Tier 4 GenSet Dominant Hybrid Rebuild/Repower Package for Switcher Locomotives

Task 1 Report

for:

New Technology Research and Development Program

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Submitted by:

Alternative Motive Power Systems, LLC

Principal Investigators:

Dan Frederick

Brian Couchene

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Table of Contents

Abstract/Executive Summary

The primary problem addressed in this project is emissions from Switching and Road Switching Locomotives including current GenSet offerings. Our approach is to create a “mild” hybrid power and control system, in modular form/package, that will totally eliminate idle emissions and minimize emissions with cleaner Tier 4I engines that will be controlled in a way that will allow them to operate at maximum efficiency. Smokeless start and the ability to move the locomotive or “index” railcars without starting an engine will contribute to further emissions reduction. The availability of this technology will enable clients to quickly incorporate this technology into existing locomotives. Overall contribution will be lower fuel consumption, reduced emissions, improved low speed tractive effort, and greatly enhanced diagnostics.

Introduction/Background

Locomotives used in switching and low speed short line applications are typically purchased from larger railroads once the locomotives are no longer suitable for Regional or Class 1 use. There are currently several GenSet options available; some even in kit form. To our knowledge no one has implemented a practical hybrid solution to date. Rising fuel prices, tightening emissions standards, and diminishing qualified maintenance personnel for aging fleets makes the development of this kind of solution practical and significant.

Attempted solutions so far have been implemented, primarily, by engineers and manufacturers with a locomotive background rather than experience with locomotives as well as experience implementing the development of control schemes for a variety of hybrid vehicles. In some instances, poor battery technology was chosen. Hybrid technology is not the answer for every locomotive application.

AMPS' approach differs from other attempted solutions because of our ongoing experience and the development of new technologies that have finally matured. Our modular approach allows us and potential users of this equipment to choose a variety of engine and alternative fuel options depending on operational requirements. It also affords the option of incorporating more efficient and mature technologies as they are developed.

Project Objectives/Technical Approach

AMPS will finalize the design of a modular package for converting a conventional switcher locomotive into a hybrid gen-set switcher locomotive. AMPS will build a prototype modular package and contract with Railserve to install it and do performance testing on the resulting prototype locomotive. AMPS will work with Railserve to partner with a rail yard in Houston, Texas, to demonstrate the locomotive in a representative working environment and to complete load and emissions testing of the prototype in comparison to a conventional switcher locomotive.

Project Objectives included in the Grant Activities (Scope of Work) are:

- To demonstrate that repowering of an in-use conventionally powered road switcher locomotive with a Multiple Gen-Set/Hybrid Gen-Set package reduces NO_x emissions from a conventionally powered diesel locomotive by up to 98% and by 25% compared to a non-hybrid gen-set package.
- To demonstrate the commercial viability and cost effectiveness of the modular approach to the design and installation of the Multiple Gen-Set/Hybrid Gen-Set package.

In order to achieve these objectives AMPS will:

- Refine the gen-set package modules in order to make system integration into the locomotive chassis as quick and simple as possible.
- Undertake in-use measurement of the emissions before and after the installation of the multiple gen-set/hybrid gen-set dominant package.
- Determine the fuel consumption before and after repowering with the gen-set package.
- Assess operator acceptance of use of the installed system.

The prototype Multiple Gen-Set/Hybrid Gen-Set package will be installed on a GP9 road switcher locomotive purchased by AMPS from Railserve. The gen-sets will be provided by a contractor to meet

AMPS specifications and AMPS will provide any interface components required. The gen-sets will be installed in the road switcher by Railserve at the Union Tank Car Repair Shop in Longview, Texas.

The energy source for the initial commercial version will be two generator sets installed in parallel in the road switcher locomotive in place of the original 1,500 – 2,000 hp diesel engine, one of which will be a battery hybrid module with a 150 kw diesel generator and, the other a 400 kw diesel generator set. Both engines in the gen-sets will be Tier 4 certified engines (as allowed under 40 CFR section 1033.150 Interim provisions). In the hybrid module, in addition to the 150 kw diesel engine, there will be battery pack / module.

