STRATEGIES FOR REPLACEMENT OF OBSOLETE EQUIPMENT – INCLUDING REVERSE ENGINEERING

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Abstract

The presentation shall detail the challenges facing nuclear power plants with the replacement of obsolete equipment and the strategies used to overcome those challenges. The presentation will outline the common equipment types which are either obsolete or are becoming obsolete, with a focus on safety related components. The four options of the obsolete equipment replacement philosophy will be presented with replacement examples from each of the options shown for discussion purposes. Detailed examples from each of the four obsolete equipment replacement options of, (1) commercially available equivalent component, (2) modification of a commercial available component, (3) reverse engineering of the original component and finally (4) design changes using a new component, shall be presented to evaluate the advantages and disadvantages of each option. The presentation will include the technical challenges, cost and schedule concerns for each of the four options.

Emphasis will be placed on the technological challenges associated with replacing old and obsolete equipment. The following is a bullet list of the challenges which will be discussed:

1) Missing, misleading or no information on the original component.
2) Acquiring information from the original equipment manufacturer and the plant.
3) Using a sample component for the replacement evaluation and or reverse engineering.
4) Reverse engineering old equipment with newly available discrete components.

The presentation will include the equivalency documentation using the EPRI guidelines when replacing an original component with a different yet form, fit and functional equivalent component.

The presentation will conclude with a discussion of the advantages and disadvantages of the replacement of the obsolete component with a form, fit and functional equivalent component vs. the replacement of the original component with a new component with today's technology.

As nuclear plants age the components which make up the operating systems age even faster. Most nuclear plants were designed thirty years ago with the majority being built twenty years ago. To compound this problem many of the components were specified by the design engineering companies building the plants over twenty five years ago.

The average industrial electrical component has a life of 20 years. The average instrumentation component has a life of 15 years. Mechanical equipment is much more application specific and can be much less or the life of the plant depending on the mechanical component and the application.

As a result the nuclear industry is faced with many obsolete components and many components on the verge of becoming obsolete.

There are many different categories of equipment in a nuclear plant. Each category is affected by obsolescence in varying degrees of difficulty. The equipment types are as follows:

- Commercial Grade
- Essential to Plant Operation
- Augmented Quality
- Safety Related

There may even be more categories than this in your plant but the above covers the major types. In order to focus our discussion we will look at safety related equipment types in a currently licensed nuclear plant. Safety related equipment being defined as equipment which is needed to safely shutdown the plant in the event of an accident or equipment needed to mitigate the release of radiation.

Safety related equipment is comprised of electrical, instrumentation & control and mechanical equipment types. The electrical and instrumentation and controls equipment types have been the hardest hit with OEM changes, technology upgrades and quality program changes, resulting in component after component becoming obsolete. In addition the electrical/I&C vendors were the first to drop their nuclear specific QA programs in the early 1980's. forcing the nuclear plants to find equivalent replacements.

Since we are focusing on safety related equipment any replacement component would need to be a form, fit and functional replacement component for the original component eliminating the need for a costly engineering design change and resultant modification to the plant. In addition any replacement would need to be qualified to meet the requirements of the original plant application. We will discuss these requirements later in the paper.

In order to better understand the need for form, fit and functional replacement components, lets look at how some major component types have changed since nuclear plants began operation. The following is al list of common components and how they have changed with technology:

- Relays – new models include digital timers.
- Circuit breakers, contactors, starters (MCC components) – changes due to NEMA and or IEC standard changes
- Controllers – changing to digital
- Power supplies, transformers, inverters, chargers, switches, regulators – changing to digital meet computer & telecommunication industry specifications
- Motor – changes due to NEMA Std. Changes
- Discrete components: resistors, diodes, transistors, SCR's, capacitors, potentiometers - changing to meet computer & telecommunication industry specifications

Anyone in the material supply chain at a nuclear plant would agree, as a result of company changes, technology updates and quality assurance program changes, finding the original component as currently installed is increasingly difficult if not impossible.

In order to maintain and increase plant availability and reliability an equipment replacement philosophy must be understood:

"To provide a form, fit and functional equivalent component to the original component which will not require any modifications in the field and will require minimal or no engineering documentation".

If the above statement is not possible than a design change is explored.

