University of Strathclyde Engineering

Interface and Network Infrastructure to Support EV Participation in Smart Grids

EPSRC

Engineering and Physical Sciences Research Council

NSFC 国家自然科学基金委员会 National Natural Science Foundation of China

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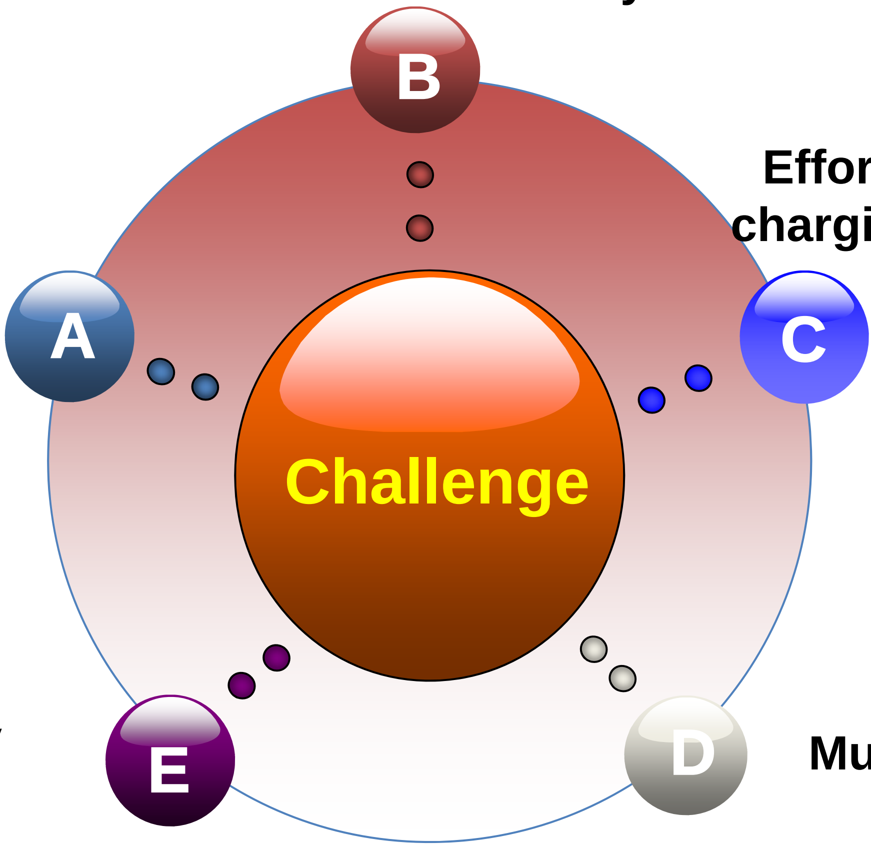
国家电网 STATE GRID

中国电力科学研究院 CHINA ELECTRIC POWER RESEARCH INSTITUTE

China Electrical power Research Institute

Challenge for EV integration



Understand the behaviour of E.V. rich systems and investigate technical solutions

Observations

- High penetrations of E.V. will increase energy flows which will have to be supplied through the distribution network. Peak power requirements may be significantly greater than present.
  - Problems of phase unbalance.
  - Problems with voltage regulation .

- Peak power requirements could be reduced by 'smart charging' techniques which disperse the charge time of individual connections. However this approach may limit the functionality of E.V. charging networks. :
  - Optimise use of available clean energy
  - Provide network support through vehicle to connection.

- E.V. charging may become the dominant load on distribution networks.
  - Network behaviour dominated by power electronics.
    - Harmonics
    - Filter currents
    - Interactions between E.V. chargers (+ other devices such as P.V.)

Network and Interface Technology (Themes)

Distribution Networks For High EV Penetration

- Network management.
- Distribution level FACTs

Distribution Network to Charge System Interface

- Improved efficiency (without impacting on network performance)
- Improved power quality
- Improved control
- Multiple function converters (e.g. combining drive and charge power electronics)

Vehicle Interface

- Wireless Charging

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Distribution Networks for High EV Penetration

国家电网公司
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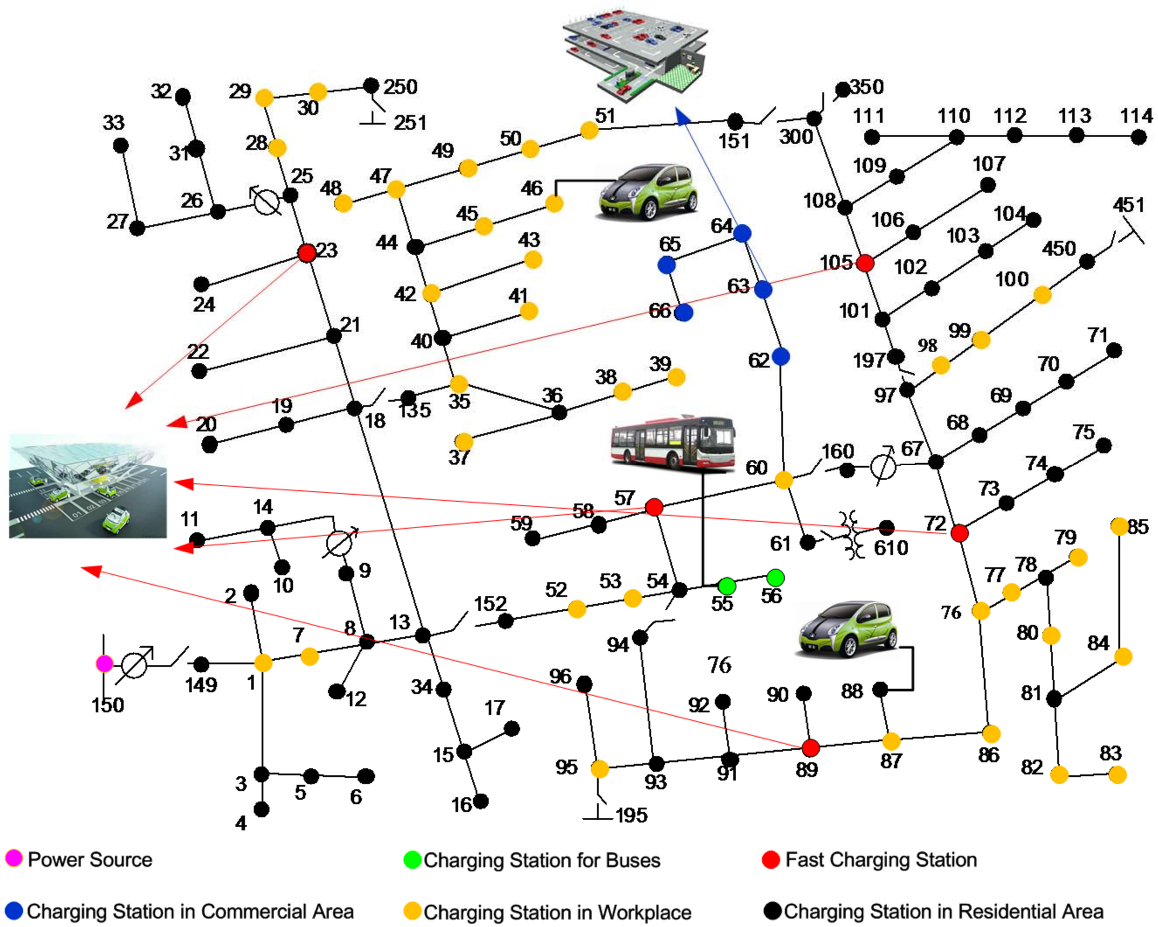
An Assessment Method of Distribution Network's Ability to Accommodate Electric Vehicles

Junrong Xia
China Electric Power Research Institute
September, 2015

中国电力科学研究院
CHINA ELECTRIC POWER RESEARCH INSTITUTE

Case Studies

Case Network



Network: IEEE 123 Node Test Feeder

Rated Voltage: 4.16 kV

Rated Capacity: 5000 kVA

Conclusions and Future Work

Conclusions

- A method based on Monte Carlo simulation is proposed to forecast load of PEVs applied with different charging strategies. A PEVs integration scenario under smart charging is simulated , and the effectiveness of the method is proven.

