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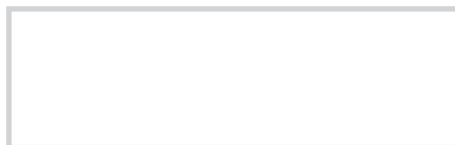
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In the past few years, *FEA* has had many more clients interested in the hardening of their mission critical facilities. This is mostly due to the fact that present computer equipment is much more powerful allowing smaller facilities to serve mission critical functions for an organization. We have found 1,500 square foot data centers that house the entire computing capability for the company: (i.e. general accounting, production and inventory control, accounts payable and receivable, payroll, network operations - local and worldwide, point of sale authorization, web hosting, etc.). It is important that the client realize that the design of mission critical facilities is very different from normal facilities and requires extensive involvement of the client, cooperation of all team members, application of redundant and ultra-high reliability systems, attention to design detail, extensive testing; and, after project completion, training on the operation of all critical systems with ongoing maintenance.

## Client Involvement

by *Leo P. Soucy, Jr., P.E.*

During the past several years we have found that client involvement has evolved from primarily facilities personnel to include the end users (i.e. IT personnel, broadcast engineers, etc.). This has been due to the following:

Hardware and software are more robust and inherently redundant so that power and air conditioning problems are responsible for an increasing proportion of service interruptions.

Equipment is much more integrated with the utility systems - dual power cord, ultra-high watts per square foot load densities, etc., requiring total system design integration with the utility support systems.

IT personnel and broadcast engineers are much more aware of how power and air conditioning system limitations affect their operations.

New technologies (static transfer switches, 2N redundancy, etc.) have not delivered the promised increase in reliability.

This development of end user involvement has been very positive with regard to the overall design of mission critical facilities.

As we develop the design of the systems, it is very helpful when the end user is involved so that they will know how the facility will operate and how the installation of equipment will affect the system's overall performance. In fact, if the computer or broadcast equipment is not installed properly, the system may not deliver the intended result and may result in very inferior performance.

One example of this equipment and system design inter-relationship is the application of cooling systems to meet the new ultra-high rack cooling requirements. The increasing requirement for providing cooling for ultra-high power consuming equipment has led to the concept of "hot" and "cold" aisles. For this type of cooling system to operate properly, it is imperative that a substantial amount of cool air be delivered to the "cold" aisles. This requires either a ducted system or a deep raised floor - 24 to 36 inches. It is also necessary to lay out the equipment properly so that the cold air is routed through the equipment and into the hot aisles providing the necessary equipment cooling before it returns to the air conditioning system. This normally means aisles that are closed off at the ends thereby ensuring that the cold and hot air does not mix before it performs its cooling function.

Another example of this equipment and system design inter-relationship is

the application of dual power cord equipment. In designing for dual power cord equipment, it is imperative that the power distribution to the individual racks be properly designed to afford the necessary power diversity. The dual power cord equipment does provide the best solution to eliminating power outages, but if it is not properly applied by the end user, its effectiveness is compromised.

While most of the technology being applied to the design of mission critical facilities is not new, it is becoming much more important to provide an integrated facility design closely tied to the utilization equipment capabilities and layout.

## Integration Testing

by Leo P. Soucy, Jr., P.E.

The successful completion of any mission critical project requires extensive 'after design' services. These include factory witnessing testing of major equipment, extensive construction review to ensure that all systems are installed as designed, proper equipment start-up and comprehensive system integration testing, which is sometimes referred to as commissioning. There is a big difference between Integration Testing and Commissioning in that commissioning oftentimes is thought to mean only equipment start-up.

The criterion for integration testing is not only to ensure that the equipment operates properly but that it operates as a totally integrated system with the other major systems

even in extreme circumstances. The proper operation of the equipment is the responsibility of the manufacturer and contractor but the system integration is the engineer's responsibility.

Integration testing should not only verify normal system operation but also test system performance under rigorous circumstances and also under stress. The following are some examples of Generator System test procedures.

