Tier 4 Gen-set Dominant Hybrid Rebuild/Repower Package for Switcher Locomotives

Task 3 Report

for:

New Technology Research and Development Program

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Submitted by:

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Abstract/Executive Summary

The primary problem addressed in this project is emissions from switching and road switching locomotives including current gen-set 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 make 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 and 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.

Alternative Motive Power Systems' (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 Longview, 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 to 2,000 horsepower (hp) diesel engine, one of which will be a battery hybrid module with a 150 kilowatt (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 a 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 alternating current (AC) inverter. This inverter, by varying the electrical slip in the generator, generates a constant direct current (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:

- Task 1: Finalize design of gen-set package modules
- Task 2: Control and power system design, assembly, and programming
- Task 3: Locomotive systems installation and performance testing
- Task 4: Emissions and fuel economy testing of conventional and prototype locomotive, and
- Task 5: Evaluate operator acceptance of prototype locomotive

The Task 3 accomplishments are summarized below.

Task 3

From the Grant Activities (Scope of Work):

Task 3: Locomotive Systems Installation and Performance Testing

2.3. Task Statement: The PERFORMING PARTY will install all sub-systems onto the demonstration road switcher locomotive and will test the performance of the assembled prototype locomotive to ensure all is in working order, complete an adequate break in period, and undertake load testing in preparation for emission testing.

2.3.1. The PERFORMING PARTY will install all sub-systems onto the demonstration road switcher locomotive as per the engineering drawings finalized in Task 1. The PERFORMING PARTY will ensure the proper installation and functioning of all individual systems. The PERFORMING PARTY will ensure that the completed prototype is ready for testing.

2.3.2. The PERFORMING PARTY will test the performance of the prototype locomotive including: static testing of locomotive systems with power applied; voltage testing of traction motors, control systems, cooling fans, and the air compressor; physical inspection of all instrumentation and devices; re-inspection of all torque values and crimps in electrical connections; a rolling test of the locomotive; and assuring programming and functioning of all systems and sub-systems including making any necessary changes.

2.3.3. The PERFORMING PARTY will transport the repowered prototype hybrid gen-set switcher locomotive to the working railyard in Longview, Texas, selected in Task 2.2.5. and place it in regular use including 16 to 24 hour shifts and normal stops and starts. The PERFORMING PARTY will ensure that the prototype hybrid gen-set switcher locomotive completes a break in period of up to one month or sufficient time to demonstrate proper operation and appropriate tuning of the locomotive. The break in period must include load testing.

2.3.3.1. Load testing will include at least: ten forward and reverse load tests with proper time delays to pull the equivalent of 7000 tons on minimal grade; and 10 load tests to pull the equivalent of 7000 tons on minimal grade on wet track. The PERFORMING PARTY will evaluate the prototype's performance in these load tests as compared to the conventional locomotive.

2.3.4. Schedule: The PERFORMING PARTY shall complete this task within 22 months of the signed Notice to Proceed Date as issued by TCEQ.

2.3.5. Deliverables: The PERFORMING PARTY shall submit a report to the TCEQ upon completion of this task including pictures of the installed prototype locomotive, results of the load testing, and an evaluation of the performance of the repowered prototype locomotive in both load testing and the rest of the break-in period.

All sub-systems were installed on the locomotive and verified for proper operation statically. Figure 1 shows a picture of the finished locomotive.

Figure 1. Finished locomotive

The engines were started and ran and the generators are mechanically sound. Both gensets were "loaded" by performing battery-charging functions. The hybrid battery module was provided with a firmware update from the manufacturer. Traction control modules and propulsion system underwent static testing. The pack was discharged and charged by means of the generator sets and was discharged using hotel loads to discharge the pack. The pack underwent several charge/discharge cycles prior to on-site testing. The battery pack air cooling system was tested for proper air-flow and functions as planned. All of the wiring for the control system and auxiliary equipment was checked and verified correct. Power was applied to traction motors and the air compressor. All systems were powered and functioning properly prior to shipping the locomotive.

The "break-in" period was shortened due to delays at the Railserve Shop and the Union Pacific Railroad. The locomotive has performed satisfactorily in normal switching functions at Texas Eastman and has undergone load testing.

Discussion/Observations

Objectives vs. Results

All load testing and performance testing has been accomplished successfully. The locomotive moved 57-loaded railcars at about six miles per hour (mph). The conventional locomotive tested cannot make this move. Initial operator acceptance is good. We will have a better feel for overall performance and fuel economy over time. We are very pleased with overall locomotive functionality and performance. We will make necessary, minor modifications to programming as we get more operator feedback and are able to compile information recorded by our data acquisition system (DAS).

