Vehicle to Grid Power

Briefing for:

Federal Energy Regulatory Commission

23 October 2007

by

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Trends

- Gasoline increasingly untenable; electricity likely to be a major energy carrier for cars
- CO_2 limits, air quality, and price will shift more generation to non-dispatchable resources (i.e. renewable energy)
- Thus, much greater need for dispatchable storage, in market terms,f or ancillary services (regulation, spinning reserves, etc)

Why V2G?

- There is almost no storage on the electric system; storage is valuable, and can be sold via Ancillary Service (A/S) power markets
- BEV and PHEV will have large batteries connected to the grid
- Grid needs some control of timing: e.g., charge during electricity surplus, and (less often), discharge during electricity deficit.

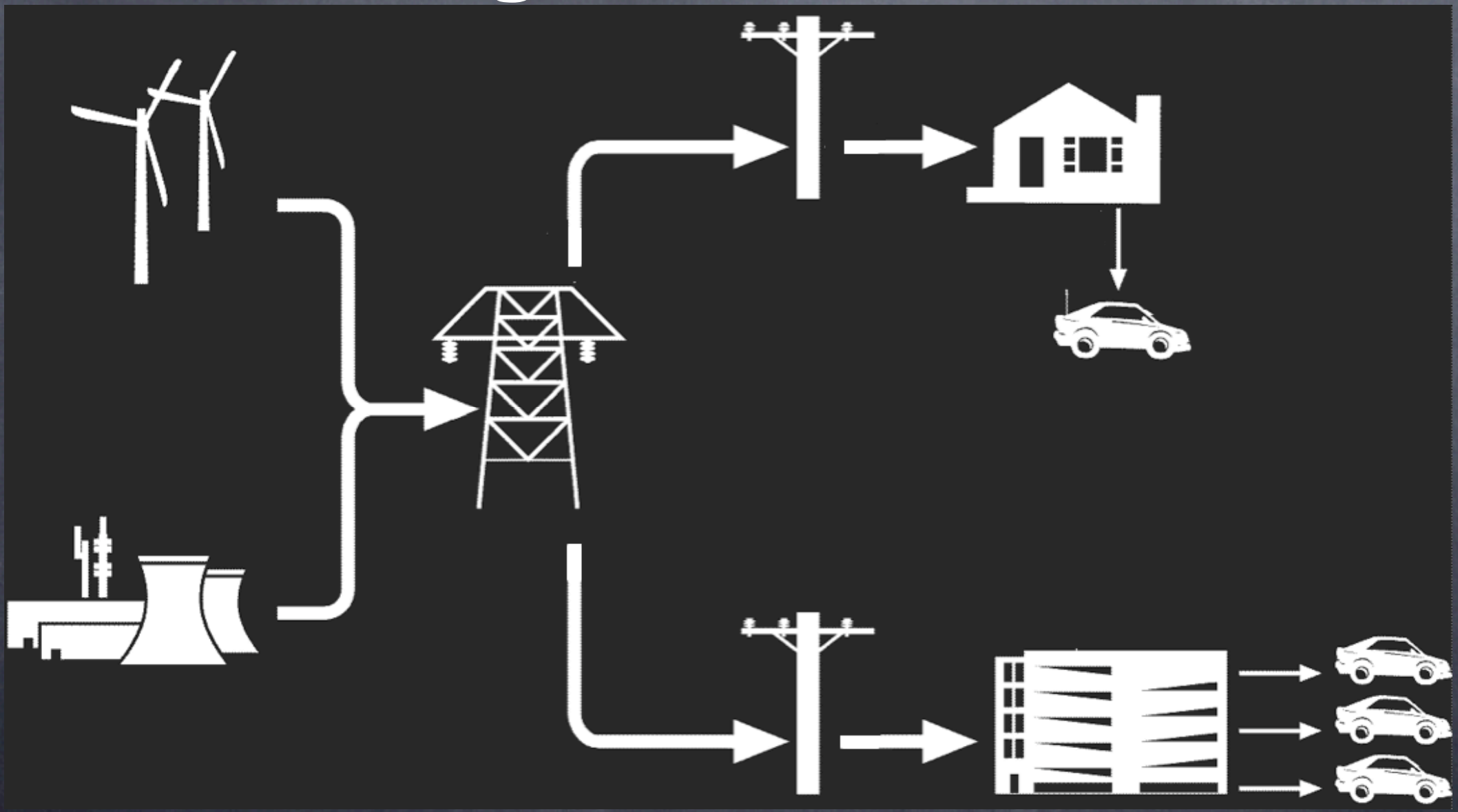
Plug-in Cars are Here

- Today: Tesla, AC Propulsion, Prius retrofits
- Plans: GM Volt, many other OEMs, both plug-in hybrid and all-electric
- But OEMs' designs are not suited for V2G: one-way flow, low power (1.5 kW), no anti-islanding, etc.
- OEMs lack familiarity with, and motivation to address, electric system opportunities and risks

