Proceedings of ASME Turbo Expo 2011
GT2011
June 6-10, 2011, Vancouver, British Columbia, Canada

GT2011-45911

FULL AUTHORITY DIGITAL CONTROL (FADC) LOCAL OPERATING PANELS (LOCOPS)…THE FOUNDATION FOR IMPROVEMENT

Christopher Corso
Naval Surface Warfare Center Ships System Engineering Station Code 934/936 In Service Surface Combatant Gas Turbine Electric Power Generation/Distribution
Philadelphia, PA, USA

Andrew Bigley
Naval Surface Warfare Center Ships System Engineering Station Code 936 In Service Surface Combatant Electric Power Distribution
Philadelphia, PA, USA

Brian Connery
Naval Surface Warfare Center
Ships System Engineering
Station Code 934/936 In Service
Surface Combatant Gas Turbine
Electric Power
Generation/Distribution
Philadelphia, PA, USA

Jeremy Nichols
Naval Surface Warfare Center
Ships System Engineering
Station Code 934/936 In Service
Surface Combatant Gas Turbine
Electric Power
Generation/Distribution
Philadelphia, PA, USA

ABSTRACT

Full Authority Digital Control systems are the premier control system. The applications are limitless (motorcycles to power plants and everything in between). Over the past 15 years, the US Navy has worked successfully with Woodward Governor Co. to develop and implement FADC LOCOPs for use in a number of applications including DDG and CG class ships gas turbine generators. The FADC LOCOPs provide closed loop control features as did the old analog control systems. But the FADC LOCOPs add the ease and speed of control improvements via software change, constant data monitoring/recording and network connectivity. The network connectivity advantage is still early in development; however this key feature of the control system opens up many doors. Distance support can be taken to an entirely new level via the network. Imagine a setup where if the control detects an abnormality…an email containing control system data gets sent to the blackberry of the In Service Engineering Agent (ISEA) so immediate action can be taken to maintain system reliability and reduce overall system cost. This future can help save money and avoid expensive catastrophic failure via condition based maintenance. In this future, it is possible that eventually the ISEA suggestions can be prompted right back to the FADC LOCOP so the sailors onboard can communicate with the ISEA via the FADC LOCOP. Essentially, every ship could have the ISEA (or an ISEA representative)onboard 24 hours a day seven days a week via FADC LOCOP communicating over a network. The system is not this evolved yet. However, several Navy Programs are working in conjunction towards a similar future including DDG Modernization and Integrated Condition Assessment System (ICAS) via Maintenance Engineering Library Server (MELS) and Integrated Performance Analysis Reports (IPAR). FADC LOCOPs are the foundation upon which these improvements rely to be implemented…thus the premier control system.

INTRODUCTION

From the mid 1990s until the mid 2000s, FADC LOCOPs were developed and implemented aboard DDG-51 class(Figure 1, 60+ ships and counting) destroyer gas turbine generators. Follow on work for CG-47 class(Figure 2, 21 ships) cruiser gas

turbine generators resulted in the development and implementation of another FADC LOCOP. There are three gas turbine generator sets per each hull…so total FADC LOCOP implementation on gas turbine generators is at 243 units and counting.

The two FADC LOCOPs are different units…however they are alike in both concept, capability and challenges.(Figures 3 and 4, DDG FADC LOCOP and CG FADC LOCOP respectively). Since these ship classes received these control systems, some newer gas turbine FADC LOCOPs have been and are being developed by Woodward Governor Co. with Rolls Royce Naval Marine Inc. for use aboard LCS Littoral Combat Ship class and future DDG 1000 class destroyers. The success of the FADC LOCOP aboard both the DDG51 and the CG47 class gas turbine generators has provided a new standard in local digital control systems upon which an entire support network is being built and utilized to make equipment more reliable and ultimately reduce total ownership cost (TOC).