Better than expected performance included:

- performance of AMPS' axle generators for wheel slip control;
- modularity of "populated" cab and short hood module;
- populated with operator control stand, propulsion system, heating ventilation and air conditioning (HVAC) system, etc.;
- modularity of long hood and roll-up doors; and
- detail of data we can access by means or our DAS.

Worse performance than expected occurred in the charge acceptance of the battery pack and the size of "small" genset.

Regarding the charge acceptance of the battery pack, the pack was quoted at a charge rate of 1,000 amps (a) for five-minutes, however the manufacturer's programming limits charge rate to 150 a for 30 seconds. This will be remedied by later installation of "chiller plates" or other cooling system. Currently, we have programmed a "load following" scheme to assure that the pack stays within safe operating parameters. This has almost no effect on switching performance but an additional pack will likely be required for higher horsepower Short Line use

Regarding the size of "small" genset, the physical size of the 150 kw genset is nearly the same as the 400 kw unit. For production, we will pursue a smaller package.

Critical issues

There were some small issues such as: some rust residue in the air system, a faulty coolant pump, radiator punctured during assembly of long hood, and faulty circuit board on HVAC. All were relatively easily addressed.

Technical and commercial viability of the proposed approach

AMPS is extremely pleased with the performance of all systems as well as the integrity of the overall design. Currently, we have two locomotive manufacturers and two Class 1 railroads wishing to see the locomotive in operation. We anticipate that these visits will occur sometime after the July Fourth holiday. A representative of one of the Class 1 railroads who has seen our cab/short-hood module said, "Your locomotive is perfect." Based upon initial responses to this design, we anticipate that viability of the design is excellent both as a complete locomotive and as select modules for repower. We will make

minor changes in some component selection for production along with minimal programming changes but the locomotive has proven to be a very good prototype platform. As configured, this locomotive is a very good option for switching in large manufacturing facilities and at Transload and Intermodal locations.

Intellectual Properties/Publications/Presentations

- Patent Pending: A CONTROL SYSTEM, A HYBRID CONTROL MODULE, AND METHOD FOR CONTROLLING A HYBRID VEHICLE Serial No. 61/324,283 filed on April 14, 2010
- IP: AMPS Programming and control methodology

Summary/Conclusions

The locomotive has completed all load testing successfully. While we pulled a maximum of 57 loaded railcars, we did not have sand available in order to improve adhesion. Only the small genset, with some assistance from the battery pack, was required to make our maximum pull. Traction and wheel slip control is excellent. Our feeling is that, at this location, the locomotive is capable of pulling a maximum of 65 to 70 loaded cars.

The locomotive performs as expected with the exception of the amount of power we are able to send to and draw from the battery pack. This is an issue with temperature that we were not made aware of when we purchased the pack. This issue has almost no effect on locomotive performance in a switching application however but will be a factor for short line or Class 1 railroad use. We will be installing "chiller plates" under the cells to keep the cells at optimal operating temperature. We are implementing a "load following" scheme for the gensets in order to accommodate the pack limitations. The hybrid system, as configured, still eliminates any engine idling and minimizes transient loads on the engines in order to reduce emissions that need to be captured by the engine after-treatment system. This will reduce the frequency of regeneration required by the after-treatment system and extend intervals between replacement or cleaning of the system.

Contact Information

For further information about this project please contact:

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Appendices

Appendix A: Written proof of the delivery of components and systems to Railserve

AMPS
Alternative Motive Power Systems

October 15, 2012

Below is a list of items that have been shipped by AMPS to the Railserve Longview, TX facility for the AMPS grant project with TCEQ.

Item	Manufacturer
DC/DC Converter	US Hybrid
Traction blower fan and motor	Cincinnati Fan
Reverser (Magnetic Switch 24V)	DLL, Inc.
Engine 600hp	Superior Diesel
Engine 250hp	Superior Diesel
Generator 150Kw	Marathon Electric
Generator 400Kw	Marathon Electric
HVAC	Motive Equipment
Coupler (for 150Kw generator)	American Vulkan
Coupler (for 400Kw generator)	American Vulkan
Batteries	Corvus Batteries
Bellows for radiator	A&A Manufacturing
EMI Filter for Hotel Power	Radius Power
Transformer for Hotel Power	Pepco

Please confirm and sign below.

Railserve Representative