Where the induction generator is coupled to an engine in the more conventional diesel engine gen- sets, AMPS uses an induction generator electrically connected to an AC inverter. This inverter, by varying the electrical slip in the generator, generates a constant DC bus voltage. This voltage is then fed to either a set of storage batteries or to individual traction motor controllers, or to both.

In the hybrid gen-set, the electricity will flow directly to the DC bus on the traction motor propulsion drives. The batteries will be charged by the smaller gen-set once a predetermined state of charge is sensed. This will allow the smaller gen-set to run at peak efficiency almost 100% of the time. If the full capacity of the larger gen-set is not required for locomotive propulsion, it will be used for additional battery charging. If required the locomotive can operate on batteries alone.

The gen-set modules will be assembled by a supplier designated by AMPS. Both the operator control stand and the locomotive will be equipped with quick connectors to the control cabinet and the Traction Motor Propulsion Drive Skid respectively. This will allow for major systems testing to assure proper function and quick, on-site assembly.

Tasks

Tasks included in the Grant Activities (Scope of Work) are:

- Finalize design of GenSet package modules
- Control and power system design, assembly, and programming
- Installation of the GenSet package modules
- Performance testing of prototype locomotive
- Emissions and fuel economy testing of conventional and prototype locomotive, and
- Evaluate operator acceptance of prototype locomotive

Task 1

From the Grant Activities (Scope of Work):

> *Task 1: Finalize Design of GenSet Package modules*
>
> *2.1. Task Statement: The PERFORMING PARTY will finalize the prototype design for the hybrid gen-set package.*
>
> *2.1.1. The PERFORMING PARTY will finalize the prototype design for the hybrid and gen-set package. The PERFORMING PARTY will review the design, amend the design as necessary, and approve the final design.*
>
> *2.1.2 Schedule: the PERFORMING PARTY shall complete this task within 3 months of the signed Notice to Proceed Date as issued by TCEQ.*

2.1.3 Deliverables: The PERFORMING PARTY shall submit a report to the TCEQ upon completion of this task including a final implementation-ready design for the prototype.

Working from the original designs for the Railserve LEAF (Low Emissions and Fuel) switch locomotive – for which AMPS developed the gen-set (power and control system) – it was decided that the main control components will be in their original locations, but the main traction invertor module will be located under the short hood and the battery module and gen-set module will be located under the long hood.

Components and systems that will remain similar to the Railserve LEAF®

Operator control stand

The operator control stand will be identical or nearly identical to the LEAF® locomotive. As the control stand in the LEAF® locomotive is nearly identical to the stand in conventional locomotive design, this allows operators familiar with other locomotives to be able to operate this locomotive with little additional training.

Control cabinet

The control cabinet will be similar to the LEAF® in that many of the same relays and Input/Output (IO) modules will be present for locomotive control. There will, however, be several additional relays, terminal blocks, and IO modules for functions that the LEAF does not have. These functions are described in the components unique to the AMPS hybrid locomotive.

Drives / inverters

The drives and inverters will be the same as in the LEAF® and be provided by American Traction Systems. However, the AMPS hybrid locomotive will utilize more modules than the LEAF® because the AMPS locomotive adds a separate field chopper, dynamic braking chopper, and two generator inverters.

Traction motors

The traction motors will be unchanged and identical to the LEAF® locomotive and be rebuilt standard EMD (Electro-Motive Diesel Inc.) traction motors.

Traction motor blowers

The traction motor blowers will be identical to the LEAF® locomotive and may only change in their location.

Air compressor

The air compressor will be the Atlas Copco GAR 30. AMPS has decided this product best meets the needs of the AMPS locomotive based on size, capability and proven reliability.