### Rigorous Circumstances

An example of an integration test of a generator is not only that it operates properly as a stand-alone item (load test) but that the generator system operates properly in its most vulnerable state. One test should confirm that the generator system will properly power the design load with the redundant unit off-line on the hottest day during a power outage.

### Under Stress

Integration testing should also stress the systems beyond their design limits in an effort to verify that protective devices provide the proper protection and to determine how the system operates under stress. An example would be to overload a generator system and verify that the system properly sheds loads, recovers and continues to serve the most critical loads; again, with the redundant unit off-line on the hottest day during a power outage.

There are a number of different mind-sets as to who is best suited to implement the integration testing - the contractor, design engineer or a

third party.

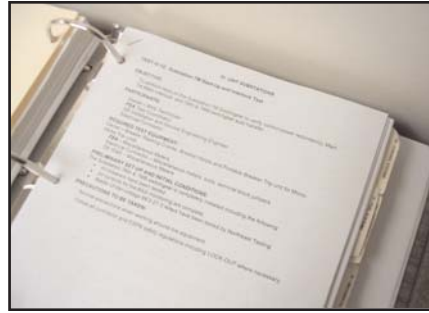
If a third party is selected, it is imperative that they be on board during the design process and attend all factory witness tests. While this is a duplication of effort and costly, it is necessary that they have this level of involvement in order to have a thorough knowledge of the system's features so that comprehensive tests can be developed. If not, the test procedures may be incomplete - not testing all features - or provide for the testing of features that were not specified. Not performing comprehensive testing of the system is a real problem, but also trying to test a system for features that have not been specified can result in added expense and contention between the third party tester, design engineer, owner and equipment manufacturer. This normally results in confusion during the testing, which results in added cost and delays in the completion of testing.

It is very difficult for the contractor to assume the responsibility for the integration testing as they normally do not have sufficient knowledge of all the design intricacies of a system, especially as it relates to the controls of the various systems. They also have the same handicaps as listed above for the third party but with less technical expertise. We recently assisted a client in the integration testing of selected systems because the testing provided by the contractor was thought to be incomplete. We found numerous system deficiencies that a contractor should not have been expected to identify let alone correct. In this case, the integration testing was specified in the

technical specifications to be the responsibility of the contractor with engineer oversight. The result of this was a spreadsheet listing necessary tests with no detailed test procedures.

**FEA** recommends that integration testing be developed, coordinated and conducted by the design engineer. This is the only entity that is fully aware of all the system inter-relationships needed to develop comprehensive testing plans.

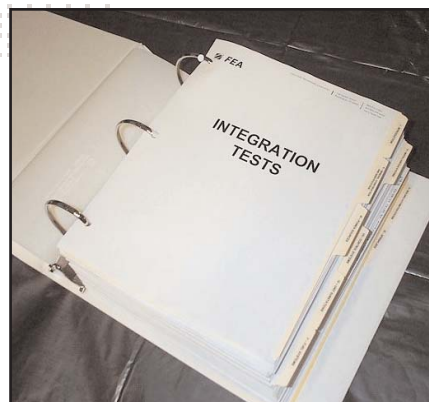
Some Owners may have a concern that the design engineer may not fully test the systems due to known design deficiencies. This may be a concern with firms that are not usually involved in mission critical design, but knowledgeable firms normally bring a wealth of knowledge to the testing process that significantly increases its effectiveness. If the Owner still feels that they need a third party to assist in reviewing the test procedures, one can be engaged who can provide an increased level of quality control. Again, the best results will be obtained if the third party is involved early in the project so that they understand the system design, assist in making design recommendations in addition to just reviewing the test procedures to ensure they are complete and comprehensive. **FEA** has been asked to provide third party review but is very reluctant as it involves a level of liability even though we did not perform the detailed design. Obviously, the Owner has engaged the third party as a check on the design engineer so the Owner expects the third party reviewer to assume some liability if the systems do not perform correctly. Do not be surprised if the



#### Integration Test Outline

third party requests a "no liability" clause absolving them of any design or system deficiencies and any responsibility for equipment failures during testing.

