Handout for Pre-Submittal Meeting on Common Qualified Platform Topical Report (WCAP-16097-P-A) Planned Revisions NRC Meeting April 2020 (Non-Proprietary)

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LIST OF ACRONYMS AND TRADEMARKS

Acronyms used in the document are defined in WNA-PS-00016-GEN, "Standard Acronyms and Definitions" (Reference 28), or included below to ensure unambiguous understanding of their use within this document.

AC	Alternating Current
AC160	Advant® Controller 160
ACC	AMPL Control Configuration
AISC	Application Specific Integrated Circuit
AMPL	~~ABB~~ Advant Master Programming Language
API	Application Programming Interface
BIOB	Backplane I/O Bus
BSP	Board Support Package
CDI	Commercial Dedication Instruction
CDP	Cyclic Data Packets
CEA	Control Element Assembly
CEO	Cognizant Engineering Organization
COTS	Commercial-Off-The-Shelf
CPC	Core Protection Calculator
CPCS	Core Protection Calculator System
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CS	Communication Section
DB	Database
DBE	Design Basis Event
DC	Direct Current
DI	Digital Input
DNBR	Departure from Nucleate Boiling Ratio
DPM	Dual Ported Memory
DSP	Data Set Peripheral
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPLD	Erasable Programmable Logic Device
EPRI	Electric Power Research Institute
ESF	Engineered Safety Features
ESFAS	Engineered Safety Features Actuation System
FAT	Factory Acceptance Test
FCB	Function Chart Builder
FE	Function Enable
FMEA	Failure Modes and Effects Analysis
FOM	Fiber Optic Modem
FPD	Flat Panel Display
FPDS	Flat Panel Display System
FSAR	Final Safety Analysis Report
GUI	Graphical User Interface

LIST OF ACRONYMS AND TRADEMARKS (cont.)

SRAM	Static RAM
SVVP	Software Verification and Validation Plan
SW	Software
SWC	Surge Withstand Capability
SWT	Software Stall Timer
TCB	Task Control Block
TMI	Three Mile Island
V&V	Validation and Verification
WDT	Watchdog Timer
WWDT	Window Watchdog Timer
WYSIWYG	What You See Is What You Get

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GLOSSARY OF TERMS

Standard terms used in the document are defined in WNA-PS-00016-GEN, "Standard Acronyms and Definitions" (Reference 28), or included below to ensure unambiguous understanding of their use within this document.

Term	Definition
Advant	~~Advant is a registered trademark of ABB Process Automation Corp.~~ The Common Q™ platform includes the Advant Controller 160 (AC160). ~~The AC160 is part of the ABB Advant Power system.~~ It is used in applications that require high availability and redundancy.
Baseline Common Q™ Equipment	Baseline Common Q™ Equipment is the Common Q™ Equipment that was referenced in the NRC Safety Evaluation, dated February 24th, 2003.
MDAT	The data set used within multiprocessing applications between processors and global memory.

REFERENCES

1. GKW F 310 708, "Advant Power Reliability and Availability, Reliability Data Sheet, Advant Controller 160 Including S600 I/O~~,~~" ~~ABB PPC~~.

2. "Quality Management System," Westinghouse Electric Company LLC.

3. "Automation Level 3 Policies & Procedures," Westinghouse Electric Company LLC.

4. "Westinghouse Management System Quality Procedures," Westinghouse Electric Company LLC.

5. WCAP-16096-P-A, Rev. 5, "Software Program Manual for Common Q™ Systems," Westinghouse Electric Company LLC.

6. CENPD-255-A, Rev. 3, "Class 1E Qualification – Qualification of Class 1E Electrical Equipment," Nuclear Power Systems Combustion Engineering, Inc.

7. CEN-356(V)-P, Rev. 01-P, "Modified Statistical Combination of Uncertainties," Nuclear Power Systems Combustion Engineering, Inc.

8. 3BDS 003 340R701, "System Software Extension Designer's Guide~~,~~" ~~ABB Process Automation Corporation~~.

