AN/FPN-63(V)
Precision Approach Radar 400-Hertz Converter Replacement

Award Winner: SPAWAR Team
The AN/FPN-63(V) Precision Approach Radar (PAR) is the Navy and Marine Corps’ primary precision landing aid for pilots during periods of inclement weather. The system was fielded in 1978, and 37 years later it is facing severe obsolescence issues. Failures of the 400-hertz converter, used for the high-speed cooling fans in the transmitter, was the number 3 system degrader, affecting operational availability (Ao) with 18 failures over a 3-year period. The Space and Naval Warfare Systems Center’s PAR In-Service Engineering Team developed requirements for a replacement, conducted market research, and located a small business currently supplying similar converters to the Army. Working closely with the vendor’s engineers, the government-commercial team created a design that was 98 percent identical to the Army’s converter. This unique design allowed the vendor to standardize its production line so that both converters can be produced during the same production run. This effort resulted in increased Ao for fleet units, a 400 percent increase in mean time between failures (MTBF), and a 67 percent decrease in unit cost. With this converter being used by the Navy, Army, and Marine Corps, the standardization of this part offers the Department of Defense cost savings through increased operational readiness, improved performance, lower cost, interoperability, and a reduced logistics footprint.

Background

The AN/FPN-63(V) PAR is used at Navy and Marine Corps air installations in conjunction with an airport surveillance radar system to provide air traffic control services for Navy, Marine Corps, and other military and civilian aircraft as required. The PAR is the Navy and Marine Corps’ fixed-based primary approach aid used during conditions of poor visibility to provide radar guidance to an aircraft on final approach. The PAR has been in service more than 20 years beyond its estimated product life cycle, is experiencing parts obsolescence issues, and has degraded Ao. Over the past 5 years, repair parts have had an average turnaround time of 194 days. The major reason cited is the difficulty locating or developing new part suppliers. As a result, 47 percent of the PAR systems operated in a severely degraded condition, and 15 percent were non-operational.

A component that has plagued the PAR for quite some time is the 400-hertz converter, which is used to run high-speed cooling fans in the transmitter and is a critical single point of failure item. High-speed cooling fans operated by 400 hertz are required because of the amount of heat generated by the magnetron and charging circuits within the transmitter and the small confined space the transmitter occupies. During a 3-year period, 18 400-hertz converters failed, creating a backlog in the Naval Supply System because the sole-source vendor was slow to respond. The original manufacturer design had a mean time between failures of 1 to 2 years. The original design had several issues that caused the low MTBF to be greatly accelerated by temperatures over 77 degrees Fahrenheit and by worn bearings in the fans, which would cause a failure of a 1-ohm, 5-watt resistor that was in series with the entire 400-hertz converter. With a consumable cost of $6,000 per unit, a low MTBF, and a sole-source vendor with low production runs and poor quality, the fleet stakeholders were extremely frustrated with the sustainment of this part.
Problem/Opportunity

The In-Service Engineering Agent (ISEA) engineers analyzed the existing converter, finding several design vulnerabilities. These vulnerabilities generated a considerable amount of heat inside a sealed metal enclosure, leading to breakdown of all other components within, and an oscillator circuit dependent on a custom wound toroidal transformer and transistors in an “H-bridge” switching arrangement. The team logistician determined that the toroidal transformer and transistors were obsolete and unobtainable. Based upon this knowledge, the project manager determined that it was not cost-effective to reverse engineer the existing converter and approved research to identify a replacement unit. The engineering staff built several breadboard prototypes, and the data gained from those prototypes led the team to consider industrial variable-frequency drive models as a potential solution.

Requests for information and requests for quotes were sent to industry based upon the developed requirements for a replacement converter. The team evaluated the responses and ordered several potential solutions for evaluation; however, all were evaluated to be insufficient for the application and would require extensive nonrecurring engineering costs. Though each of the evaluated solutions could have been designed to work for this application, the team did not want another “one-of-a-kind” solution that only worked for this system. Through this journey, the team was led to an association with a small business named Invention House, LLC, a customizer of commercial off-the-shelf (COTS) variable-frequency drives, which happened to make three-phase 400-hertz converters for the Army.

