SIMULATION SYSTEM FOR CONTROL SOFTWARE VALIDATION

Scott McWhorter and Brian Baker
Woodward Governor Company
E-mail: *smcwho* or *bbaker@wgc.woodward.com*
3800 N. Wilson Ave., Loveland, CO 80538

Greg Malan
Framatome Technologies
E-mail: *gmalan@framatech.com*
3315 Old Forest Road, Lynchburg, VA 24501

KEY WORDS: Control Systems, Validation, Dynamic Simulation

ABSTRACT

The Woodward Governor Company has used dynamic simulation to advance their methodology for developing and validating control system software. The Woodward control software/hardware is typically used to provide high-fidelity control for complex turbomachinery used in the power and process industries. Benefits identified include increased product quality/reliability, reduced testing time, expedited delivery schedule, post-installation testing, internal and customer system training.

INTRODUCTION

Verification and validation of control system software functionality is critical to a safe, timely, and successful control system installation and commissioning. Traditional techniques utilized in control system validation include full control system stimulation that involves physically connecting the system to a programmable or analog test fixture and/or performing an internal simulation using the control system software as the simulator. Both of these approaches require the control system hardware and generally require significant time and resources. Additionally, depending on the system used for testing, the software may not be suitable for developing accurate and balanced models.

Plant simulation has been utilized extensively by the process and power industries to model and simulate processes within the plant. These simulations have primarily been used to verify proposed changes in the process and operating procedures, as well as training staff and gaining insight into the plant processes.

The requirement for software validation and the capabilities of a dynamic simulation system are a natural match for the control industries.

SOFTWARE SIMULATION PROJECT

The Woodward Governor Company has provided programmable digital controls for prime movers in the process and power industries for 20 years. Woodward has a long standing tradition of testing control system application software including the use of software simulation systems to validate the control systems applications. However, the capabilities of the current simulation system were limited and could only be applied to a few of the many applications developed by Woodward application engineers worldwide. It was concluded that a more flexible, PC based software simulation system would greatly benefit the testing process.

Also, it was concluded that to fully realize the benefits of a software simulation system, the control system software had to be moved from the operating system environment used by the Woodward control system to the environment used by the selected simulation system.

The specification for the system included requirements for the following topics:

- Control System Software Translator
- Control System Executive
- Modeling Software Interface
- Control-to-Model Interface
- Engineering Station
- Interface to External Devices.

Framatome Technologies was selected to be the simulation tools provider. The standard simulation tools used for this project included the Modular Modeling System (MMS), the MMS Model Builder, MMS CompGen, the Action Center and Simulation_Master for interactive model control, and Graph_Master for real-time trending (McKim and Matthews 1996; Matthews *et al.* 1996). The MMS provides a large library of plant components based on first principles modeling along with the MMS Model Builder that is used to construct model schematics using component icons having their own on-line data input forms. Figure 1. is a block diagram of the runtime configuration for the software used by the controls testing simulator. All of these tools extensively exercise the robust functionality provided by the Microsoft Windows NT operating system.

Control System Software Translator

The automated C code generated by Woodward's control programming tools for the control hardware instructions had to be translated to the simulation environment. The development of a translator allows the representation of the Woodward control hardware and its control logic functions to be executed completely by software without the control hardware. The core control source was able to be preserved intact resulting in the actual logic flow as the original source. Similar I/O memory addressing was retained as well, minimizing the changes necessary to the original source.

Control System Executive

Real-time simulation was not a requirement for this system; however, the simulator "clock" must be controlled to allow for stopping, single-time stepping, and restoring the simulation to a previous time. Controlling the "clock" is crucial to the software debugging environment. A control system executive was required to interface with the simulator clock, and at the same time, guarantee preserving the execution order and timing relationships between the blocks as designated by rate groups in the source code. The Woodward control code can designate execution times of 5ms, 10ms, 20ms, 40ms, 80ms, 160ms, and "free run." In addition to the timing relationships, this task converted the Woodward library of control functions to the simulation environment to preserve the original code and resulted in a true representation of the Woodward controls system software. This capability was integrated into the MMS simulation environment on the PC platform using the Windows NT operating system.

