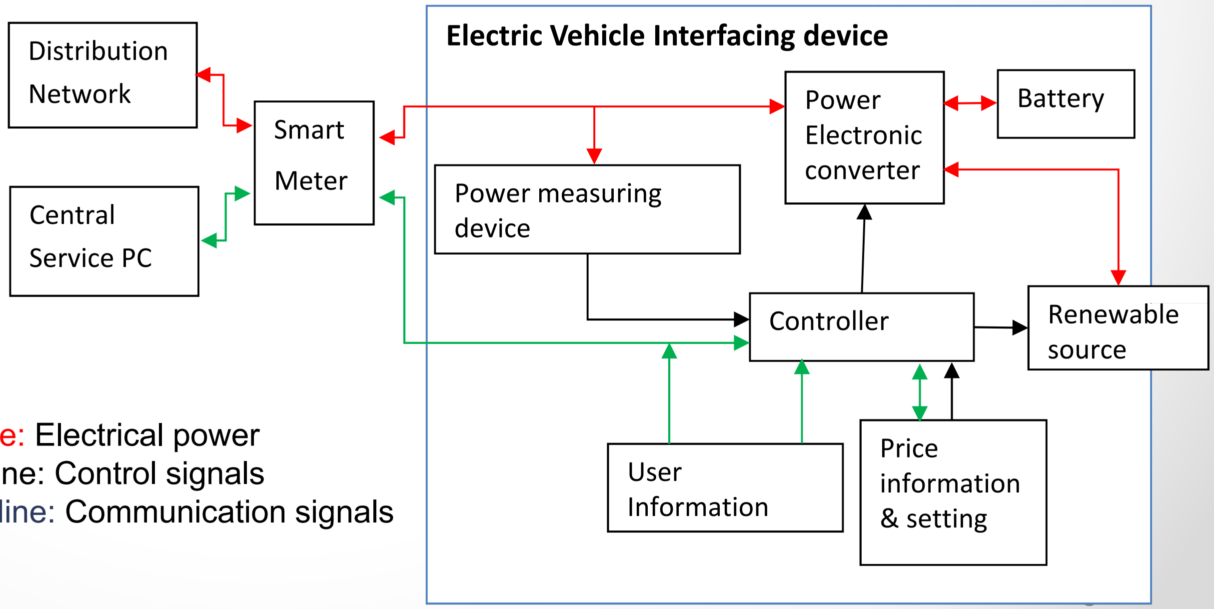
- Development of a smart controller for Small-Scale Combined Heat and Power (CHP) system

  Jointly with the School of Built and Natural Environment



- Development of a grid interface controller for dynamic energy management of Electrical Vehicles (EVs)

  Jointly with the School of Design



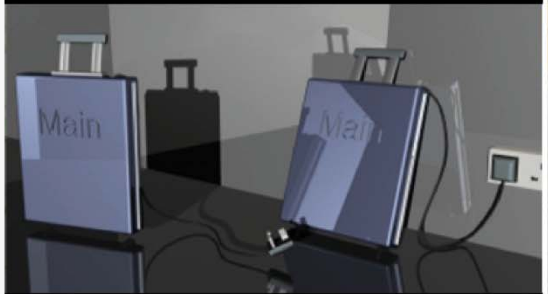
Red line: Electrical power
Black line: Control signals
Green line: Communication signals

School of Design

CASE STUDY ONE : HVLC PILOT PROJECT

To envisage functional and experiential value made possible by the commercial development of electric vehicle platforms & new technologies.

ELECTRIC VEHICLE BATTERY INTELLIGENCE & RANGE SCREEN SHOTS



MULTIPLE BATTERIES FOR ELECTRIC VEHICLES

ELECTRIC VEHICLE WIRELESS CHARGING CONCEPT

CASE STUDY TWO : AVID CUE-V EXTERIOR DESIGN

The aim was to find an appropriate aesthetic for a car to be converted into an electric powertrain. As a result the vehicle exterior was redesigned to produce new bodywork in clay for future production purposes.

SUGGESTED EXTERIOR PROPOSALS FOR CUE-V

REDESIGN OF VEHICLE FRONT-END

EV EXTERIOR DESIGN PROPOSALS

CASE STUDY THREE : ZET - ELECTRIC MOTORHOME

To develop concept ideas for future hybrid/electric motor homes in terms of creating improved interior layouts, flexible cabin designs and distinctive exterior forms reflecting the next generation of motorhomes.

FLEXIBLE INTERIOR LAYOUTS & IMPROVED USE OF CABIN SPACE

EXTERIOR RENDER OF MOTORHOME & ITS FEATURES

FUNCTIONAL INTERIOR DESIGN SOLUTIONS

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Barrier to EV Uptake

Current

Barriers	Overall ranking
High purchase cost	Very high significance
Limited range of EVs (and range anxiety issues)	Very high significance
Lack of recharging infrastructure (and issues relating to implementation and operation of infrastructure)	Very high significance
Uncertainty about future resale value	High significance
Limited performance and limited choice of vehicles	High significance
Weak image association	High significance
Uncertainty about future energy costs	High significance
Limited environmental benefits associated with current models	Moderate significance