- A method for evaluating distribution network's ability to accommodate electric vehicles is proposed. This method can be used to study the impact of PEVs on distribution network, and be used to compute the maximum PEVs hosting capacity in a given network.

- IEEE 123 node test feeder is taken as a case network for PEVs hosting capacity evaluation, and the results indicate that distribution network can accommodate more PEVs with advanced charging strategies.

China-UK Workshop, UK

Coordinated Dispatch of Electric Vehicles and Wind Power Considering Time-of-use Pricing

Ms. Liya Ye, Research Student

College of Electrical Engineering, Zhejiang University

Sep 24th 2015

NSFC-EPSRC

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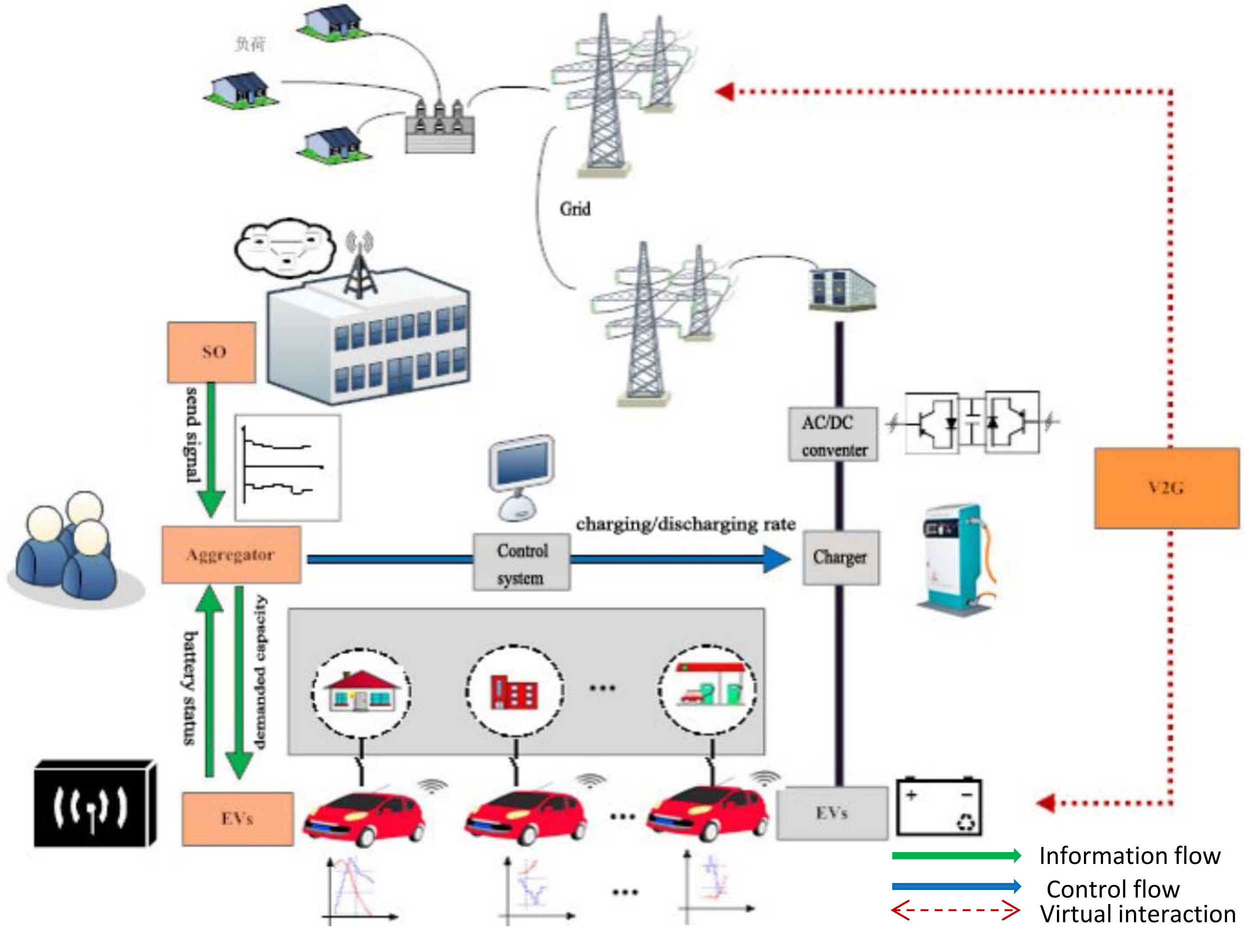
4. EV Load Management

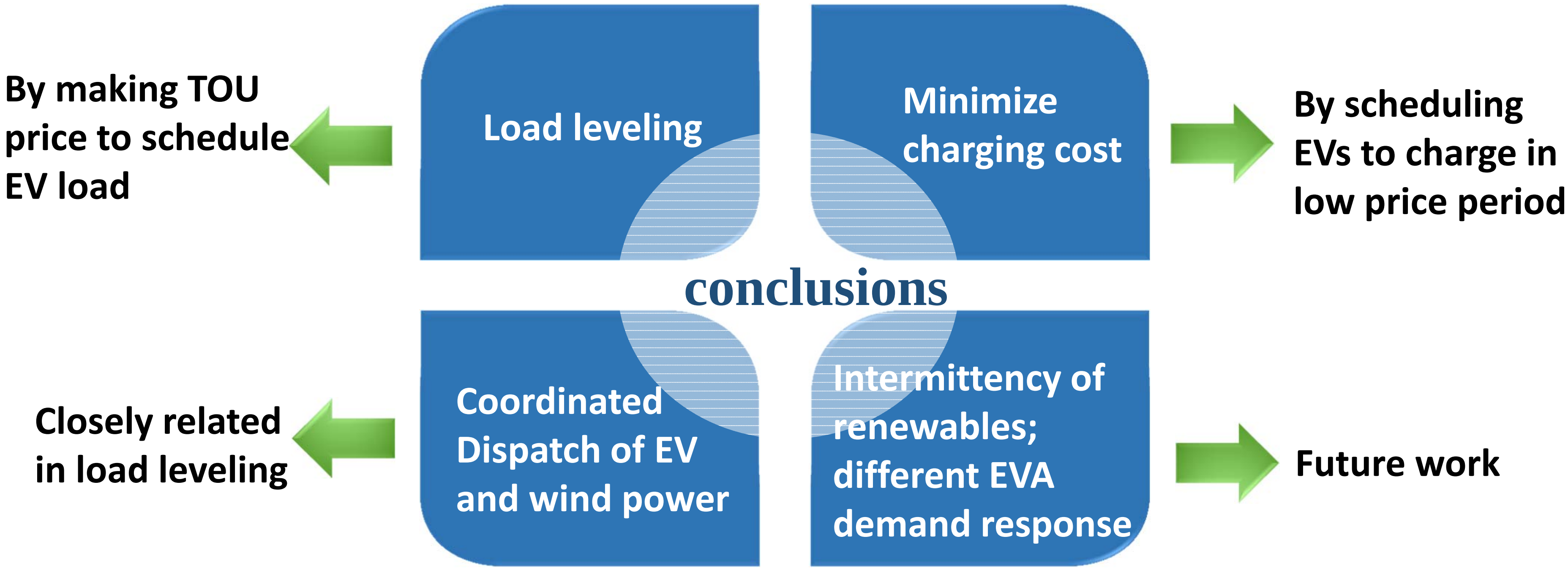
☐ EV load management on an EVA unit



EVA assigns the output power of pertaining EVs , considering their various charging demand, charging behaviors (e.g. expected time to plug to grid).

