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The Value of Anti-Idle and Start/Stop Technology to Military Vehicles

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ABSTRACT

The 2015 defense budget, announced in March, 2014 was requested to be $496 Billion, which is down from $553 Billion three years ago [1]. This means that existing equipment, which has been trained on for numerous years, and fought two major wars, will be required to last longer and be maintained at a high state of readiness for years to come. In addition to acquisition and maintenance costs, fuel that propels these vehicles continues to also be at a premium. According to Forbes magazine, the US Department of Defense is the single-largest consumer of fuel in the world [2]. With fuel costs as volatile as ever, and an aging military fleet, researchers need to bring technology to the table that extends the life cycle of our vehicles and reduces the US DoD's dependence on fuel.

Technology that addresses both life cycle cost and fuel savings of commercial vehicles has been used for almost 40 years. This technology is a game changer for specialty vehicles such as police cars, ambulances, utility vehicles, delivery trucks and Semi-trailers. This technology, often described as "anti-idle" or "start/stop" technology is also currently being applied to passenger vehicles. The technology is typically a small embedded computing device that runs a "rules based" fuel saving anti-idle and charge control algorithm that is designed to turn the engine off when it is not needed.

Anti-idle technology has been widely adopted in commercial vehicles and has the potential for having a large impact on new and legacy military vehicles. Lithiumstart has developed an advanced fuel saving algorithm which dynamically manages the vehicle's engine and electrical systems and can be implemented in a wide variety of military and commercial platforms. The hardware developed in a phase I SBIR program is implemented easily without changing how the soldier operates the vehicle or reducing mission readiness. Using a variety of innovative approaches, this functionality can be obtained quickly and cheaply using an adapted COTS bolt on embedded controller. This paper describes the commercial adoption of anti-idle technology and how it is ready to take the next step on the US military vehicle fleet.

INTRODUCTION

Anti-idle and start stop technology dates back over 40 years when Toyota fitted a crown sedan with an electronic device that switches off the engine after sitting stationary for more than 1.5 seconds [3]. The goal of the Toyota program was to gain fuel economy, especially for cars that operate in urban areas. Since then, various vehicle manufacturers have toyed around with the technology mostly to improve fuel economy, but also for other reasons (especially in the 1980's) such as reduction in carbon emissions. Although these technologies showed fantastic potential in fuel savings, their widespread adoption was not realized and has started to make a comeback over the past 10 years as gas prices started rising significantly. Now, a growing number of major car manufacturers have models that utilize this technology.

Start/stop technology is commonly used to gain fuel economy, but also demonstrates impact on commercial, specialty vehicles for reasons other than fuel economy and reduction of carbon emissions. Other key benefits of this technology include reduced engine operating hours (thus prolonging the life of the engine), more time between

maintenance, reduced noise (compared to gas-based auxiliary power units) and the ability to maintain cabin temperature in commercial vehicles without having to run the engine. These benefits extend beyond commercial semi-trailers and are gaining widespread adoption in municipal vehicles (such as ambulances, fire trucks and police cars), public utility vehicles, delivery trucks and buses.

This paper will describe the benefits that anti-idle and start/stop technology have made to commercial vehicles over the past 40 years. It will present well-documented case studies that quantify the benefits of the technology as well as describe how this technology is ideally suited for today's military. Finally, the paper will describe the Lithiumstart Intelligent Charge Control system and its demonstration on a commercial box truck that utilizes the same engine/transmission and alternator configuration as a number of combat service and combat service support vehicles.

Commercial Uses of Battery Based Anti-Idle and Start/Stop systems.

Battery based anti-idle technology actually fairly common in the commercial world. The technology is commonly found in semi-trailers, municipal vehicles (police cars, garbage trucks and ambulances), public utility vehicles, buses and delivery trucks. In most applications, improvement to fuel economy is the key driver, but in some cases there are other benefits that gain significant credibility to its use. This section will describe various commercial applications as well as present trade studies that demonstrate the capabilities of this technology on the specific platform.

Semi-Trailers

Semi-trailers are to date the biggest users of anti-idle technology and also show the greatest potential for benefit. Argonne National Laboratory estimates that more than 650,000 long-haul heavy-duty trucks idle during required overnight rest stops every day [4]. By law, the operators of these trucks need to rest at least 10 hours for every 24 hour period and during this period, the driver's main motivation for idling their vehicle is to maintain a comfortable cabin temperature and operate convenience devices such as TVs, radios and portable electronics chargers. According to sustainableamerica.org, approximately 1.2 billion gallons of diesel fuel are consumed per year from idling alone [5]. Vehicle APUs, fuel fired heaters and shore power connections at rest stops are starting to become more common, but are not as available as needed to solve this problem.