9. 3BDS 005 665R501, Rev. C, "Data Base Elements Advant Controller 160 Reference Manual~~,~~" ~~ABB Process Automation Corporation~~.

10. 3BDS 005 666R101, Rev. E, "PC Elements Advant® Controller 160 Version 1.3 Reference Manual~~,~~" ~~ABB Process Automation Corporation~~.

11. (Reference Deleted)

12. (Reference Deleted)

13. (Reference moved to Bibliography)

14. (Reference moved to Bibliography)

15. (Reference moved to Bibliography)

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16. (Reference moved to Bibliography)

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19. 3BDS 005 740R501, "S600 I/O Hardware, Advant Controller 160 Reference Manual~~,~~" ~~ABB Process Automation Corporation~~.

20. (Reference moved to Bibliography)

21. (Reference moved to Bibliography)

22. MOD 97 – 1250, "Oskarshamn 1 – Project Mod Evaluation of Collected Operating Experience for Advant Controller 110~~,~~" ~~ABB Atom~~.

23. GKW F 310 291, Rev. 0, "Survey of Operational Experience with Software Advant Controller AC160~~,~~" ~~ABB Power Plant Controls~~.

24. "TÜV Product Service GmbH, Automation, Software and Electronics – IQSE Technical Report Of Software Approval (Proven In Use Demonstration) No. 960113399b/e March 4, 1998," Revision 1.0.

25. NUREG-1462, "Final Safety Evaluation Report Related to the Certification of the System 80+ Design," Volume 1.

26. WCAP-8587-(NP), Rev. 6-A, "Methodology for Qualifying Westinghouse WRD Supplied NSSS Safety Related Electrical Equipment," Westinghouse Electric Company LLC.

27. WCAP-17266-P, Rev. 0, "Common Q Platform Generic Change Process," Westinghouse Electric Company LLC.

28. WNA-PS-00016-GEN, "Standard Acronyms and Definitions," Westinghouse Electric Company LLC.

BIBLIOGRAPHY

1. 3BSE 000 506R801, "Advant Fieldbus 100 User's Guide~~,~~" ~~ABB Process Automation Corporation~~.

2. 3BSE 009 626R501, "AMPL Configuration, Advant Controller 100 Series Reference Manual~~,~~" ~~ABB Process Automation Corporation~~.

3. DPPS-97-011, "Minutes of Meeting in Mannheim with ABB Industrietechnik AG, February 17-28, 1997," ~~ABB Process Automation Corporation,~~ April 17, 1997.

4. "QNX Operating System – System Architecture for QNX 4.24," 2nd Edition, October 1997.

5. "QNX Photon microGUI™ Programmers Guide," 2nd Edition, December 1996.

6. "QNX Watcom Compiler & Tools User's Guide," First Edition, July 1996.

7. GKWF 700 894, Rev. 2, "Requirements Specification for ACC Tool for use in RPS Applications of BU Nuclear~~,~~" ~~ABB Process Automation Corporation~~.

8. GKWF 700 891, Rev. 2, "Requirements Specification for Advant Controller 160 AC160 SW-Version 1.3 and Controller HW PM646A for use in RPS applications for BU Nuclear~~,~~" ~~ABB Process Automation Corporation~~.

9. "Green Hills Software Corporate and Product Overview", Green Hills Software, May 2015.