Atkins Ltd's report for WWF Scotland; Electric Vehicles: Driving the change

For the power network

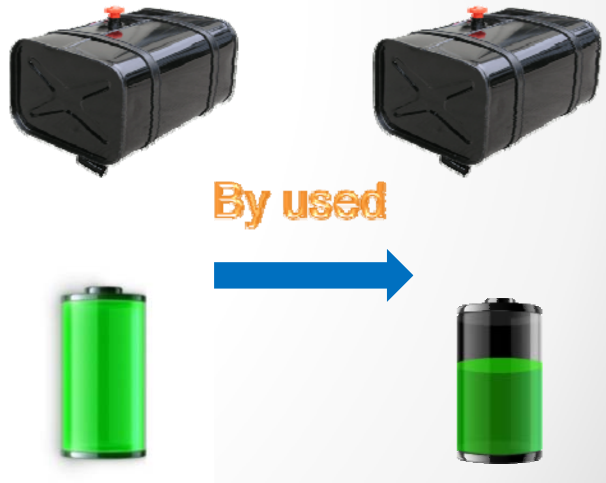
Barriers	Overall ranking
Heavy loading on power network due to uncontrolled charging	High significance
Charging from power plants fired by fossil fuel (not renewable)	High significance

Aim

- Batteries that have low cost, high energy/power capacity and long working life. Current commercial battery technology can not meet these requirements.
- Network security and utilization of renewable generation

So this project aims to develop a smart charger which can

- ➢ Extend EV battery life span
- ➢ Solve range anxiety issue
- ➢ Meet user needs and allow the user to have a proactive role.
- ➢ User-friendly and more interaction with the user
- ➢ Reduce maintenance cost
- ➢ Improve the reliability of grid
- ➢ Maximize use of renewable energy



