Auxiliary Power Unit (APU) for Military Vehicles

Jeff Humble
General Dynamics Land Systems
Muskegon, MI

ABSTRACT

General Dynamics Land Systems has developed an Auxiliary Power Unit (APU) that provides 508A at 28VDC, for 14.2 KW. It is a stand-alone system, independent of the vehicle systems, except for utilizing vehicle fuel and vehicle batteries. Power is generated by a 570 amp alternator that is belt-driven by a diesel engine. It is load following which improves fuel efficiency and eliminates the probability of "wet stacking." All the major components are commercially available and the APU is ready for production.

INTRODUCTION

The APU is a diesel powered generator system utilizing commercially available major components (Figure 1). It is externally mounted and is a stand-alone system, independent of the vehicle's systems, except for fuel and batteries. It is capable of providing up to 508A at 28VDC directly to a vehicles primary power distribution system to augment the vehicle electrical power. The APU operates as a load following system and runs automatically once started by the user. It is housed in an unarmored enclosure and can be reconfigured for different vehicle applications and still utilize the same major components. The primary components consist of a Kubota V1505-T 1.4L, 4-cylinder liquid cooled turbo charged diesel engine and a C.E. Niehoff N1609 570A alternator.

Figure 1 – APU

APU ENGINE

The engine is a Kubota V1505-T turbo charged, 44.2HP diesel. It is commercially available and has been in production since 1991 with approximately 37,000 sold to date. The V1505-T engine complies with EPA Interim Tier 4 emissions regulations that are effective through the end of 2012. The compact engine weighs 251 lbs. dry and measures 24"L x 24.5"H x 17"W. It is fuel injected, has a remotely located fuel filter/water separator and is compatible with a variety of fuels including DF-2, JP-8 and Ultra Low Sulfur Diesel (ULSD). The turbo charged engine provides the required horsepower for elevations, up to 12,000 ft. It is shock mounted inside the APU enclosure to minimize noise and vibration. The engine has a 24VDC electrical system including its electric starter motor. Basic functions such as engine starting and warm-up are controlled by a Woodward engine control unit (ECU). The ECU also controls the engine speed, running between 2000 rpm at idle up to 3000 rpm for max power. The ECU is programmed to shut the engine down if it senses that the coolant temperature or oil pressure has exceeded safe limits to protect the engine from damage. A user can connect a computer to the ECU via an outboard computer interface to read and clear diagnostic codes.

APU ALTERNATOR

Power is generated by a C.E. Niehoff N1609 alternator rated for 570A at 28VDC, weighing 115 lbs., and measuring 8.9"diameter x 15.5"L. This alternator is a recent offering and is part of C.E. Niehoff 1600 series which has over 23,000 units fielded to date. The 570A alternator is based on a previous 400A military qualified production design with over 4,800 units of the N1609 currently in use on Mine Resistant Ambush Protected (MRAP) vehicles. The alternator is air cooled by a self contained cooling fan and its voltage regulator contains built-in thermal protection to protect against overheating. It is rated for ambient temperatures of -65°F to 200°F and produces power between 1500 and 8000 rpm. It is mounted above the engine by a mounting bracket bolted to the enclosure. The alternator is driven by a belt system consisting of a 10 groove Gates Micro-V belt, a custom pulley bolted directly to the engine flywheel, and a spring loaded belt tensioner.

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APU COOLING SYSTEM

The APU has a self contained, closed loop water-ethylene glycol (WEG) cooling system, independent of the vehicle's cooling system. The radiator is custom sized to fit in the space constraints of the APU enclosure and has two variable speed electric fans. The radiator with fans measures 26"L x 15.5"H x 4.2"W and weighs 30 lbs. dry. The cooling system is rated to provide 38kW of heat rejection at 131° F ambient temperatures. A coolant surge tank is located inside and near the top of the enclosure and is used for filling, bleeding, and maintaining coolant level within the system. It has visual gauges for checking coolant levels and the surge tank can be filled through an access door at the top of the enclosure. Cooling air is drawn into the APU from the vehicle side of the enclosure and exhausted through grills and the screened bottom. The variable speed fans automatically reverse direction for 15 seconds at start and at ten minute intervals to clean the radiator fins from dust, sand and other debris.

ENGINE AIR CLEANER

The system uses an oversized air cleaner assembly which is 60% larger than required for the engine to overcome harsh sand and dust environments. This system consists of the assembly housing, filter element and pre-cleaner. It is mounted on top of the APU enclosure which provides easy access for inspection and periodic cleaning.

APU CONTROLS

The APU is operated by a Man-Machine Interface (MMI) panel that measures 7.8"L x 4.8"H x 3.5"W (Figure 2), it can be remotely located within the vehicle. The MMI provides for all APU operation with an engine On/Off switch, vehicle system voltmeter display, APU current output display, and a Battle Override switch that disables the APU's automatic shut down sequence. The MMI has indicator and warning lights to allow the operator to monitor the APU's operation.