Ref. No.	Document No.	Title/Conformance	Revision No., Issue Date
52.	EPRI TR-107330	Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants	1996
53.	NUREG-0737	Clarification of Three Mile Island (TMI) Action Plan Requirements All Common Q™ Post Accident Monitoring Systems shall meet these requirements.	1980
54.	NUREG-0800	Chapter 7 of the USNRC Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, Rev. 7 The NRC will use this NUREG as the basis for their review of this topical report. Refer to the conformance statements for each Branch Technical Position listed herein.	2016
55.	NUREG/CR-6303	"Method for Performing Diversity and Defense-in-Depth Analyses of Reactor Protection Systems" The Nuplex 80+ certification includes a methodology for analyzing the defense against a common mode failure. The methodology is similar to this NUREG. The Integrated Solution Appendix describes how this methodology would be applied to Common Q™.	1994
56.	NUREG/CR-6421	A Proposed Acceptance Process For Commercial-Off-The-Shelf (COTS) Software in Reactor Applications This NUREG shall be used as guidance when developing the Software Commercial Grade Dedication Plan for the Common Q™ COTS software (e.g., [ ]^{a,c} ~~and ABB Advant®~~). Section 10.1 discusses the Software Commercial Grade Dedication process.	1996
57.	10 CFR 50 Appendix A	GDC 1: "Quality Standards and Records" The Common Q™ Quality Assurance procedures shall conform to these criteria. GDC 2: "Design Bases For Protection Against Natural Phenomena" GDC 4: "Environmental And Dynamic Effects Design Bases" Common Q™ hardware and software qualification procedures shall conform to these criteria. GDC 12: "Suppression Of Reactor Power Oscillations" The Common Q™ CPC implementation will still have the Local Power Density Trip function that addresses this criterion. GDC 13: "Instrumentation And Control" Common Q™ systems shall be designed and tested to meet this criterion.	

4.1 ADVANT CONTROLLER 160 (AC160)

The AC160 is used for executing the protection algorithms for the Common Q™ applications.

~~ABB's~~ The Advant Controller 160 (AC160) is a high performance modular controller with multiprocessing capability for logic control. The processor module (PM) used in the Common Q™ applications is the PM646A.

AC160 is fully modular with modules mounted in 19" subracks. A typical Common Q™ configuration consists of processor module(s), input/output (I/O) modules and communication modules contained in one or two subracks. Each rack can accommodate up to 10 modules.

To provide scalability in performance and reliability, up to six processor modules could be used concurrently in one controller. Presently the Common Q™ Applications require an upper limit of four PM646As. Any applications of more than four PM646As will be evaluated for compliance with Section 7 requirements when needed. The processor modules within an AC160 controller share data with each other using the global memory resident on the AF100 Communication Interface (model CI631, twisted pair).

Each processor module supports two high speed communication links (HSL). The HSLs will be typically used in the broadcast mode to transmit data to other divisions of the safety system. These data links are electrically isolated using fiber optic cable. The HSL is discussed in Section 4.5 and subsection 5.2.4.2.

The processors are programmed in the ~~ABB~~ Advant Master Programming Language (AMPL). In addition to the logic constructs, this language provides logic block interfaces to the AF100 network, global memory, I/O and the HSL. AMPL is discussed in subsection 5.2.1.2.

The processor module has a built in window watchdog timer module (WWDT) that is to be used in the Common Q™ systems. Depending on the specific system application, the WWDT can be used to annunciate a failure, actuate a divisional trip, or set output states to predefined conditions. For example, the WWDT may be used to control the power to the relays on the digital output module. Isolation is provided for those applications where the watchdog timer is connected to external systems. The watchdog timers are discussed in subsections 5.2.1.2.1 and 5.2.1.3.

Fiber optic modems that have gone through a commercial grade dedication process will be used for electrical isolation from other safety divisions and non-safety systems.

4.1.1 AC160 Software

Software programming is done on a ~~x86~~Windows-based Personal Computer using the ~~ABB~~ AMPL Control Configuration (ACC) software development environment. The target code is generated. ~~and~~ The application is downloaded to the AC160 controller via ~~the~~ a Personal Computer serial port. The AC160 software development environment is called ~~ABB~~ Advant Master Programming Language (AMPL) Control Configuration (ACC). The ACC product consists of the following utilities:

- Application Builder

- Online Builder[1]
- Function Chart Builder
- Bus Configuration Builder

The tools use the ~~ABB~~ Advant Master Programming Language (AMPL). AMPL is based on a library of predefined function blocks, called Process Control (PC) elements, and database elements, called DB elements. The PC elements and DB elements are combined into programs that form a complete control function. In addition to the base PC and DB libraries, there are optional libraries that can be configured to expand the PC and DB element set. Refer to subsection 5.2.1.2 for more information on the AC160 software.