5. Simulation and Conclusions

□ Conclusions



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NSFC-EPSRC Collaborative Research Initiative in Smart Grids and the Integration of Electric Vehicles

Management and Control of EV Charging Infrastructures by Modeling Stochastic Behavior of Electric Bus Fleet

Qian Dai, Tao Cai, Shanxu Duan, and Feng Zhao
Power Electronics Research Center
School of Electrical and Electronic Engineering

Huazhong University of Science & Technology

1. Background and Tasks

EV Battery Swap Station

Bus Service Route

Swap Service Channels

Battery Swap Robot

4. Conclusions

The charging load characteristics of BSS is investigated to guide the **coordinated battery charging** for mitigating the impact of disorderly charging behaviors on the distribution network.

Charging load demand can be modelled from Four variables.

1) Hourly number of EVs for battery swapping;
2) Charging start time;
3) Bus travel distance;
4) Charging duration.

Simulation of an actual typical BSS results show that the proposed prediction methods of the BSS charging load are suitable for forecasting the horizon 24 h ahead. According to the charging load demand forecasted, different optimized schedules for charging batteries group can be proposed to get better economy or smaller load fluctuation.

Imperial College London

Multi-level Converters for Distribution Networks

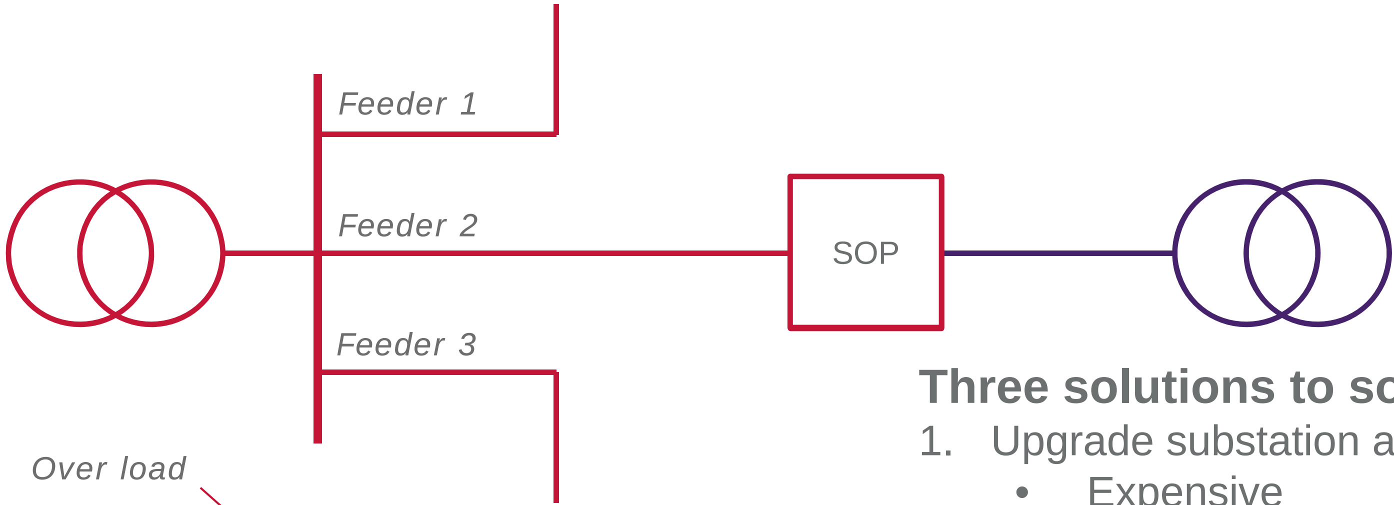
Prof. Tim Green
Dr. Phil Clemow

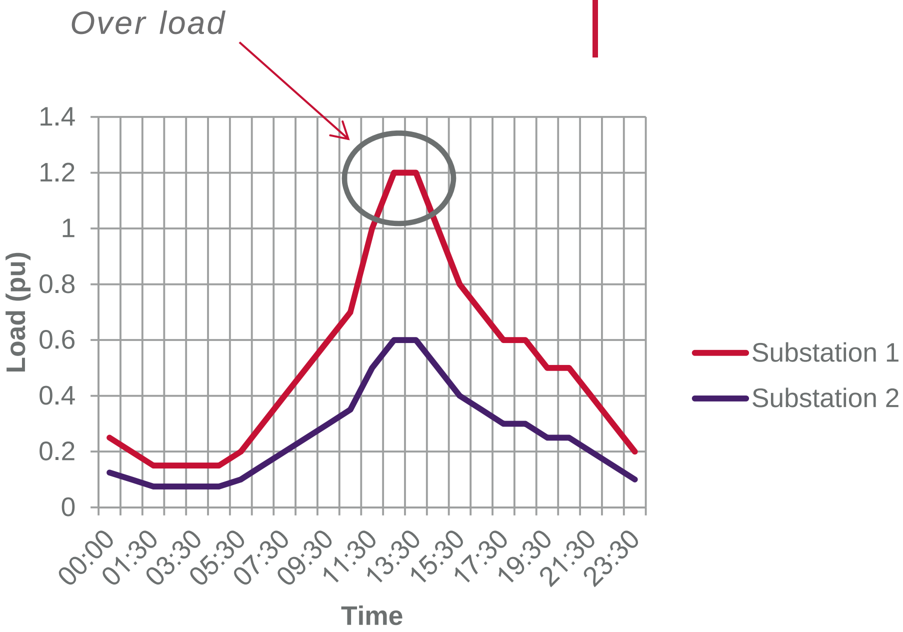
Control & Power Research Group

Distribution-level Power Electronics

- Distribution network is traditionally passive from the substation to load
- Voltage control using tap-changers at the substation transformer keeps feeder voltage in limits and compensates for voltage drop along the line
- Increase in distributed generation (PV and Electric vehicles) can dramatically change load profiles and current flows (crucially current direction)
- Tap changers cannot change quickly enough to counter changes in PV generation
- A number of solutions available at mid-feeder and feeder ends
- Soft Open Point (SOP) is a power flow controlled device which is connected where a normally open point would be found and allows many control techniques
- A SOP is typically a pair of back to back inverters