The four methods for replacement equipment to meet the equipment philosophy as stated above in the order of cost and schedule preference are:

1) Supply commercially available equivalent component.
2) Modify and supply a commercially available component.
3) Reverse engineer, fabricate and supply a component to meet the critical characteristics of the original component.
4) Perform a design change to install a new component.

Option 1

Commercially Available Equivalent Component

Detailed research needs to be performed to find an OEM which manufactures an equivalent component. Once an equivalent component is found a detailed item equivalency evaluation needs to be performed to the guidelines of EPRI NP-6406, documenting the comparison of the original components critical characteristics to the newly proposed components critical characteristics.

The selected equivalent component then needs to have its safety function verified and accepted. In addition the item needs to be qualified for its intended application in accordance with the applicable IEEE Standards, usually IEEE Std. 344-1975 and IEEE Std. 323-1974 at a minimum.

The plant now has a safety related qualified equivalent replacement for the original component.

Option 1 Advantages and Disadvantages:

As with any solution there are Advantages and Dis-Advantages to evaluate:

Advantages

- Quickest solution
- Least expensive option
- No field changes required
- Minimal engineering documentation

Disadvantages

- Option 1 is becoming more and more difficult to find equivalent replacements from today's available OEM's.

Option 2

Modified Commercially Available Component

Detailed research needs to be performed to find an OEM which manufactures the closest equivalent component. Once the closest equivalent component is found it is modified as necessary to meet the form, fit and function of the original component. Example modifications would be mounting adapters and electrical modifications to coils (relays, contactors, starters, etc.) to meet plant specifications.

Once the modifications are complete a detailed item equivalency evaluation needs to be performed to the guidelines of EPRI NP-6406, documenting the comparison of the original components critical characteristics to the newly proposed modified component critical characteristics.

The selected modified component then needs to have its safety function verified and accepted. In addition the item needs to be qualified for its intended application in accordance with the applicable IEEE Standards, usually IEEE Std. 344-1975 and IEEE Std. 323-1974 at a minimum.

The plant now has a safety related qualified equivalent replacement for the original component.

Option 2 Advantages and Disadvantages:

As with any solution there are Advantages and Disadvantages to evaluate:

Advantages

- Still inexpensive compared to other options
- Can be quick depending on the nature of the modification
- No field changes required
- Minimal engineering documentation
- Opens the door for more commercially available items

Disadvantages

- Depending on complexity of modification can be long schedule and more expensive.

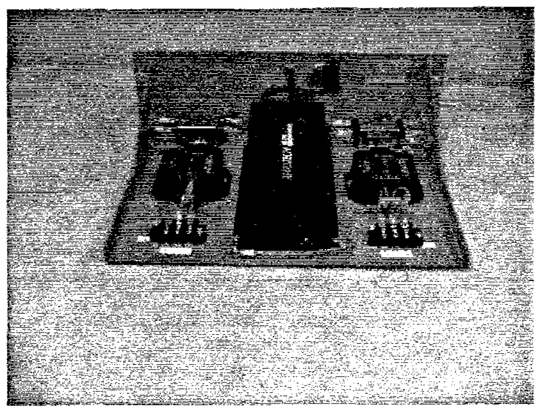

Fig. 1 – Replacement Inverter

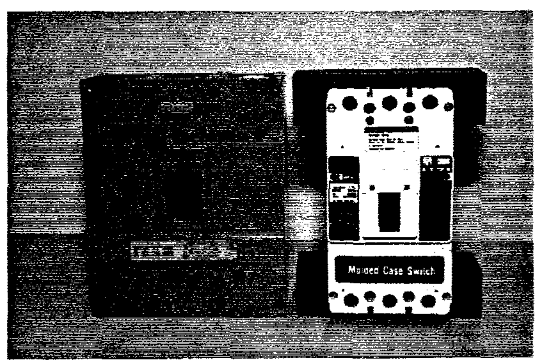

Fig. 2 – Replacement MCCB

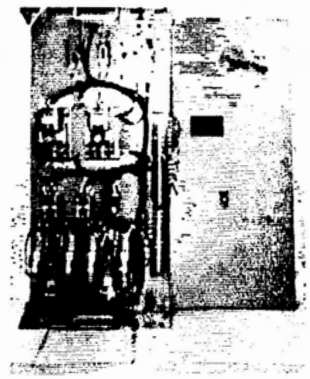

Fig. 3 – Replacement MCC cubicle

Option 3

Reverse Engineer, Fabricate and Supply a Component

When the first two options are exhausted the reverse engineering option is explored. Technical information on the original component must be identified. One or more of the following must be available to perform Option 3:

- Sample working component
- Original information from discussions with the OEM.
- O&M Manual with drawings of the original component
- Plant specific test or calibration procedures

If it is decided that there is enough reliable information available to reverse engineer the original component then the reverse engineering of the design is started. Specifically, it must be determined if the component can be built with today's discrete components to meet the original design.