V2G Terminology

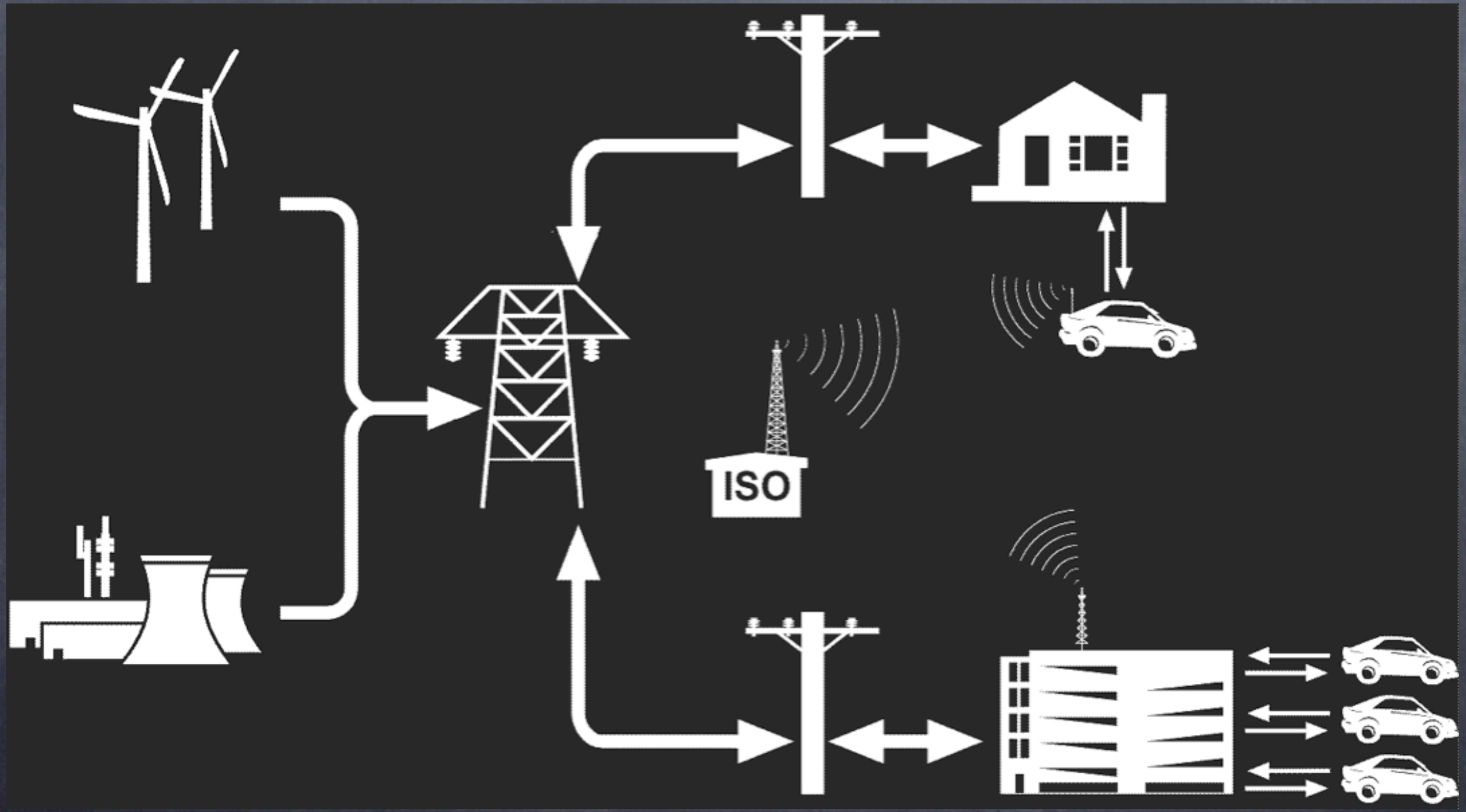
- Emphasis varies with terminololgy
  - "Vehicle to grid" -- bidirectional circuit
  - "Cash-back Plug-in Hybrid" -- financial value
  - "Grid interactive car" -- communication & control
- Non-V2G
  - Plug-in cars (PHEV, BEV, etc)
  - Good, but not exploiting opportunities or even addressing peak load

Plug-in Vehicles



Arrows indicate direction of power flow

Vehicle to Grid



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V2G Basic Math

- Average car driven 1 hour/day, thus, time parked is 23 hours/day; Daily average travel: 32 miles, storage for 100 - 250 miles
- Practical power draw from car: 10 - 20 kW
- US power: generation=978 GW; load=436 GW avg (EIA)
- US 241 million cars (FHWA 2005) x 15 kW = 3,615 GW, thus...

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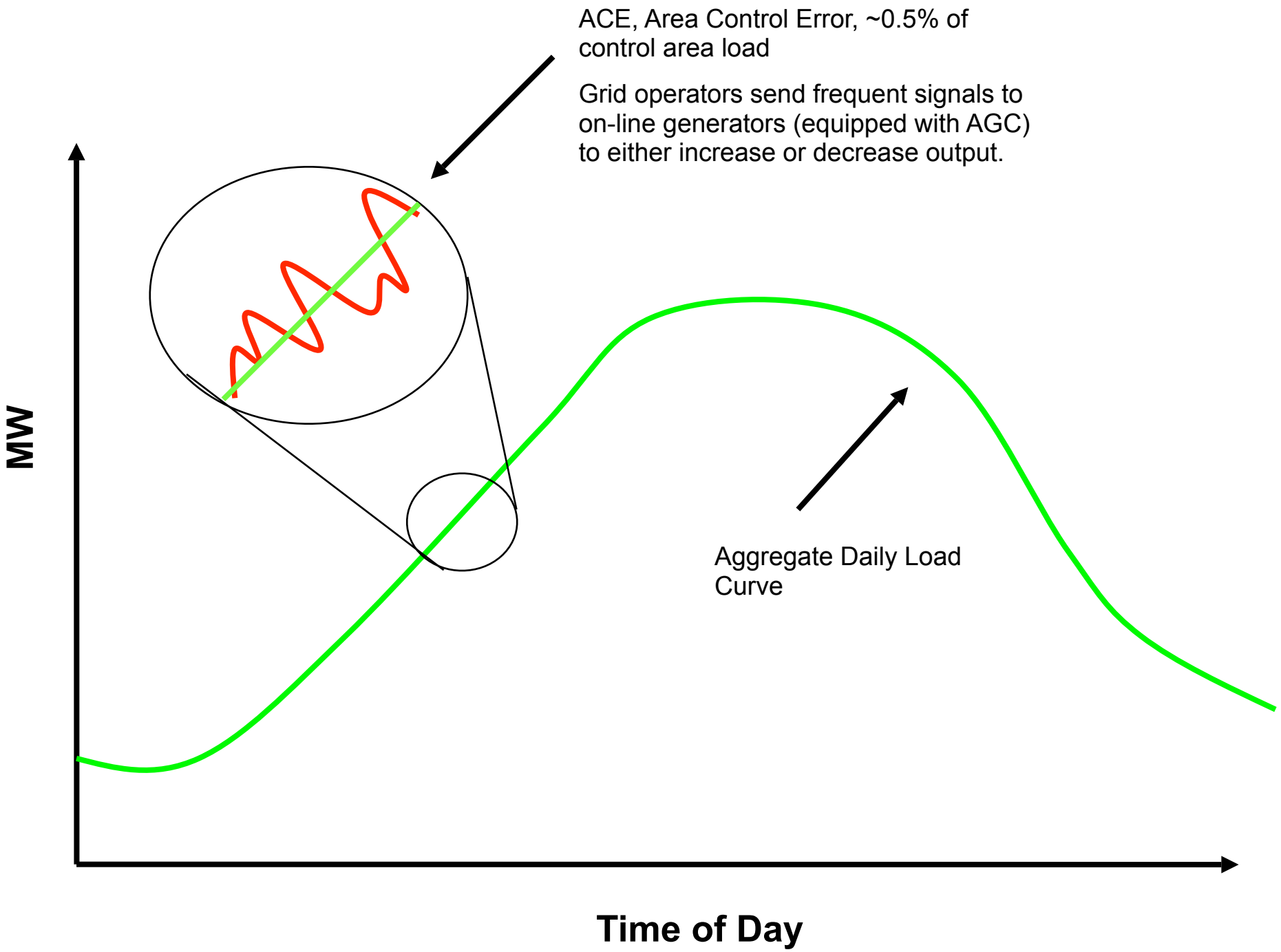
Daily Load versus Regulation (=correction of ACE)



