

Grid-Integrated Vehicle Implementation: Learnings and Looking Ahead

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presented at:

CONFERENCE ON THE IMPACT OF ELECTRIC VEHICLES
ON THE ELECTRICITY SYSTEM

Conference of the Chaire European Electricity Markets (CEEM)
at the Université Paris-Dauphine

17 October 2016

Topics for this Talk

- Conference is “Impact” of EVs on grid
- My focus: EVs as a *resource* for grid, qualified for markets and earning revenue
- Our experience and learnings
 - PJM, BMW MiniEs
 - Nuvve commercialization in Europe
- Looking ahead

Our idea and motivation

- Use batteries and chargers in EVs for grid storage, and participate in electric markets...
- Create a second use when the car is parked (average 23 h/day)
- Brings a payment to the EV owner, thus lowering TCO
- Makes very low-cost storage available to the grid, enabling renewable energy to provide >> 50% of electricity

We call it the
Grid Integrated Vehicle (GIV)

With
Vehicle to Grid Power (V2G)

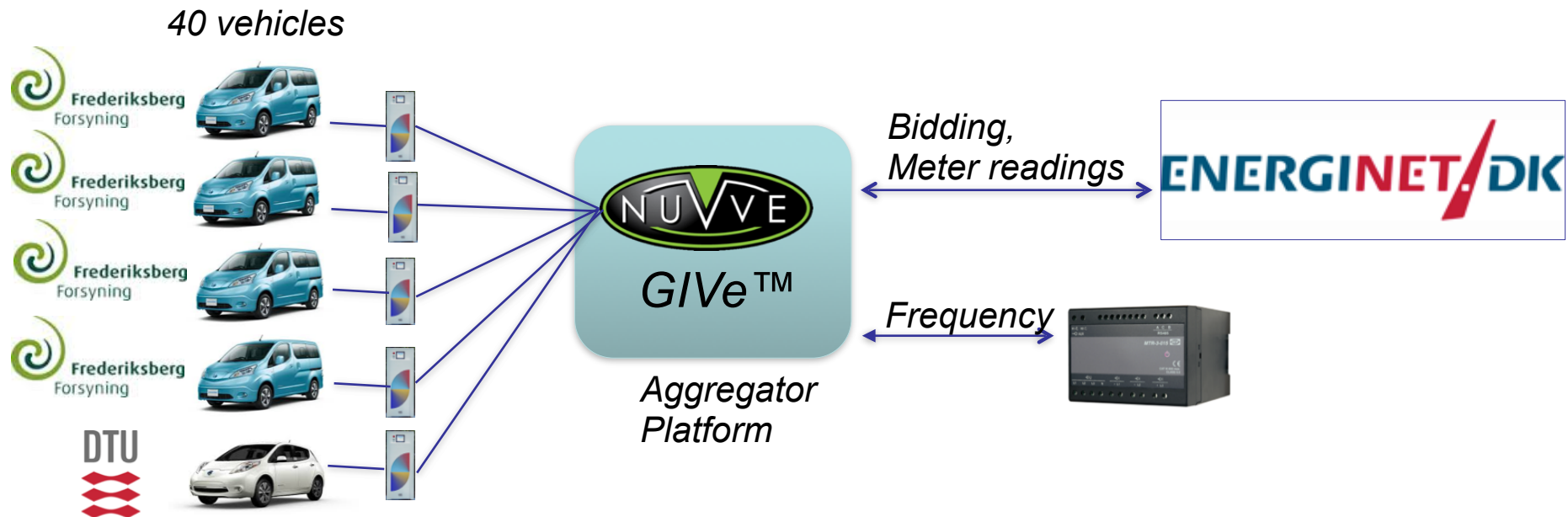
Three Components of GLV

- **Aggregation Server** (in central location)
 - Real time operation of a set of vehicles
 - Provide services to an electric grid entity
- **Vehicle Smart Link** (VSL, in car)
 - Control charging, report to server
- **Electric Vehicle Supply Equipment** (EVSE)
 - Grid location, internet portal, power