An evaluation of the cost and minimum quantities to fabricate new components based on a reverse engineered design need to be established to determine if the project is worth going forward.
If it is decided to go forward then a proto-type is fabricated. The proto-type is then tested to determine if it meets the critical characteristics of the original component. Once the proto-type is adjusted as necessary it is burned-in (as applicable) and completely tested to meet the form, fit and functional requirements of the original component.

Once the reverse engineered proto-type is complete a detailed item equivalency evaluation needs to be performed to the guidelines of EPRI NP-6406, documenting the comparison of the original components critical characteristics to the newly proposed reverse engineered component critical characteristics.

The reverse engineered component then needs to have its safety function verified and accepted. In addition the item needs to be qualified for its intended application in accordance with the applicable IEEE Standards, usually IEEE Std. 344-1975 and IEEE Std. 323-1974 at a minimum.

The supply units are then fabricated for their intended application in the plant.

The plant now has a safety related qualified equivalent replacement for the original component.

Option 3 Advantages and Disadvantages:

As with any solution there are Advantages and Disadvantages to evaluate:

Advantages

- No field changes required
- Minimal engineering documentation
- Eliminates need for design change

Disadvantages

- Can be expensive depending on complexity.
- Long lead time (longer with less information up front)
- Need as much technical information on the original item as possible.

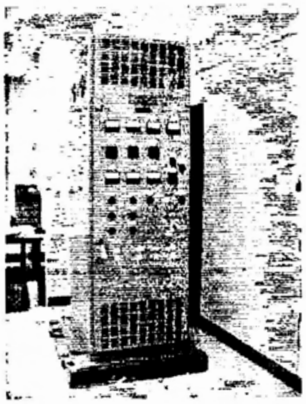

Fig. 4 – Exterior view of reverse engineered 7.5 kVA inverter

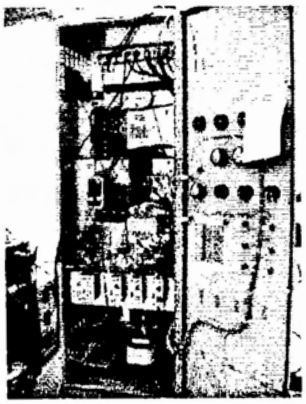

Fig. 5 – Interior view of reverse engineered 7.5 kVA inverter

Fig. 6 – Reverse engineered printed circuit boards

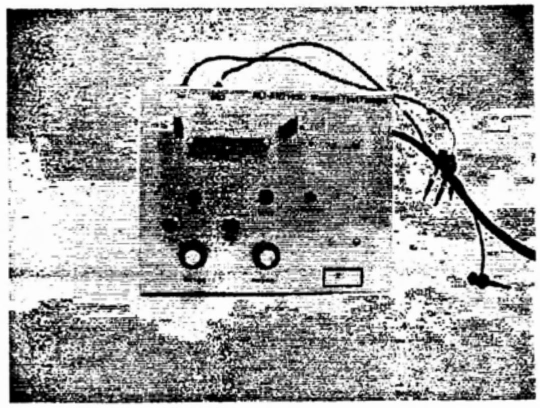

Fig. 7 – PCB test board for reverse engineered PCB's

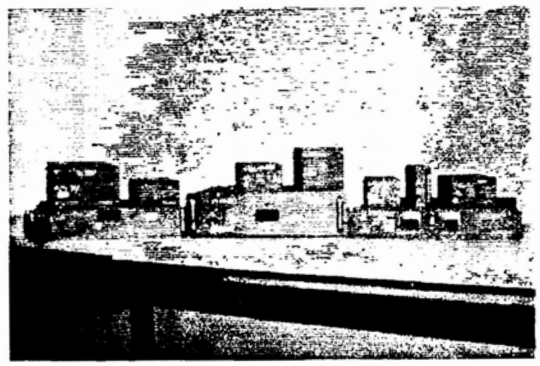

Fig. 8 – Reverse engineered power supplies

Fig. 9 – Reverse engineered phase sensing transformer

Option 4

Design Change

If the first three options do not prove prudent then a design change is explored.