About half of the states in the United States of America have passed state and local laws that are focused on limiting the amount of idling on commercial trucks [6]. The state mandated anti-idle laws, federal tax exemptions, high fuel prices and the need to reduce carbon emissions have stimulated the anti-idle system market in this category of vehicles, which has resulted in numerous products becoming available at truck stops and trade shows. These products have made a huge impact on this market and will continue to gain momentum in the future.

Municipal Vehicles

As state and local budgets continue to decrease, operating costs for municipal vehicles are being stretched to their limit. This includes police vehicles, ambulances, fire trucks and school buses. Rising fuel prices are not helping the budget situation and many municipalities have looked to anti-idle technology to not only reduce the amount of fuel consumed, but also to increase the life of the vehicles' engines and increase the time between maintenance.

In the movies and TV, police vehicles are portrayed in high speed chases and constant patrolling. The reality of the matter is that these vehicles spend a significant amount of time in one place, observing traffic or areas of interest. Because our police forces operate often 24 hours a day, the mileage on the vehicles may not accumulate quickly, but the engine hours add up significantly! Much like the truck drivers mentioned in the previous section, the vehicle operators want to stay warm in the winter and cool in the summer and run their engines during these times to maintain cabin temperature.

In addition to cabin temperature, police are also concerned with ensuring their mobile data terminals are operational at all times and also that their signal lights are functional for long periods. Rules based anti-idle systems solve this problem by simply implementing algorithms that turn off the vehicles after a certain amount of idle time and run the auxiliary loads from a battery integrated on the vehicle. Battery charging occurs as necessary by turning the engine on (only when needed), or when the vehicle is started and driven.

CASE STUDY [7]: In 2011, the city of Columbus, Ohio installed anti-idle technology on 90 of its police vehicles. The system included and anti-idle system controller and auxiliary heater. The system implemented a rules based algorithm that automatically turned the vehicle off after a pre-programmed amount of time and used a battery to power auxiliary loads and the auxiliary heater to maintain cabin temperature. Based on preliminary data, the city projects a 34% reduction in idling with projected fuel savings of more than $3500/yr per vehicle. This implies that the system will pay for itself in less than a year and there will be more time between maintenance intervals as well as prolonging the life (and performance) of the engine.

Public Utility Vehicles

Public utility vehicles are important to our way of life and include man lifts, cargo vans and pickup trucks used to support our electricity, telephone and cable TV. These vehicles are typically used for maintenance, repair, meter reading and personnel transport. Although fuel savings can be a key driver for anti-idle technology on these vehicles, it is realized that these vehicles often require idling during stationary use, which can significantly impact engine life. These vehicles are not usually high on the priority list of year to year replacement, so increase in vehicle life and increased time between maintenance intervals can have a significant impact on the bottom line.

CASE STUDY [7]: Clark County public utilities in Vancouver, WA outfitted 10 large man lifts and 8 one-ton cargo vans with anti-idle technology. The system automatically starts and stops the engine based on a controlled set of programmable values. The system augments the existing vehicle with a 3kW inverter and multiple sets of auxiliary batteries to provide power to emergency lights, work management systems and other auxiliary systems for more than 3 hours. 6 years of data has shown about a 10% reduction in idling without any impact in how the workers perform their job.

Other Commercial Vehicles

The two case studies presented in this paper show a pretty significant impact on fuel economy and vehicle maintenance/life of commercial trucks, municipal vehicles and utility trucks. As more of these case studies are presented, more commercial and government entities are studying how anti-idle technology can be applied more broadly to save money. These applications include any commercial or municipal vehicles that spend a lot of time idling. Vehicles currently being studies include delivery trucks, buses, garbage trucks and most recently…..Military Vehicles.

Potential benefits of anti-idle and start/stop technology to Military vehicles

The Department of Defense currently operates a myriad of different types of vehicles from Special Forces two seat "dune buggies" to F-35 jets. According to dailyenergyreport.com, the DoD is the single most oil consuming entity in the world, consuming and average of 350,000 barrels of oil per day! [8] Although the amount of oil use has been declining slightly over the past few years, it is imperative that technology is introduced, especially to military ground vehicles, that not only reduce fuel consumption, but allow for longer operation of our ageing fleet.

The US military ground fleet has a number of missions that it supports. Combat vehicles, which include M1 Abrams and the Bradley fighting vehicle are the backbone of the US Army and USMC's fighting force. These vehicles and the men who operate them, however, are of minimal impact without the ground tactical vehicles that make up the supply trains that support them. These vehicles are typically referred to as Combat Support (CS) and Combat Service Support (CSS) vehicles which often travel in convoys to support the front line combat vehicles with food, fuel and bullets.