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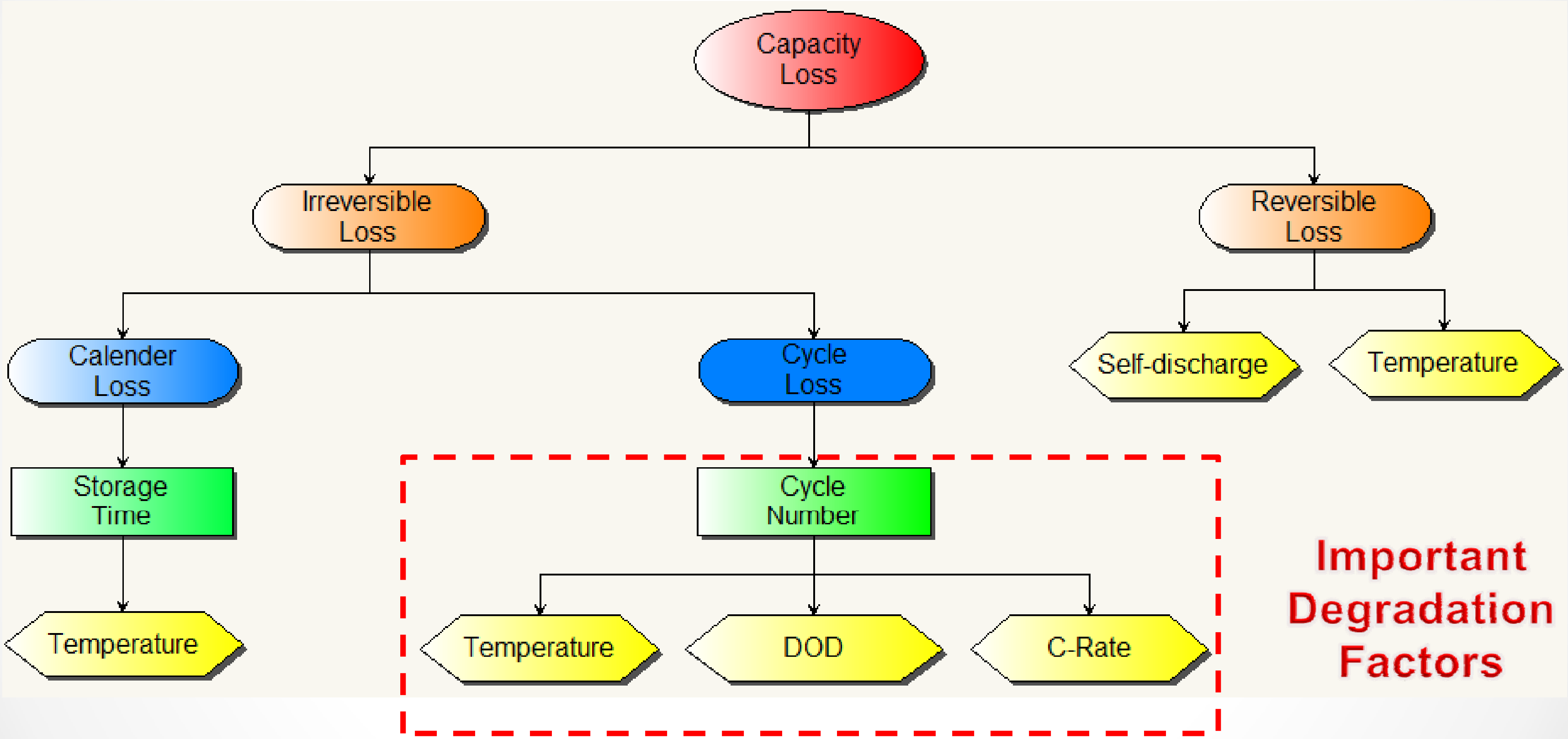
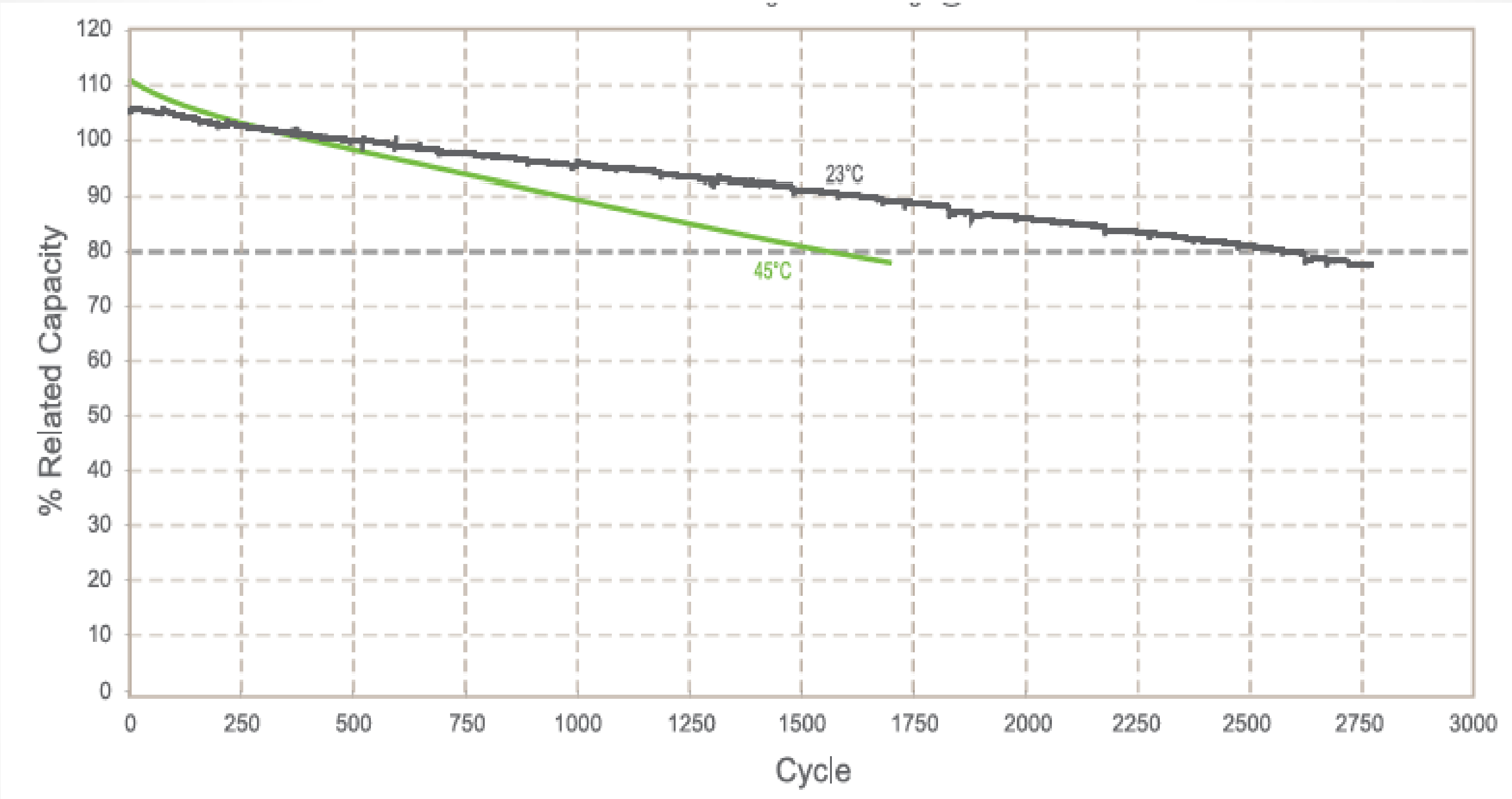
Battery Aging – From Customers Side