Figure 2 – APU MMI Panel

The "Engine On" light indicates the APU engine is running. The "Voltage Low" light indicates the vehicle system voltage has dropped below 22VDC, APU and the vehicle batteries are discharging. "APU Shut Down" light provides a warning that a system fault, a high coolant temperature or a loss of oil pressure, has been detected and the APU will automatically shut down in 30 seconds. "Door Open" light indicates the APU door is open. A "Fire Detected" light provides a fire warning indication.

ENCLOSURE

The APU components are housed in an unarmored lightweight aluminum structure that is mounted externally to the vehicle. The structure is 33"L x 45"H x 24"W and weighs 128 lbs. The enclosure has aluminum walls to protect the APU components from rain, mud and brush. The APU is designed with maintainability for the user as a high priority, providing easy access to APU components from four different sides. The enclosure's main exterior surface is a large door that provides access to the system for routine inspections and maintenance. The door can be locked for safety and security. Visual indicators located on the Man-Machine Interface panel also alert the operator inside the vehicle when the door is open. The top surface of the structure is a bolt-on aluminum cover which is easily removed for access during installation and maintenance. The bottom and rear surfaces are grills to provide for cooling airflow and drainage, and are removable for routine maintenance. The enclosure has been designed to withstand 10G vertical loads. A bulkhead interface panel is located on the back side of the enclosure to allow for power and signal cables pass through to connect to the host vehicle. Additionally, two bulkhead connections are located at the interface panel for the fuel supply and return lines. These connections use standard quick disconnects for installation and maintenance.

The enclosure is specifically designed for MRAP vehicles, but can be easily reconfigured for any vehicle application while utilizing the same major components (engine, alternator) to adapt to other footprint requirements. The enclosure can also be configured with integral armor for small arms protection at an additional weight and cost.

APU OPERATION

The APU is operated and monitored by the user from within the vehicle, once started, operation of the APU is fully automatic and requires no user involvement. The APU is load-following and slave to the vehicle's voltage regulator. The APU reads a voltage change from the vehicle's voltage regulator and automatically controls the RPM of the engine to match the alternators output to that of the demand from the vehicle. The load following capability of the system helps to eliminate wet stacking of the engine associated with running a diesel engine at a constant RPM, and provides better fuel economy.

APU MAINTENANCE

The APU design was strongly influenced by Specialty Engineering for maintainability, reliability, availability and supportability during its development. Key components were required to demonstrate a high level of reliability to ensure a robust product. Reliability predictions were generated using data from the Non-electric Parts Reliability Data (NPRD) which resulted in a system reliability prediction of 1213 hours mean time between failures (MTBF). Maintainability assessments resulted in a mean time to repair (MTTR) of 0.4 hours.

All components within the system can be removed and replaced without removing the APU from the vehicle. Clear areas of access are provided by the main door and access panels which support conducting preventative maintenance checks in less that one minute. The engine air filters external location makes it easy to quickly check and clean. The engine oil filter and dip stick are immediately accessible from the door and the oil drain plug is accessed via the removable panel on the bottom of the enclosure which permits a quick oil change in under 15 minutes.

There are four components that collectively make up 50% of the systems unscheduled maintenance burden, in order they are forward cooling fan 19.9%, engine 14.1%, rear cooling fan 13.3% and water pump 3.7%. The APU is designed to ensure adequate access to these, and all components for maintenance. Analysis of replacing the forward fan was performed to verify that APU design is consistent with current combat vehicle maintenance concepts.

CONCLUSION

The GDLS APU is production ready, all major components are readily available as Commercial Off The Shelf (COTS). Four pre-production units were fabricated as both test hardware and to provide the learning curve for production hardware. An APU has many advantages over a vehicle engine driven generator system, intrusive integration that depending on how the generator is powered and mounted, may require re-certification of the vehicle engine. For a vehicle engine driven generator system, failure of the generator could affect vehicle mobility by causing a failure of the engine. Adapting an engine driven generator system from one type vehicle to another may require significant integration and configuration differences due to differences with the vehicles engine compartment/configuration, different engines, etc. An APU on the other hand needs only a space on the exterior of the vehicle to attach to making it very portable from one type vehicle to another. A significant performance difference between an APU and a vehicle engine driven generator systems is the RPM of the vehicle engine will affect power output. Driving a vehicle under a variety of road conditions and speeds makes it impossible to maintain a constant RPM or keep within the RPM range required for a constant power output resulting in brown-outs and power failures. An APU which is independent of the vehicles engine, can produce power on demand at a more economic fuel consumption independent of the vehicle engine speed, and is decoupled from the vehicle mobility.