Increase Feeder / Transformer Capacity



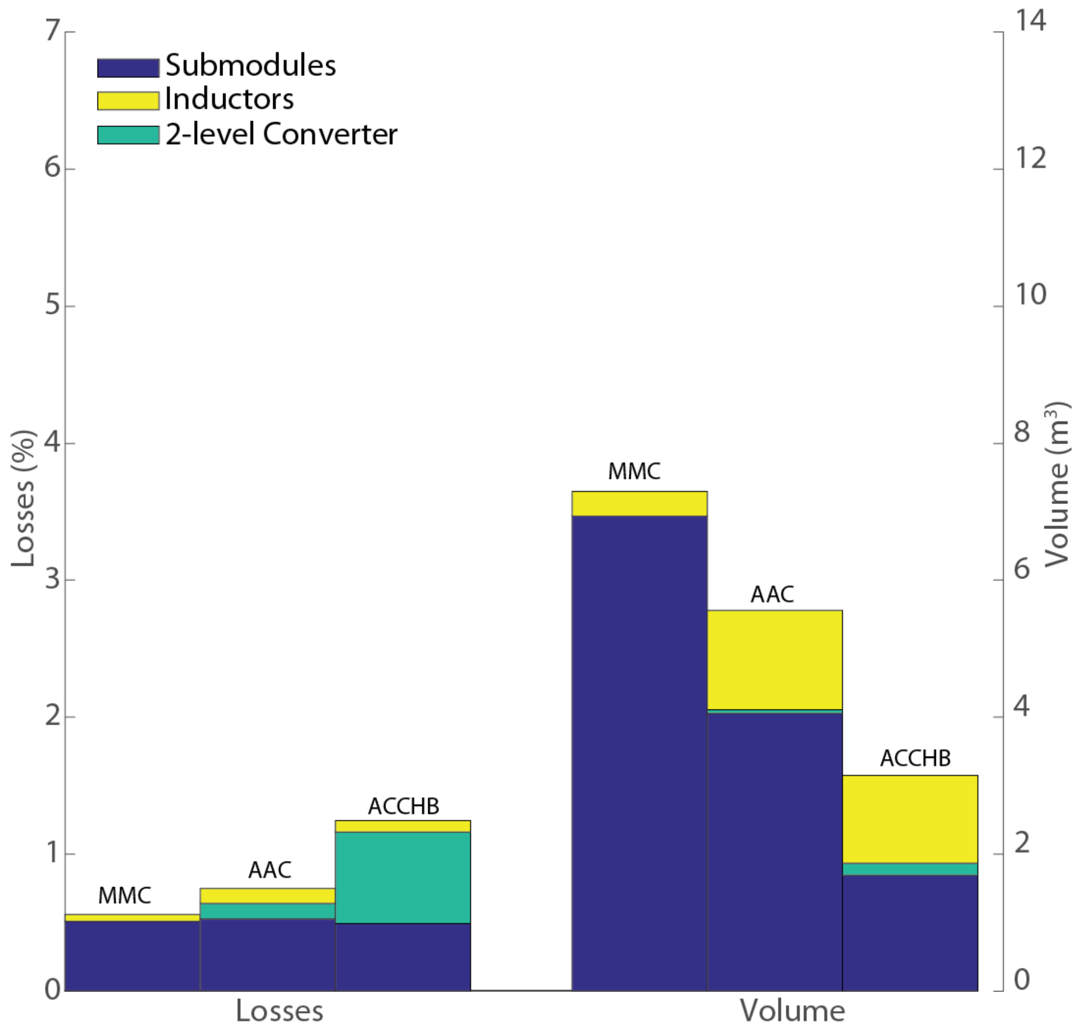


Three solutions to solve

1. Upgrade substation and feeder
   - Expensive
   - Disruption
   - Increase in load might be temporary
2. Close NOP and mesh network
   - Fault current increases,
   - Power flow not controlled
3. SOP at the NOP
   - Blocks fault current
   - Can be controlled to only transfer power when there is an overload

Slide courtesy of Dr Nathaniel Bottrell

Converter Comparison



- All converters are compared with fewest SMs (3300V IGBT)
- MMC is most efficient with a small jump to AAC and a larger jump to ACCHB
- MMC is larger in volume than the AAC and significantly larger than the ACCHB.

Conclusions

- Work on designing multi-level converters for distribution networks is nearing completion
- Final designs for the three circuit layouts are complete with comparisons of efficiency, volume and THD
- AAC shows very good balance between losses and volume

Distribution Network to Charge System Interface

PEDEC
Power Electronics, Drives and Energy Conversion

University of Strathclyde Engineering

Comparing SiC MOSFET, IGBT and Si MOSFET for L.V AC/DC interface

Nina Roscoe, Yanni Zhong and Stephen Finney
University of Strathclyde
9th November 2015

Introduction: Design Requirements (L.V MMC)

- **Two level converters:**

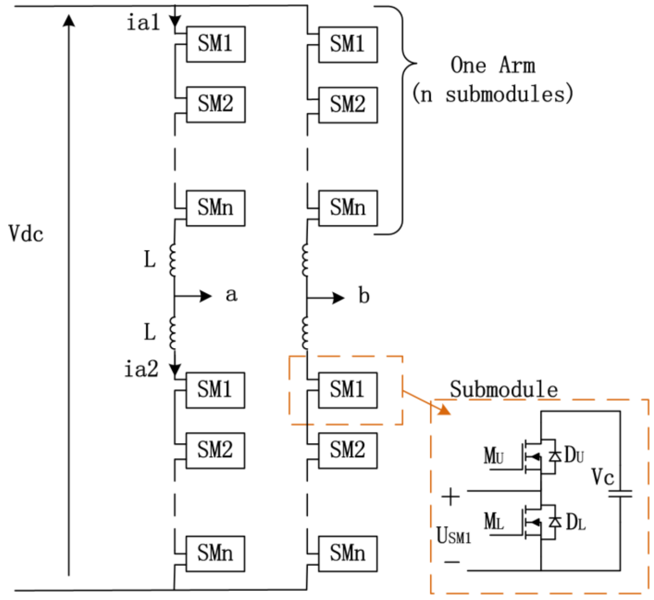
Harmonic and AC filter requirement is linked to switching frequency. (SiC, GaN) may allow higher switching speeds (lower switching loss) at voltages suitable for E,V charging systems.

  - Fast switch speeds may increase high frequency EMI.

- **Multi-level converters**

Decouple power quality from switching loss.

  - Switching loss may be dramatically reduced.
  - Relatively cheap, high performance Si-MOSFETs may be used
  - Circuits are more complex than two level converters.



