ECE Senior Design Reliability Analysis Report
For

Scalable Regulated Three Phase Power Rectifier

October 18, 2004 Rev. 1.0

Sponsors:  Dr. Herb Hess (University of Idaho)
           Dr. Richard Wall (University of Idaho)

Instructor: Dr. Jim Frenzel (University of Idaho)

Prepared By,

Tao Nguyen
nguy1484@uidaho.edu

Tyler Budzianowski
budz6104@uidaho.edu
Reliability Analysis Report of the Three Phase Rectifier Senior Design Project  
(October 2004)

Abstract - This technical paper is intended to provide the reader with the necessary information to fully understand the reliability analysis that was performed on the Three Phase Rectifier Senior Design Project. It is based on content and format requirements that were specified by the instructor.

I. Introduction

The reliability characteristics of a designed system are important to incorporate into a successful end product. By analyzing the behavior of integrated components and individual subsystems, the performance and lifecycle characteristics of an entire system design can be determined. This information can be used to identify any potential design problems or flaws as early as possible in the design process and to allocate effort and resources into the research and prevention of any identified problem. By dividing an entire system into smaller subsystems and individual components, the reliability of the entire system can be comprised of the total of each individual section. This divide and conquer technique is useful in focusing on only subsystems or components that most need attention following a reliability analysis. Using software and FMECA standards and techniques, an accurate and beneficial reliability analysis can be performed.

II. System Failure Rate Calculations

A. Reliability Analysis Overview

The overall failure rate of the system was calculated using the Relex Analytical Tools (demo version) from the Relex Software Corporation. This software program has the ability to calculate the overall failure rate and Mean Time Between Failure (MTBF) values based upon the actual components utilized within the system design. Because each individual component and the subsystems comprised of these components has its own individual performance and reliability characteristics, the overall failure rate and MTBF can be comprised of the sum of each individual component failure rate and MTBF. The demo version used for these calculations unfortunately did not contain all of our specific components utilized in the design (such as the PIC16C74B microcontroller) within its component library. Similar components to the actual components were selected as an estimating alternative.

Our particular design has been divided into three main subsystems and are as follows: zero-crossing detector, microcontroller, and the three phase rectifying circuit. The zero-crossing detector is comprised mainly of a comparator circuit utilizing an LM393 integrated circuit, resistors, capacitors, and a supply voltage source. The microcontroller system includes a PIC16C74B processor, 9 volt DC voltage source, and demonstration board. Finally, the rectifier circuit requires 6 silicon-controlled rectifiers (SCRs), a snubbing circuit comprised of resistors and capacitors for each SCR, MOVs, and an SCR gate firing circuit system. The following table (please see Table 1) illustrates the results of the Relex failure rate and MTBF calculations.

Table 1.
<table>
<thead>
<tr>
<th>Part</th>
<th>Failure Rate</th>
<th>MTBF (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Crossing</td>
<td>0.045784</td>
<td>21842000</td>
</tr>
<tr>
<td>Rectifier Circuit</td>
<td>0.312870</td>
<td>3196217.33</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>0.015281</td>
<td>65440800</td>
</tr>
</tbody>
</table>

B. Failure Modes and FMECA Analysis

1) Potential Failure Modes

All potential failures modes that may be associated with the system design throughout its lifecycle are presented in the following table. They are based on each individual subsystem and the components used to implement each subsystem (please see Table 2).

Table 2.

List of potential failure modes

1. Firing gate circuit failure
2. SCR failures
3. Software failure
4. Zero crossing detector
5. Snubber and protection circuit failure
6. Physical damage
7. Improper set up or use
8. Over voltage
9. Microcontroller malfunction
10. Mechanical Problem
11. Three phase input line noise
12. Temperature increase/decrease
13. Uneven load/output current
2) **Failure Mode Severity Rating**

The severity of each failure mode has been determined based upon the FMECA Failure Effect Rating Scale and is based on a range of ‘1’ to ‘10’. The scale spans the categories of ‘Not Noticeable’ to ‘Moderate’ to ‘Hazardous’, respectfully. These ratings are determined by the severity of the effect on the system/customer, the potential for property damage, and the potential injury hazard.