Approach

Armed with the knowledge of the design vulnerabilities of the original 400-hertz converter, the ISEA engineers began a reverse engineering process to see if it was feasible to build a solution in-house. They produced a prototype “H-bridge” substitute 400-hertz converter, which functioned while driving the target load fan assembly at one-third power for an hour and was extremely stable. However, when it was run at one-half power for 10 minutes, the converter was unstable. After investigation, it was found that lower-quality components caused the instability during power increase. With a proof of concept under partial load achieved, the team set out to identify a higher-quality construction and standard components for the next design.

During this period of research, industrial variable-frequency drive models were identified as a potential solution. An existing COTS solution was identified as the most efficient solution, as the unit was already in production. The project manager discussed the approach with the sponsor and secured funding to procure an article for testing and evaluation. After discussing the requirements with the vendor, the ISEA obtained a unit that was advertised as capable of accepting an input from 110 to 115 volts and providing an output from zero to 500 hertz. Throughout testing, there was difficulty getting this unit to work within this application. After much discus-
sion with the vendor’s engineers, it was determined that this unit was not capable of providing a stable 400 hertz as advertised. Additionally, this unit required a 28 vdc input, which would have negated the form-fit-function requirement. The vendor apologized for the inconvenience and provided the ISEA with the contact information for Invention House, LLC. After discussing the requirement with Invention House engineers, the ISEA thought that a three-phase 400-hertz model it produced for the Army could work for this application. Because the unit was composed of an individual 400-hertz converter for each phase, it appeared practical that this could become a standardized part for Army, Navy, and Marine Corps applications.

The ISEA obtained a unit for evaluation and testing that worked well within this system. However, the ISEA remained concerned about two critical areas of operation: Could it survive an overload condition, such as a fan-bearing seizure, and could it survive in the PAR operating temperature range of −40 degrees to 131 degrees Fahrenheit? These were the main sources of failure of the original 400-hertz converter. After much discussion with the engineers, many design changes, and subsequent testing, a solution was found for both areas of concern.

Originally, it was thought that excessive high-current draw causing an overload fault would happen during motor start-up in high temperatures due to the increasing resistance in the motor windings. What was found was just the opposite. Because the air is denser at colder temperatures, a greater load was placed on the motor during start-up, causing an overload fault. The programmable read-only memory was adjusted through several iterations of testing until an optimized solution was discovered. If an overload fault were detected, the 400-hertz converter would go into an overcurrent cycle sequence where it would shut down for 40 seconds, then come on for 25 seconds, to see if the overload condition was removed. If the overload condition was still in effect, the converter would shut down for 60 seconds and then come on for 19 seconds to test for an overload condition. This sleep then wake up and test sequence would progress, incrementally increasing the sleep time until the overload condition was removed. This created an overload capability of 350 percent for 25 seconds. During environmental testing, the 400-hertz converter passed while operating two fans for 24 hours throughout the temperature range of −40 degrees to 131 degrees. It also passed the same 24-hour test while both fans were locked, simulating an overload condition.

The resultant product is a military design with conformal coating that has passed vibration and temperature testing. Invention House engineers were so impressed with the overload protection design that the ISEA helped them create, they incorporated it into the Army product as well. This standardized improvement will provide increased performance, reliability, and readiness for Army, Navy, and Marine Corps applications.
Outcome

