2018
State Public Transportation Partnership Conference
Minneapolis, MN

# *Zero Emission Vehicles*

## *"Link Transit's Lessons Learned Operating Battery Electric Buses"*

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# Why Did Link Choose Battery Electric?

- Zero Emissions
- Natural Gas not available inadequate infrastructure
- Wean our transit system off of fossil fuel dependency
- Competitive Funding Availability $$$$$
- Geographical Location “True Four Seasons” for Testing battery Technology triple digit summer temps and -0 degree winter temps with mild spring and fall temperatures
- And the Real Driving Reason……..
- Out of the Eleven U.S. Hydroelectric Dams on the Columbia River “providing 40% of the U.S. power requirements” Link Transit draws its power from four of these dams and we pay a Non-Demand power cost of 2.3 cents per kilowatt hour, lowest in the nation

# MILESTONE TIMELINES RELATED TO LINK'S BATTERY ELECTRIC PROJECTS

- **2009** Awarded ARRA Grant funding for 5 Opportunity “fast charged” Battery Electric Vehicles for $2.5 million 100% funded no-match Recovery Funding
- **2010** Performance Based RFP was solicited for 5 Opportunity “fast charged” battery electric vehicles utilizing glycol cooling and Lithium Titanate (LTO) chemistry….. contract awarded to EBUS Inc. “Single proposal Received”
- **2011** Prototype trolley was delivered with LTO battery chemistry “initial testing looked promising” development continued on Conductive Fast Chargers

# 22 Foot Battery Electric Conductive Fast Charged EBUS Trolley

- **Late 2011** Two Conductive fast chargers were delivered and installed at Link Transit's Intermodal facility simultaneously with Slow Charging installation at the Operations and Maintenance facility

- *Chargers were rated  at 450 to 800 volts DC*
- *Charged at 600 volts nominal DC*
- *375 kw at 400 amps*
- *Very complex chargers “operated with 95% reliability”*
- *95% does not work in Transit!*

Fast Charge Connection took
approximately 50 Seconds to connect added addtional dwell time

# Timeline Continued……

- 2012 Inherent issues with coolant plate failure and terminal corrosion lead to the decision to abandon Lithium Titanate chemistry and redesign the energy delivery of the vehicle
- 2013 Trolleys were retrofitted with Nickle Cadmium (NiCd) (2nd Battery Chemistry) slow charge liquid batteries as a “bridge” technology until a fast charge chemistry could be developed
- 2014 Lithium Iron Phosphate batteries (3rd Battery Chemistry) were selected as the final energy source and designed to fast charge at a reduced voltage and amperage