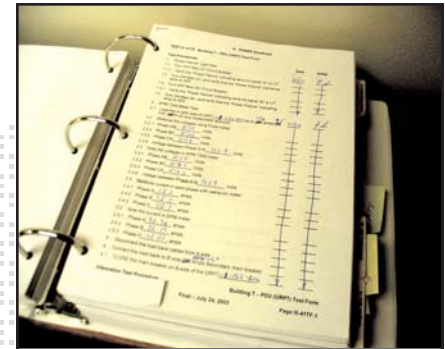
Integration test procedures must outline the features to be tested, participants, test equipment required and any conditions necessary to conduct a proper test including safety issues. Each test procedure must be a step-by-step procedure outlining each test to be performed. Bullet items like "Test the Generator" are not acceptable. Each step of the test should be initialed and dated. This ensures not only that each item is completed, but also establishes a time line when the test was conducted. As testing progresses some equipment may require revisions to meet the test criteria, which may affect other systems that have already



#### Major Project Integration Test Book

been tested. In these cases, it is helpful to know when a system was tested so that a determination can be made as to whether it requires re-testing.

The integration testing procedures for large projects developed by **FEA** have comprised large bound books outlining the necessary step-by-step test required with added field notes on actual test results or any non-standard occurrences. These provide the client with a very comprehensive description of system operation and response to different circumstances.



#### Completed Integration Test Procedure

**FEA** strongly encourages that the client and their maintenance staff be fully engaged in the integration testing phase of the project. The client should actively participate in developing the test procedures and question the engineer to ensure that all different scenarios are fully tested - the more eyes the better. Integration testing is an excellent time for the client and their maintenance staffs to become acquainted with the equipment and the inter-relationship of each system. It also provides the staff with the opportunity to work closely with the equipment manufacturer's service engineers fostering long term relationships. With the

equipment not yet on-line, the maintenance personnel can receive excellent training in a non-threatening environment thereby removing some of their apprehension regarding the operation of the new systems.

One of the benefits of integration testing is that it sets a base line of system performance. We have received calls from clients indicating that the system operated in a certain manner and they did not know if this was correct. It is very helpful if an integration test can be referenced to determine if the observed operation is normal for this system operating under specific conditions or if there has been a change since the integration test indicating a sub-component failure or system degradation. On the other hand, we have assisted clients in resolving problems with equipment that has never been tested. In these cases we had to test the system while the mission critical facility was live to determine what exactly occurred and make revisions so that the system would operate as desired. In many cases the system never operated as intended but the lack of integration testing did not uncover these deficiencies.

Integration testing is a very lengthy/involved process and must be incorporated into the overall project schedule. We have seen test periods as short as a few days (not normally) or up to 12 to 14 weeks. The tests themselves take a lot of time to complete but there is also a tremendous amount of time required due to scheduling multiple vendors and contractors to be on-site for a test, implementing system revisions due to failure to meet the test criteria, software or control revisions, equipment re-

testing and coordination with the equipment manufacturer's home office regarding system operating parameters and potential revisions.

There is no question that mission critical systems will be tested at some time. It will either occur in a controlled environment during integration testing and before the system goes on-line or be imposed on the system due to uncontrollable environmental events or equipment failures after the system is on-line. I think we all agree that it is best to perform all testing in a controlled environment during integration testing before the systems go on-line.

## Choosing a Mission Critical Design Firm

In the past few years, **FEA** has been involved in several mission critical projects which required substantial upgrade of the infrastructure to meet the Owner's business objective.

