CNG/Hybrid Commuter Locomotives

Faster, Cheaper, Cleaner and Soon!

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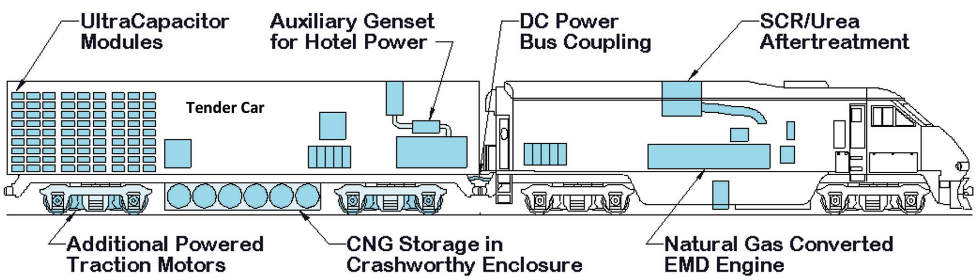
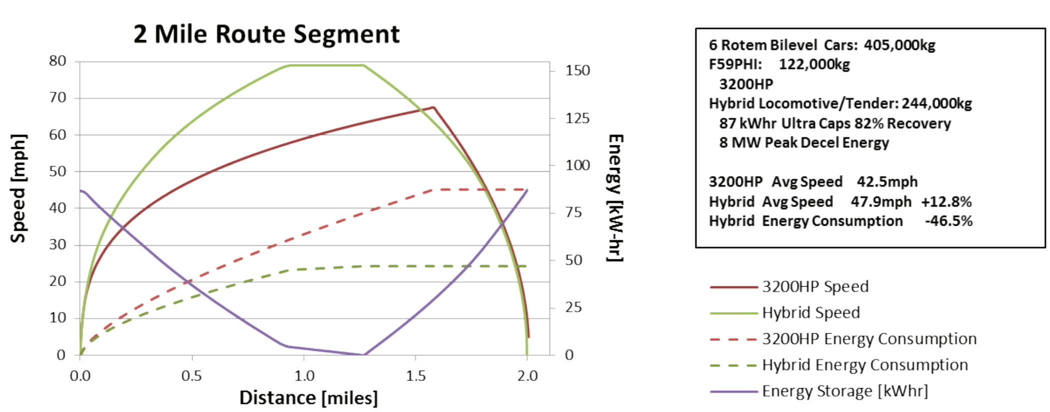
The combination of compressed natural gas (CNG) as a fuel, and onboard electrical hybridization, offers a new paradigm in commuter rail operations. By synergistically combining off the shelf old technologies (CNG conversion) with a few new developments (banks of ultra-capacitors), it makes possible a commuter locomotive that accelerates twice as fast, at less than half the fuel cost, while emitting pollution at near zero levels.



The above illustrates the system. The locomotive's existing engine is overhauled and converted to CNG. The tender car has traction motors the same as the locomotive and it holds banks of ultra-capacitors and additional engine fuel. This is a combination of well-known technologies that have been maturing in different areas of transport. CNG locomotives exist in niche markets – The Napa Valley Wine Train has operated a passenger locomotive on 100% CNG since 2001. Hybridization of transit buses with ultra-capacitors is well known– Maxwell alone has their ultra-capacitor modules in over 4000 buses. Emissions control systems have been developed for passenger rail – Metrolink recently tested a selective catalytic reduction (SCR) system on one of its locomotives for over a year.

Faster

One psychological hurdle of this concept for commuter rail executives is reverting to the tender car. But this concept puts the tender to work. Not only does it provide the space needed for the ultra-capacitor banks and alternative fuels, but the four additional traction motors doubles the locomotive's traction on the rails. That is how the acceleration can be doubled. And those ultra-capacitors are why most of the braking energy can be recycled and used to produce those super accelerations. Faster accelerations mean faster trips between stops. The graphic below demonstrates this for a typical commuter rail route segment.



The chart at right indicates the radical performance increase due to hybridization of the locomotive with a powered tender car. For a 2 mile route segment, using the equivalent of a typical 6 car commuter train as a baseline, the standard locomotive (solid red) would reach a top speed of 67 mph before it had to decelerate. The hybrid locomotive (solid green) actually reaches the rail line top speed of 79 mph and maintains that speed for over ¼ mile before it has to start decelerating. The purple line illustrates the energy flow into and out of the ultra-capacitor modules. The dashed green and red lines indicate the energy consumed by the two different locomotives. Frequent starts and stops are a hybrid's friend. In a 2 mile route the hybrid locomotive reduces the energy used by 46%. On a 4 mile segment this energy reduction drops to 36%. We have established 35% as the average energy reduction for this system in commuter rail applications.

Cheaper

Commuter rail organizations consume significant amounts of fuel. For example, Metrolink consumed 6.7 million gallons of diesel fuel in 2012 at $3.63/gallon. Using natural gas as a fuel will reduce fuel cost by an estimated 55% and regenerative braking and accelerating using ultra-capacitors will reduce energy consumption 35%, combining for a savings of 75% in fuel cost. For Metrolink that would mean an annual savings of $18.2 million or $1.5 million a month!