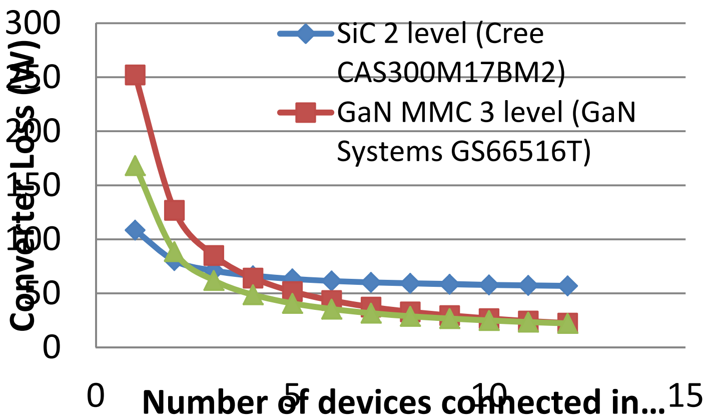
Modular multilevel converter, with n+1 levels (showing only 2 of the 3 phases)

Conclusions

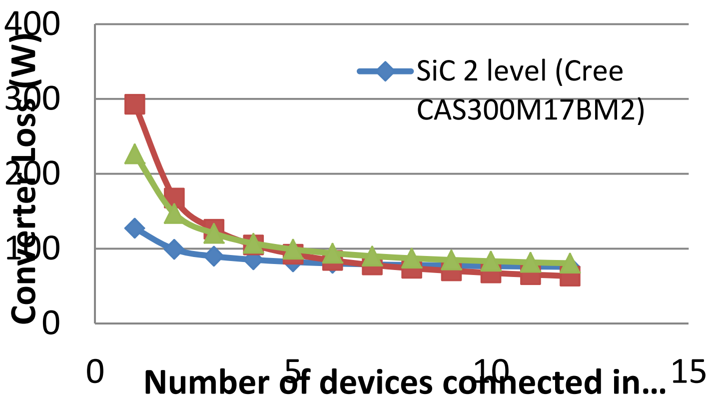
- Extensive and careful modelling has been used to predict loss in
  - Si MOSFET MMC
    - 7 levels to 43 levels
    - Including inter-cell resistance, parallel combination resistance
  - SiC MOSFET 2-level
  - Baseline comparison with IGBT
  - Si MOSFET demonstrates lowest loss
    - SiC offers interesting high performance in simple circuit, at the cost of poorer power quality
- Modelling accuracy for Si MOSFET MMC has been demonstrated with single cell measurements
  - Estimations of track resistance also verified during this exercise
- Effectiveness of slowed gate-drive on reducing ringing experimentally demonstrated

Power Loss Comparison

Loss comparison for two phase-leg Si MOSFET 5-level MMC, SiC 2-level, and GaN 3-level MMC converters *(10kW, 10kHz, 600Vdc, M=0.57 and unity power factor)*



Semiconductor conduction and switching power losses



Semiconductor conduction and switching power losses and capacitor losses

Power Electronics, Drives and Energy Conversion

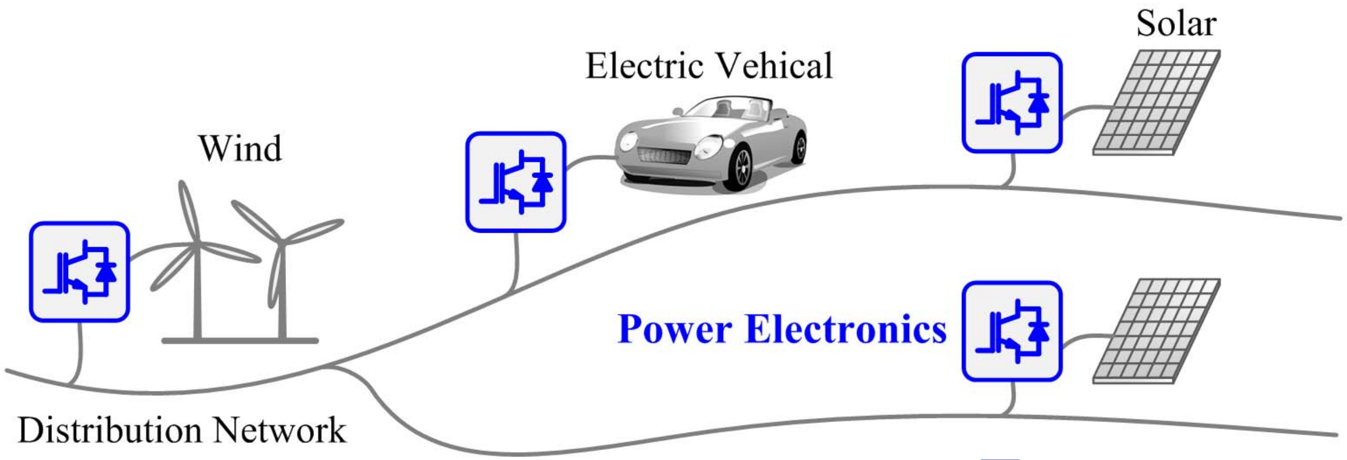
Synchronization Stability of PLL-Based Grid Connected VSC