Modeling Software Interface

The Woodward generated FORTRAN or C control models are interfaced with the models of standard plant components supplied by the MMS to simulate plant responses. The ability to create new standard plant model components was also required. This capability allows Woodward to build specific components to better satisfy the specific requirements for individual customers. The MMS CompGen™ fulfilled this need by providing Woodward the ability to develop their own simulation modules, as needed, and the ability to incorporate these modules into the MMS Model Builder's graphical modeling environment.

Framatome Technologies' Modular Modeling System more than met the imposed requirements. Woodward engineers have adapted several existing FORTRAN codes for modeling generic gas turbines, compressors, and generators. The conversion to date has been painless.

Control-to-Model Interface

A typical Woodward Control System consists of a CPU module and a number of I/O modules that allow the control software to communicate with the field transmitters and drivers. The I/O modules are in most cases "smart" modules that have a processor on board to pre-process the input or post-process the output, which eases the loading of the main CPU. Replacing the I/O module functionality is the Control-to-Model interface.

A structured Control-to-Model interface was required to minimize the manual effort associated with cross-referencing control I/O with process model variables. A spreadsheet-based interface was used by Framatome Technologies. The control-side addressing, description, and emulated module function are all automatically populated during the execution of the Controls System Software Translator. Another notable feature includes the series multifunction conversion capability. Functions handling such parameters as unit conversions, filtering, signal noise, failures are easily implemented on any I/O signal. Up to 10 individual functions in series are supported. Additional functions are easily programmed. The incorporation of a high level of flexible automation into the integration process has provided a significant reduction in data handling errors and resources.

Engineering Station

A multi-tasking graphical engineering interface providing interactive control of the simulation was required. Features of the engineering station include:

- Run/Freeze: Restarts or freezes the control and process models.
- Save: Allows the current status of the control and process models to be saved as an initial condition.
- Restore: Allows the saved file to be reloaded and restarted.
- Simulation Speed: Allows the engineer to adjusts the speed simulation execution up or down while preserving relative time.
- Single step execution: Provides the ability to increment by a single time step and observe or have access to all control and model variables for debugging purposes.
- Backtrack: Allows the engineer to return the simulation to previous states in the current simulation run.
- Trending: Permits the designation and trending of any number of variables in multiple graph windows with auto- or user-specified scaling.
- Data logging: Permits the designation of variables to be stored in a data file at various specified increments.

Framatome Technologies' Simulation_Master, Action Center, and Graph_Master tools provide all the above features (and more) without any further development effort associated with this project. Figure 2. illustrates an application of the tools for a feedwater control system.

Interface to External Devices

A Woodward control system can interface with a wide variety of devices using industry standard communication protocols. Two of the most widely used interfaces were required of the simulator system.

The first interface is associated with a Man Machine Interface (MMI). The control is typically connected to a Modbus® master MMI. The simulator was required to preserve this interface via a serial or an ethernet connection. The connection type and Modbus® variable list is automatically generated from the control source code without manual intervention. This feature allows engineering to fully stimulate and test the custom MMI during the software simulation and test.

The second interface is associated with the alarm printer. The control is typically connected to an alarm printer to log alarms and trips. The simulator was required to provide the alarm log to an alarm file instead of a hard interface to a printer.

BENEFITS

Many benefits will be realized through the use of a simulation system for control software validation.

- Increased quality/reliability
- Reduced test time
- Shorter system lead times
- Better tested field changes during commissioning and after-market activities
- Enhanced internal and customer training via computer-based usage of the simulation

Increased Quality/Reliability

As control systems become larger and more complex, it is becoming increasingly difficult and costly to test and validate the control system software. Very large and complex systems can be tested using the software simulation system. By using the engineering station and its capabilities, the engineer can perform many test functions and iterations that are difficult or impossible with traditional test stand control system software testing techniques. Additionally, the new software testing allows for simpler and more precise reproduction of tests and easier storage and retrieval of archived results.

Reduced Test Time

Overall system test time will be reduced by eliminating the dependency on production hardware and providing the engineer with the capability to develop and test control system software incrementally.