The Advant Controller 160 (AC160) software consists of a real-time operating system [ ]^{a,c}, task scheduler, diagnostic functions, communication interfaces, and user application programs, all of which reside on flash programmable read only memory (PROM) in the PM646A processor module. Refer to subsection 5.2.1.2 for a more detailed description of the AC160 software.

The application program in an AC160 coexists with the other AC160 system software programs such as the diagnostic routines and communication interfaces. The task scheduler schedules the execution of all these different entities.

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]^{a,c} Data is acquired over the I/O backplane (BIOB), the AF100 communication interface and the high speed link (HSL) interface. The AC160 base software resides in the AC160 Central Processing Unit (CPU) module flash PROM (non-volatile memory).

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Creation of the application program (PCPGM) utilizes the ACC software development environment that includes a function block library (PC element library). The programmer references the PC element library to create specific logic for the application. Refer to subsection 5.2.1.2.2 for a description on how the software is developed.

The executable code for the standard set of logic blocks (PC elements) is part of the base software. In addition, custom PC elements can be created as an extension to the base software.

4.1.2 Input and Output Cards

The Advant Controller 160 uses the S600 I/O system. A range of I/O modules is available, covering analog and digital signals of various types. In addition, there are modules for temperature measurement

1. Only applicable to the AC400 series controllers which are not part of Common Q™.

5 COMMON Q™ PLATFORM

5.1 FUNCTIONAL REQUIREMENTS

Functional Requirements for each application of the Common Q™ platform is discussed in application specific appendices to this topical report. The following applications shall be defined in the appendices:

- Core Protection Calculator (CPC)
- Reactor Protection System (RPS)
- Plant Protection System (PPS)
- Post Accident Monitoring Systems (PAMS)
- Engineered Safety Features Actuation System (ESFAS)

The specific appendix for each of the above systems will be submitted independently of the base topical report. Additional applications of the Common Q™ building blocks may also be submitted in additional specific appendices.

5.2 SYSTEM DESCRIPTION (BUILDING BLOCKS)

The Common Q™ Platform is based on the idea of using a consistent set of qualified building blocks that can be used for any safety system application. The building blocks are:

1. Advant Controller
2. Flat Panel Display
3. Power Supply
4. Communication Subsystems

5.2.1 Advant Controller

Advant Controller 160 is ~~part of the ABB Advant Power family. It is~~ used in applications that require high availability and redundancy.

5.2.1.1 AC160 Hardware Description

The Advant Controller 160 (AC160) consists of a number of hardware modules that can be configured in a chassis. These hardware modules fall into the general categories of processor, inputs and outputs, and communications.

~~ABB's~~ The Advant Controller 160 is a high performance modular controller for logic control with multiprocessing. Advant Controller 160 and its S600 I/O can be used stand-alone or it can communicate with other controllers.

The controller is specifically designed for high speed PLC type applications, but it also brings considerable problem solving power to all analog signal handling and arithmetic applications. Advant Controller 160 covers a wide range of programmable functions such as logic and sequence control, analog data handling, arithmetic, and pulse counting.