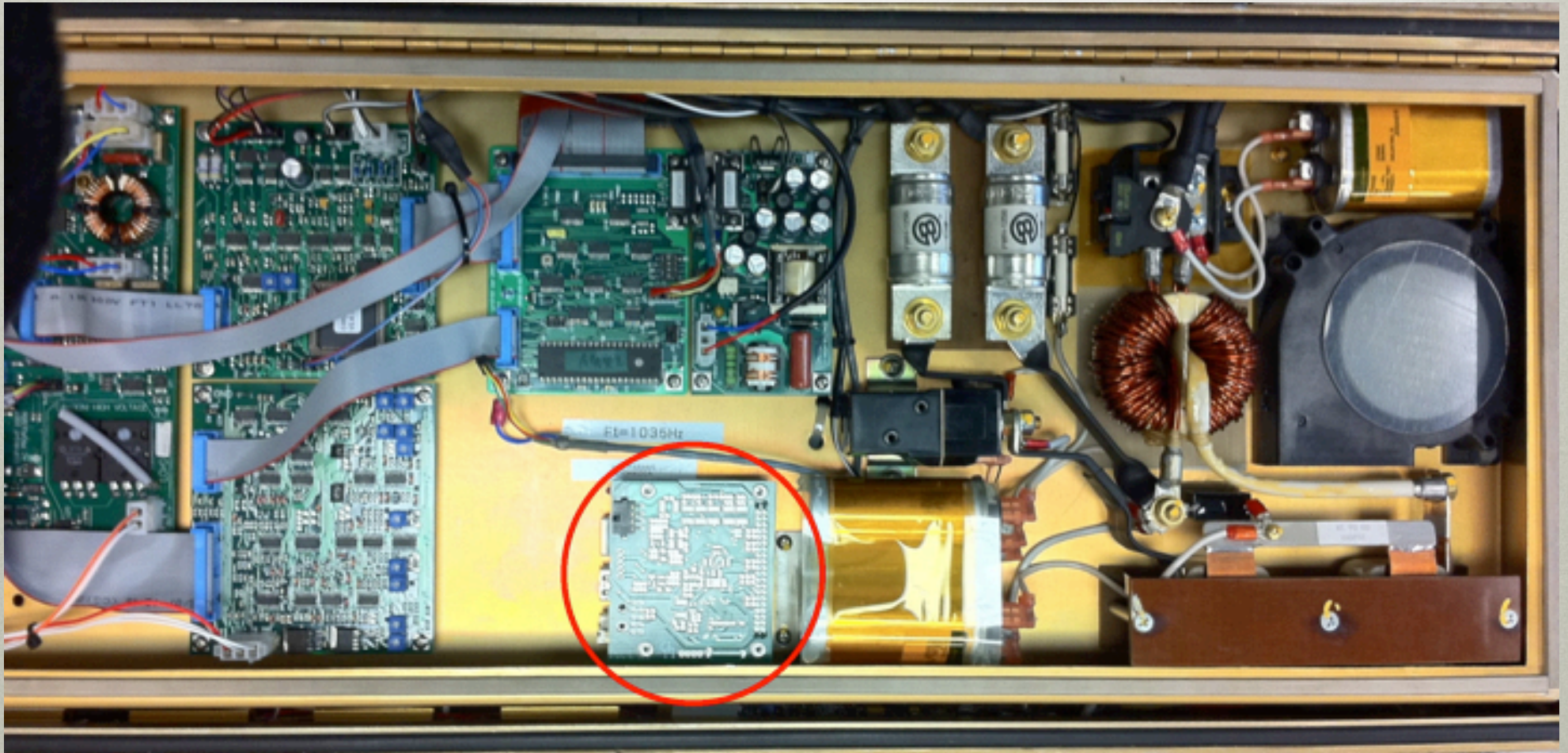
Architecture

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- ▶ GIVe platform will aggregate cars in different locations (DTU, Frederiksberg Forsyning, Nissan, within DK2)



