Lessons Learned from System Integration and Testing for PMAS

Jeong-Kweon Lee *, Yong-Chul Shin, and Jang-Sik Moon
KEPCO E&C I&C System Engineering Department,150 Deokjin-Dong, Yuseong-Gu, Daejon, 305-353
**Corresponding author: jklee@kepco-enc.com*

1. Introduction

Four units of the Plant Monitoring and Annunciator System (PMAS) for Shin-Kori and Shin-Wolsong Nuclear Power Plants 1 and 2 have been integrated and tested at the staging area of KEPCO E&C for 4 years. The PMAS consists of Plant Computer System (PCS), Plant Data Acquisition System (PDAS) and Plant Annunciator System (PAS). KEPCO E&C, system designer was responsible for providing Plant Computer System(PCS) software. The equipment supplier was in charge of providing PMAS hardware with its firmware. A rigorous project plan for system integration and testing of the PMAS was established to avoid any discrepancies that could be caused by these different companies. The system integration and testing were thoroughly performed by the system designer in accordance with the integration and testing procedures developed to satisfy the requirements of PMAS design specifications.

This paper summarizes system integration, system testing and the lessons learned from these experiences.

2. System Integration

The PCS software consists of system software, Man-Machine Interface(MMI) software, and application software. The software was designed and completed under the environment of development system facility and simulator equipment without the PCS hardware. The PMAS hardware had been tested to meet the requirements of the procurement specification by the equipment supplier before shipment was made to the staging site.

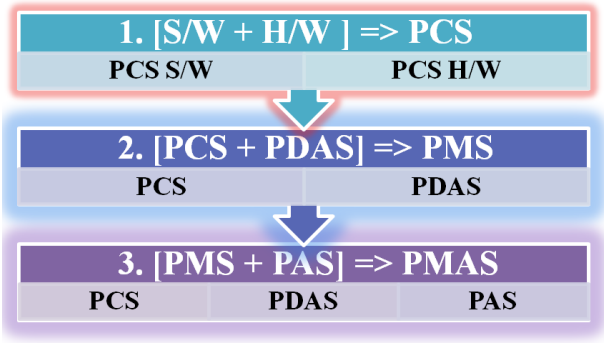

Fig. 1. System Integration Phases for PMAS

The PMAS integration was performed in three phases as shown in Fig. 1 after the hardware was delivered to the staging site. In the first phase, the PCS software was integrated into the PCS hardware per the integration procedure. Integration testing was conducted on the PCS software programs whose individual software modules are combined and tested as a group. The PCS and the PDAS were integrated into the PMS(Plant Monitoring System) as a complete system which performs signal conditioning, data display, and logging during the second phase. The PMS was combined with the PAS which alerts the operator of the abnormal plant conditions that require the operator's attention by means of visual and audible alarm signals during the last phase. The database used in these systems also was consolidated and optimized to maximize integrity and efficiency in design, operation and maintenance.

The system configuration for the PMAS is provided in Fig. 2[1].

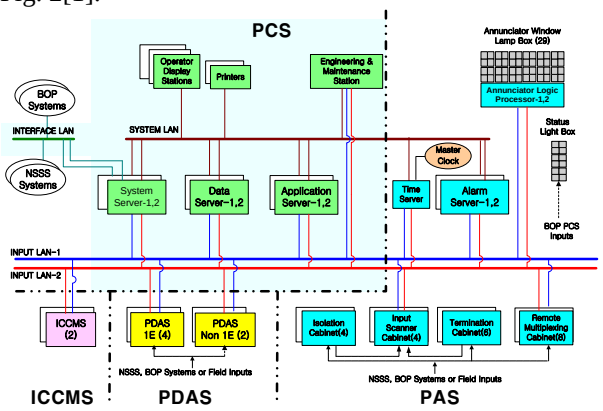

Fig. 2. PMAS Configuration

3. System Testing

Industry data have shown that the majority of design errors, whether they are software or hardware based, were found by intensive system testing. The system testing was performed through various types of testing to verify that the system meets function, performance, and interface requirements. The test was conducted with a thorough, structured test program that validates the software implementation and integrated system performance consistent with the intended requirements. The following tests were performed on the subassemblies and the completed systems to ensure compliance with the system requirements.