# ORIGINAL BATTERY DESIGN
# 1ST Battery Chemistry

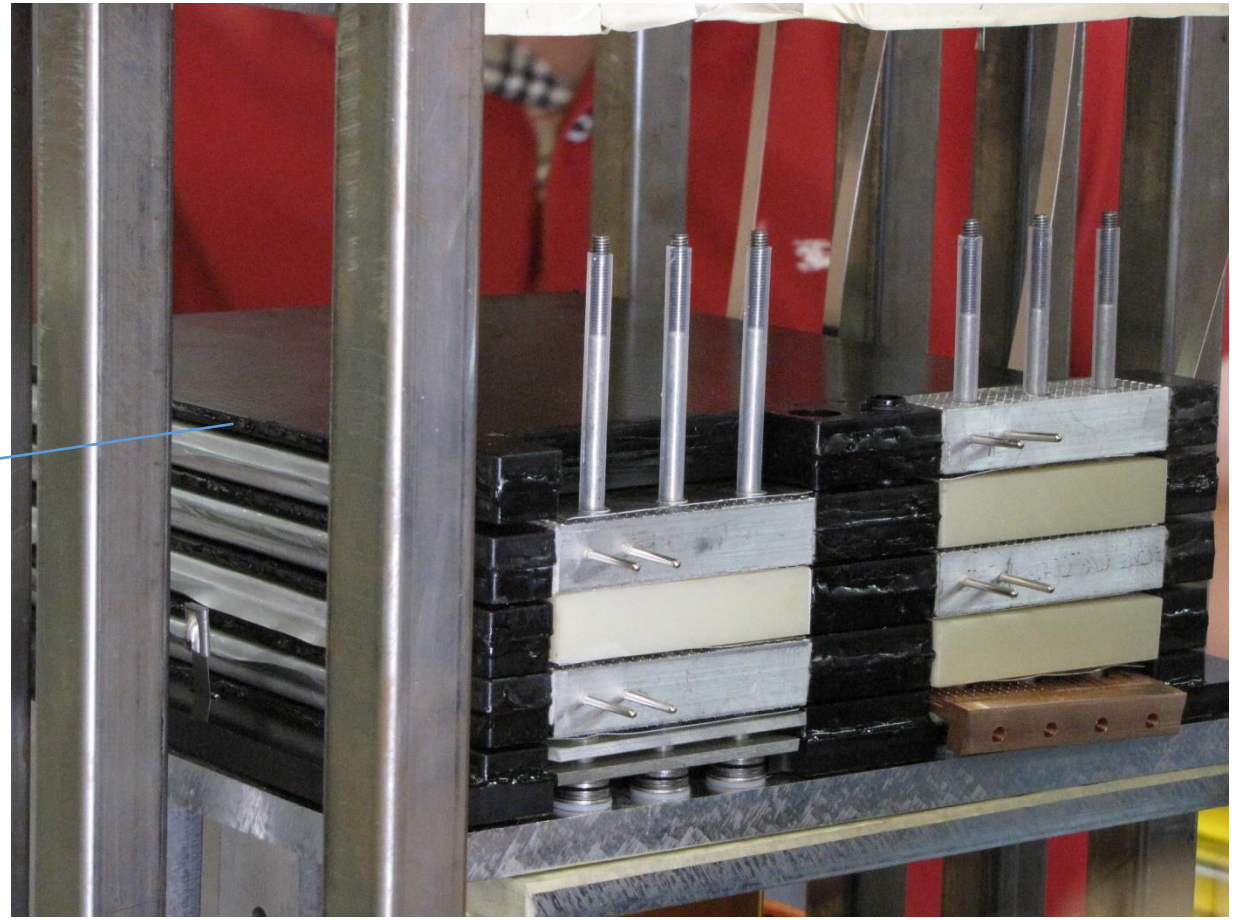
- **Lithium-Titanate Li2TiO3**
- **Superior fast charging capability**

***DESIGN ISSUES***

- **Water Cooling Plate leakage**
- **Battery corrosion issues**
- **Manufacturer Dissolved**


# Original Design Cooling Plate Technology

Cooling Plates



# 3.2 volt Iron Phosphate Battery  Selected to Power the EBUS TROLLEY

# EBUS Battery Electric/Diesel Operating Fuel Cost Comparison
# Apples to Apples

Operating same route in 2016 with Diesel Trolley and Electric Trolley

Diesel Fuel cost $1,500

Battery Electric cost $90.00 non-demand  $230.00 peak

- Cost per mile Diesel included labor, parts and fuel **.44** per mile
- Cost per mile Battery Electric including Electricity, parts and labor **.58** per mile