from Letendre et al 2006

Electric Markets

- Initial markets (high value, low impact on battery, no system changes):
  - Regulation ("Frequency regulation")
  - Spinning reserves
  - Intrahour adjustment
- Larger but more challenging markets
  - Peak power
  - UPS for the distribution system

How many cars for an A/S contract?

- PJM minimum A/S contract: 3 MW
- CalISO minimum A/S contract: 1 MW
- Assume 2/3 availability (1/3 unavailable because driving, battery at wrong SOC, etc
- Calculation: 2/3 availability means ...
  ___ kW/car * ___ cars * 2/3 = ___ MW
  - for 1 MW at 15 kW, need 100 cars
  - for 1 MW at 1.5 kW, need 1000 cars

Mid-Atlantic Grid-Interactive Car (MAGIC) Consortium

- Partners
  - University of Delaware
  - PHI: Delmarva Power, Atlantic Electric, PEPCO, etc
  - ACUA
  - PJM
  - AC Propulsion
  - Comverge
- Observers
  - Tesla Motors
  - Google.org
  - State of Delaware (DEDO, PSC, Energy Office)
  - anon

PJM as Part of the Eastern Interconnection

KEY STATISTICS

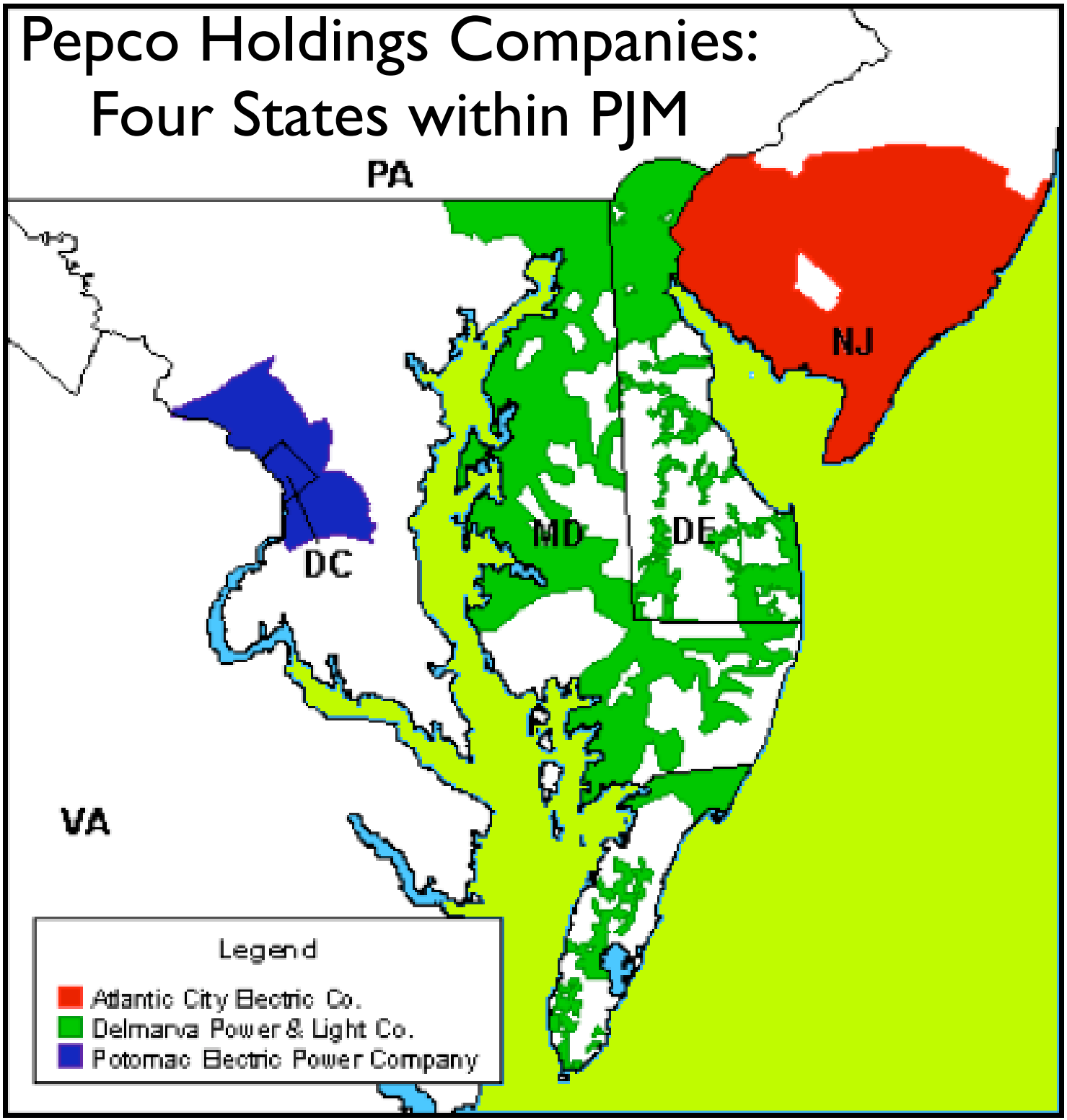
-PJM member companies	400
-Millions of people served	51
-Peak load in megawatts	144,796
-MWs of generating capacity	164,634
-Miles of transmission lines	56,070
-GWh of annual energy	728,000
-Generation sources	1,271
-Square miles of territory	164,260
-Area served	13 states + DC