Shorter Lead Times

Separation of the control system hardware and software provides flexible scheduling and paralleling of tasks that were previously dependent on each other. This separation

results in approximately a 30% reduction in lead time. In some cases the hardware could ship months before the software allowing site work to begin and resulting in a significant project time savings.

Post-Installation Testing

After the control system has been installed and commissioned in the field, it currently is very difficult to test and simulate changes. Changes are often tested on actual equipment and/or simulated in an open-loop manner. Again, these procedures are costly and potentially dangerous. The software simulation system provides the ability to test and retest software using the original model years after the installation.

Training

The simulation system and the control model provide an excellent computer-based training for Woodward and end users. Extensive training simulations and models can be developed to train personnel on the control system and prime mover fundamentals. Additionally, the end user of the control system can use the same model and application software that were used to prove the system at the factory to train operations personnel. This feature is extremely valuable in mission critical applications where the prime mover may run continuously for three years.

SUMMARY

The requirement for control software validation and the capabilities of a dynamic simulation system are a natural match for the control industries. Using the software simulation system to test and validate the controls software results in better, more accurately tested control systems, as well as reduced lead times.

REFERENCES

McKim, C.S. and M.T. Matthews. "Modular Modeling System Model Builder." In the Proceedings of the 1996 Intersociety Energy Conversion Engineering Conference (Washington D.C., August 11-16, 1996).

Matthews, M.T., W.T. Sneed, and G.F. Malan, "An Instructor-Friendly, Object-Oriented Approach to Training Simulator Control." 1996 International Fossil Simulation and Training Meeting - EPRI Supplement to the 1996 Proceedings of the 1996 Simulation Multiconference (New Orleans, LA, April 8-12, 1996).

ACKNOWLEDGEMENT

Special appreciation is owed to the technical contributors to the project, notably Randy H. Ellison and Stanley H. Levinson of Framatome Technologies for their hard work and innovation, and the many contributors from the Woodward Governor Company staff who provided critical information and insight into the design of the Woodward control system.