# The BYD Project
# Not The Flux Capacitor!

- **2015** 5 K9S 35’ buses were ordered “off the WA State contract #09214” to include Wireless Inductive Charging
- Funded by a 2011 Tigger III Grant **$3.3 million**
- Delivery fell Nine months behind schedule. 1st bus arrived in January 2017
- Wireless Charging was cancelled on this order due to development delays
- Slow charge infrastructure was installed at Operations Base for overnight “Top Off” and two chargers were located at our Intermodal facility to incorporate Mid-Day charging until Fast Charging became operational
- **2016** NoLo Grant awarded for 5 additional 35’ K9S buses and included the reinstatement of one 200 Kw Inductive Charging Station **$3.9 million**
- NoLo also included in-kind fund to partner with local college and develop Battery Electric Internship Program
- **2017** partial cold weather testing occurred in January which included the testing of slow charging, bus start up, systems stability, supplemental coach heating and range
- **Spring 2017** Link authorized $500,000 for the purchase and installation of a Momentum Dynamics “MD” 200 Kw Wireless Inductive Charger
- **December 2017** construction and installation of charger was completed at Link’s Intermodal facility
- **January 2018** the MD charger was UL certified
- **February 2018** secondary receivers installed on a test bus
- **March 2018** Inductive charger testing

# Grant Funded College Cooperative
# WORK EXPERIENCE
# Battery Electric Internship Program

- Funded by 2016 NoLo in-kind match $60,000
- Competitive Application Process for Wenatchee Valley College Students Only
- Two Year Internship
- Program supports two students
- Program is funded for 6 years
- Drawing Talent from the Engineering Program, Industrial Electronics and Automotive program
- In-House Training Syllabus supported by classroom and On-the-job training
- College credits earned each semester

# BYD K9S

# BYD 80 Kw Slow Charger
# Overnight Battery Slow Charging installed at Operations

# MID-DAY CHARGING

# INDUCTIVE CHARGING

- Primary In-Ground station installation
- Momentum Dynamics 200 kW
- Infrastructure scaled for three additional 200 kW chargers

# VEHICLE ALIGNMENT

**Drivers use a combination of visual alignment and dash mounted electronic position indication showing alignment %**


# Power Control Module

## Graphics Tell The Story Of Hydrological Cycle To Hydroelectric Distribution To Charging

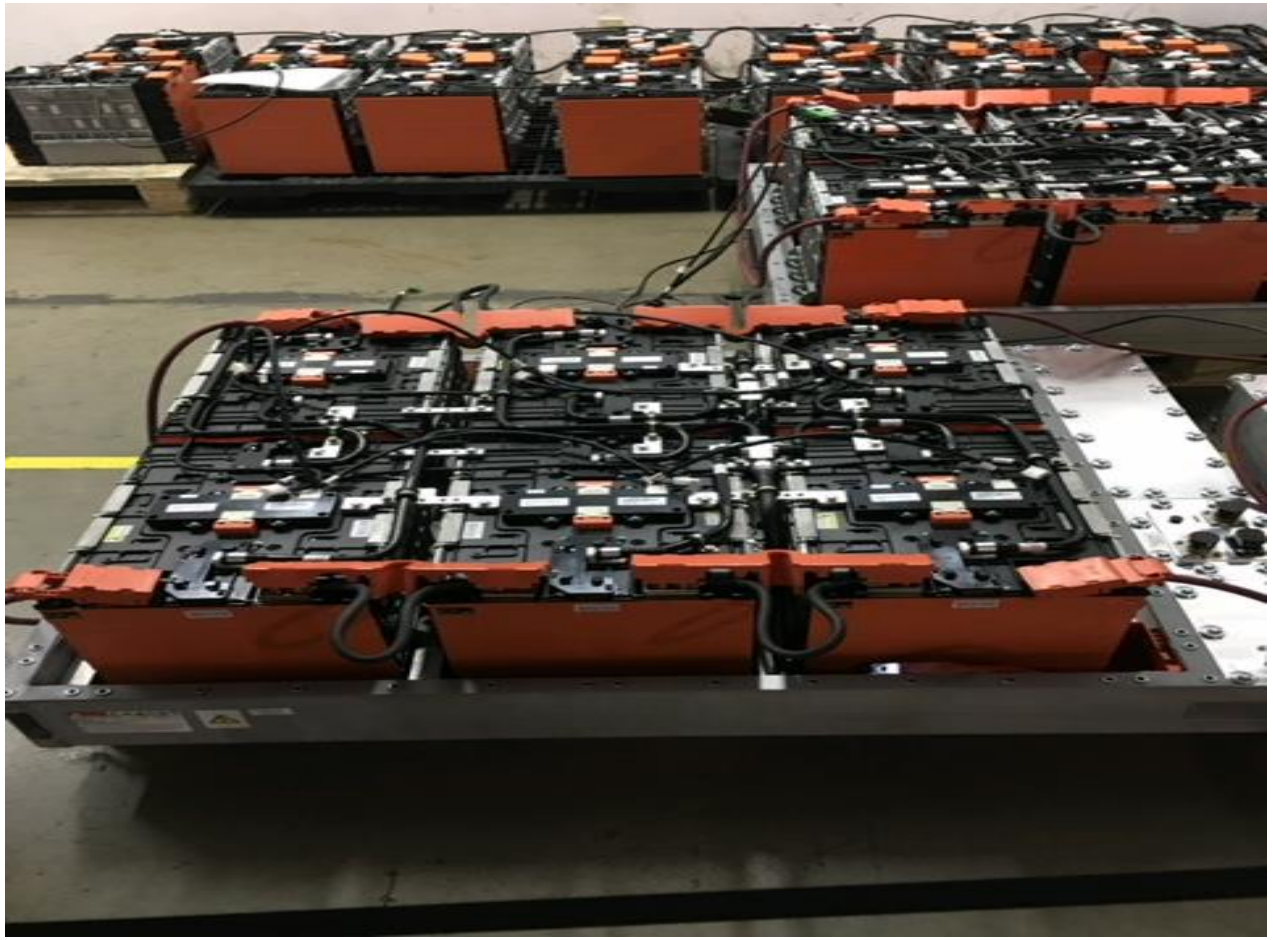
# Primary Transceiver In-Ground (4) 50 kW Pads