6,038 substations

- 26% of generation in Eastern Interconnection
- 23% of load in Eastern Interconnection
- 19% of transmission assets in Eastern Interconnection

- 19% of U.S. GDP produced in PJM

Pepco Holdings Companies: Four States within PJM



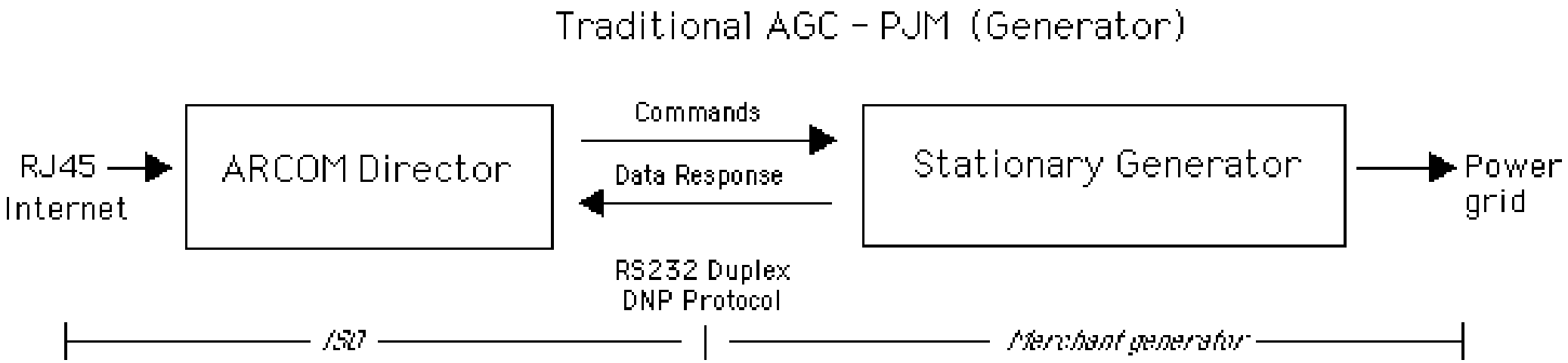
MAGIC Current Project and Planning

- Phase I: ~5 cars + one bus, V2G directly from PJM regulation signal ($1 M in hand)
- Phase II: ~300 cars in PHI, aggregator between PJM and cars, paying A/S contract (about $15 M needed)
- Phase III: Self-sufficient businesses (OEMs, aggregators, ISOs)

MAGIC Phase I

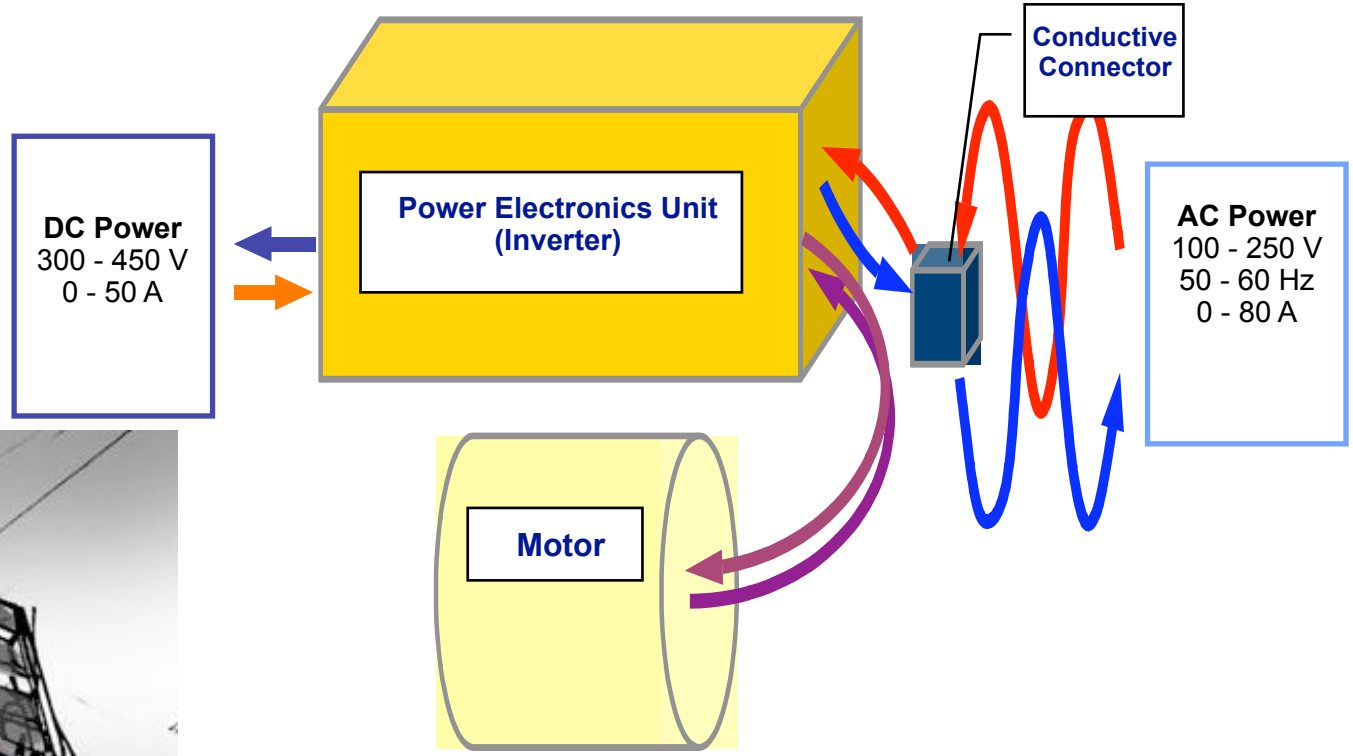
- Connect 5-6 vehicles to PJM Automatic Generation Control (AGC) signal
- Drive, charge, V2G -- develop, test and demonstrate technology
- Document parameters, and create opportunity for a V2G aggregator
- Then ready for Phase II