3) **Probability of Occurrence Rating**

The probability of the occurrence of each outlined failure mode has been determined based on the FMECA Probability of Occurrence Rating Scale and illustrates how likely a determined failure mode may or may not occur. Spanning from ‘Extremely Remote’ to ‘Occasional’ to ‘Extremely High’, this is also based on a scale from ‘1’ to ‘10’, respectfully.

4) **Probability of Failure Detection Rating**

This rating is based on the FMECA Probability of Failure Detection Rating Scale and is used to determine how likely it may or may not be to detect a potential failure mode before actual failure or malfunction actually occurs. It ranges from ‘Almost Certain’ to ‘Moderate’ to ‘Almost None’. Also based on ‘1’ to ’10’, the scale defines more detectable failure modes to have a higher number than less detectable failure modes.

5) **Risk Priority Number**

The Risk Priority Number (RPN) was determined from the product of the previously determined failure mode severity, probability of occurrence, and probability of detection ratings: 

\[ \text{(severity)} \times \text{(prob. of occurrence)} \times \text{(prob. of detection)} \]

This calculated value ultimately determines the overall priority of system risks and influences what and how each subsystem’s potential problems and hazards are addressed. As a general rule, the greater the value, the higher the priority. It can be determined from the RPN value which subsystems and individual components need immediate additional resources allocated such that these potential failures can be reduced and eliminated. The RPN for each failure mode has been calculated and is listed in Table 3.

### Table 3

<table>
<thead>
<tr>
<th>Failure Mode</th>
<th>Severity</th>
<th>Occurrence</th>
<th>Detection</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys. Damage</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>384</td>
</tr>
<tr>
<td>Improper Use</td>
<td>9</td>
<td>3</td>
<td>7</td>
<td>189</td>
</tr>
<tr>
<td>Zero Crossing</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>168</td>
</tr>
<tr>
<td>AC Line Noise</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>150</td>
</tr>
<tr>
<td>uC Failure</td>
<td>8</td>
<td>2</td>
<td>7</td>
<td>122</td>
</tr>
<tr>
<td>Gate Ckt Failure</td>
<td>7</td>
<td>4</td>
<td>4</td>
<td>112</td>
</tr>
<tr>
<td>Voltage Transients</td>
<td>8</td>
<td>4</td>
<td>3</td>
<td>96</td>
</tr>
<tr>
<td>Thermal Shock</td>
<td>5</td>
<td>2</td>
<td>8</td>
<td>80</td>
</tr>
<tr>
<td>Software Failure</td>
<td>5</td>
<td>2</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Protection Ckt</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>48</td>
</tr>
<tr>
<td>Uneven Load</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>24</td>
</tr>
<tr>
<td>SCR Failure</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>21</td>
</tr>
</tbody>
</table>

III. **Conclusion of Failure Mode and Effect Critical Analysis**

Based upon the FMECA assessment, we have determined which top three component and subsystems need to receive the highest design assessment priority. The failure modes that are most likely to occur in the design are failure of the zero crossing detection subsystem, gate firing circuit subsystem failure, and failure of the microcontroller system. It is noted that from the FMECA ratings table, modes such as physical damage, improper use, and AC three phase input line noise are listed as the top failure modes. These modes however, cannot be fully prevented by means of design changes or additions and have therefore been excluded as failure modes that are preventable and at high risk to the design.

Physical damage can be prevented by means of a solid system enclosure, while AC line noise is practically unpreventable, although should be accounted for. Improper use will be minimized as much as possible by means of a useful and easily understood operating manual. While these particular events and situations are out of the designer’s ultimate control, it is helpful to understand that these risks are present and can potentially occur. For our application, it is uncertain as to the accuracy of the FMECA calculations because our particular components were not all contained within the software library. It is the intention that this is not a major problem. This aside, the FMECA analysis is a useful tool in determining how resources need to be allocated in a design to achieve the best possible solution.
IV. Appendix

- Please see attached calculations using the Relex Analytical Software Tools.

V. References