VSL INTEGRATED WITH MINIE ON-BOARD CHARGING ELECTRONICS

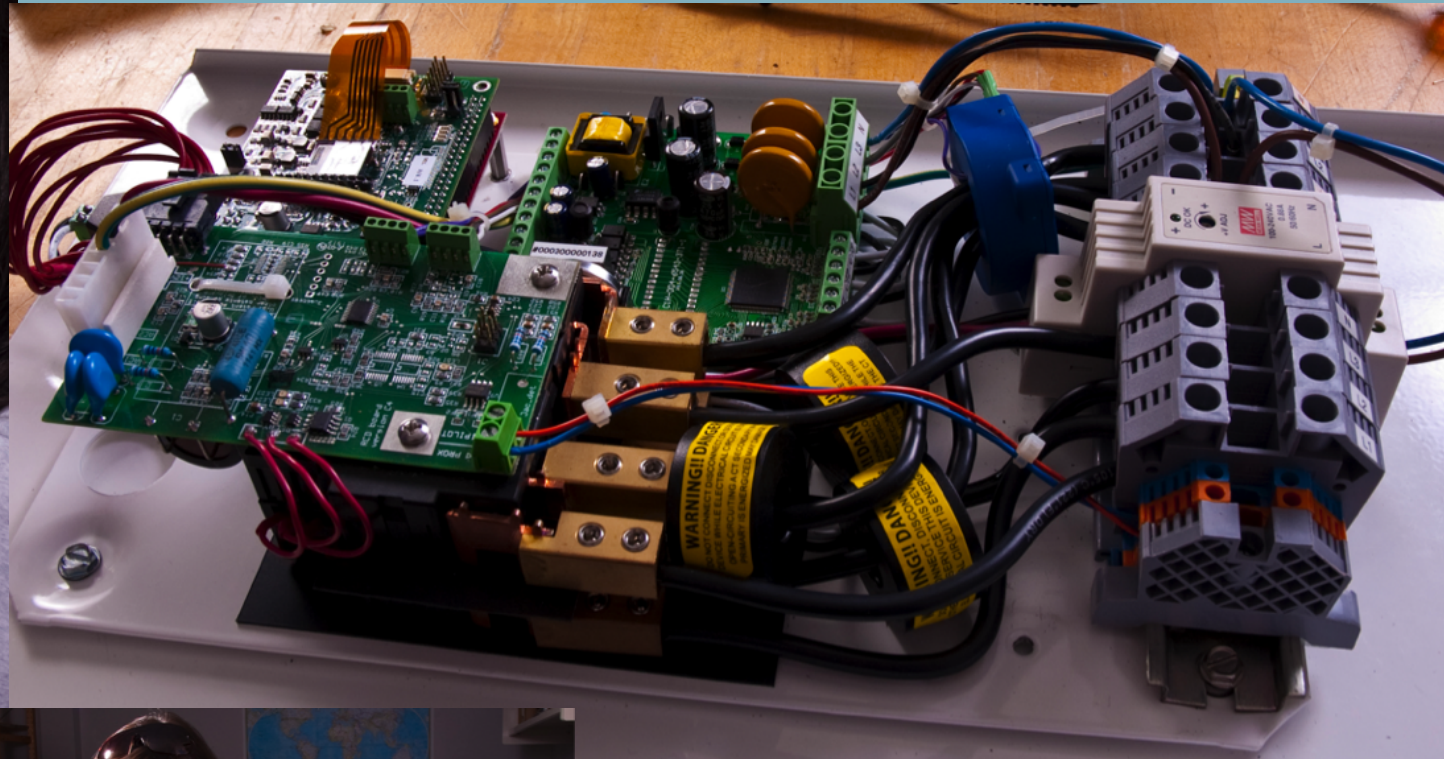
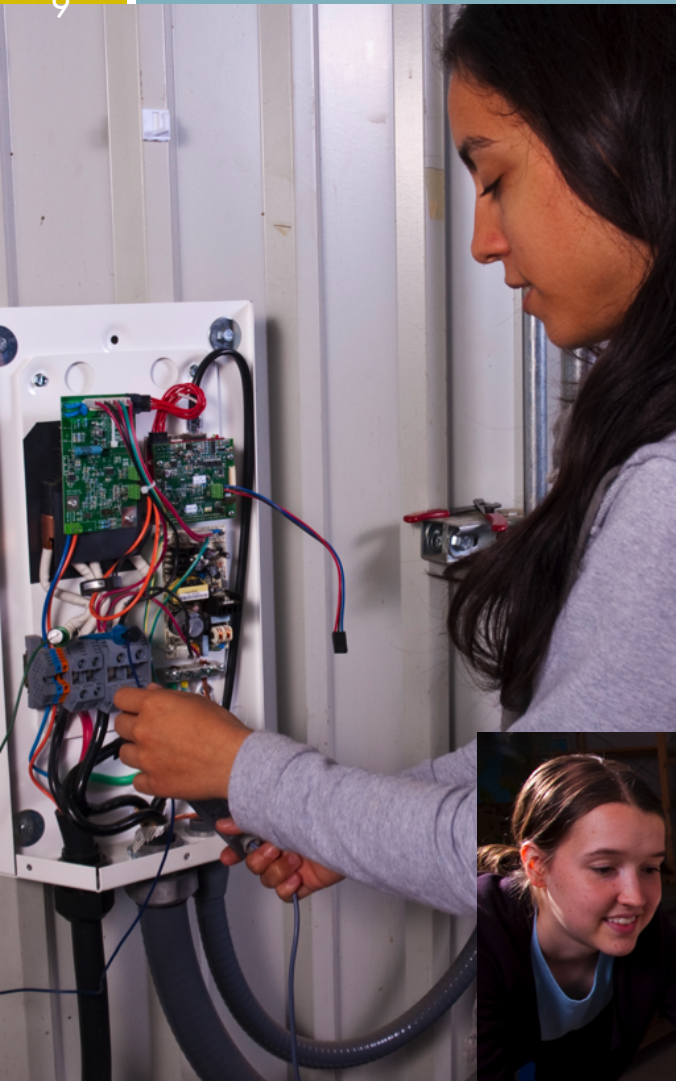