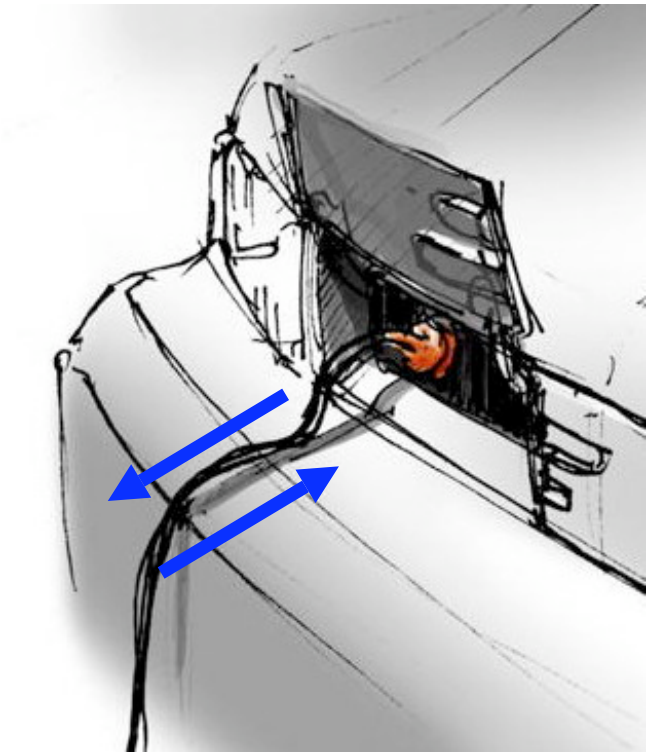
AGC control


Traditional AGC - PJM (Generator)
RJ45
Internet
ARCOM Director
Commands
Data Response
Stationary Generator
Power
grid
RS232 Duplex
DNP Protocol
ISO
Merchant generator

AC Propulsion Onboard Charger Is Bidirectional

Power can flow to or from vehicle

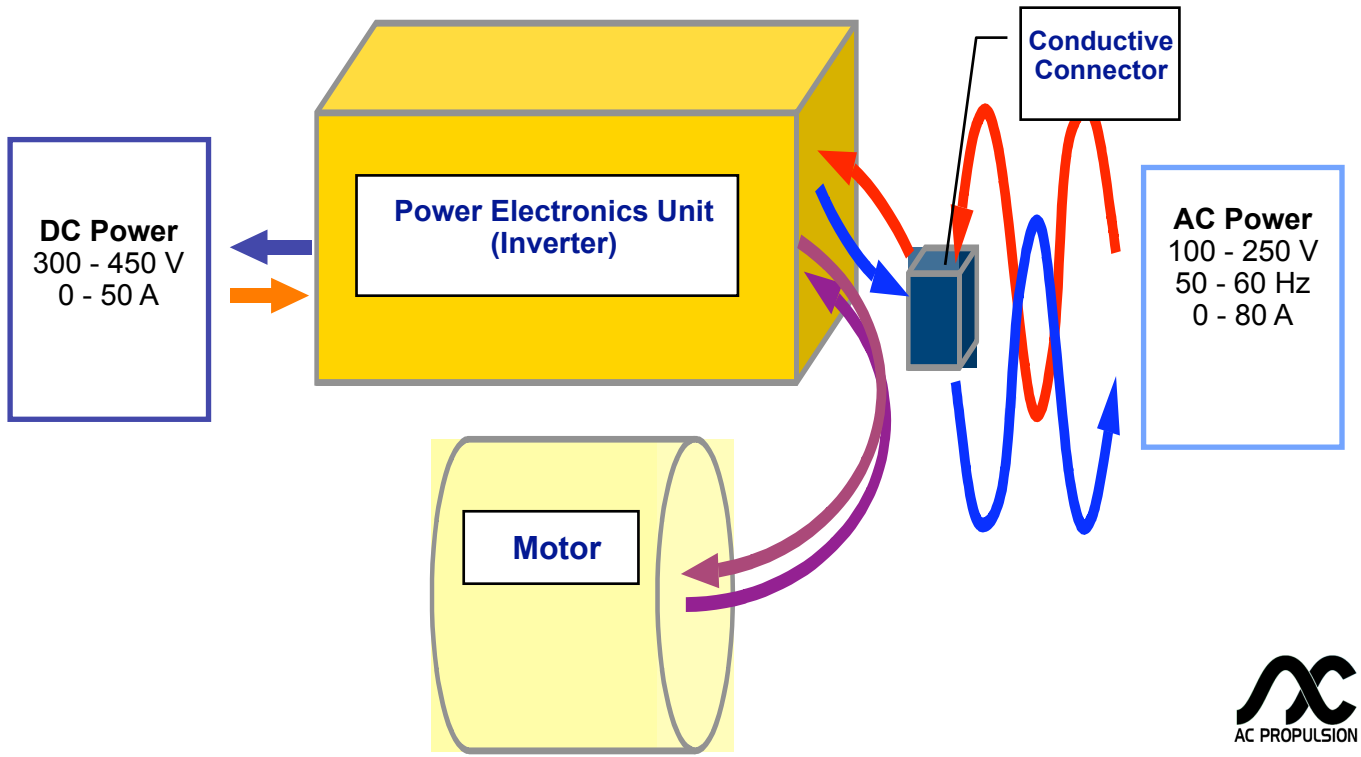




- Stand-alone or grid-tied
- Unity power factor
- Sine wave current draw
- GFI compatible