Figure 1. DDG-51 Class Destroyer

Figure 2. CG-47 Class Cruiser

Figure 3. DDG-51 FADC LOCOP (similar to LCS and DDG1000)

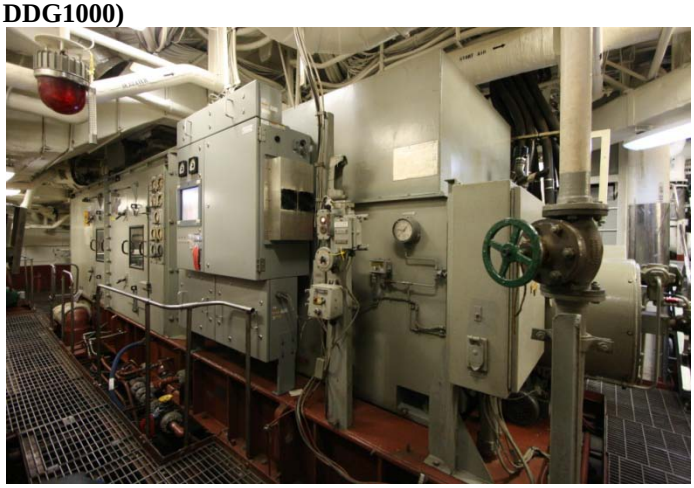

Figure 4. CG-47 Class FADC LOCOP

FULL AUTHORITY DIGITAL CONTROL LOCAL OPERATING PANELS (FADC LOCOPS)

Prior to FADC LOCOP implementation, system troubleshooting frequently resulted in costly parts being replaced unnecessarily as maintenance personnel guessed based upon real time information about exactly which component(s) may be faulty (Dennis M. Russom P.E., 2005). The old style LOCOP has no data recording capabilities which made trouble isolation difficult. The system also lacked the flexibility required to adapt to changing needs (Dennis M. Russom P.E., 2006). Often, if distance support were required, the support process depended on people talking or maybe emailing trying to explain what the generator set did or failed to do to someone who may be thousands of miles away. The FADC LOCOP was the answer to improving these issues. The FADC LOCOP provides data recording, trending, graphing and downloading capabilities. Once the ships were equipped with the FADC LOCOPs, troubleshooting capability was catapulted to really two entirely new levels. The shipboard troubleshooting went from a local real time observation based troubleshooting technique to a remote data analysis technique.

For example, before FADC LOCOPs were implemented, if a ship were having an issue starting a generator, it would not be uncommon to have one person watch the old LOCOP while a second person watched a gauge panel for various pressures and a third person watched inside the gas turbine module or maybe watched an electrical meter setup someplace. A start would be attempted and if nothing happened, the person at the LOCOP would communicate what they saw and discuss it with the other two people who were watching and based upon those observations action would be taken and a start would be reattempted to see if there were any change. Now that FADC LOCOPs have been implemented, a similar trouble starting a gas turbine generator issue will result in one failed start worth of data being saved at the FADC LOCOP and subsequent data analysis to isolate and correct the issue. Current FADC LOCOP configurations allow for the saving of 3 different types of data. Alarm data is a very small file which provides an output file which shows different discrete values in the software as they cycle. Heater data (.htr) is also a relatively small data file(easy to transfer) which logs data in 4 hour increments with a 1Hz sampling rate and produces a chart output. This type of data is effective for long term trending information, but not as effective if troubleshooting a gas turbine start issue, an electrical issue or an unexpected generator shutdown. The third kind of data is the burst data. The burst data is configurable (different durations and/or sampling rates), but right now most signals are sampled every .08s and saved for 2 minute durations and then overwritten. This data also is presented in chart form with a variety of options to aid analysis (configurable parameters to display, scaling, two moveable cursors, zoom in/out, etc…)(Figure 5). This has proven to be a very effective compromise between available data and file size for data analysis concerning most generator issues (start/stop issues, loadshare issues, alarm isolation, transient response, etc…). Figure 5 is a 1500Kw transient experienced by a generator with ~2.5s between the cursors.