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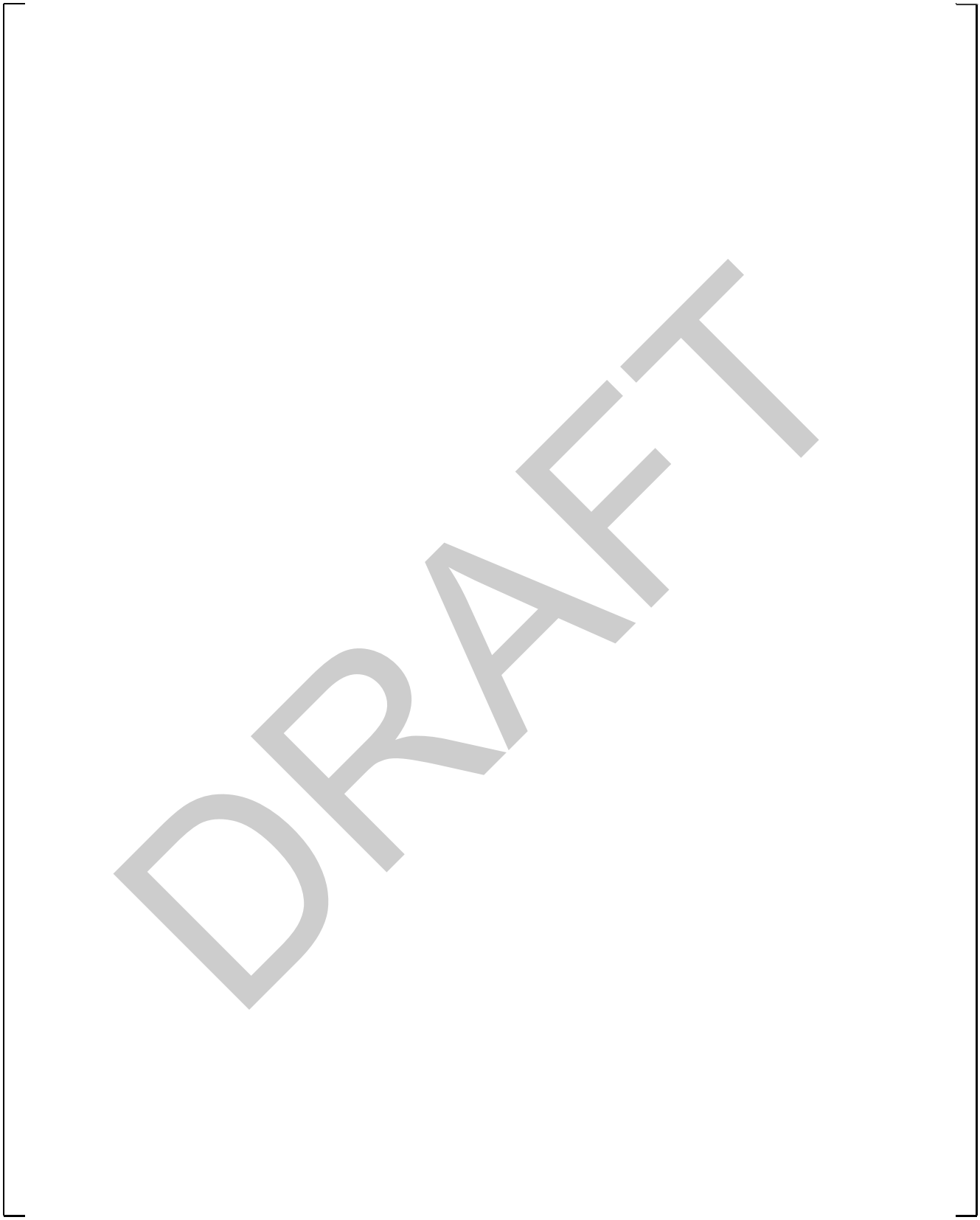

Calibration of Analog Input and Outputs

During the course of manufacture, all measurement and output ranges of analog I/O modules are calibrated at an ambient temperature of approximately 25°C. Normally, the modules need no further calibration. If the accuracy is outside the specified limits (e.g., due to component failure), the module must be replaced. There are no calibration adjustments.

The analog modules are designed in such a way that component aging has little affect on specified accuracy. This is the result of:

- Use of high quality, low drift components. For example, the analog circuits do not include any potentiometers (which are often the cause of drift problems).

- Use of self calibration techniques in modules of high specified accuracy (high end modules). The self calibration techniques are based on high precision resistors and on voltage sources with extremely low drift due to temperature and aging.