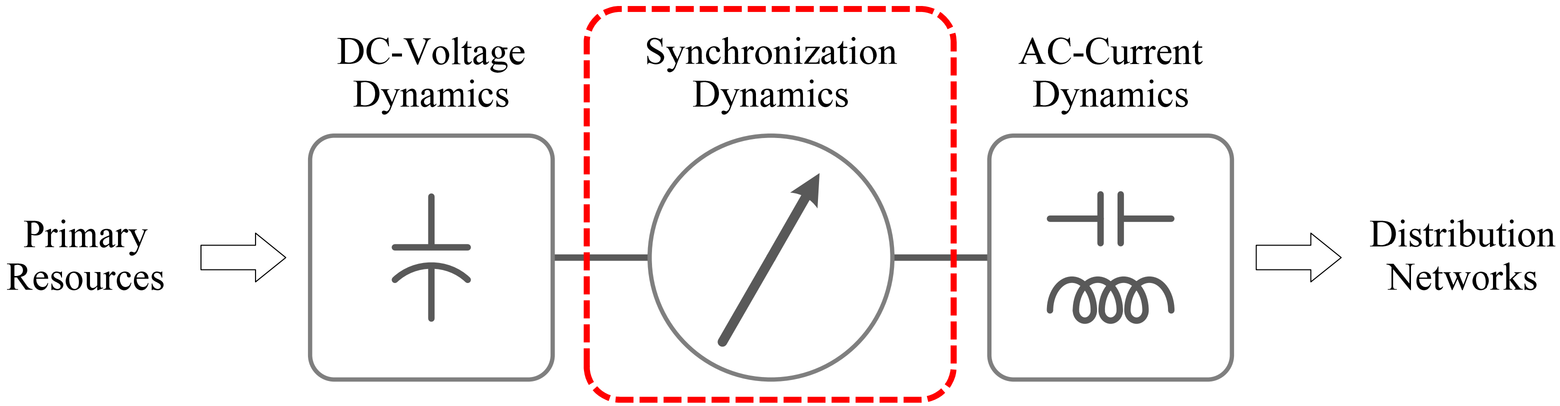
Yunjie Gu, Wuhua Li, Xiangning He

College of Electrical Engineering, Zhejiang University

E-mail: guyunjie@zju.edu.cn

Power-Electronics-Based Distribution Systems





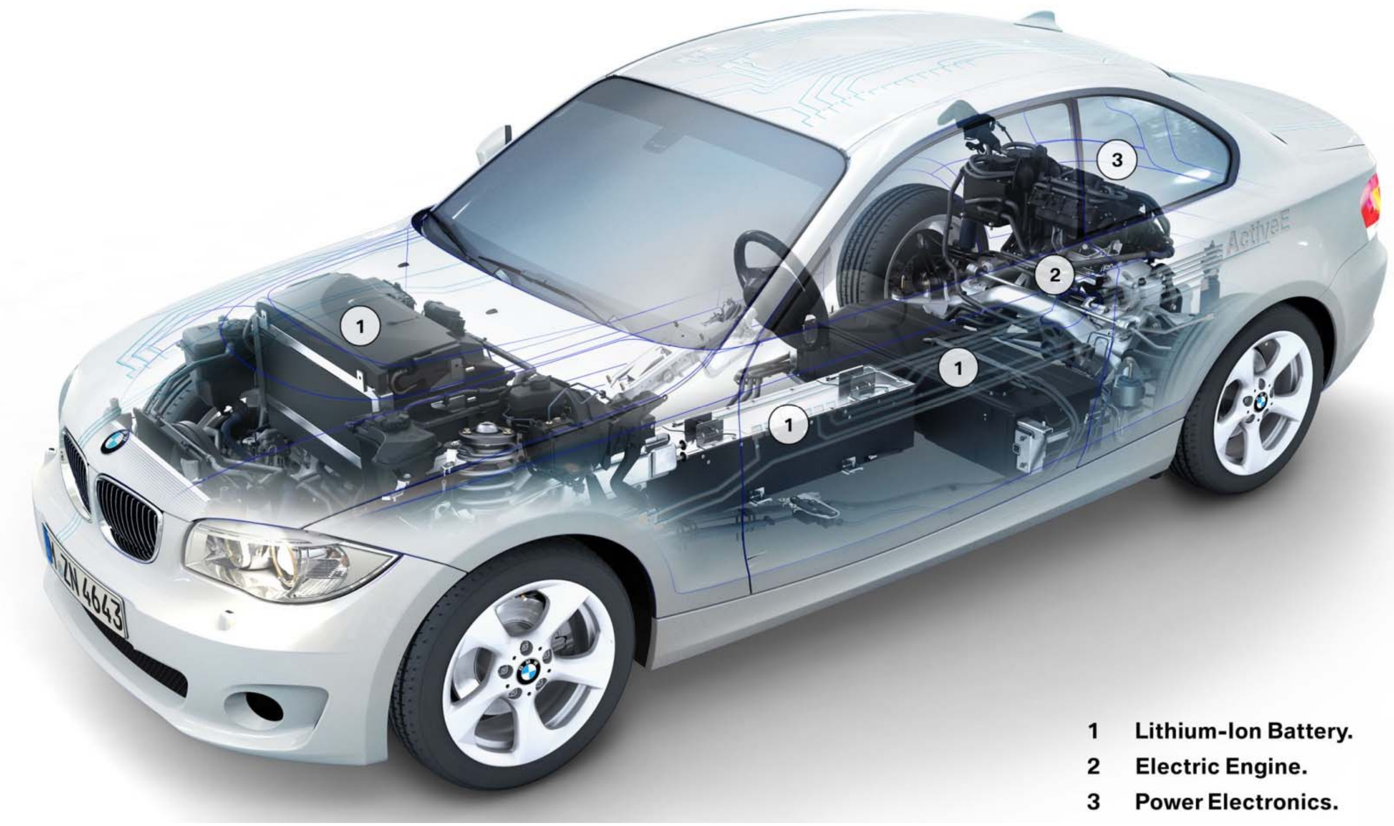
Dynamics Categorization of Voltage Source Converter (VSC)

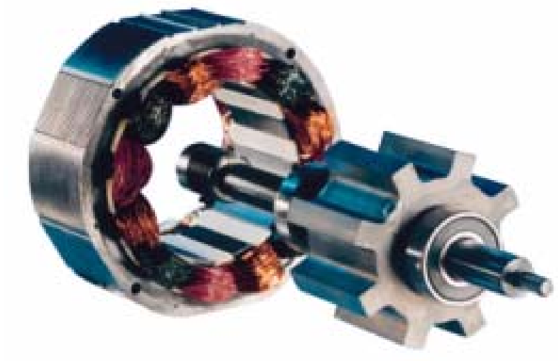
Conclusions

- PLL synchronization instability may be induced due to the dynamic interaction between PLL angle and PoC voltage angle
- The interaction is more significant in a weak grid with large line impedance
- The synchronization instability can be damped by reducing the PLL control coefficient