MINIES WITH VSL INSIDE



Development of 1 ϕ and 3 ϕ AC EVSEs

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1 ϕ 19 kW
3 ϕ 42-133kW



Add Controls in DC Chargers



TYPES OF MARKETS

Storage Uses and Markets

- Electric markets were not designed for storage, but in many cases new storage can fit existing markets
- Storage purposes (markets):
 - Balance second-by-second to adjust for small fluctuations that can't be predicted (“primary reserves,” “frequency control” or “regulation”)
 - Move electricity from excess hours to hours of shortage within a day (“arbitrage” or “hourly market”)
 - Hold extra electricity in readiness, to be released only for unexpected failures (“spinning reserves” “contingency reserves” etc.)

Categorizing Markets

- TSOs have organized markets; generators produce and sell energy; storage can offer capacity or time-shifting of energy
- DSOs: DSOs do not have organized markets, but bilateral agreements are possible
- V2B value: can be captured by lowering building energy bills, or by providing new services such as emergency power or PV balancing
- Generally, certain TSO markets will be the highest value but most technically challenging, and with the most complex rules

Specialized Applications

- Solar balancing (UD with NREL)
 - Highly predictable 24-hour cycle, but misalignment with load (“duck curve”)
 - DSO over-voltage on some feeders
 - Unpredictable short interrupts on cloudy days
- Question: Should solar balance be a specific service? Or fit into existing market services?

COMMERCIAL OPERATION TODAY

Current TSO Projects

- Licensees: Nuvve and eVgo
- eVgo & U Delaware, project in US with TSO PJM Interconnection - *Operating commercially*
- Nuvve, DTU, Nissan, PSA, Enel project in Denmark, with TSO energinet.dk - *Operating trial*
- Nuvve, The New Motion project in Netherlands, with TSO TennenT - *Commercial trial*
- Nuvve, Nissan, Enel, in England and Wales with TSO National Grid - *Operating pre-commercially*

Denmark Fleets





Denmark Team

Nuvve, DTU, Nissan, Enel, Endesa

November 2015



Transitions

- NRG Energy and eVgo: R&D & validation
 - 4 years development effort
 - Now passing commercialization to Nuvve
- Nuvve Corp
 - Successful commercialization in Europe
 - Starting commercial operation in US now
- BMW reclaimed MiniEs (gave us some i3s)

What did we learn?

- Driving and grid services can be compatible
- Considerable HW and SW development needed to satisfy both power grid and customer
- Test, Test, Test! (and, consult with users)
- Regulatory and standards issues, e.g.
 - SAE J3072 certification for on-board inverter
- Revenue is substantial with the right markets
 - But DC charging station adds a large cost at customer site

Plans Moving Forward

- Reach production of additional OEM vehicles
 - Now, Nissan Leaf and eNV200 via CHAdeMO
 - A series-produced EV with AC charging and V2G would be significantly lower cost to customer
- Continue DK, UK, NL to full commercial offering
- Expand to other TSOs in the US: NY-ISO, ISO-NE, California

END

MORE INFORMATION:

WWW.UDEL.EDU/V2G

WWW.NUVVE.COM