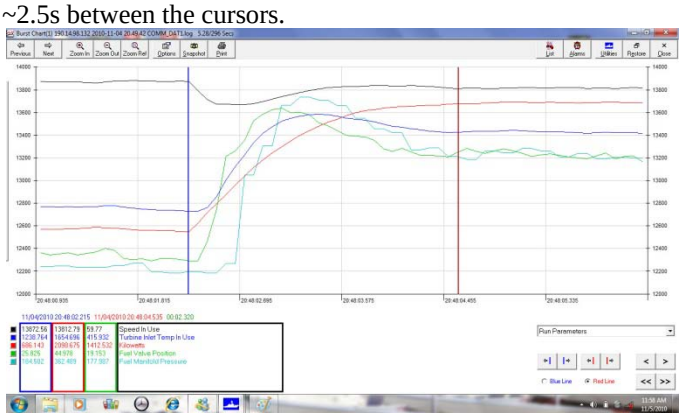

Figure 5. 1500KW Transient

With the old LOCOP, many times for trouble isolation, if the problem could not be isolated and resolved between the three personnel watching each failed start attempt, they could call (more recently email) Regional Maintenance Center (RMC) subject matter experts for help. If additional assistance were required, then the In Service Engineering Agents (ISEA)s could be contacted for help. However, the distance support effectiveness with the old LOCOPs was completely dependent upon the accuracy of the story of events being relayed first to the RMCs and then to the ISEAs. Data capture with the old LOCOP required the connection of external recording equipment. These were major hurdles which the FADC LOCOP overcame.

Distance support troubleshooting went from a word of mouth/human observation/memory technique to a distance support data analysis and recommendation technique. So, same scenario, except ship is equipped with FADC LOCOPs, the capabilities are far greater. If the individuals at the generator cannot isolate a problem, they can copy data to a CD from the FADC LOCOP human machine interface (HMI) computer and then transfer the data to the RMCs and/or the ISEAs. Data transfer options consist of both Navy email and Weblog. Weblog is a Navy operated web site for both foreign and US Navy personnel. The data can be uploaded there and then downloaded elsewhere for analysis. So, given the first generation of FADC LOCOPs, the verbal communication hurdle was overcome with the advent of data capture and transfer capability. However, this ability is somewhat compromised by forcing the use of CDs (a media which will be obsolete long before the service life of these ships has passed).

The original chop at overcoming the hurdles associated with data transfer via email or Weblog was in the form of Integrated Condition Assessment System (ICAS). However, ICAS looks at the entire ships machinery, not just the generators for bandwidth is limited. It becomes a challenge having to choose what information and at what sampling rate is pertinent. On DDGs, the FADC LOCOPs communicate with ICAS via serial port. Essentially, ICAS combined with Maintenance Engineering Library Server (MELS) and Integrated Performance Analysis Reports (IPAR)s provides a continual flow of data from the DDGs (and more) for daily review by both RMCs and ISEAs. The systems are very large picture and cover much more than just the gas turbine generators. From the gas turbine generator perspective, these systems currently rely on a serial connection from the FADC LOCOP. The bandwidth limitations of the serial connection are a factor in future growth designs. Also, the fact that the ICAS/MELS/IPARS systems are so all encompassing/large scale does present challenges in trying to optimize SSGTG cost savings/reliability improvement. Despite these limitations, the proof of concept is here. The programs are highly successful and provide valuable tools for the Navy to use to increase reliability and reduce operating costs.

So, this has been the progression over the past 10-15 years. Now we (US Navy) have reached the DDG Modernization upgrade. The machinery control system for the DDGs is being completely upgraded. Combine that upgrade with the pending obsolescence issues of the current DDG51 class FADC LOCOP Woodward Netcon control computer and we are at another stage of evolution in the local controller environment(first evolution was LOCOP to FADC LOCOP, we are now at the FADC LOCOP to Modernized FADC LOCOP evolution).