3.1 Unit Testing

For new software, a standalone test should be done for each software element before it is integrated with the other software modules. The unit testing was conducted for all software modules. A unit is the

smallest testable part of an application. Unit test procedure for each software unit was written and run by software developers to ensure that the code meets its design and behaves as intended.

3.2 Software Verification and Validation (V&V)

The SPADES programs were designed, verified, and validated in accordance with a V&V plan. The V&V for PDAS and PAS programs were performed by the equipment supplier. Software V&V shall be a method to systematically assure that the program is correctly implemented, and meets the system functions and the performance requirements.

3.3 Integration Testing

Integration testing provided the first opportunity to test the complete integrated system specified in section 2 of this paper. It was performed in accordance with the integration test procedure.

3.4 Factory Acceptance Test (FAT)

FAT was performed on the manufactured equipment prior to its shipment to the site. It included hardware functional tests, software functional tests, and system functional tests. The PMAS was subject to a range of tests to demonstrate the system's ability to simultaneously satisfy functional requirements while maintaining adequate performance margins. The simulated static and dynamic input signals or test equipment signals for these tests were provided.

4. Lessons Learned from Integration and Testing

The PMAS was integrated and tested through various tests to verify that the system meets functional, performance, and interface requirements as described above. Table 1 provides lessons learned during the integration and testing process.

Table 1. Lessons Learned from Integration and Testing

Items	Descriptions
Manpower & Cooperation	- Reliable manpower operation - Cooperation among organizations
Configuration Control	- Management of database input - Software configuration control - Administrator's role - Developer's correct understanding
Comm. Protocols	- Optimization of comm. protocols and message structure on inter-subsystems - Completeness of comm. protocols
Tests	- Removing all errors in each test phase before Integration Test and FAT - Testing on the fully integrated system
Completeness of Test Procedure	- Approval of vendor test procedure before vendor test - Tester's need to be familiar with test environment - Preparedness based on system design document (high level requirements) - Test prerequisites to be written in very specific detail - Pre-test required before the issue of the test procedure
Test Equipment	- Testing depends on test equipment's capability (signal generator, S/W simulator, test emulator) - Test emulator needs to simulate all possible situations in actual system - Test emulators for all interface systems need to be integrated and tested at the same time
Test Engineer	- Enough Knowledge of system design requirements - Enough experience in similar testing - Capability to check, analyze and document software & hardware problems - Test experience for technicians to support the Test Engineer
Documentation of Test Result	- Test procedure marked up with test results - Correction of test procedure marked up with reason, date, and signature for revision - Failed test to be notified to S/W developer and retest after S/W correction or test environment change - Another means for documentation or recording of S/W correction, improvement, questions, and answers between testers and developers

5. Conclusions

For the Shin-Kori and Shin-Wolsong units 1 and 2, KEPCO E&C successfully completed the integration and testing tasks by July 2010. Lessons learned were acquired from these projects and experience. Valuable lessons are summarized as follows:

- Effective management of manpower
- Strict configuration control for database and S/W
- Completeness of integration and test procedures
- Test equipment to simulate actual system functions
- Test experience for engineers and technicians
- Documentation including test results, corrections and changes by testers and S/W developers

These will be useful information for the system integrator or the tester and will play an important role in the process of the integration and testing of I&C equipment for newly constructed plants and operating plants.

REFERENCES

[1] S.M.Baek, J.K.Lee, Y.C.Shin, S.C.Jeong and H.B.Kim "Development of PMAS and Its Application to Kori Unit 2 Plant Computer System Replacement," ANS International Topical Meeting on NPIC&HMIT, p. 4, 2004.