The system software in the Advant Controller 160 automatically checks that all I/O modules are operating correctly. In the event of a defective or missing module (e.g., during replacement), the module and associated signals are flagged at the “ERR” terminal of the data base elements. The signal value (VALUE) is not updated as long as the error persists. Common Q™ applications shall monitor the ERR terminal for each DB element.

The I/O module runs a self-testing routine following power-up and during operation. Provided, no serious defect is detected, the red LED (FAULT) extinguishes. The system software checks that:

- The module is in the correct position
- The module is of the right type
- The module is not defective
- The process connector is in place

If all these points are in order, the green LED (RUN) lights, the error flag on the data base element is reset, and the module switches to the operating mode.

5.2.1.2 AC160 Software Description

The Advant Controller 160 Software consists of a real-time operating system [ ]^{a,c}, AC160 task scheduler, diagnostic functions, communication interfaces, and user application programs, all of which reside on flash PROM in the PM646A processor module. Refer to subsection 5.4.1 for a description of diagnostic functions, and subsection 5.2.4 for a description of the communications.

5.2.1.2.1 Base Software

Processor system software consists of the standard AC160 system software products ~~developed by ABB Automation Products, GmbH,~~ [
]^{a,c}. The system software [ ]^{a,c} executes the control

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5.2.1.2.2 Application Software

Creation of the application program (PCPGM and CONTRM) utilizes the ACC software development environment that includes a function block library (PC element library). The programmer references the PC element library to create specific logic for the application.

The application program is written in the AMPL (~~ABB~~ Advant Master Programming Language) language and consists of a PC (process control) part and a DB (database) part.

The software for each application of Common Q™ is described in the Appendices to this topical report.

PC Part

The PC part of a user application program describes the control algorithm and the control strategy. It contains the PC elements (logic blocks), their interconnections and the connections to the DB elements. A PC program can be divided into several executable units (control modules-CONTRMs), each consisting of PC elements. Each executable unit can be given its own cycle time and its own execution conditions. PC elements are the smallest "building blocks" in a PC program.

There is a PCPGM PC element that is required for each PM646A application program. It has a separate cycle time than the CONTRMs. It represents the transfer rate of data between the PM646A and the CI631 AF100 Communication Interface.

The I/O modules continuously scan and store values independent of control module execution. When the control module executes, its first operation is to get the process input values over the Backplane I/O Bus (BIOB) from the I/O modules.

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5.2.1.2.3 Software Tools

Software programming is done on a Windows~~n x86~~-based PC and then the target code is generated. ~~and~~ The application is downloaded to the AC160 controller via ~~the~~ a PC serial port. The AC160 software development environment is called ACC ~~which is a product of ABB Automation Products, GmbH~~. The ACC product consists of the following utilities: Application Builder, AS100 Edit, Function Chart Builder and Bus Configuration Builder. The tools use the ~~ABB~~ Advant Master Programming Language (AMPL). AMPL is based on function blocks, called PC elements, which are combined with each other into programs which form a complete control function.

For further description see References 9 and 10.

These tools can be used for on-line programming of the controller. However, for safety-related Common Q™ applications, this capability ~~will~~ can be controlled administratively with additional password protection.

Type Circuits

ACC supports the development of type circuits. A type circuit is a logic block composed of PC elements that can be used many times in a control program. The same tool (Function Chart Builder) is used for both type circuit and control program development. Once a type circuit is developed it can be used in a control program just like any other PC element.

Although the type circuit appears as a single block, each PC element in the type circuit becomes part of the application program, much like a macro represents a set of language instructions. Therefore, the purpose of type circuits is to increase readability of the control program and to provide configuration control for a set of code, and not for performance enhancement or memory conservation.

The type circuit is considered a module and therefore must undergo documented module tests when used in protection class software as described in the Software Program Manual (Reference 5).

Custom PC Elements

Custom PC elements appear as standard PC elements with input and output terminals when inserted in a control program. They are developed outside of the ACC development environment and then added to the library of PC elements. Once in the library, the custom PC element is available for the programmer to use in a control program.