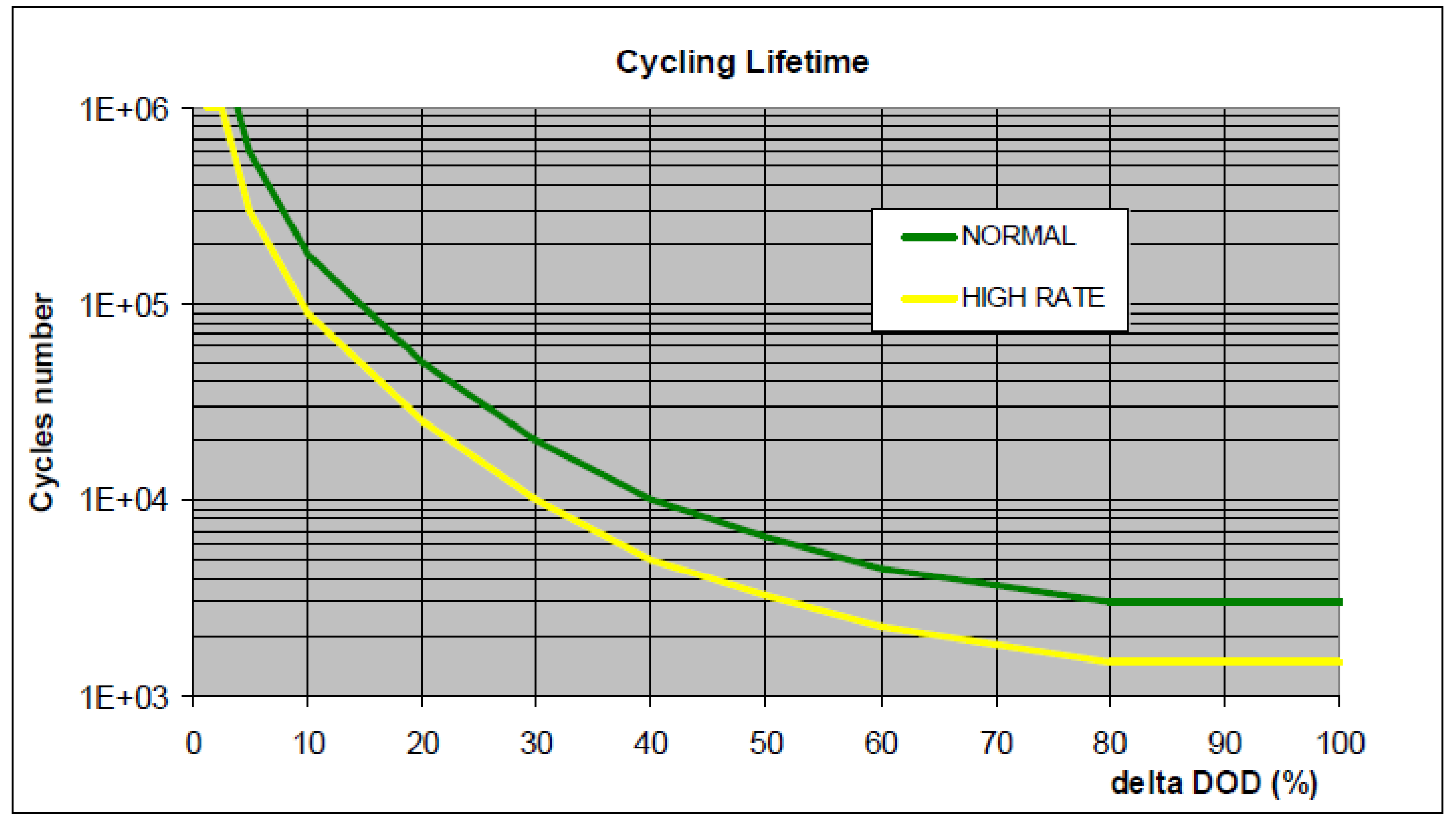


Important Degradation Factors

Temperature

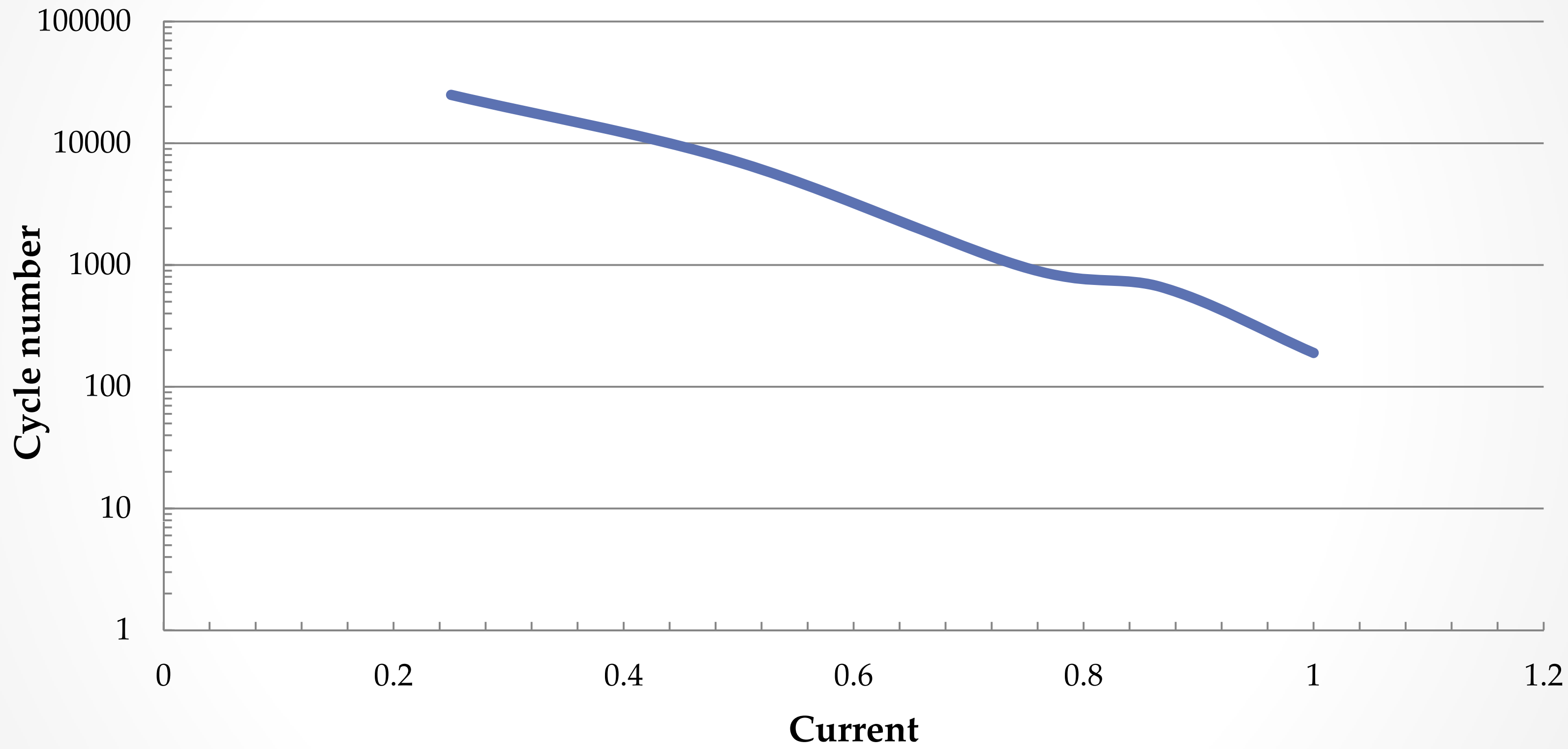


Depth Of Discharge (DOD)



Ref :LIFEMIT

C-Rate



nC means the current in amps equals n times the capacity in ampere-hours

($LiCoO_2$/ $Li_{4/3}Ti_{5/3}O_4$) battery

Ref : Development of long life lithium ion battery for power storage

