Extreme Fast Charging

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Oak Ridge

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island

August 2nd, 1939

F.D. Roosevelt,
President of the United States,
White House
Washington, D.C.

Sir:

Some recent work by E.Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations:

In the course of the last four months it has been made probable - through the work of Joliot in France as well as Fermi and Szilard in America - that it may become possible to set up a nuclear chain reaction in a large mass of uranium,by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable - though much less certain - that extremely power-

ORNL Campus

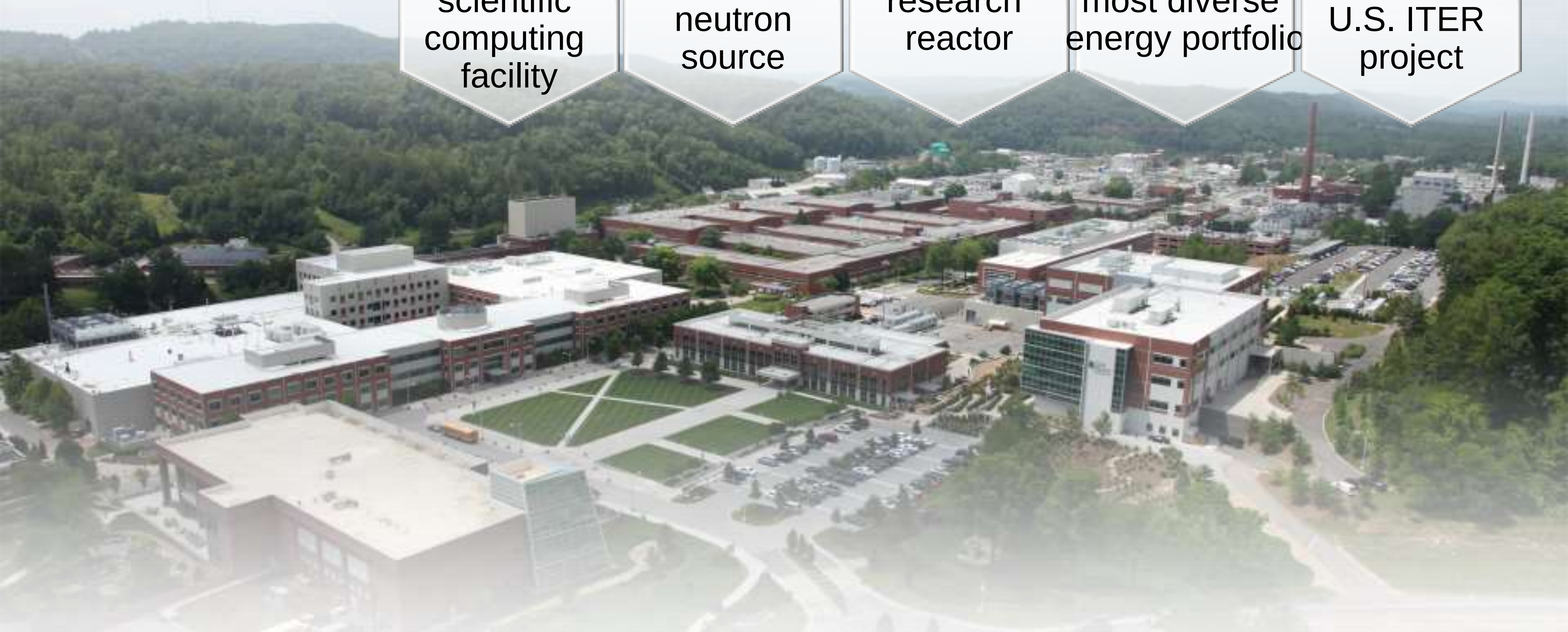
Oak Ridge National Laboratory evolved from the Manhattan Project

ORNL in 1943

The Clinton Pile was the world's first continuously operated nuclear reactor

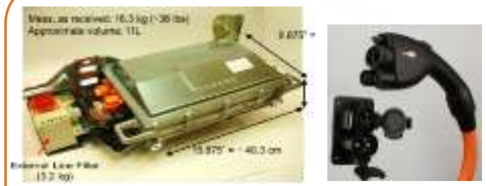
Today, ORNL is DOE's Largest Science and Energy Laboratory

- $1.65B budget
- 4,400 employees
- 3,000 research guests annually
- $500M modernization investment
- Nation's largest materials research portfolio
- Most powerful open scientific computing facility
- World's most intense neutron source
- World-class research reactor
- Nation's most diverse energy portfolio
- Managing billion-dollar U.S. ITER project



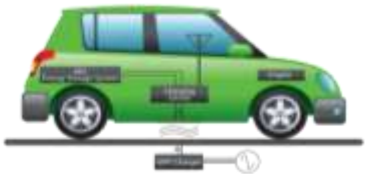
Charger Technology for Automotive Applications

EV Charger Technology



Wired (Conductive) Chargers

- High efficiency > 90 %
- on-board chargers: are up to ~3.3 kW slow charging times
- Weight and volume and cost constraints – higher power
- Off-board charger: higher power levels and fast charging options;
- Plug-in options: danger electric shock, heavy and inconvenient.



WPT (Inductive) chargers

- Safe, convenient and flexible charging method for PEVs and battery electric vehicles.
- Independent charging process.
- Cost and efficiency are a challenge for level I and level II charging.
- Electric and magnetic fields.