The Grid to EV Interface

SRM Based EVs/HEVs Top-to-Toe Solution

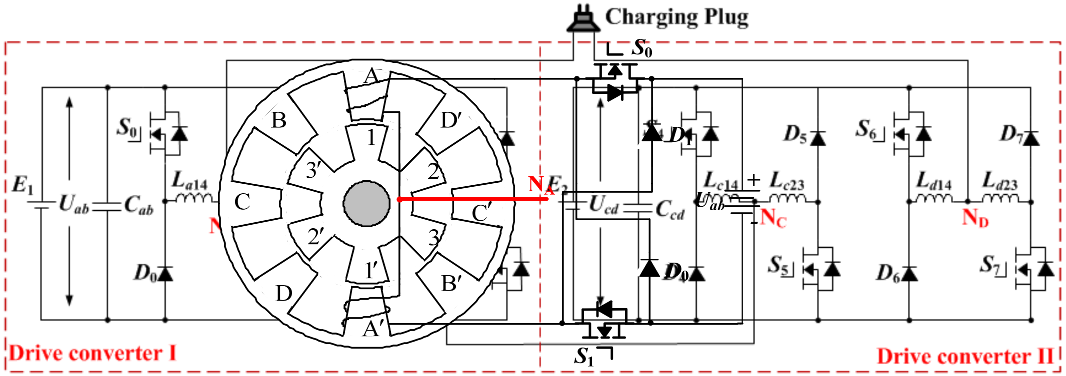


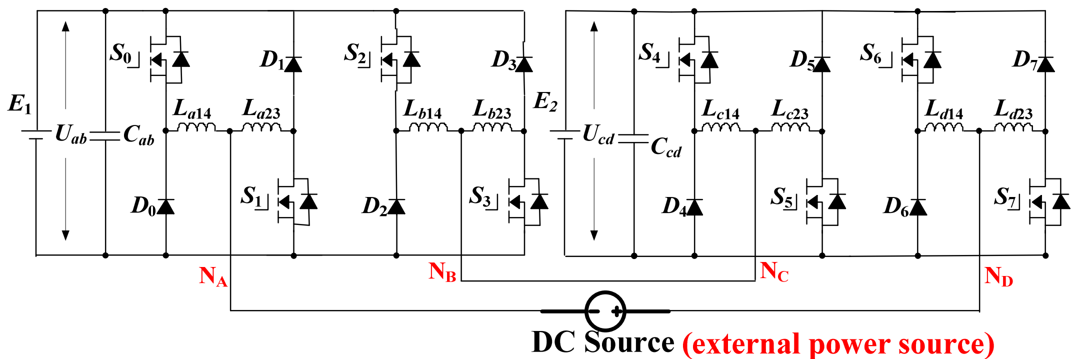


Dr. Yihua Hu

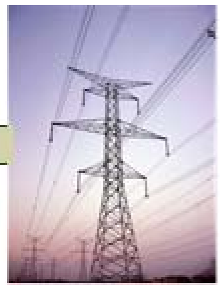
25/9/2015

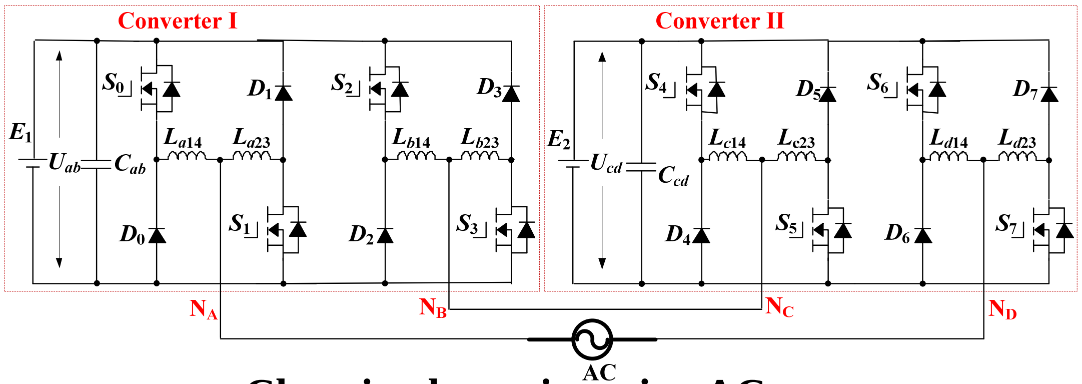
Charging without a charging station





Charging batteries using DC power





Charging batteries using AC power

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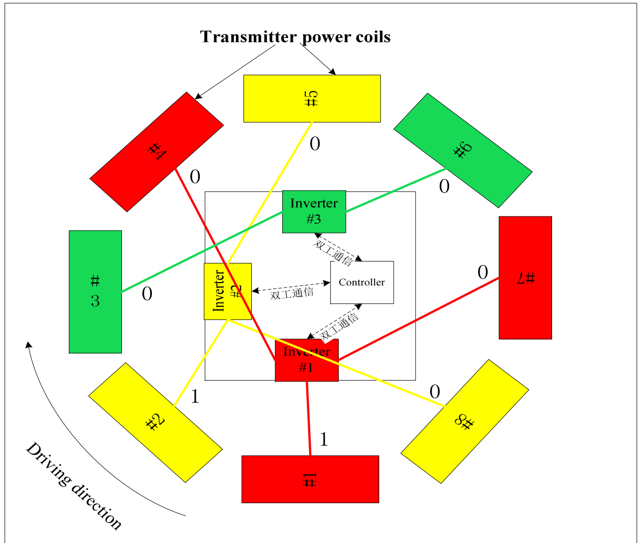
Design Consideration for Compensation Topology Against Coupling Variation in Inductive EV Chargers

2015.09.26
HUST

华中科技大学

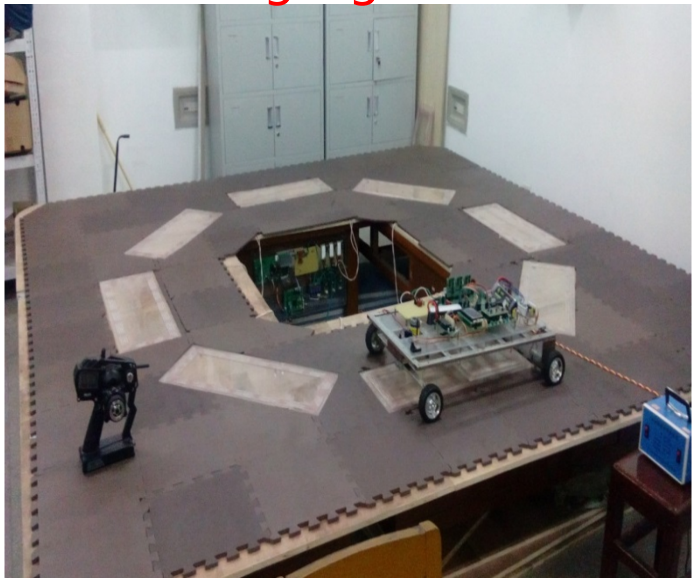
Dynamic WPT Prototype

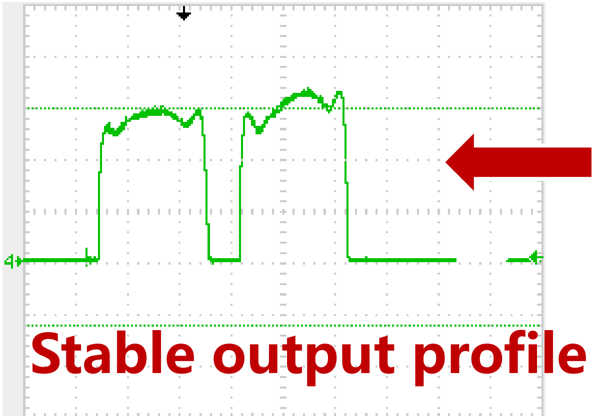
- the power roadway



Two transmitter coils case

The chain including eight transmitter coils





Charging current without any regulation

Stable output profile

3. Implementation and Conclusion

- Robust reaction against the coupling variation is necessary to keep effective power transfer

- Through careful design of resonant tank, the sensitivity to coupling variation is reduced to minimal extent

- Stationary and dynamic charging experiment shows its potential application

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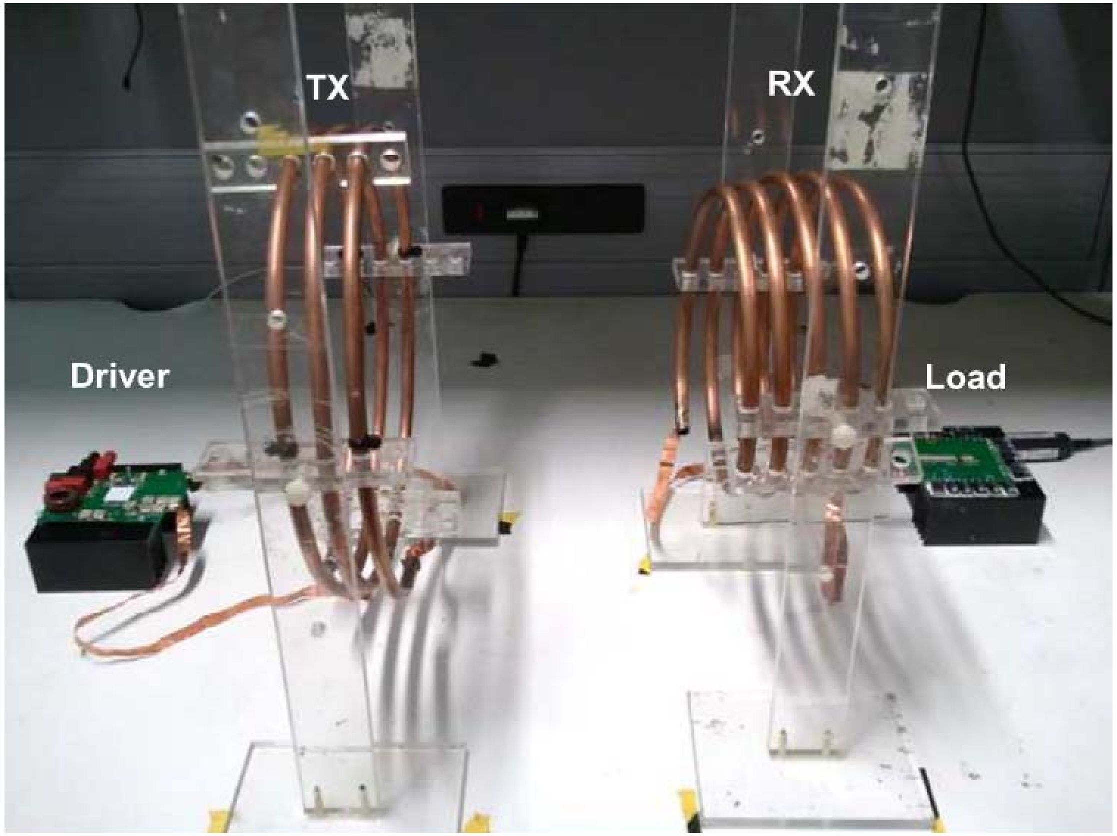
Imperial College London

Link Efficiency-Led Design of Lightweight Inductive Power Transfer Systems for EVs

Paul D. Mitcheson, David C. Yates, George Kkelis, Samer Aldhaher, James Lawson, Chris Kwan, and Tim C Green
Department of Electrical and Electronic Engineering, Imperial College London, U.K.