The custom PC element is developed using the system software extension option for the AC160 that allows custom PC elements to be added to the controller. The tools used to develop the custom PC element include a C compiler (MCC68K) and linker (LNK68K) from Mentor Graphics Microtec division. The linker generates a Motorola S-Record image file for the PC element. This image file is downloaded to the AC160 processor module's flash PROM using the same tool for installing the base software. Reference 8 describes the methodology for creating these elements.

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5.4.3 [ ]a,c Flat Panel Display Diagnostics

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5.4.4 Surveillance Testing

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5.4.4.1 Passive Testing

Passive testing requires the AC160 processors to periodically transmit sufficient data to the ITP so that it can validate the correct operation of the processors and compare its divisional data with corresponding data from other divisions (via other ITPs). Any deviations or errors are transmitted to the MTP for display and alarm.

5.4.4.2 [ ]a,c

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5.4.5 Application Watchdog

The design of the Common Q™ platform includes a hardware watchdog function within the processor module (i.e., WWDT) to override the activation outputs of the safety system should the processor halt. The AC160 internal diagnostics that monitor the activation and execution of each application task eliminates the need for application level software watchdog counters. Application level watchdog timers do not need to be implemented for HSL and AF100 communications either because the AC160 internal

5.6.10 ISG-4 Position 10

ISG-4, Position 10 states:

> *"Safety division software should be protected from alteration while the safety division is in operation. On-line changes to safety system software should be prevented by hardwired interlocks or by physical disconnection of maintenance and monitoring equipment. A workstation (e.g., engineer or programmer station) may alter addressable constants, setpoints, parameters, and other settings associated with a safety function only by way of the dual-processor/ shared-memory scheme described in this guidance, or when the associated channel is inoperable. Such a workstation should be physically restricted from making changes in more than one division at a time. The restriction should be by means of physical cable disconnect, or by means of keylock switch that either physically opens the data transmission circuit or interrupts the connection by means of hardwired logic. "Hardwired logic" as used here refers to circuitry that physically interrupts the flow of information, such as an electronic AND gate circuit (that does not use software or firmware) with one input controlled by the hardware switch and the other connected to the information source: the information appears at the output of the gate only when the switch is in a position that applies a "TRUE" or "1" at the input to which it is connected. Provisions that rely on software to effect the disconnection are not acceptable. It is noted that software may be used in the software system or in the workstation to accommodate the effects of the open circuit or for status logging or other purposes."*

Compliance

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5.6.11 ISG-4 Position 11

ISG-4, Position 11 states:

> *"Provisions for interdivisional communication should explicitly preclude the ability to send software instructions to a safety function processor unless all safety functions associated with that processor are either bypassed or otherwise not in service. The progress of a safety function processor through its instruction sequence should not be affected by any message from outside its division. For example, a received message should not be able to direct the processor to execute a subroutine or branch to a new instruction sequence."*

Compliance

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5.6.12 ISG-4 Position 12

ISG-4, Position 12 states:

> *"Communication faults should not adversely affect the performance of required safety functions in any way. Faults, including communication faults, originating in nonsafety equipment, do not constitute "single failures" as described in the single failure criterion of 10 C.F.R. Part 50, Appendix A. Examples of credible communication faults include, but are not limited to, the following:*

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8.2 MEAN TIME BETWEEN FAILURES (MTBF) ANALYSIS

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Table 8-1 [ ]a,c a,c

8.3 OPERATING HISTORY

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8.3.1 [ ]a,c

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Figure 8-1 ~~ABB~~ AC160 Nuclear Product Migration

10 COMMERCIAL GRADE DEDICATION PROGRAM

10.1 SCOPE

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11 COMMON Q™ PLATFORM COMPONENTS

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Table 11-1 [ ]a,c

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Table 11-1 [ ]a,c	

Table 11-1 [ ][a,c]	

13 CONCLUSIONS

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