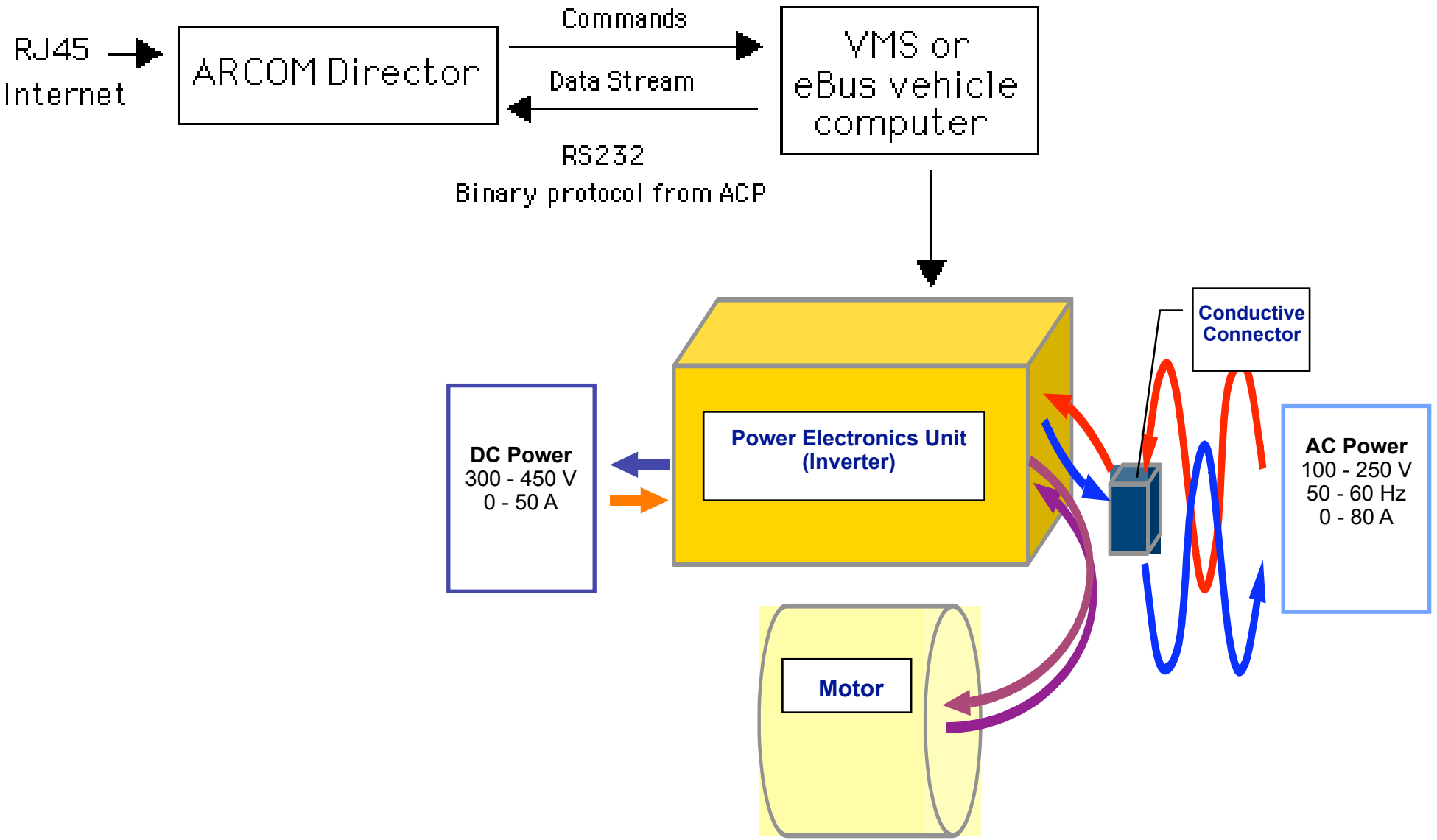
AC PROPULSION

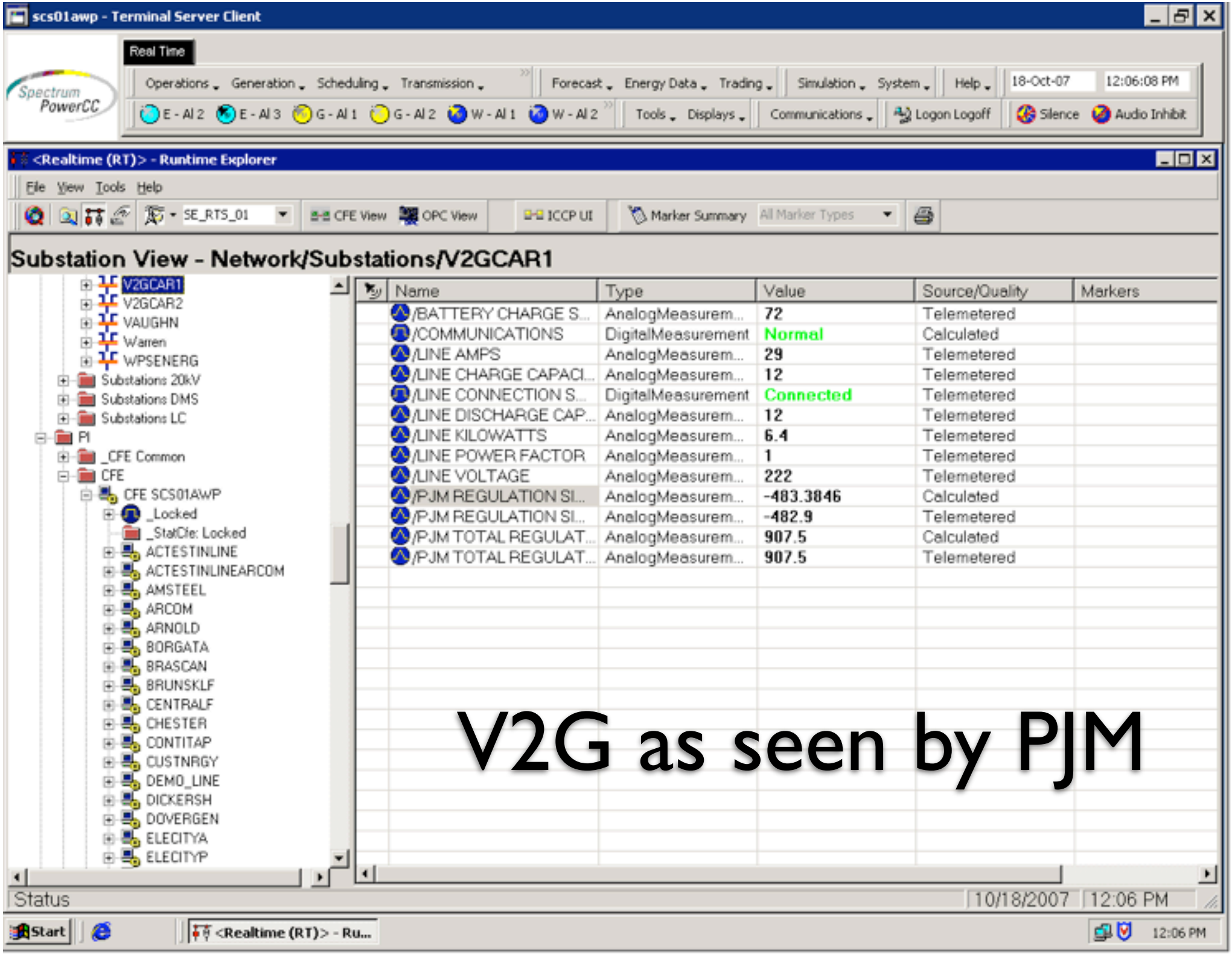
V2G opportunities with bidirectional charger