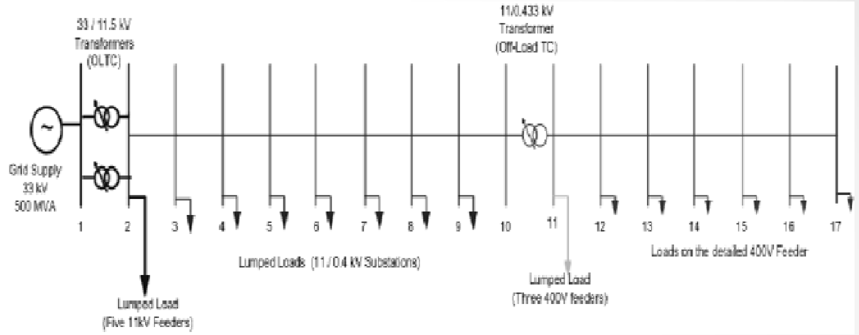
Issues to Consider

- Battery ageing accelerate when charging at:
  - High temperature
  - High current rate
  - High DOD

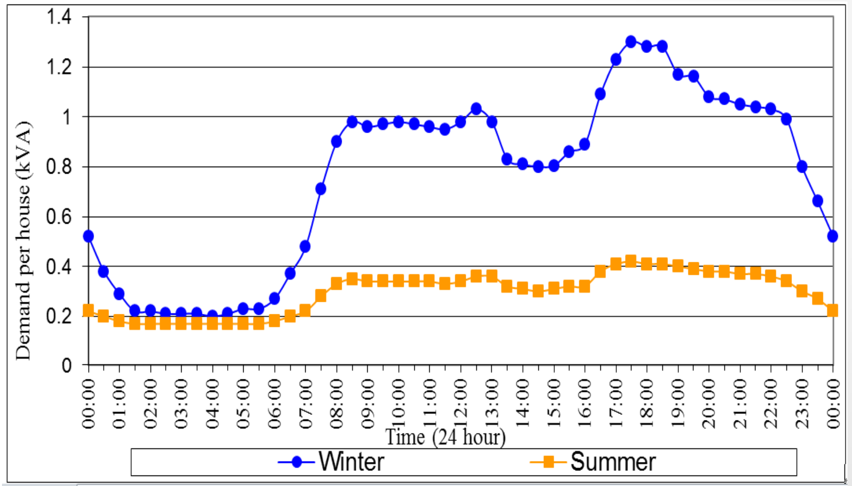
Network Security and Stability – From grid side

1. Voltage is one of the important reference for network security. For LV distribution networks (230/400 V):
   0.94 ≤ V ≤ 1.1 p.u.