# 200 kW Secondary Charger Cold Plates (4) Reciever Plates Installed Under the BYD K9S

# Monitor Showing Bus Charging
# 1st U.S. Inductive Charge Of 207 kW On A Revenue Transit Vehicle

# BYD Thermally Controlled Battery Pack
# First Five Bus BYD Order Is Currently Being Retrofitted With These Batteries
# 350 kW

**Thermal Control Of All Battery Cells Is Critical and Necessary When Fast Charging Is Part of Your Specification**



# The Future Of Inductive Charging

# LESSONS LEARNED “Things to Consider” if Your Contemplating Moving forward With Battery Electric Vehicles and Advanced Charging Technology

- Make sure you have Adequate power available on-site
- Plan for expansion of services “scalability”
- Understand your utilities demand charges and peak power times
- Mitigate Demand Charges, time of day, length of charge, on-site Battery Storage for Fast charging power
- Design your bus around the charging you anticipate operating
- Is your staff, Board and the public aware of your plans
- Talk to your Unions get them on-board
- Insist on a full training program for your team
- Work with your local educational institutes to promote internship programs…EDUCATION and SKILLS
- Develop a solid First Responder training program for police and fire
- Be realistic with key milestone dates
- Understand the elements that effect range, Ambient Temp, Geography, dwell time and operator driving efficiency
- Operational Charging Complexity….the logistics when to charge, how its managed “dispatch” bay assignments, training DEER IN THE HEADLIGHTS
- Dealing with winter use of chlorides “salts”
- Emergency power generation “on-site” and “portable”
- Plan for capital replacement in the future $$$$$$$!
- Choose your venders wisely are they new to the industry?  Are they financially stable?  Will they be here to support me tomorrow?
- Understand that the technology you operate today is obsolete tomorrow “rapidly advancing”

# A Famous Quote

***Any Intelligent fool can make things bigger and more complex…….It takes a touch of genius-and a lot of courage to move in the opposite direction.***

***Albert Einstein***

***THANK YOU!***