Hybrid Integrated Chargers – (Combination of on board and off board)

- Cost benefits: utilization components for different functionalities
- Charging & traction drive components can be integrated for multi functional operation
- Higher power levels > 3.3 kW: higher rated traction drive components

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- Need isolation: adds complexity to the system control and the hardware
- Achieving efficiencies greater than 85 %
- Reliability of the components is also a major problem

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Charging Overview- Conductive Chargers

Conductive Chargers

Static low power (Level 1 and 2)

- 3.3 – 6.6 kW OEM on-board chargers available
- Efficiencies > 90 %

Static High Power (level 3 and 4)

- CHAdeMO/SAE combo upto 50 kW
- Tesla 120-135 kW

Dynamic

- Catenary lines
- Rail concept

Bidirectional

- Nissan V2G bidirectional charger

Extreme Fast Charging

DOE's Objective: *"* to examine the vehicle, battery, infrastructure, and economic implications of fast charging of up to 350 kW."

Logistics challenges

Shows potential issue of grid locations Vs. the need

Needs apps to find charging stations

URBAN Infrastructure has issues like lack of generation close to the load, space limitations and safety concerns

Highways – need to be planned for high traffic areas and match that will available grid resource as well

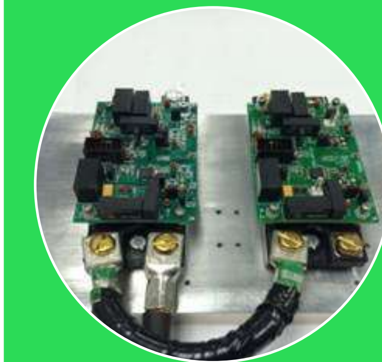
The front end grid interface design becomes challenging

Grid quality

Voltage level (2.4 kV or 6.9 kV, 7.2 kV and 12 kV distribution is more common in the U.S)

DER penetration will become a key need

Charging cable and plug specifications will be a challenge to meet for the voltage a current needed



Power Density and Thermal system

Semiconductor technology limitation : Currently, 6.5 kV is the max.

Efficiency would not be high due to high conduction losses and very low switching frequencies (a few kHz only).

Cooling system infrastructure will affect the cost (operating and installation) , performance and energy requirements

Safety and Load Barriers

- **Currently the battery loads in cars are at ~30 kwhr**
- **High power charging will require 175 kWh capacity to be able to charge faster (with lithium –ion technology)**
- **Cable length and the currents required to deliver 350 kW will be a big challenge (the cable itself needs cooling)**
- **Handling bulky cables and plugs will be a safety hazard for the user**

Challenges and Barriers for 350 kW Chargers

https://cleantechnica.com/2016/12/15/usa-gets-1st-non-tesla-high-power-ev-charging-station-evgo

https://shop.teslamotors.com/products/high-power-connector

http://evobsession.com/electric-car-charging-101-types-of-charging-apps-more/

Research Roadmap for 350 kW Charging using WPT Technology

Modular High power density

160 mm air gap (if needed)

95% wall to battery efficiency

Bi-directional level 3 charger

IEEE and IEC standards compliant

Vehicles Integrated and Tested at ORNL

Chevy Volt	Toyota Prius Plug-in	Scion IQ EV	Toyota RAV4 EV
			

- **Power transfer level (>6.6 kW),**
- **Efficiency ~ 90%**
- **Misalignment tolerant (up to +/- 40mm),**
- **System integration for 7 vehicles**
- **Airgap:162 mm**
- ***Met the IEEE and ICNIRP safety standards***

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Opportunistic/ Quasi-Dynamic Wireless Charging

- **33 kW bench prototype**
- **20 kW static power -OEM vehicle**
- **Efficiency >90%**
- **Designs for 100 kW underway**

In-motion/ Dynamic Charging

- **Demonstrated up to 3 kW using a GEM vehicle**

- **Demonstrated up to 9 kW using Toyota RAV4**

Bi-directional WPT

- **Printed car and printed house and bi-directional WPT demonstration in an integrated energy systems concept**
- **Demonstrated bi-directional capability up to 10-kW on a bench top setup (dc-dc)**
- **Demonstrated up to 1 kW with a house load and vehicle charging up to 6.6 kW.**

#1: High-efficiency (85%) Wireless Charging Nominal Ground Clearance of upto ~10 Inches

Challenges and Risks:

Flux density required to meet > 20 kW

Misalignment tolerance might be limited and requires more dynamic control

More active power and reactive power which increases the VA rating of the inverter

Efficiency of the total system will be a challenge

#2: Vehicle-to-grid Mode Wireless Power Transfer to Building or Grid Loads

Challenges and Risks:

Needs a mirrored identical overall system topology for bidirectional power flow

Needs a coordinated overall control architecture to determine the direction of power flow

Needs a protection system to engage and dis-engage the grid connection and vehicle

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#3: Provide Grid Support Functions

Challenges and Risks:

Increase the complexity of the grid tied front end converter closed loop control

Needs more safe and reliable interface control and provide the grid support functions

Ancillary service support: system dynamic response for different modes of operation

#4: Integration of the WPT System into the Vehicle

<u>Challenges and Risks:</u>

Location of the coupling system and Shielding the drive components

EMS integration of the hardware prototype

Communication requirements, addressing the latencies, communications with a main controller

Thank you !

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