2. The loading on the network should not exceed the thermal capacity of the distribution transformer and feeders.



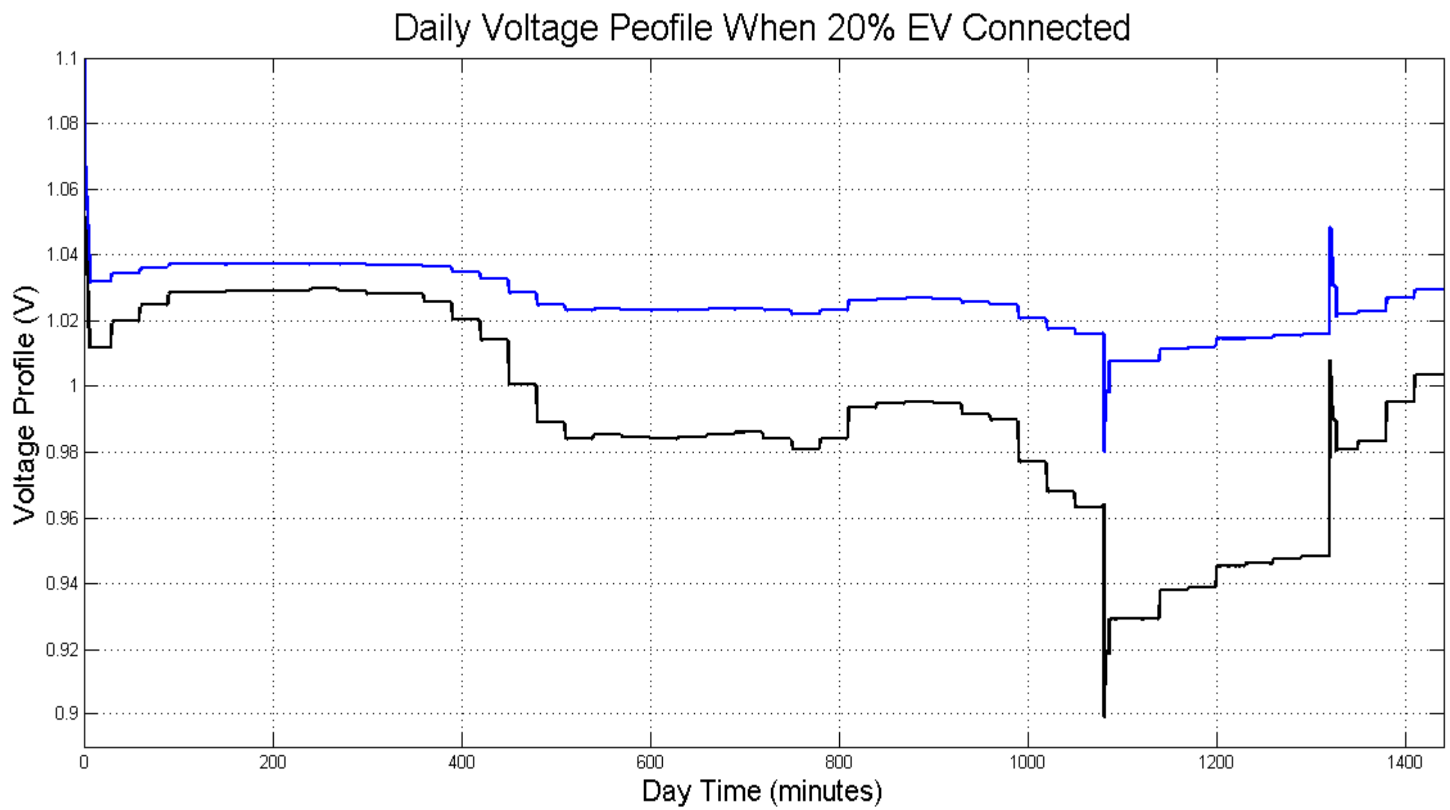
UK Typical Distribution Network



UK Winter & Summer Household load

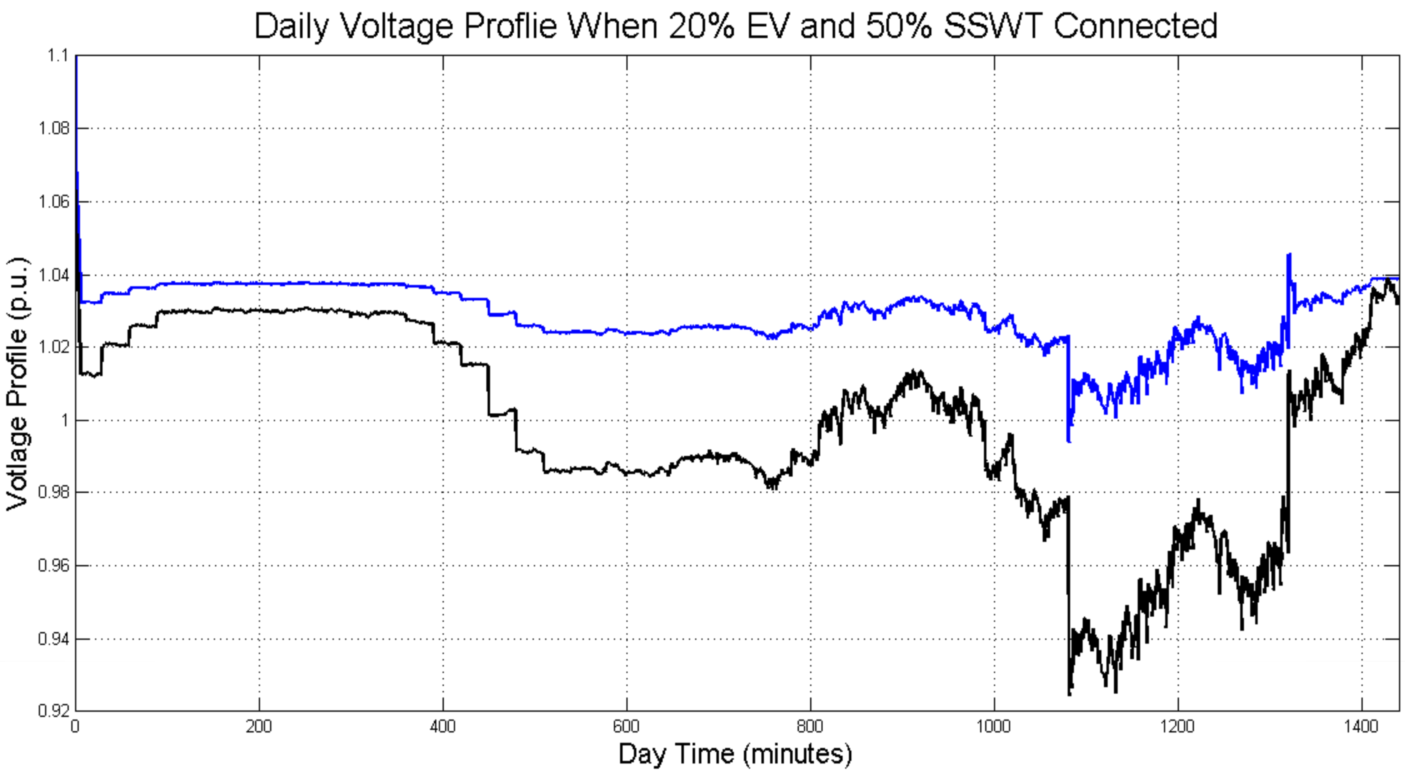
Network Voltage Profile with EVs Charging