In conjunction with DDG Modernization, the DDG FADC LOCOPs are being upgraded. The Woodward Netcon control computer is being replaced with the Woodward Micronet control computer. The largest benefit is the Woodward Micronet(FADC LOCOP) is going to be on the ships MCS network via Ethernet. So, now the bandwidth issues of the old serial connection to ICAS have been addressed (hardware in place). The CG FADC LOCOPs were designed several years after the DDG FADC LOCOPs. As a result, the CG FADC LOCOPs already have the Ethernet capability that the DDG FADC LOCOPs are now receiving.

So, what the fleet is moving towards is Ethernet capability for all the gas turbine generators. The hardware is either in place or going to be installed as part of DDG modernization. That data connection is really key. Once the FADC LOCOPs are placed on a network, the potential cost savings/reliability improvement benefits really grow. However, with this upgrade, new challenges are presented. Managing the data vice the available bandwidth is a challenge. Over time, bandwidth capabilities will grow…as will bandwidth requirements as more subsystems incorporate local digital controls with high density data capture functions. The local control systems will have to be setup with software which will filter through the data and only send relevant high speed data snippets as required(for example when a generator unexpectedly shuts down or fails to start).

Communication between the operator(s) and the RMC/ISEA subject matter expert(s) is instrumental in maximizing operating hours per maintenance dollar spent. If the FADC LOCOPS are placed on an Ethernet network which can provide for direct real time communication and data analysis between ships force, RMCs and ISEAs, the Navy Gas Turbine World will benefit greatly in the form of reduced maintenance costs and increased mean time between failures.

Back to our original scenario, a ship is having problems starting a gas turbine generator. If the gas turbine generator FADC LOCOP is on a network, a software help button could be setup such that the operator can depress the button and open a dialogue with RMC or ISEA experts. More buttons could be added…like a send data button so the operator could send the data via network directly to whoever is on the other end of the help button connection for immediate analysis and recommendation. ICAS/MELS/IPARS could be incorporated to the DDG modernized machinery control system and existing data transfer paths could be utilized for communication and FADC LOCOP data transfer.

One caveat to the entire thought of maximizing communication between the experts and the operator(s) would be to design the control with automated data analysis which could provide basic analysis and troubleshooting advice. Ideally, both the near limitless communications direct from the FADC LOCOP via Ethernet between the experts and the operators and also the implementation of automated local data analysis should be fully pursued. This way, the sailor would use the automated tool(s) and if those do not help, then they could easily communicate with experts. It is very similar to calling into a help line and having to go through the automated menu first(troubleshooter software) before depressing 0 to get an operator(RMC or ISEA). Current software upgrades and maintenance are accomplished by either CDs being snail mailed to ships to self installation or by RMCs or ISEAs visiting the ships and accomplishing upgrades. As the fleet expands, this task is ever growing. With full connectivity as made available via Ethernet connection, software upgrades/maintenance could be accomplished completely over the network in a transparent manner much like how software maintenance is accomplished in many office environments today.

Current revisions of FADC LOCOP software do include automated data analysis and troubleshooting tools. These tools, like the FADC LOCOPs themselves, are constantly evolving.

The FADC LOCOPs, like the LOCOPs which preceded them are subject to the same changing environment that the rest of the electronic world is subject to. The Woodward Netcon Control computers are programmed not by Ethernet or USB…but by serial cable and hyperlink (dated concepts to recent college grads and modern developers) or PCMCIA card. The PCMCIA cards are very difficult and relatively expensive to purchase as are the readers to support the cards. Hardware obsolescence issues such as these face the FADC LOCOPs. The FADC LOCOPs are flexible enough to adapt. The Netcon control computer is being upgraded to a Micronet control computer. The Micronet can be programmed via Ethernet. The HMI computers started as Pentiums, then evolved to Pentium 3s, then Pentium 4s and now Core Duos(over the course of 10 years!). However, the FADC LOCOP design is flexible enough that HMI computer changes are minimally invasive on the hardware side (software adaptations need to be accomplished). All the current HMI computers support USB connectivity. At the moment, the USB features are not being used, but in the future those USB ports may be used for any number of items including but not limited to software restoration/upgrade, operating system functionality, Web Cam/conference call troubleshooting support, data transfer, etc….