Light, medium and heavy tactical vehicles spend a lot of time in convoys both in training and in combat. They spend significant amount idling during convoy line-up, refueling halts, halts due to mechanical failure and rest and meal halts. [9] Other ground vehicles, such as Mine Resistance Ambush Protected (MRAP) vehicles, spend a significant amount of time in the combat area, often operating in a "silent watch" capacity, with power hungry auxiliary loads requiring the vehicle to idle.

With the IED attacks common in theaters like Iraq and Afghanistan many American lives are lost in escorting fuel convoys. In 2009 Congressional Testimony, the DoD Under Secretary of Defense for AT&L stated that "protecting large fuel convoys imposes a huge burden on the combat forces". In the same year at the U.S. Marine Corps' Energy Summit, General James Conway identified fuel convoy security in Afghanistan as one of his most pressing problems related to risk of casualties. A Deloitte study on energy security concludes that fuel savings "can be a direct cause for reductions in wartime casualties and may rank on par with the business cases for development of ever more effective offensive weapons, sophisticated fuel transport tankers, [and] mine resistant armored vehicles"[10].

Although the case studies presented earlier in this paper show the direct correlation between commercial vehicles and military vehicles in regards to anti-idle technology, it is important to notice the differences between the vehicles as the differences amplify the need for this technology for military vehicles. For instance, commercial vehicles have the luxury of moving to the nearest gas station when they are out of fuel. Military vehicles typically do not. Commercial vehicles can drive to the nearest service station to perform maintenance on the vehicle, whereas, especially in a combat environment, maintenance must be performed in the field. Commercial vehicles not being available due to maintenance have a direct monetary impact on the vehicle's owner, where Military vehicles impact is more deep if the vehicle can't deliver the beans, bullets and fuel necessary for the Warfighter. Bottom line is that anti-idle technology on military vehicles has the ability to save the DoD a significant amount of money, but more importantly, has a significant impact on the lives it will save!

Lithiumstart Intelligent Charge Control System w/Anti-Idle to Minimize Fuel Consumption

Lithiumstart has developed an advanced fuel saving algorithm that dynamically manages the vehicle's engine and electrical systems and can be implemented in a wide variety of military and commercial platforms. It is critical to note that this can be implemented without changing how the soldier operates the vehicle or reducing mission readiness, while also extending silent watch and enhancing the user's information awareness. Using a variety of innovative approaches, a significant fuel savings can be obtained quickly and cheaply using an adapted COTS bolt on embedded controller.

Saving fuel is accomplished primarily by turning off the engine when it's not needed (anti-idle), and using it more intelligently when it is on (e.g. fast charging batteries, regenerative braking, etc.). This intelligence will be embedded in what is termed a Power Management Controller (PMC).

The fuel savings algorithm on the PMC will intelligently manage vehicle components like the battery, alternator, and engine control unit using a shared SAE J1939 Controller Area Network (CAN) bus. The PMC will also manage the battery's State of Charge (SoC) and present this information to the Warfighter.

The PMC hardware and the anti-idle software algorithms will be flexible enough to be integrated in current and future vehicles that utilize a wide array of engines, alternators, and battery monitoring systems. The BluFlex COTS reference platform hardware is implemented on a compact PCB and includes a general purpose micro controller, dedicated hardware CANbus controllers, temperature sensors and accelerometers, general purpose analog and digital inputs/outputs, high speed current and voltage sensing, and contactor control including bus pre-charging. The platform runs on 5-30VDC input and is extremely power efficient. It draws under 10mA in standby at 28VDC and less than 50mA while running in typical implementations, all on a PCB less than 2x4 inches in size and 1/2 inch high.

Figure 1. Lithiumstart BlueFlex hardware.

BluFlex platform code is written in standards based C and runs on top of a micro real time operating system for guaranteed deterministic performance and low latency event handling. The software is modular and loosely coupled, with the algorithm rules engine (which will run the anti-idle algorithm) and business logic abstracted from the driver layer enabling hardware abstraction and portability. BluFlex has both a GUI and a scriptable Command Line Interface (CLI) which supports automated unit testing, to ensure high quality code releases, as well as rapid prototyping and tuning of the platform during R&D and drive cycle testing. In the future, this feature can enable the learning algorithms that can be integrated.

The BluFlex platform has data logging capabilities that could be used to record system data for later retrieval during maintenance of the system. This data can be used to manage fleet wide fuel efficiency by providing algorithm feedback for new systems or updates to existing systems. The platform logging utilizes state of the art linked data (aka Semantic Web) ontologies and open data interchange formats including JSON-LD and XML. This data could also be used for vehicle diagnostics such as comparing the effects of different control strategies on battery life, and could provide a wealth of information that is not currently available to assist in further energy efficiency research. The BluFlex platform also has contactor controllers, fan controllers, several additional communication interfaces, and multi-channel temperature sensing, providing options for expansion that could see load shedding, BMS, and other functions integrated into a common BluFlex PMC platform.