The benefits of a design change can be a component with a newer more reliable technology. The new component is selected based on the plant application, but can provide new features, accuracy and benefits as a result of the newer technology. These newer features and better reliability can help off-set the increased cost of the design change package and any resultant plant modifications.

Option 4 Advantages and Disadvantages:

As with any solution there are Advantages and Disadvantages to evaluate:

Advantages

- Can use the benefit of a newer technology

Disadvantages

- Expensive (engineering and equipment)
- Long lead time (longest of 4 options)
- Field changes required
- Significant engineering documentation

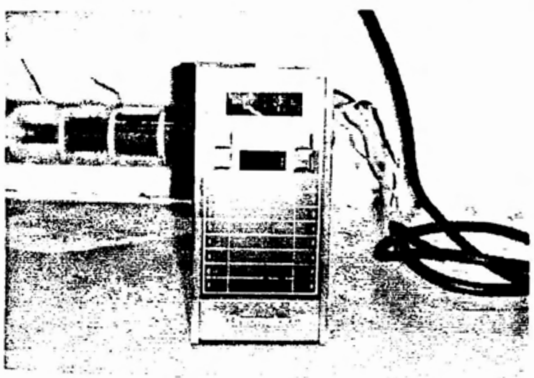

Fig. 10 – Exterior view of digital controller

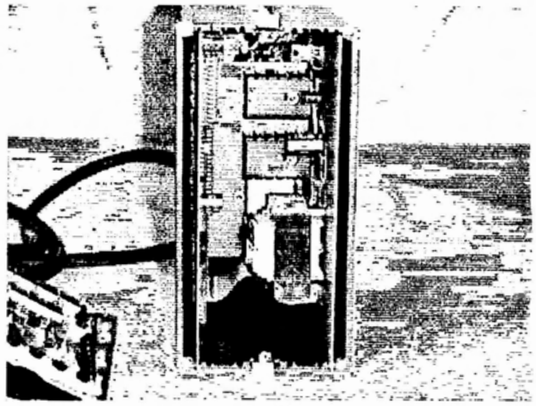

Fig. 11 – Interior view of digital controller

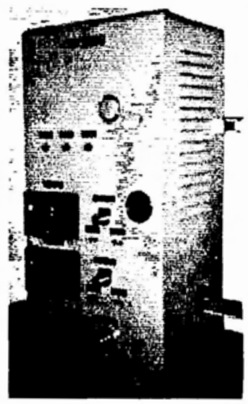

Fig. 12 – Replacement panel (new design concept)

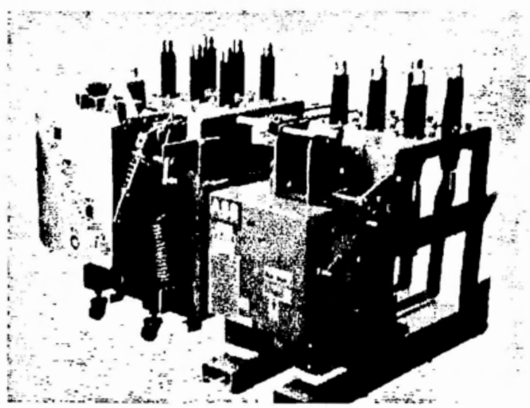

Fig. 13 – Replacement 4kv vacuum circuit breaker

Dedication and Qualification Requirements

All four options will require verification of the new components safety function and qualification activities for safety related applications.

Qualification by similarity to existing component is not likely and therefore new qualification testing is necessary.

Safety function shall be verified to the guidelines of EPRI NP-5652 and the applicable Commercial Grade Item (CGI) Evaluations.

Qualification needs to be performed in accordance with IEEE Std. 323-1974/1983 and IEEE Std. 344-1975/1987, at a minimum. The applicable IEEE Standard daughter standards may be invoked as applicable.

Equipment Types

The modification of a commercially available component and the reverse engineering of a component has and can be performed for numerous component types.

