All-Day Hybrid Power On the Job

Optimization of Hybrid Systems for Combined Driving/Stationary Duty Cycles
About Odyne Systems LLC

• A clean technology company focused on development and deployment of hybrid systems for trucks over 14,000 pounds.

• Odyne has been recognized by Allison Transmission, the world’s largest manufacturer of fully-automatic transmissions for medium- and heavy-duty commercial vehicles, as the only approved supplier of PTO-based electric hybrid systems and ePTO systems.

• Large trucks with high fuel consumption can save up to 50% or greater (1,750 gallons/year depending upon duty cycle).
About Odyne Systems LLC

• Odyne plug-in hybrid systems interface with new and existing transmissions
  • Installed during new vehicle build process or as an aftermarket product
  • Saves fuel during drive cycle and stationary operations at work site
  • Lower emissions
  • Improved performance: additional power for acceleration, regenerative braking
  • Quieter work site operation
  • Reduced operating and maintenance cost

• Allison Transmission made non-controlling equity investment in Odyne

• Supply Agreements
  • Johnson Controls: lithium ion batteries
  • Remy: electric motors
Target Market applications

Aerial Device (Bucket Truck)
• For maintenance and construction of electric lines
  – Working heights of approximately 40’ to 70’

Cranes/Digger Derricks
• For installation of electric poles and transformers
  – Sheave heights of approximately 40’ to 50’

Underground Utility Vehicle
• For construction and maintenance of underground natural gas and electrical lines
  – Compressor air flow up to 150CFM and 150psi
  – Exportable power up to 14 kW
Our “Approved” Platforms/Applications

Approved Chassis – Class 6,7,8
- Ford F650/F750 (4x2)
- International (4x2 or 6x4)
- Freightliner (4x2 or 6x4)
- Kenworth (4x2 or 6x4)
- FCCC (Class 6 step van only)

Approved Final Stage Manufacturer
- DUECO
- Terex
- Altec
- Utilimaster

Approved Applications
- Bucket Truck
- Digger Derrick
- Crane
- Underground Utility Vehicle
  - Compressor
  - HVAC/Exportable Power
PHEV System Architecture

Parallel Hybrid Solution
- Provides redundant system to operator to minimize downtime
- Can recharge battery from IC Engine while maintaining stationary work support
- No modifications required to drivetrain
- Ability to retrofit to existing vehicles

U.S. Patents 7,471,066  7,830,117  8,408,341
Other Patents Pending
Hybrid Drivetrain

Minimally Intrusive Design
- Simplified integration through power take-off (PTO)
- No modifications required to drivetrain components
- Provides opportunity to more easily retrofit existing vehicles
PHEV System Integration

**System Specifications**
- 28 kWh RESS (24 kWh usable)
- 300 Nm Peak Motor Torque
- 70 kW Peak Motor Power
- 6 kW 120/240V Exportable Power
- 2.2 kW 12V DC support
- 3.0 kW J1772 Level 2 Charging
- Independent WEG Cooling System

Standard hybrid system layout with Optional HVAC and exportable power

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Operational Strategy

• Primary focus: reduce jobsite emissions and fuel use
  – Operate equipment, tools and vehicle ancillaries off of hybrid battery
  – Eliminates idling of vehicle engine and/or diesel generator
• Secondary focus: reduce driving emissions and improve fuel economy
  – Through launch assist/battery regeneration tuned to mild charge deplete
  – Odyne PHEV is eligible for HVIP incentives

• Example of available fuel savings:
  – Driving: 5 - 40% (depleting)
  – Job site: 90 – 100%
• Optimizing battery utilization between driving and worksite requires understanding of customer use patterns / work day

<table>
<thead>
<tr>
<th>Fuel Consumption (Gallons)</th>
<th>Conventional Vehicle vs. Odyne PHEV</th>
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</thead>
<tbody>
<tr>
<td>Driving (32 miles/day)</td>
<td>Baseline Vehicle: 5.26</td>
</tr>
<tr>
<td>ePTO at job site (4.2 hours/day)</td>
<td>4.02</td>
</tr>
<tr>
<td>Hydraulic Load (1.0 hours/day)</td>
<td>1.47</td>
</tr>
<tr>
<td>Work Day Total</td>
<td>10.74</td>
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</tbody>
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Total Savings: 54.5%
Operational Modes

- The system is optimized for the stationary work cycle (jobsite, application) yet still offers improvement to the drive cycle.
- The vehicle is typically brought back to a designated area for charging, but can be charged remotely.
- The electric traction motor blends seamlessly with the IC engine as needed (no start/stop, IC engine always on during driving).