20% EVs penetration level charging at home from 18:00 pm



Network Voltage Profile with EVs and Local Generation

20%, 3 kW EVs home charging and 50% 1.5 kW micro wind generator connoted to the grid



Issues to Consider

1. High penetration of EVs charging can increase the risk of overloading; affecting the grid security.

2. Central control (e.g. on-load tap changer) may not provide adequate solution.

3. Renewable energy generation profiles may not match EV charging profiles and this may necessitate the use of storage systems.

Charging Options

	Home charging	Public charging	Fast charging
Power	3 kW	23 kW	Up to 50 kW
Time	8 hours	1 hour	20 mins (80%SOC)
Average C-Rate	1/8 C	1 C	3 C

Existing chargers provide limited controllability and flexibility to the user

- **They are not smart!**

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Issues Regarding Chargers

1. User can’t decide how much energy exactly to charge

2. User can’t decide the charging current rate, which is required to meet customers’ needs as well as optimize battery life cycle (health).

3. User can’t enjoy the low price charging benefit (renewables)

4. Current charger can not respond to grid needs

Requirement for Smart Charging EV

1. **Customers care**
   - Monitor the battery status and optimize its use
2. **Charging flexibility**
   - Customers can set the charging plan according to their own requirements
3. **Network stability and security**
   - Voltage not to exceed the statutory limits
   - Avoid overloading transformers, lines and cables
4. **Adaption of renewable energy**
   - Increase charging of EVs from renewable energy sources (when they generating!).

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Simulation Scenarios

Condition: A half aged (90% initial usable capacity) EV battery pack was chosen for simulating the following scenarios:

1. “Dumb” charging, finish charging in 1 hour
2. Smart charging without time limit
3. Smart Charging with 2 hour limit

Target: Initial SOC is assumed to be 0% and on completion, battery need to be fully charged (100).