With a usage rate of six per year and an MTBF of 1–2 years, at a cost of $10,550 per unit, the original 400-hertz converter would cost the fleet $1,139,475 over 10 years. At a cost of $1,955 per unit, it cost the Navy $144,670 to replace all 400-hertz converters. With an MTBF of 5–6 years, the Navy will save $850,135 in maintenance costs over 10 years. The government cost of developing and implementing this solution was $81,250 in labor and $1,500 for material. The 400-hertz converter reliability improved 400 percent and increased system Ao by 7 percent, and it has solved the number 3 degrader affecting the system. The original 400-hertz converter had an output of only 1.31 amps maximum and no overload protection, so any increase in the load would cause the converter to fail. The new system has a 2-amp maximum output and a programmed sensing function that puts the converter into a sleep mode, protecting the unit from overload failure. MTBF is expected to increase as long-term data are analyzed. The electronics and programming of the new 400-hertz converter are identical between the Army, Navy, and Marine Corps versions. The only difference is in the housing and base plate, which makes it a form-fit-function replacement for the Navy and Marine Corps.

Current Status

The new 400-hertz converter was fully provisioned and has a National Stock Number (NSN). The Navy and Marine Corps have implemented it, and in the years since, there have been no failures.

Challenges

SPONSOR

The sponsor was reluctant to provide funding for this project because there was a replacement for the PAR that was beginning the acquisition phase. The project manager was able to achieve the funding required by persuading the sponsor of the importance of sustaining the current system until a replacement PAR system is found to be viable.

STAKEHOLDERS

The stakeholders were comfortable with what they had been using over the past 37 years and were hesitant about the development of a new component. Again, the project manager was able to convince the stakeholders that it was in their best interest to allow the ISEA time to identify a replacement for the original 400-hertz converter.
About the Award Winner

The PAR In-Service Engineering Team included Richard Gunn, Stephen Cox, Terry Stockton, and Erin Yakes.

Richard Gunn, project manager, was instrumental in leading the team that developed the design solution. He overcame obstacles, including sponsor reluctance to provide funding, initial engineering failures, and slow user buy-in, to lead the team of government and industry engineers to develop the design solution. He was able to influence the sponsor to provide the required funding and obtain fleet buy-in by presenting the new design to fleet stakeholders at various events, demonstrating the improved capability, and selling the new system to the fleet community. Before Mr. Gunn’s involvement, the 400-hertz converter was a top degrader that was consistently cited as a major problem by the fleet at all user forums. However, thanks to his leadership and expertise, the 400 Hertz converter is now seen as an example of ISEA success by fleet stakeholders.

Stephen Cox, lead engineer, provided analysis of the failure mode of the original unit, producing the reverse-engineered schematic and toroid characterization. He then researched replacement components, mounts, and packaging for a suitable circuit substitution and originated schematics for several prototype replacement options for evaluation. He was also the principal engineer in reaching out to industry to locate a commercial firm capable of addressing the obsolescence issues. Mr. Cox’s background in manufacturing engineering, knowledge of existing and future manufacturing technologies, and practical experience were critical in the identification and development of 400-hertz converter requirements. He led the engineering effort for the ISEA, providing key suggestions for design solutions, ensuring continued forward progress to keep the effort on schedule and on budget, and ensuring that the final design met all critical design requirements.

Terry Stockton, ISEA engineer, was the key engineer responsible for initial prototype efforts, playing a critical role in developing the engineering requirements, and he brought a much needed fleet perspective to the efforts. He originated schematics for several prototype replacement options and conducted construction of replacement circuit options. He additionally provided “Simulation Program with Integrated Circuit Emphasis” circuit analysis to evaluate replacement options. Mr. Stockton conducted all testing evolutions and ensured that the final solution would indeed meet the MTBF requirements and would continue to operate successfully in the defined operational environment.

Erin Yakes, logistician, coordinated all logistics efforts required to make the new 400-hertz converter available to the fleet. She worked directly with the vendor to ensure that the new 400-hertz converter maintained a form-fit-function replacement profile. Additionally, she ensured that all drawings were accurate and complete, and she reviewed all testing data to validate indicated performance and MTBF. Ms. Yakes was also responsible for developing the provisioning data and submitting it to the Naval Supply Systems for the creation of an NSN. She also updated the system Allowance Parts List and technical manuals with the new part number.