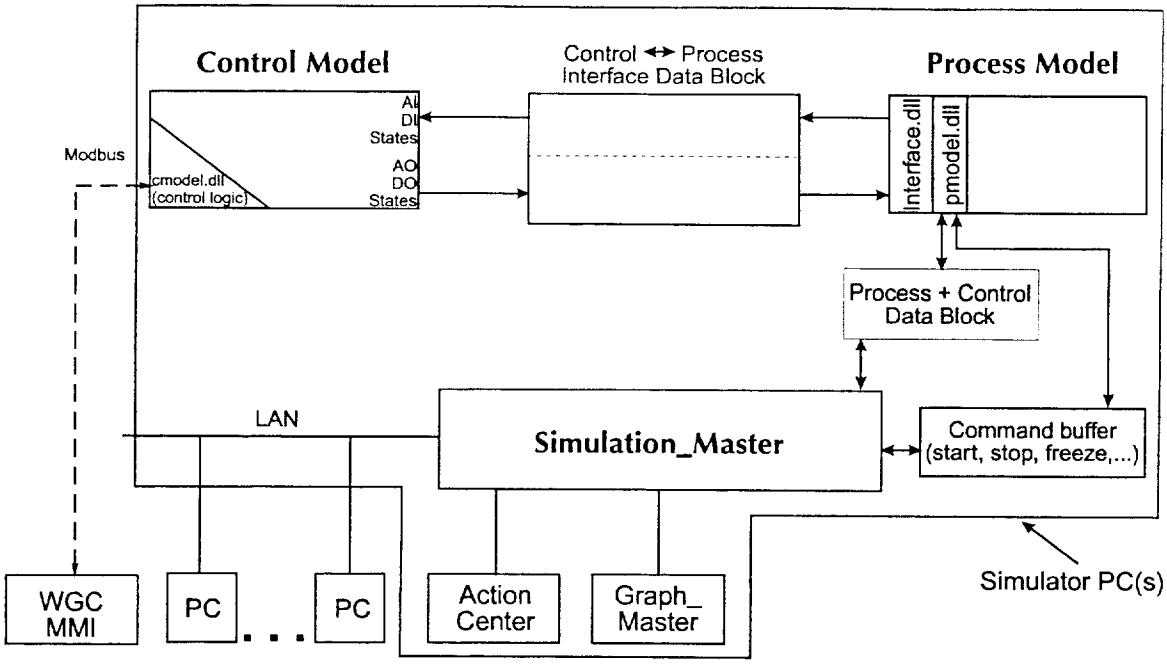

Figure 1. Simulator Runtime Configuration

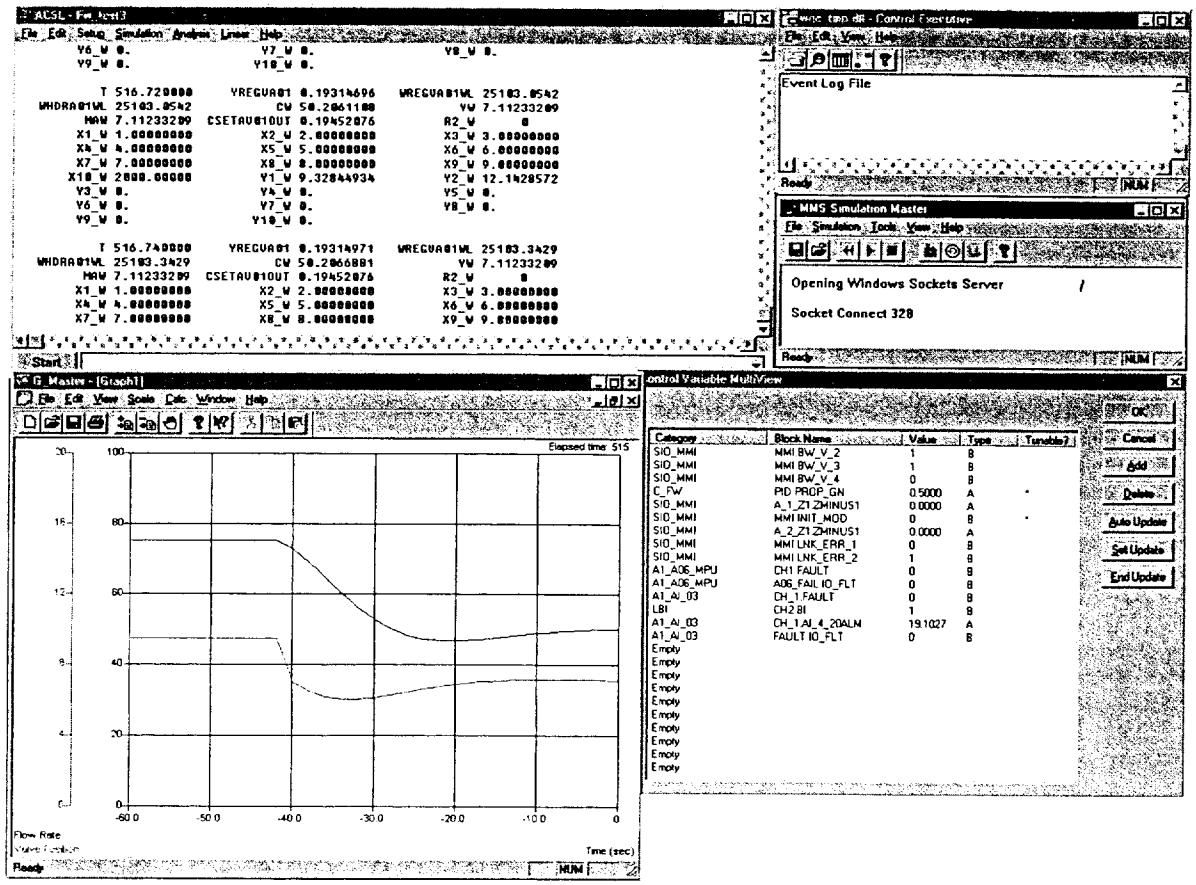

Figure 2. Simulation_Master Controlling the Process and Control Models as Two Variables are Trended in Real Time and the Control Variables and Event Log are Monitored