Integration of traffic and grid simulator for the analysis of eMobility impact on power distribution networks

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(joint work with:

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Presentation Outline

Introduction

- Motivation and aim of this research
- Context: enhancement and exploitation of IoE-SC6 results within an EIT ICT Labs activity (14053)

Summary: illustration of new Co-Simulation Framework

- Simulator of electric mobility in realistic traffic conditions (OMNet++, SUMO, Veins)
  - Detailed customizable models of EV, EVSE and their parameters
  - Detailed customizable models of urban scenarios (OpenStreetMap)
- Dynamic simulator of the power distribution network (EMTP-rv)
  - Detailed customizable models of power distribution networks
- Integration component via Smart-M3 based interoperability and co-simulation controller
- Enabling potential: enhanced systems- and service-deployment analysis of eMobility impact on power distribution networks

Results

- Preliminary analysis results in proof of concept scenario
Motivation and aim of this research:

- **What:** development of a co-simulation platform that integrates a mobility simulator of the electric vehicles and their charging requests with a dynamic simulator of the power distribution network.

- **Where:** exploitation of IoE – SC6 results (simulation framework for Electric Vehicles Operations and Services) within an EIT ICT Labs activity (14053- task A1401 Open Source Booster – Enhancement of open EV fleet simulation framework)

- **Why:** system-level and service-level planning & pre-deployment analysis
  - to assess the effects of the transients caused by the dynamic and concurrent charging processes of a large number of electric vehicles to the operating conditions of the power network.
  - developing and analyzing specific countermeasures against voltage variations, unbalances and overload of power components as well as at verifying their performances.

- **Who:**
Overall Framework

EMTP-rv

Power Distribution Network model (many customizable and parameterized components)

Integration Platform (Interoperability)

OMNet++, SUMO, Veins, OpenStreetMap

Mobility model: EV, EVSE (Traffic, Routes, Paths, Policies, Control, User, Energy, Altimetry, Resources, Maps, etc.)

Impact analysis and Planning

Energy

Mobility

EV penetration

Resources & policies
Overall Framework

EMTP-rv

OMNet++, SUMO, Veins, OpenStreetMap

Integration Platform
(Interoperability)

Now we focus here
Scheme for the INTERFACE between the model of urban traffic and the power distribution system simulator

Model of the electric power distribution system

- Initial power flow
- Transient 3ph simulation ($\Delta t=1$ms)
- Model of nodal aggregated (1ph and 3ph) EV charging systems
- Check of network constrains by using IEDs information
- Networked control EV charging systems

SIB

- ID of active EV charging systems and power

Model of the urban traffic

- Initial occupation of EV charging systems
- Traffic simulation ($\Delta t=100$ms)
  - Start and end of charging of individual EV at a specific charging station
  - Update of charging profile and duration due to electric network limitations

Model of nodal aggregated (1ph and 3ph) EV charging systems

- Check of network constrains by using IEDs information

Model of the communication network

*IED: Intelligent Electronic Devices
*SIB: Storage Information Broker

*ECSEL JU
SYNCHRONIZATION between the model of urban traffic and the power distribution system simulator

EMTP-rv

Load change

Network operating condition

EVSE profile

load change

Socket

SIB (Storage Information) + WS synchronizer

Socket

Reservation event

EVSE plug

EVSE charging

EVSE profile

EVSE unplug

External SW 1

External SW 2

...External SW n

*EVSE: electric vehicles supply equipment

e.g.: OPNET, CityService, Smartphone App, ...

Linux

Linux

MSWindows

MSWindows
Overall Framework

EMTP-rv

Integration Platform
(Interoperability)

OMNet++, SUMO, Veins, OpenStreetMap
Mobility simulator: OMNET++ - SUMO - Veins - Openstreetmap

Simulator for analysis of traffic including EV and EVSE entities in realistic scenarios (including support for ext. services and apps).

- Based on Omnet++, SUMO, Veins and Openstreetmap
- Accurate modeling of city scenarios and multiple eMobility entities
- Modeling and control of traffic (realistic data vs. model assumptions)
- Modeling EV and EVSE parameters, their distribution, use and location
- Integrated with Storage Information Broker (SIB)-based service platform for integration support of external apps and services
Overall Framework

Integration Platform (Interoperability)

EMTP-rv

OMNet++, SUMO, Veins, OpenStreetMap

ECSEL JU
Model of the Power Distribution System – SB

SB: MV/LV Substation equipped with a 15 kV/ 400 V transformer every that feeds the LV distribution lines.

Current locations of EVSEs in Bologna

In the simulations we have assumed 5 EVSEs at each location.

A new EV is generated every 10 s
Model of the power Distribution System

SB1
SB2
SB3
SB4
SB5
SB6

Bus or load center
--- Tie switch

Simulation SW for the analysis of the dynamic behaviour of power distribution feeders:

- **Time driven**
- Model of the three-phase unbalanced lines
- Three-phase HV/MV substation transformer model equipped with a on-load tap changer (OLTC).
- Model of the aggregated unbalanced loads (constant impedance / current / power) that includes the **EVSE profiles**: the amplitude of a triplet of current sources is controlled by a feed-back regulator in order to inject or absorb the requested value per-phase of active and reactive power.

Aggregate of EVSEs for each MV/LV substation ➔
Aggregate of EVSEs for each MV/LV substation

Current generators for each phases which controls the active and reactive power level:

PHASE 1

PHASE 2

PHASE 3

P

Q
Overall Framework

Integration Platform (Interoperability)

Preliminary Results about impact of eMobility on PDN
Preliminary results

**Proof of Concept:** implemented a very simple policy: every EVSE can recharge the vehicles with a power of:

- 90kW if the voltage at the SB connection is greater than a predefined minimum voltage limit equal to 0.94 pu
- if the voltage at the SB connection is lower than 0.94 pu, then the charging power is reduced to 50kW until the voltage becomes greater than 0.95 pu.

**Further work** will be the development of other and more articulated countermeasures against voltage variations, unbalances, overloads of active power and analysis of the effects of the control of reactive power too. Also possible to model more complex and articulated behaviors (via OCPP emulation and other).
Preliminary results (example)

Initial condition:
24 EVSEs connected

Graphs showing the power (kW), number of plugged EVSEs, and voltage (pu) over time for different EVSEs.
Conclusions

- Realization and demonstration of co-simulation framework integration for SoA Power Distribution Network and Mobility Simulators
- Proof of concept of analysis potential of variable and dynamic EV mobility impact on power distribution network under variable system policies’ and their tuning realized in realistic scenario assumptions
- Future work will include model extensions and exploitation directions, impact analysis of target scenarios, what-if analysis, new policies’ design
  - Analysis of the effect of the communication network
  - Voltage variations,
  - Unbalances,
  - Overloads of active power
  - Analysis of the effects of the control of reactive power too.
REFERENCES