AC PROPULSION

Additions by MAGIC

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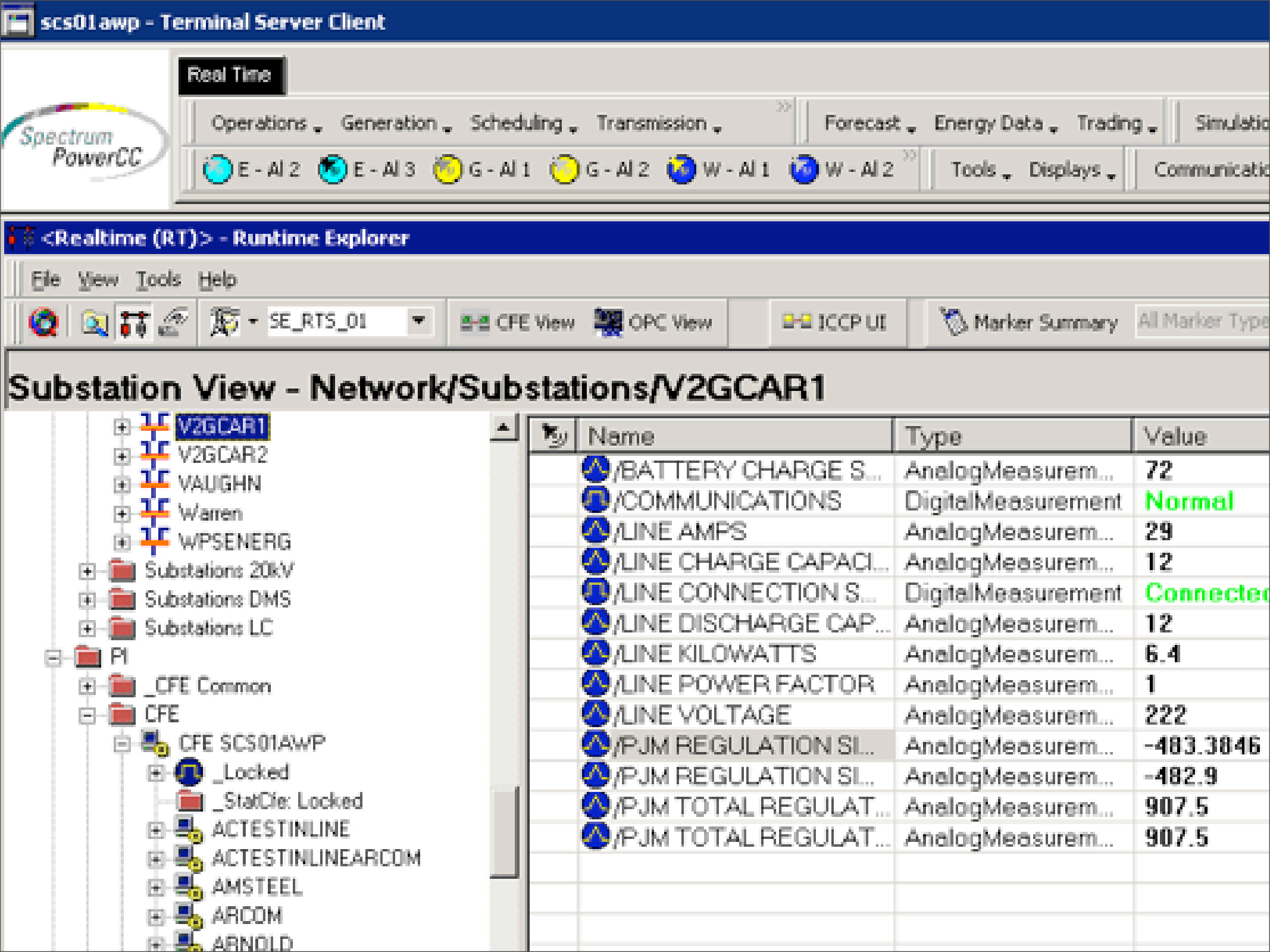
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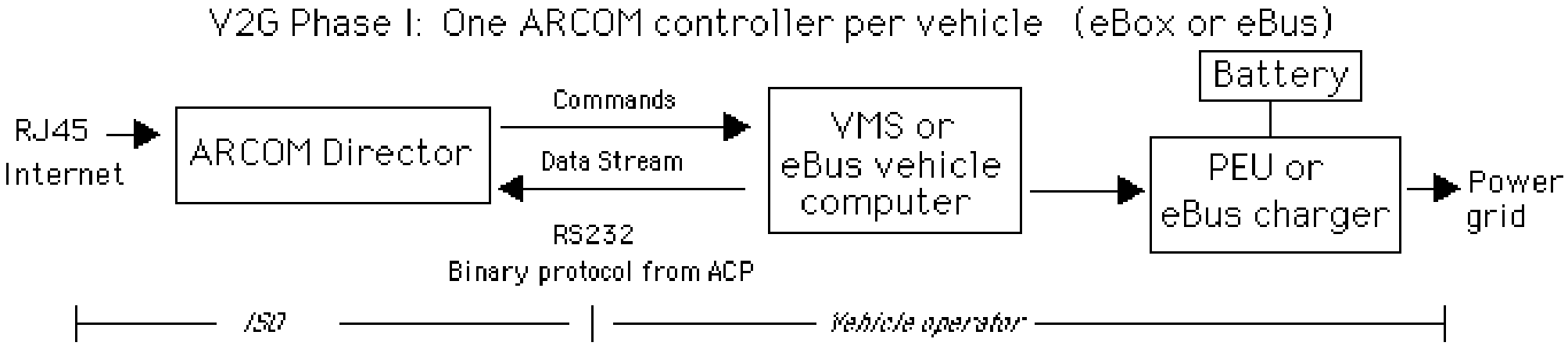
The Grid Interactive Car