Yet the current thinking on near-term reduction of commuter rail emissions focuses on the conventional, higher cost option of continuing with diesel. Not only does that option cost more overall, it also needs significant development and it offers no performance improvements. For example, Metrolink is currently purchasing prototype Tier 4 diesel locomotives that will cost $6.3 million each. They are expected to be fully developed by 2016. A fully updated and remanufactured CNG/Hybrid locomotive would cost nearly $7.5 million and could be ready in the same time-frame with an agressive development program. That CNG/hybrid cost premium for one locomotive could be paid for with one month of fleet fuel savings!

Cleaner

Most North American commuter rail locomotives have little or no emissions upgrades. Over half of Metrolink's locomotives have no emissions upgrades at all. The 15 newer locomotives meet Tier 2 standards which emit 27 times the NOx and 10 times the PM emissions per horsepower as a 2010 diesel truck. Of course, the rest of the fleet has even higher emissions. When some of them are replaced with a Tier 4 locomotive sometime after 2016, they will still put out 6.5 times the NOx and 3 times the PM as a 2010 diesel truck.

On the other hand, if their engines were converted to natural gas and had an SCR system installed (like the new diesels will most likely have), they will have NOx emissions 75% lower than the diesels – meeting policy maker's definition of 'near zero' locomotive emissions. In addition to the drastic reduction in criteria pollutants, this system will reduce GHG emissions 48% due to the switch to CNG and the improved fuel efficiency. Converting from diesel fuel to natural gas will reduce CO2 emissions 20% and the hybridization further reduces CO2 emission by another 35%.

Soon! (Phase 1)

Sticking with the Metrolink example, it won't be until 2016 that the first 3 Tier 4 Metrolink diesel locomotives begin service. Their current fleet has 15 F59PH locomotives with over 1 million miles since their last overhaul. There are an additional 14 F59PHI locomotives with over 700,000 miles that should be overhauled before 2016. All 29 of these locomotives have minimal emissions upgrades and require high maintenance rates that impact Metrolink's performance.

Starting almost immediately, as the first phase in a CNG/Hybrid locomotive program, these old polluting locomotives could be rebuilt as locomotives that meet CARB's Ultra-Low Emitting Locomotive guidelines (ULEL). With the simple addition of a current technology NOx aftertreatment system (SCR), modern low oil consumption piston rings and updated electronic injectors these locomotives could reduce NOx emissions to below Tier 4 levels and PM emissions below Tier 3.

These ULEL rebuilds could start happening in a matter of months and would be one third the price of the new locomotives that won't be in service until 2016. The fact that this isn't happening is an example of 'The Perfect being the Enemy of the Good' as it is politically difficult to fund these rebuild updates with Carl Moyer funding because the PM emissions are not below Tier 4 and the system has not been CARB verified yet. Yet Carl Moyer funding is available to purchase nonexistent locomotives that won't be here for 3 years because they fit the conventional mold.

It is preferable to rebuild and hybridize the current locomotives instead of buying new ones for several reasons.

- Lower emissions will start immediately – not in 2016.
- The cost for these preliminary ULEL reductions for the entire fleet (52 locomotives) would be less than the price of 20 new locomotives.
- This would be a first step along the path to the ultimate goal 'near zero' emissions, since the NOx after-treatment in these units is required anyway.
- Hybridization and more traction motors in a tender car is the solution for longer, faster commuter trains (not more diesel power and higher than necessary emissions).
- The EMD 2-stroke engines in the current locomotives are the only current high power engines that can be converted to natural gas without a loss in power. This will not be the case with the currently ordered 4 stroke engines – they are a dead-end.

From Prototype to Full Production

In parallel with the ULEL rebuild plan there would be parallel development programs for the hybrid energy system, CNG storage system, and an improved gas engine conversion system with higher efficiency and lower emissions.

After 2 years of aggressive development, a CNG converted F59PHI with NOx aftertreatment would be integrated with a Hybrid/CNG tender car and tested at the Transportation technology Center, Inc (TTCI) test track in Colorado. This durability shakedown at TTCI would be the last step before the full system could go into revenue service with a commuter railroad. With the right team of small flexible companies and a private/public partnership with CEC and SCAQMD development funding support, these could be going into service the same year that the currently proposed Tier 4 diesels show up.

Energy Conversions Inc. converts high horsepower diesel engines to natural gas operation. The company has over 20 years of experience and currently has converted natural gas locomotives operating in six countries.

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The NOx aftertreatment system described here (Compact SCR™ by EF&EE in Rancho Cordova, CA) was tested in commuter service by Metrolink for a year on one of Metrolink's 15 high mileage F59PH locomotives. This system, on a very tired engine that consumed large amounts of lube oil, achieved ULEL emissions levels and was close to achieving Tier 4 NOx and Tier 3 PM levels. A third generation of this NOx aftertreatment system is now available that will fix several of the short comings in the Metrolink tested system. These new systems are currently in service on a fleet of Ferries in the S.F. Bay area.

Figure 1: Compact SCR catalyst assembly installed in SCAX 865