The following is a growing list of equipment types that have been designed for replacement of an originally obsolete component:

- MCC cubicle replacements
- Molded case circuit breakers
- Power supplies
- Printed circuit boards
- Electronic modules
- 480v, 5kv and 15kv circuit breakers
- HVAC: chillers, airhandlers and fans
- Transformers
- Relays
- Limit switches
- Transfer switches
- Inverters

As more and more equipment types become obsolete the types of newly designed form, fit and functional replacements will increase.

Digital Equipment

As discussed above, when the first three options of the equipment replacement philosophy do not prove prudent a design change is initiated. Since the cost of a design change has been justified it makes sense to take full advantage of the newest technology to replace the original obsolete component.

In some cases a decision will need to be made whether to perform reverse engineering of the original component or perform a design change to put in a new component. Depending on the complexity of the original component the cost to reverse engineer can be equal to the cost to perform a design engineering package.

At this point the benefits of a newer technology can help justify the cost of the design change. In most cases today the newer technology is the use of digital technology in the replacement component.

Digital equipment can provide the following benefits over the older electronic technology it replaces:

- Extremely accurate timers/timing relays
- Excellent regulation for transformers, regulators and inverters
- Reliable and programmable controllers
- Better system control and diagnostics information

The above benefits can help with the justification to perform the design change using a digital replacement component. However, when digital technology first appeared on the nuclear safety related equipment scene it was perceived as a negative.

Nuclear power plants viewed digital equipment as an unproven technology and therefore did not embrace the benefits this equipment type could provide. The fear of common mode failures and the cost associated with additional qualification requirements kept most nuclear plants from using digital equipment until late 1998.

Now with a better understanding of the requirements for using digital equipment in safety related applications most nuclear plants are installing digital equipment in safety related applications when possible.

In addition to the typical environmental and seismic qualification requirements specified for safety related equipment, digital equipment also needs to be qualified for electromagnetic interference (EMI/RFI) in accordance with EPRI TR-102323 and Software Verification and Validation (V&V) in accordance with IEEE 7-4.3.2.

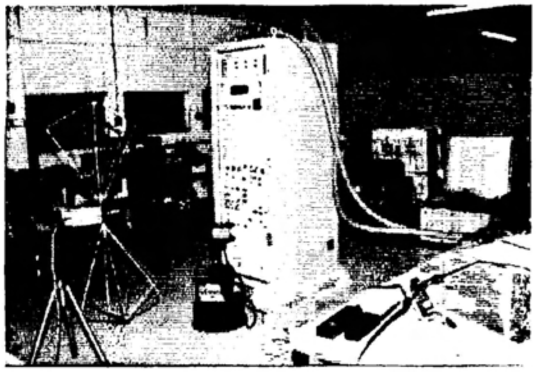

Fig. 14 – EMI/RFI test of digital panel

Typical Digital Equipment

The following is a list of typical digital equipment which is used in safety related applications:

- Frequency drives
- Controllers
- Timing relays
- Inverters
- Regulating transformers
- Videographic recorders
- Pressure switches

Required Documentation

Independent of which option is chosen there will be some documentation necessary to meet the safety related requirements of the component.

Options 1 through 3 will require an item equivalency evaluation (IEE) comparing the critical characteristics between the original component and the newly proposed component.

The IEE is written to the guidelines of EPRI NP-6406 and is typically supported by OEM date, plant data and functional test and inspection of the components.

Options 2 – 4 will require a new Instruction Manual (IM) detailing the installation, start-up, operation and maintenance of the new replacement component. A typical IM will include a complete drawing package consisting of a general arrangement, wiring diagram, P&ID (as applicable) and Bill of Materials at a minimum.

All options will require a new Qualification Report documenting the qualification testing and or analysis of the new component. The qualification will be in accordance with IEEE Std. 344-1975 and IEEE Std. 323-1974 at a minimum. Digital equipment will require additional qualification to the requirements of EPRI TR-102323 and IEEE Std. 7-4.3.2.

Conclusion

The combination of nuclear plants getting older, nuclear plants extending the operating license and equipment technology increasing at an alarming rate is forcing equipment obsolescence to be one of the nuclear industry's largest challenges in the new millennium.

The use of a good equipment replacement philosophy will help nuclear plants maintain high capacity factors while planning for the future.