Life Cycle Considerations for Microprocessor Relays

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Paper initiated in 2012 where real-life scenario drove the need for data and solutions.

A lack of general knowledge concerning MP relay aging and design life on the part of users.

General inquires for replacement of aging MP relays.

A user case study with over 200 20+ year old distribution relays.

A noticeable lack of MP relay asset management (mv level).
What is Covered?

- History
- Manufacturer design considerations
- Design life factors
- Firmware and software
- Service life versus supported life
- During life
- Manufacturer end of life
- User end of life
- Options to replace
- A user case study
Evolution of protective relays

Electromechanical

Solid State

First Generation Microprocessor

Present Generation Microprocessor
First generation microprocessor relays were released to market in the early 1980’s.

8 bit structure.

Previous electromechanical technology life was 60+ years.

A shift in asset management was required but not wholly embraced.

Aging microprocessor relays require replacement but solutions limited. E/M relays “simple”. 
From 8 bit and beyond...

- 50/51
- Reclosing
- Event Recording
- ASCII Communications

- Many protective elements
- Complex waveform analysis
- Multiple comm channels and protocols
- Automation and networking
- PLC functionality
- Pinpoint fault location
- Comprehensive breaker monitoring
- Etc...
Manufacturer Development Challenges

- Design to current, stable and available components.
- Consider multi-source component availability over many years.
- Design for available capacity for future enhancements over design life.
- Rigorous testing IEEE / IEC and beyond:
  - Functional
  - Environmental
  - Aging
Design Considerations – Firmware / Software

- Design with ability to enhance for future functionality.
- Design for backwards compatibility.
- Design for simplicity.
Service and Supported Life

Service Life
- The actual time period that the relay performs its duty without fail.
- General population, no aging trend.

Supported Life
- The time period that the relay is supported by the manufacturer.
- Ability to repair or replace.
During Life – Critical Updates

- Update required – protection affected.
- Can be hardware or firmware.
- Critical updates not always required but always recommended.
- Inherent costs associated with critical updates.
  - In the case of a utility with hundreds of affected relays, the cost can be substantial.
  - Consider the example case:
    - 300 relays affected
    - $2000 per truck per day
    - 2 relays updated and tested per day (150 days to update all)
    - Cost estimated at $300,000
Updates not required for product to function as intended or expected.

- Product enhancements
- Update compatibility for non-vendor specific software (web browsers, RTU’s)
- Communications updates
- Manufacturer specific software
- Can be updated at periodic test interval
During Life – MTBF

- MTBF: Mean Time Between Failure
  - Used as a means to determine hardware failure rate.
  - Firmware not considered in metric.
  - Out of service time not considered.
  - General MTBF factors change dramatically when considering hardware and firmware.

- Example case:
  - 100 relays in service for 2 years = 1,752,000 total hours
  - 5 hardware failures = 350,400 hours MTBF or 20 years
  - If 50% required one update, MTBF drops to 10 years.
  - Two updates = 5 years
Factors Affecting In-Service Life

Consideration to life needs to be given to:

- Environment – wide temperature swings
- Damage but no failure (lightning strikes)
- Number of operations
Maintenance

PRC-005-2

Self checking negates need for periodic testing assuming self check is monitored. 12 year cycle.

Metered values generally show health of analog channels.

Trip testing recommended to exercise trip outputs.
Failure Modes

Self checking will generally indicate an internal failure for monitored data such as:

- RAM
- ROM
- CPU
- I/O
Security Concerns

- Aging relays may not have the capability to be updated to meet more stringent security standards.
  - Multi-level passwords
  - Data encryption
Manufacturers discontinue a product when no longer viable or unable to manufacture.

Cost to manufacture becomes too high.

Demand drops in favor of newer technologies.
User End-of-Life

How is end of life determined by a user?

- Users see an unacceptable rate of failure.
- Planning for newer functions drives MP relay change.
- Support for existing relays no longer available.
- Security and regulatory mandate require change.
Replacement Solutions

- EM relay replacement
- Extended supported life
Replacement Solutions

- Microprocessor relays
- Form fit and/or wire alike chassis extends supported life.
- Adapter panels
Replacement Solutions

A form fit, wire alike, or adapter panel may not be a viable solution if:

- New protection schemes are not supported.
- Aging of other related components.
- The entire bay is due to be replaced.
- Additional engineered solutions desired.
- Additional I/O desired although can be achieved by means of communications and remote I/O.
User Case Study

- Medium to large size IOU.
- 20+ year old MP distribution relays in service across regions.
- Failure rate increase at 18+ year mark.
- Reliability metrics affected.
- Limited asset management or planning for end of life.
- Engineering days to replace longer than acceptable when considering increasing failure rate
## User Case Study - Retrofit

<table>
<thead>
<tr>
<th>Cost Analysis Per Installation</th>
<th>Retrofit Solution</th>
<th>Engineered Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relay Cost</td>
<td>$6,000</td>
<td>$2,000</td>
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<tr>
<td>Installation Days</td>
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<td>4</td>
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<tr>
<td>Relay Tech Cost</td>
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<td>Engineering Days</td>
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<tr>
<td>Engineering Cost</td>
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<td>$10,000</td>
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<tr>
<td>Total Cost Per Install</td>
<td>$10,500</td>
<td>$20,000</td>
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</table>

Available solutions to replace end-of-life MP relays
# User Case Study - Retrofit

## Total Cost Analysis

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<tbody>
<tr>
<td>Total Cost per install</td>
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<td>$20,000</td>
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<tr>
<td>Number of relays</td>
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<td>120</td>
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<tr>
<td>Total Project Cost</td>
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<tr>
<td>Savings Realized</td>
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<tr>
<td>Tech Days per install</td>
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<td>Total Project Days</td>
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<td>480</td>
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<td>Day Savings Realized</td>
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**Summary**

- E/M relay asset management and planning no longer viable for MP relays.
- Average first generation MP life is 18-20 years (no aging trend).
- Pushing past design life is costly and reliability affected.
- Asset management is key to reducing end of life costs.
- Total cost of ownership needs to be considered.
- Cost / time savings can be seen with retrofit options if available.
- New technologies expectation for life past 20 years.
QUESTIONS?

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