Engine for main generator(s)

The engine for the large genset will be the same as the LEAF® locomotive unless it becomes unavailable in a tier 4 version. In that case, AMPS will investigate another engine vendor that can supply a tier 4 engine in the hp that is required.

Components unique to the AMPS hybrid locomotive

Battery pack

AMPS will use Odyssey P1800 batteries as specified in the grant applications

Main generator and secondary generator

AMPS will be using two induction generators manufactured by Marathon. The small generator will generate 150KW and be coupled to a QSB Cummins 225hp Tier 4 engine. The large generator will generate 400KW and also be connected to a QSX15 Cummins 600hp Tier 4 engine. The engine generator combinations or "gen-sets" will be controlled by the locomotive control module and will be used for battery charging and propulsion. Their speed and torque will be used to control the rate of charge of the batteries and the amount of propulsion power. The Railserve LEAF is not a hybrid and does not use the generators for battery changing in this way. They use conventional belted alternators to charge their small engine starting batteries. The two gen-set sizes were chosen based on AMPS study on the average power requirements of locomotives in various switching applications.

FRA approved LED headlights

AMPS will be using LED type headlights in the locomotive. An LED headlight has a nearly unlimited bulb life and, although initially more expensive, hardly ever needs replacing. This eliminates locomotive downtime due to the inability to operate without an operable headlight.

Ground, ditch, and cab lighting

AMPS will be utilizing LED type lights for these applications. The LEAF® uses conventional incandescent bulbs for these lights. Because of their nearly indefinite lifespan, the bulbs do not burn out and require replacement, thus there should be almost zero instances where the locomotive crew does not have adequate lighting due to burned out bulbs.

Main generator rectifier

The amps locomotive will not utilize a main rectifier as the LEAF® does. The LEAF® generates 480V 3 phase and utilizes a diode rectifier to generate a DC bus. The DC bus is then used for the traction choppers. The AMPS locomotive will utilize an inverter connected to each generator

Generator inverters

The AMPS locomotive will have an inverter connected to each generator. This allows the inverter to generate full DC bus voltage for propulsion or battery charging even with lower engine speed. The Railserve LEAF has to maintain the engine at 1800rpm in order to maintain a 60Hz frequency. With the inverter connected to the generator, the inverter can also use the hybrid battery pack to crank the engines using the generators as a starting motor. The LEAF® utilizes a standard 24V engine starter. Starting using the generator reduces starter wear and allows for higher cranking speed and torque. This reduces emissions during starting as well as improving cold weather starting.

Traction motor field regulator

The AMPS locomotive will utilize a separate chopper module for the traction motor fields. The LEAF® places each motor field in series with the armature. This works well enough for low speed switching and is an economical approach. AMPS will have a separate chopper module for each traction motor just as the LEAF® does. The difference is that the AMPS locomotive will have all four motor series fields wired to a separate chopper. This allows for the field current to be lower than the armature current. Lower field current allows for higher tractive effort at higher locomotive speeds.

Complete design

The final design is depicted in Appendix A.

Discussion/Observations

Objectives vs. Results

All objectives of Task 1 have been met and work is proceeding to subsequent tasks.

Critical issues

There is nothing to report in this section at this time.

Technical and commercial viability of the proposed approach

At this point in time, we see no technical barriers. The AMPS / Railserve team has demonstrated its ability to work together in implementing successful, reliable, cost conscious locomotive designs. Our anticipated price point will likely be somewhere between the Railserve LEAF® locomotive and other GenSet offerings but with improved traction control, efficiency, and performance. This design should be both technologically sound and commercially successful.

Scope for future work

Upon approval and receipt of the Notice to Proceed, AMPS will begin to purchase the necessary components required for subsystems, assemble components into modular subsystems, perform required programming, test subsystems, and ship them to Railserve.

Summary/Conclusions

Work is proceeding as expected and now we are awaiting approval to move on to the next Task.

Appendices

Appendix A: Locomotive Design Layout