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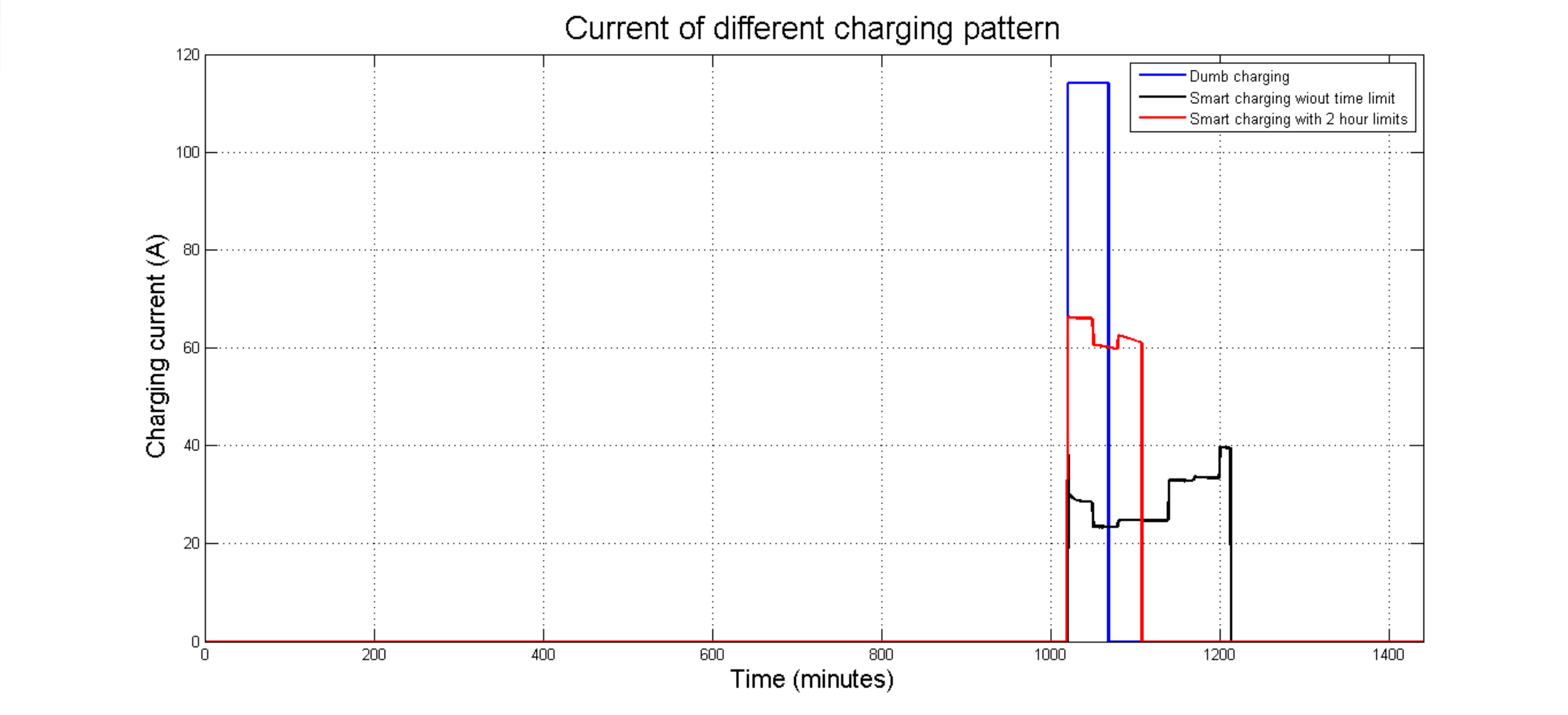
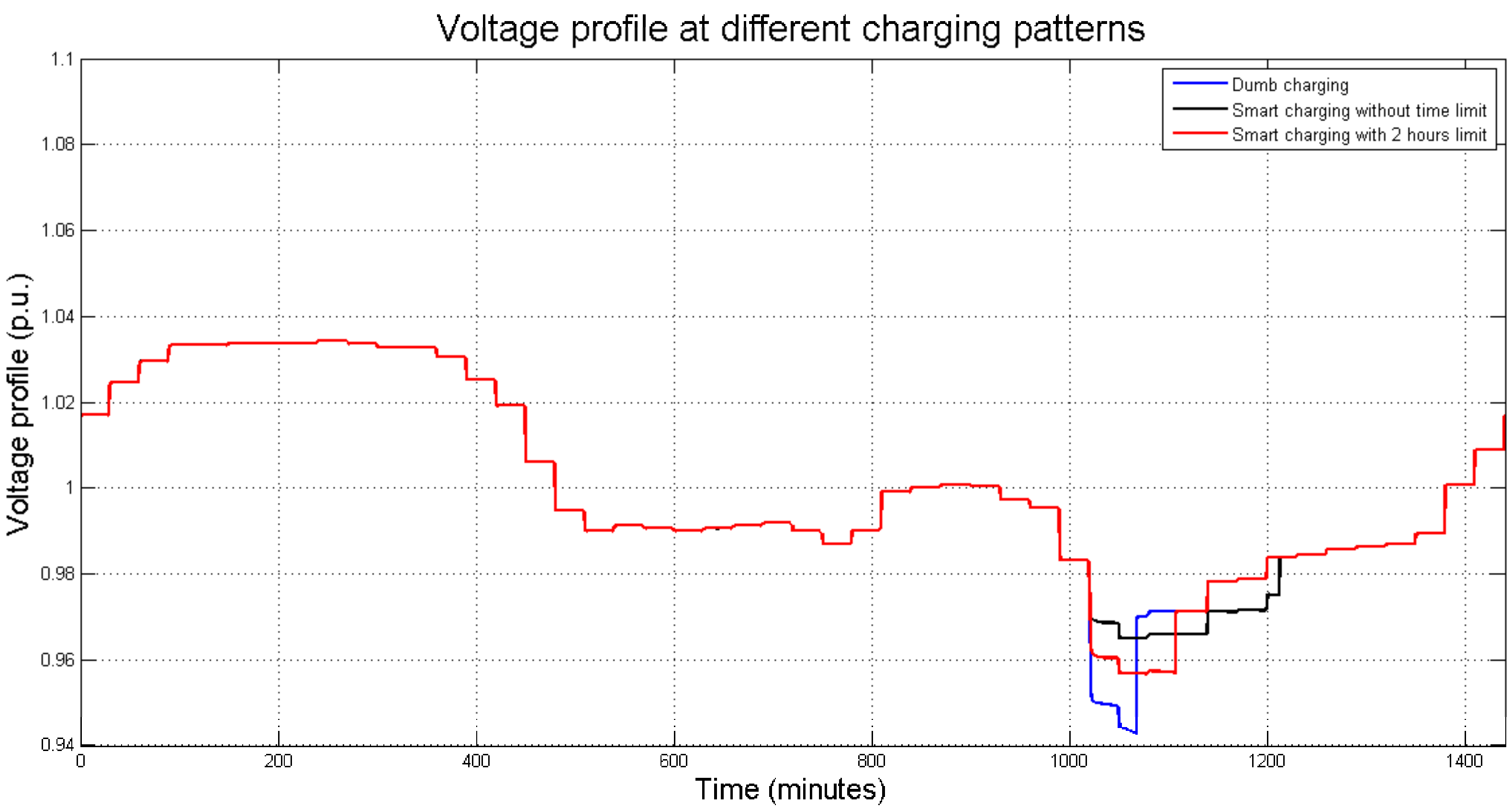
Charging Current



	Dumb charge	Smart no T limit	Smart with T limit
Time	1 hour	3.3 hours	1.6 hours
Current rate	1 C	0.3 C	0.625 C
Capacity loss per cycle	0.52%	0.005%	0.05%

Voltage Profile



Summary

Compared with current charging schemes, smart charging can provide the following:

- Extent the EV battery life by appropriate control and communication with the Battery Management System (BMS)
- Offer better controllability and flexibility to charge the EV
- Improve the security and reliability of the power network
- Maximize charging from renewable energy sources

Northumbria University Power and Wind Energy Research (PaWER) group is happy to build partnerships with you!

Thanks for your attention
Any question?