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APPLYING HYDRAIL AS A ZERO-EMISSION RAIL POWER GATEWAY TECHNOLOGY TO IN-SERVICE SWITCHER LOCOMOTIVE DUTY CYCLES

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Abstract: Switcher locomotives are typically below 1500 HP and are used to move railway cars around a yard, usually to assemble or disassemble a main line train consist. This results in very different power dynamics from main line locomotives. Switcher locomotives are rarely operated at constant power, their power profile is highly dynamic for a railway vehicle due to the nature of their usage. Most freight locomotives, including switcher locomotives, in North America are diesel-electric. Diesel engines are typically not more than 55% efficient when operated at certain RPMs. This efficiency drops significantly when the power output of the engine is changed. This characteristic of diesel engines makes switcher locomotives highly inefficient and the most polluting locomotive type on a per horsepower basis. The motivation behind studying the power dynamics of switcher locomotives is to produce a standardized duty cycle which can be used in the study of alternative propulsion systems.

1 PROJECT OVERVIEW

The stated goal of the project is to study the impact of hybridization between hydrogen fuel cells and lithium ion batteries for switching applications. Specifically, the research team assessed the different possible options to retrofit the 1000 HP switcher locomotive labelled the "Green Goat". Currently, Southern Railway of British Columbia (SRY) owns a Green Goat switcher locomotive which is sitting idle in their New Westminster facility. The once battery powered switcher has had its batteries removed and is no longer in service. Restoring the Green Goat to working service will help SRY better understand the technology, troubleshoot most of the technical issues that may arise (malfunctions), and give SRY personnel enough time to learn how to operate and maintain such a locomotive. Moreover, the results of this research can also be applied to retrofit all of SRYs diesel-electric locomotives, which is SRY's immediate need, in order to reduce air emission costs.

2 Innovation

The research team designed and deployed a telemetric system made up of an on-board wireless voltmeter and ammeter. These sensors measured the locomotive's generator voltage and current, relayed the measured real-time data to an on-board laptop, which then relayed the measured data to an off-site database using cellular communications. This setup aided in the collection of high integrity data for an entire month. The paper also presents the work performed in analyzing the collected data, and in combining the collected data with data from the on-board event recorder to more accurately understand the operation and performance characteristics of switcher locomotives. Monitored variables included: speed, pneumatic brake system pressure, throttle position, power output, time, distance and position. The overall raw collected data consisted of 11.48 million recorded current readings, and 8.34 million recorded voltage readings, for a total of a little less than 20 million readings. The data collection started on 11th of May 2018 at 12:53:17 PM and ended on 24th of June 2018 at 04:29:21 PM spanning a little over 1047 hours not accounting for data gaps.

3 Lessons Learned

To produce a practical retrofit for a locomotive, its duty cycle must be thoroughly studied. A duty cycle is data recorded over time that captures the locomotive's power demand. It is an attempt to parametrize the power demand of a locomotive over a period. Typically, duty cycles have been used to calculate locomotive emissions. The Railway Association of Canada's Locomotive Emissions Monitoring Program relies on such data for emissions calculations. Specifically, the duty cycle is composed of the percentages of time the engine is operated at a specific power level (notch) or at idle. The need for diesel engine idling stems from the difficulty to restart diesel engines, especially in cold climates. Since diesel engine idling power is not transmitted to the wheels for traction, it can be thought of as wasted energy, and therefore an efficiency reducer. For this reason, there have been attempts to reduce engine idling time. This data is important because diesel engines have different levels of fuel consumption, emissions, and efficiencies at different power levels. The duty cycle extracted from the SRY 909 Event Recorder and presented in Table 1.

Table 1: Duty Cycle of SRY 909.

Throttle	Idle	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
% of time	73.3	5.77	9.57	5.30	3.37	2.44	0.24	0.00	0.00

It was calculated that the energy efficiency of the diesel generator excluding energy consumed at idle (consumption rate unknown) was approximately 20%. Assuming 90% traction motor and gear efficiencies, the net powertrain efficiency can be approximated at 15% as presented in Figure .

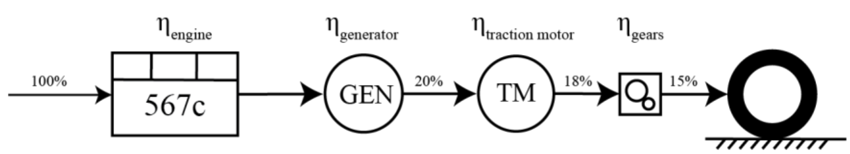

Figure 1: SRY 909 powertrain efficiency.

Any hybrid powertrain architecture that relies on a hydrogen fuel cell prime mover will draw all its energy from the on-board hydrogen storage. In other words, the auxiliary power sources will supply power but zero net energy. The on-board hydrogen storage will have to be sized in a way that will achieve the following:

1. Provide the same energy content previously provided by a 600 US Gallon diesel tank keeping in mind any change in powertrain efficiencies. This should maintain the current number of refueling events.

2. Meet the mass and volume constraints of the locomotive.

3. Allow enough space for the auxiliary power sources (e.g. batteries).

Given that the design philosophy stipulates that no net energy is provided by the battery bank, and that the batteries are only included to handle instantaneous power, factors other than the energy density will guide the decision on sizing of the bank. A relationship exists between a battery's voltage, life cycle, and current draw. A battery cell can supply multiples of its rated capacity but will rapidly deteriorate, its terminal voltage will drop, and its life cycle too. This relationship is specific to each battery chemistry. On the other hand, operating a battery bank at higher than typical current draws will help reduce the bank's size, and therefore the capital cost of a retrofit.