Another change the future holds which the FADCs Ethernet connectivity upgrade can benefit from is the coming changes to the Kato voltage regulators. The newest DDGs are being built with not only all these modernization upgrades, but also the installation of digital voltage regulators in place of the existing regulators. The modernized FADC LOCOPs provide the flexibility required to open up communications between the new voltage regulators and the FADC LOCOP. This communication link can be used to get information previously not available tied into the network and data charts. This additional information may prove to be valuable information for future troubleshooting and possibly for future voltage regulation/control features such as constant in phase operation of generators operating in split plant.

As the FADC LOCOPs are today, the Ethernet connection hardware is either in place or being installed to support a quickly evolving Navy Gas Turbine community. This hardware is the foundation upon which improvements may be developed

to further reduce costs and increase reliability. Just a few of the cost saving options which are open with the installation of the Ethernet connectivity:

1. Real Time Remote Communication and Data Transfer Over Network between ships force and shore based experts, possible future use of USB web cam and headset for video conferencing over Network
2. FADC LOCOP Software maintenance/upgrade over the Network managed by shore based ISEA
3. FADC LOCOP Constant Data Analysis and Monitoring via development of ICAS for interaction with Ethernet Network aboard DDG Modernization Equipped DDGs
4. Possible constantly available link between ISEA or RMC personnel and FADC LOCOP via PDA or future smartphone application
5. Data recording, analysis and possibly control of information provided by a digital voltage regulation system

The FADC LOCOP is a local digital controller with built in data recording, monitoring and transfer capabilities which is now being placed on networks easing the transition to remote data analysis and service recommendation. Any entity with fleet equipment which requires specialized knowledge can benefit from the ability to provide remote data analysis and service recommendation as made possible by a local digital controller. Commercial applications for such controllers (they may not be called FADC LOCOPs, but they are still local digital controllers with data recording and transfer capabilities) are already very commonplace. Cars, boats, motorcycles, aircraft, tractor trailers, agricultural equipment, pipeline equipment, power generation/distribution equipment, mining equipment, refinery equipment, etc… are already equipped with local digital controllers. The local controller is the foundation. The remote data analysis and service recommendation is the future.

An example of a fleet operator that may be interested in the ability to remote monitor and analyze system data would be an airline. Right now, when there is a mishap with an aircraft, recovery of the black box(s) containing system data become a very important part of the mishap investigation. Imagine if aircraft local digital controller(s) could communicate over a network such that any time a parameter or parameters go out of tolerance, immediately the prior 2 minutes high sample rate data for all systems on the aircraft is transmitted to a central location for analysis. June 2009, Air France Flight 447 going from Brazil to France crashed in the Atlantic Ocean. As of right now (Jan 7 2011), the black boxes have not been recovered. Had that aircraft been equipped with a system which would automatically trigger on an out of range parameter and send burst data for all aircraft systems for the prior two minutes before the out of range occurrence, the black boxes may not be required.

ACKNOWLEDGMENTS

The development of the FADC LOCOP programs have been and continue to be made possible thanks in part to by not only by:

NSWCCD Code 9343 personnel: Matt Hoffman, Helen Kozuhowski, Brian Connery, John Viercinski, Intok Park, Wilmer Ortiz, John Wallace, Keith Mummaw, Amad Green, Randall Robinson, Dennis Russom, Christopher Corso, Jeremy Nichols

Woodward Governor Co. personnel: Andy Cullis, Larry Bash, Brad Erian

REFERENCES

Dennis M. Russom P.E. (2005). Improving Operational Availability of Gas Turbine Generators aboard U.S. Navy DDG-51 Class Ships by Combining the Capabilities of the Integrated Condition Assessment System (ICAS) and the Generator Set's Full Authority Digital Controller (FADC). *GT2005-68952* (p. 2). Reno, NV: ASME.

Dennis M. Russom P.E. (2006). The Evolution of Gas Turbine Generator Set Reliability In The U.S.Navy. *GT2006-91301* (p. 5). Barcelona, Spain: ASME.