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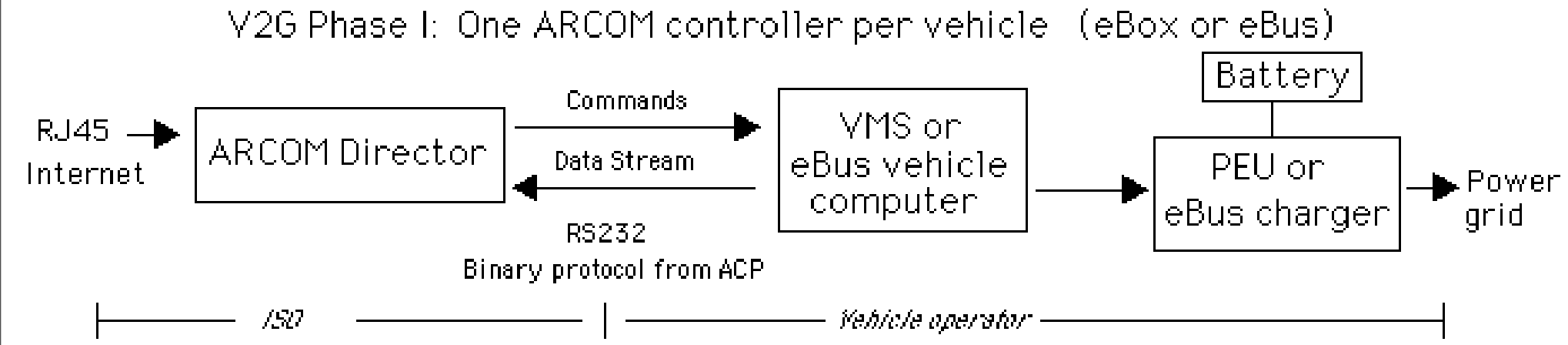

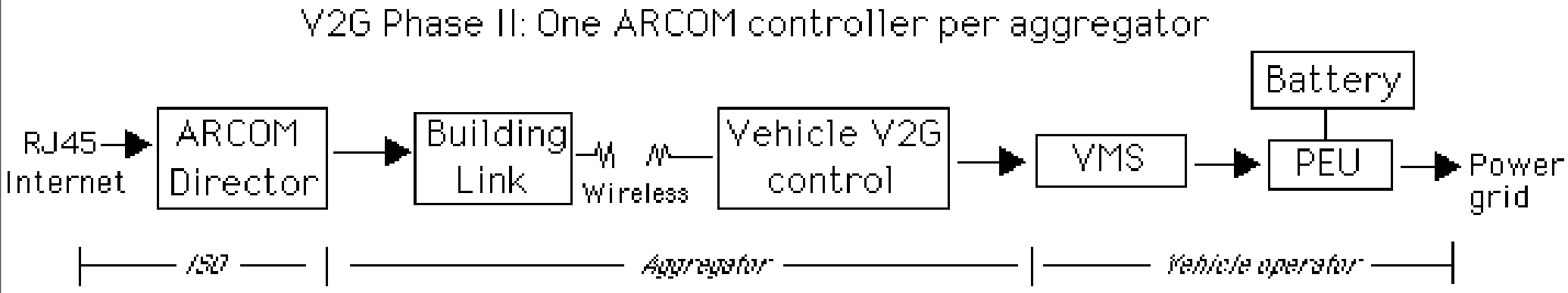

Phase II

- For A/S contract: 300 car V2G fleet = 3 MW; demonstrate V2G business models, aggregator develops or emerges.
- Prove the power market business model, develop technology, drive down component costs
- Develop standards for V2G (e.g. response time, metering, at least 10 kW/car, drawdown limits, etc)
- THEN we need the OEMs, low-cost production at > 50,000 cars/year

Regulation Market: High revenues if aggregated

- Spreadsheets from Delmarva Power show that at moderate car production (a few thousand/year), A/S can pay for cars costing $40,000
- However, to get to that production volume, first need to prove A/S business (via Phase II)
- Costs for Phase II fleet is primarily to buy down cost of vehicles for buyers, also some development, testing, and documentation

Potential Policies

- Public funds for 300 cars (3 MW) + RD&D, about $15M, optionally add $5M for a second region with 1 MW contract
- Or, tax credit for 50% subsidy on V2G cars, for 5 years
- Or, create a "fast-response regulation market" with price temporarily set at $100/MW (vs. $40 avg now). Limits: < 10% of regulation, only for cash-back vehicles, only for 5-year demonstration project

Vision

- One-half vehicle fleet is electric drive (BEV + PHEV). National security & environment benefits.
- Lots of storage on the electric system, near loads.
- Electric system storage is dispatchable by ISO/ TSO and/or load serving entity.
- Electric grid is more stable and reliable, A/S is abundant and less expensive
- Intermittent renewables can be a much higher fraction of the US generation mix.

End

more info: www.udel.edu/V2G