# Table of Contents

1. **Project Summary**  
   1.1 Statement of Objectives  
   1.2 Significance of Project  
   1.3 Methods to be Employed  

2. **Project Description**  
   2.1 Objectives  
   2.2 Significance of Project  
   2.3 General Plan of Work  
      2.3.1 Examination of Present Control System  
      2.3.2 Design of New Control System  
   2.4 Methods and Procedures  
   2.5 Additional Considerations  
   2.6 Technical Advisor  

3. **Bibliography**  

4. **Biographical Sketches**  

5. **Schedule**  

6. **Budget**  

7. **Safety**  

APPENDIX A
1. Project Summary

1.1 Statement of Objectives

The objectives of the proposed project are to improve the current waveforms drawn by Compact Engineering’s infrared (IR) paper dryers and to maintain the present overall dryer system output performance. In order to improve the current waveforms, a new controller and control algorithm will be designed and implemented. The newly designed controller and algorithm will work with the existing Compact equipment.

1.2 Significance of Project

Infrared dryers are used in the paper manufacturing process to provide supplemental, precision drying. Compact Engineering Ltd. manufactures the IR dryers currently used at the Potlatch paper mill in Lewiston, ID. The control algorithm currently used by these dryers causes them to draw current waveforms with significant harmonic distortion, leading to costly facility shutdowns and excessive wear on plant equipment. The new control algorithm, by improving the power quality of the dryer current waveforms, will eliminate these problems. This will improve the performance of Compact’s IR drying systems, making them more marketable to the global pulp and paper industry.

1.3 Methods to be Employed

A scaled model of a Compact IR dryer will be constructed using incandescent light bulbs. The scaled model will be used to investigate concepts related to lamp control and evaluate hardware implementations of future designs. Along with the model lamps, Compact’s actual IR lamps will be characterized, allowing a theoretical model of their electrical behavior to be created. The new control algorithm will focus on manipulating the lamp switching such that the power quality of the system is improved. In addition, software simulations will be created for the final design.
2. Project Description

2.1 Objectives of Proposed Work

The primary objective of this project is to redesign the switching scheme of the Compact IR dryers such that the current waveforms they draw are of a significantly higher power quality and to implement this scheme in hardware. Specifically, the Total Harmonic Distortion (THD) and Crest Factor (CF) of the current waveform must be improved. The success of a design will be evaluated based upon measurements of these two quantities. A design will be deemed acceptable if it complies with both American and European standards for power quality in industrial systems.

The second objective is to maintain the present drying performance of the IR dryers themselves. This means that the heat generated by a given lamp under the improved switching scheme will be equivalent to that generated by the lamp under the present switching scheme. Temperature fluctuation levels must also be maintained. Due to the manner in which it applies power, the present switching scheme causes lamp temperatures to vary slightly over each switching cycle. In order for a new design to be successful, this temperature ripple must be no worse than it is presently.

The third objective is to produce a final design that is compatible, both electrically and physically, with the other components of Compact’s current system. This entails compatibility of input and output signals, physical connectors, and physical size. Meeting these constraints will enable the newly designed controller to directly replace the present controller.

2.2 Significance of Project

Drying is an extremely important part of the paper manufacturing process. The majority of this drying is accomplished using large heated rollers through which the paper, manufactured as a continuous sheet, is threaded. For several reasons, IR dryers, which emit infrared radiation
that is at an optimal frequency for reacting with and evaporating water, are becoming increasingly vital parts of the paper making process. The primary reason for the increased importance of IR dryers is that they are small enough to be inserted into existing paper machines, allowing production speed to be increased. IR dryers also offer an increased level of control by adjusting the temperatures of different dryer sections based upon measurements of the moisture content across the paper sheet.

Compact Engineering Ltd. manufactures high quality electrically powered IR dryers, including the ones currently used at the Potlatch paper mill in Lewiston, ID. The control algorithm presently used by Compact to govern the switching of the various lamps within their dryers creates current waveforms with high crest factors and significant levels of harmonic distortion.

The low power quality of Compact’s IR dryers is currently causing machines in the Potlatch mill to shut down as protection circuitry is tripped. These shutdowns are occurring with a frequency of roughly once every four to six weeks, and last anywhere from two to four hours with a cost of approximately $20,000 per hour due to lost production. The creation and implementation of a new control algorithm for Compact’s IR dryers will eliminate these costly shutdowns.