- Driving Mode
  - Launch assist (depleting, acceleration)
  - Regenerative braking (charging, deceleration)
- Stationary Mode
  - ePTO (electric “PTO” operation)
  - Engine charging (charging, mechanical “PTO” operation)
- Plug-in Charging Mode
- Faulted / “Conventional” (normal PTO operation without motor)
Driving Performance

• The Odyne plug-in hybrid system is now available in two calibrations that differ in terms of the amount of launch assist provided.
  – Mild calibration provides less launch assist and more electrical power for use at the jobsite.
  – Aggressive calibration provides more launch assist and less electrical power for use at the jobsite.

• The calibration is selected by the type of application and the customer usage (driving vs. jobsite)

• System will operate in a charge “sustaining mode” once battery gets to a low state of charge.
Mild vs. Aggressive Performance

- Mild calibration applies less torque
  - Limits the amount of launch assist to save more energy for the jobsite
- Aggressive has a higher torque limit
  - Increases the amount of launch assist to increase fuel economy benefits while driving
Mild vs. Aggressive Performance

- Mild calibration is only used at lower vehicle speeds
  - Limits the duration of launch assist to save energy for the jobsite
- Aggressive calibration allows for higher vehicle speeds
  - Extends the duration of launch assist to increase fuel economy benefits while driving
In-Use Vehicle Operation

Operation of utility vehicles that are targeted by Odyne involves:

- Short drive to the jobsite
- Extensive engine idling time mixed with some work load operation at the jobsite
- Short drive back to garage
- Usually single shift operation which allows for recharge

![Graph showing RPM over time](image-url)
In-Use Vehicle Operation

• Used real customer data collected from our 2011 DOE programs utilizing onboard telematics to identify a typical “work day” duty cycle

• Based on one year of operating data from 11 utility trucks (work trucks) with different applications collected by Odyne using telematics

• Data used to determine:
  – Daily driving distance
  – Time at jobsite in work mode
  – Time spent actually using the aerial application
Driving vs. Stationary

- We have to account for a large range of driving and stationary applications
These customers average about 40 miles (20 miles each way)

There are other larger independent studies that also show around 40 miles/day (10,000 miles/year @ 250 work days)
Daily Jobsite Hours

- This is when the truck is at the jobsite and being used for work
- These customers averaged about 2.32 hours at the jobsite
Daily Application Hours

- This is when the equipment is actually being used at the jobsite
- While at the jobsite these customer average about 0.42 hours actually using the application
A lot more energy is consumed during stationary than driving
  • About a 2 to 1 ratio
Energy Consumed for Driving

Drive Energy vs. Distance

- Most of the energy is consumed during short distances but could be spread out over long distances
A lot more energy is needed for the jobsite since it operates longer in this mode.

The more demanding the application the more energy needed.
In-Use Vehicle Operation

• “Work Day” cycle used to evaluate fuel economy impacts
  – Daily drive average = 40 miles
  – Daily jobsite time average = 2.32 hours
  – Daily use of application at jobsite average = 0.42 hours

• Why use of averages is appropriate
  – Main purpose of the system is to provide ePTO function
  – Battery size limits distances over which motive power can be provided (charge depleting strategy)
  – Longer job site times mean greater offset of engine operation

• Typical fuel usage for these trucks
  – Driving = 6 MPG & Idling = 1 gal/hr (up to 2 gal/hr under load)
Daily Fuel Consumption

• Fuel consumption is reduced in both driving and jobsite operation (based on dyno test results)
  – -33% total for mild calibration / work day
  – -28% total for aggressive calibration / work day
    • This required an engine charge while at the jobsite

• Just during driving the reductions is
  – -11% for mild calibration
  – -31% for aggressive calibration

• Just during stationary the reduction is
  – 100% for mild calibration
    • Running full electric, no engine operation
  – -53% for aggressive calibration
    • Required an engine charge
Daily Fuel Consumption

Total Fuel Consumed

- Conventional: 10.0 gallons/day
- Mild Hybrid: 6.7 gallons/day (-33%)
- Aggressive Hybrid: 4.9 gallons/day (-28%)

Fuel gallons/day

- Drive
- Job Site

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Summary

• Due to driving and stationary requirements the battery system must have the proper balance of power and energy capabilities

• Due to the significant savings during the stationary application, overall optimization should always consider the trade-offs of the battery consumption

• The best balance occurs when the proper amount of energy is used for driving while leaving just enough battery to complete a full work day without causing an engine charge cycle
Contact Information

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Thank You