Imperial College London

High Frequency Semi-resonant Class-E Driver



78% dc-load efficiency, 100 W, 6 MHz, IXYS Si module

Imperial College London

Conclusion

- Well on the way to achieving a complete lightweight 3 kW IPT system suitable as an initial EV charging prototype
- Maximising the link efficiency for air core coils serves as the design starting point
- The system architecture, circuit blocks and components have been chosen to maximise the end-to-end efficiency
- AMCs are considered as a lightweight approach to shielding to meet health and safety regulations and minimise interaction with the chassis
- A comparison with wired EV charging systems is being started since realistic predictions of the end-to-end link IPT link efficiency can now be made

Wireless Power and Data Transfer via a Common Inductive Link using Frequency Division Multiplexing

Jiande Wu, **Jin Du**, Xiangning He

Zhejiang University

I. Background

Necessity of communication

For typical WPT system, communication is essential.

- Circuit control:
  - Output voltage feedback
  - Load detection
- Status monitoring
- Multi-controllers synchronization

Drawbacks of conventional solutions

Radio frequency (RF) link

- High costs
- Low reliability with increasing power

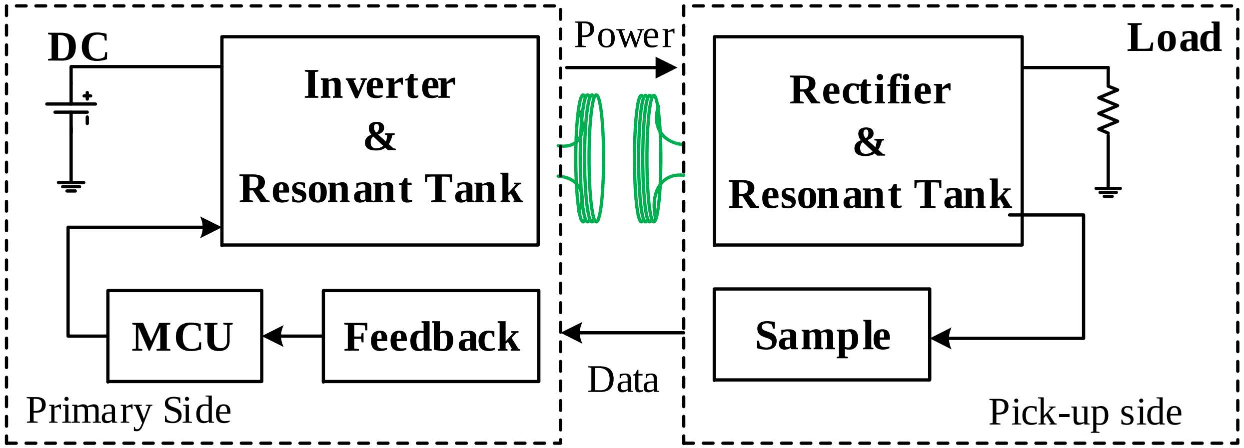
Single inductive link, single carrier

- Low data rate
- Lower power efficiency

Multiple inductive link, multiple carrier

- Strong magnetic interference limits SNR

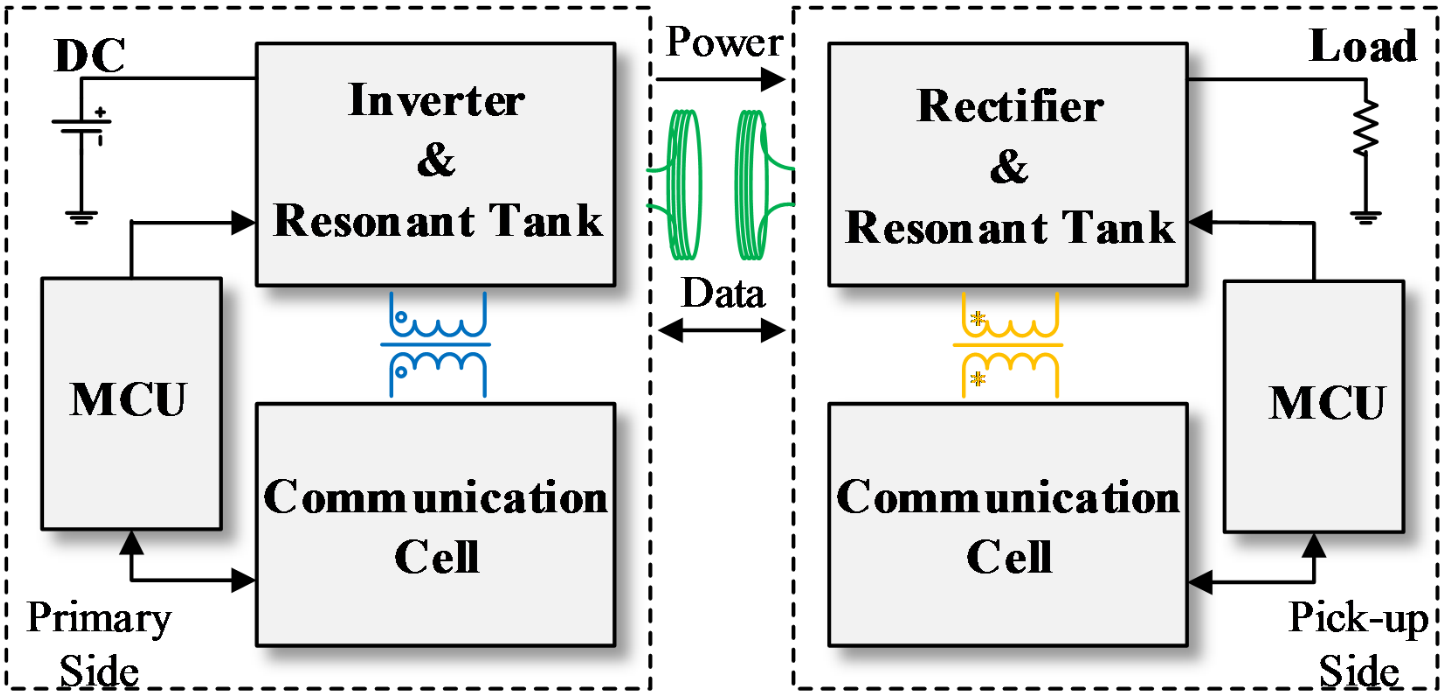
Inductive link, multiple carrier is a competitive candidate for WPT systems with several advantages



Typical WPT system structure

II. System overview

➢ The basic idea of the proposed method is to add a communication cell in both the primary side and pickup side.



Block diagram of WPDT system

V. Conclusion

- A novel method based on communication cell, which integrates near field communication with wireless power transfer is proposed.

- The performance of the power and data transfer, as well as the cross-effect between power transfer and data communication, are analysed in detail.

- The results obtained from a 500W experimental platform are in line with the theoretical analysis, which verify the effectiveness of the proposed method.

Thank You