In one project, the plan was to upgrade an old data center based on a report provided by a major computer equipment supplier. **FEA** was engaged to implement the recommendations. In reviewing the recommendations, we pointed out to the Owner that the proposed upgrades would not provide N+N reliability nor accommodate dual power cord technologies. **FEA** provided a management presentation outlining our findings, which resulted in placing the project on hold while the original recommendations were reviewed. Based on the extent of the recommended revisions, it was also decided

to look at the construction of a new data center that would incorporate 21st century mission critical design concepts. **FEA** provided a preliminary design with probable construction costs for the new facility to assist upper management in making an informed decision. The project review delayed the hardening of the existing data center but little work had been implemented on the original marginal recommendations so there wasn't much of a cost impact.

In another project, **FEA** was to extend base building services to serve a new mission critical facility. In reviewing the base building services it was determined that they would not provide 7x24 redundant services. A major study was conducted which reviewed all critical systems and it was decided to substantially upgrade the existing infrastructure resulting in a large increase to the project budget.

A mission critical facility is a very expensive project. In order to avoid the problems previously discussed it makes sense to carefully choose a consultant on the basis of their ability to do the job, and not exclusively on price.

In order for the Owner to evaluate a consultant's experience, you should request a list of previous mission critical projects they have completed and talk with the Owners of these projects including a tour of the facilities. You should also find out if the firm belongs to any associations devoted to mission critical design. Another excellent approach is to talk with the salesmen and vendors of mission critical equipment - chillers, air conditioning, uninterruptible power sup-

plies, generators and switchgear - asking if this consultant is knowledgeable in 7x24xForever mission critical design concepts, or if they can recommend consultants that are.

Designing numerous mission critical facilities is one of the best ways to develop mission critical design experience. The design concepts necessary for mission critical systems are often not obvious until implementation and start-up in the field. Experience is the best teacher. Any firm that performs comprehensive integration testing of mission critical systems in addition to the basic design will have gained extensive field expertise in system reliability and equipment inter-relationships. A consultant engaged in mission critical design should provide extensive testing services including on-site review, factory witness testing of critical equipment and extensive integration testing of the various systems.

## The designPLUS Concept

Traditional consulting engineering firms typically provide design and construction administration services. Design development and detailed design result in a set of engineering documents used to specify the desired project. Construction administration traditionally provides for shop drawing review, addressing of construction issues and final punch lists. In mission critical

design, traditional services are only half the picture. *FEA* felt that additional services were necessary and coined the term "designPLUS" to describe these added services. *FEA*'s designPLUS combines traditional services with vital added services that ensure optimum results in meeting the client's business objectives and providing a truly 7x24 facility.

As Project Technical Manager, *FEA* provides the client a single, coordinated team of architectural, environmental, structural, acoustical, and mechanical/electrical professionals. We assist in the selection of all contractors and major equipment manufacturers. Our extensive project management experience and commitment to the team approach helps ensure the most cost-effective and efficient project delivery system for meeting the budget and schedule.

DesignPLUS provides the client with detailed drawings, construction review services, and factory witness testing of major equipment to assure the equipment performs as specified. In addition to our involvement with equipment start-up, we develop test procedures and provide on-site coordination of the testing to ensure that the inter-relationship of the various pieces of equipment provides the intended functionality. Finally, we can also provide training, switching and valving procedures, operating manuals and maintenance procedures.

We believe that designPLUS makes sense to clients wishing to successfully design and build a state of the art Mission Critical facility.

## Interesting Facts Dual Power Cord Equipment

The most reliable power distribution system for dual power cord equipment is to feed the equipment directly from two UPSs. Systems with the least amount of distribution equipment between the UPS and the computer equipment are the most reliable.

Static Transfer Switches in the dual power cord equipment power path reduce the overall reliability of the dual power path equipment due to the reliability and complexity of the Static Transfer Switch.

Some equipment is being shipped with three power cords. This does not increase the equipment reliability. The third power cord is required because the load exceeds the capacity of one power supply (i.e. one power cord). A minimum of two cords must be powered at all times, which means you need three independent power sources to provide the necessary redundancy.

### Policy

**designPLUS Newsletter** is published to keep the readers current with the latest trends in mission critical systems.

### Correspondence

*FEA* welcomes any letters, articles, reports and comments for publication. Please mail, fax or email written material to:

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