The abundance of data available to the PMC enables it to make smart decisions and allows for diagnostic capability such as state of charge of the battery and peak output current of the alternator. Future variants of the PMC will use this data and integrate prognostic capabilities through learning algorithms that will account for varying parameters such as state of health of the battery, starter efficiency and alternator efficiency. This data can have a profound effect on the decision making process based on changes to the subsystems over time, temperature and usage, ensuring the vehicle power system is controlled optimally, no matter what the age/condition.

The BluFlex platform is proven in multiple DoD and US Government applications with versions at TRL 9, deployed by the US Navy. BluFlex is also the chosen BMS platform for the Army TACOM Power Brick program led by BAE/SAIC which is currently at TRL 4/5. BluFlex is also the BMS platform for another SBIR award from MDA for a UAV based pulse power laser battery pack designed for the experimental USMC OBVP HMMWV Program, and for a new generation of NOAA weather buoys currently contracted by the National Data Buoy Center. A representative BluFlex PMC board is shown in Figure 1.

The Lithiumstart anti-idle system was demonstrated on a commercial box truck in a phase I SBIR effort, which utilized the same engine, alternator and batteries as a similar Military vehicle. Using a standard operating profile, the introduction of the start-stop algorithms

showed significant fuel savings compared to the same operating profile without the Lithiumstart system.

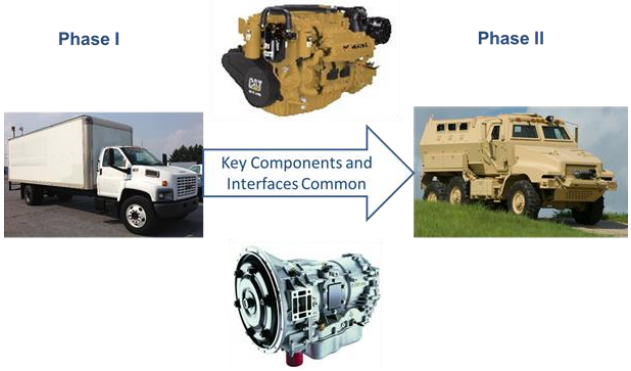

Figure 2. Current status and path forward of Lithiumstart's anti-idle technology.

In the next phase of this TARDEC funded SBIR program, Lithiumstart will integrate the anti-idle technology on a standard MRAP vehicle. During this phase of the program, the main focus areas of the work will include:

- Configuration Definition and Roadmap
- Enhancement Evaluation
  - *Dynamic Engine Idle Speed Control*
  - *Lithium Ion 6T batteries*
  - *Load shedding/relay control for starting*
  - *Mild Hybridization*
  - *Algorithm Self Learning*
- Algorithm Demonstration Preparation
- Algorithm Demonstration
- Detail Design of Prototype
- Preliminary Environmental Testing
- Final Design and Fabrication

SUMMARY

Commercial vehicles have experimented with anti-idle technology for over 40 years. Despite early success, these technologies did not gain traction for a number of years. Due to rising fuel costs, longer life cycle requirements and mandates for emission reduction, anti-idle technologies continue to gain traction in the commercial market. Although the Department of Defense's mission is different than that of commercial missions, the vehicles are typically used in similar capacities and spend a significant amount of time idling. The differences between commercial vehicles and military vehicles highlight the need for this technology sooner than later. Anti-idle technology will not only bring fuel savings to an oil hungry fleet, but it also has the potential for reducing time between maintenance, increase the life cycle of the vehicle's engines and keep Warfighters out of harm's way. Lithiumstart has demonstrated the effectiveness of this technology on a commercial vehicle using similar vehicle components as a typical Military vehicle and is currently executing a program to integrate this technology on an MRAP vehicle. Upon completion of the program, Lithiumstart will be in a position to demonstrate the impacts of the anti-idle system on a Military vehicle and show applicability to other vehicles in DoD's fleet.

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ABOUT THE COMPANY

Lithiumstart, Inc. designs and builds cutting edge lithium ion Energy Storage Systems (ESS) for marine, motorsport, aerospace, industrial, and government customers. We are a turnkey integrator, sourcing the best

cells from around the globe and then packaging them with enclosures and management electronics. We change the way people communicate, travel, work and play, by taking on unique and challenging projects that bring disruptive new products to market. We are proud to work closely with Fortune 500 companies, major universities, research institutions, government entities, and innovative private sector small businesses from around the globe. Lithiumstart is US owned and based, and is ITAR compliant. Our state of the art R&D lab Facilities are located at our headquarters in South Francisco, California. For questions or comments, please visit our website at www.lithiumstart.com.