2.3 General Plan of Work

2.3.1 Examination of Present Control System

The first task necessary to successful completion of the project is the generation of a functional project description. The remainder of work to be completed will be dependent upon this specification, giving this task primary importance. Research will be done to understand the current dryer control system and to compare other design possibilities. Once generated, the functional description will be reviewed by Compact Engineering for verification of concept and
acceptance of description. A functional diagram of the proposed system is included in Appendix A.

The electrical behavior of Compact’s IR lamps and the incandescent bulbs will be characterized to account for their effects in the final design and allow for software modeling of potential designs. However, a demonstration of concept will be developed before software modeling will be completed. This demonstration will illustrate the gross functionality of the scaled array in modeling the performance of the actual system.

2.3.2 Design of New Control System

The basic functionality of the modeling approach will be analyzed by constructing a minimal lamp array consisting of 3 lamps. Using the small model, software and hardware concepts will be tested and compared. Based on the success of the small model results, a similar design will be used in the construction of the large model. Following the construction, control design ideas will be tested and compared through software simulation. This process will insure quality of design before prototyping.

Once a preferred design is determined through software simulation, it will be implemented in hardware. The performance of the prototyped design will be analyzed using the scaled lamp array. Not only will normal operating conditions be considered, but error handling and start-up/shut-down procedures will also be designed into the system. Given that the prototype performance is deemed successful in light of the goals of this project, the final design will be applied to the Compact dryer system.

2.4 Methods and Procedures

After generating a functional description, a 3 lamp array will be constructed using incandescent bulbs, switching hardware, and a basic microcontroller. The components will be mounted to a piece of plywood, allowing for effective demonstration and testing. In order to
model the behavior of the IR dryer filament and the incandescent bulbs, each will be characterized. This will involve measuring the current given an applied voltage with respect to time, taking into consideration the effects of lamp temperature.

Software simulations will be done to verify the expected behavior of the new designs prior to prototyping. The analysis will include the electrical current THD, crest factor, and temperature variation measurements. These parameters will be evaluated for both normal and start-up operation. Designs will also account for necessary safety considerations through an error handling procedure. The most effective software design will be implemented in hardware. This will require designing and producing a printed circuit board using components that will meet the physical design constraints.

The final prototype will be tested using a larger scaled lamp array. Measured data will be taken to verify success of the design in regards to observed lamp output, THD, crest factor, and temperature variation, given a specified power level input. Again, these metrics will be considered for both normal and start-up operation of the system. The functionality of the error handling procedure will also be tested.

2.5 Additional Considerations

The manufacturing process for the new design will not require processes or equipment not normally used in PCB manufacturing. The components and PCB will not need any special disposal process. A lifetime of considerable length will be designed into the system in order to avoid the future generation of excess waste.

The redesign has the potential for large economic consequences to the paper manufacturing industry. The cost of a failure with the current control system is on the order of 20,000 dollars per hour of downtime. With each failure, the average production line restart time is on the order of 4 hours, giving a cost of system failure approximately equal to $80,000. With
the currently installed system at Potlatch paper mill, the failures have occurred approximately every 4-6 weeks [3]. Improving the power quality of the dryers will eliminate the down time of paper mills caused by the switching scheme of Compact’s IR dryer system. This will increase the productivity of these paper mills along with the marketability of Compact’s dryers. Given these sizeable benefits, we strongly encourage you to fund this project.

2.6 Technical Advisor

The technical advisor for this project will be Dr. Joseph Law from the Electrical and Computer Engineering Department of the University of Idaho. Dr. Law will provide general guidance throughout the project and will also assist in all communication between the project team and the project sponsor, Compact Engineering Ltd. We will meet with him at least once per week.
3. Bibliography

http://www.energysolutionscenter.org/GasIRPaper/Learn%20About/Paper_Drying.htm

June, pp. 758-762.


no. 3, June, pp. 378-383.
4. Biographical Sketches

Matthew R. Harvey
701 Taylor Ave. Apt. 5
Moscow, ID, 83843
208-761-0535
Email: harv3608@uidaho.edu

Education

Senior Electrical Engineering Undergraduate Student, University of Idaho
Graduation Date: December 2005

Experience

Summer 2004: Internship with Sandia National Laboratories in Livermore, CA which consisted of designing a small photovoltaic power supply for wireless sensor networks.

Relevant Coursework

Electronics I, II
Energy Systems I, II
Power Electronic Circuits
Digital Logic
Microcontrollers
Signals and Systems Analysis
Kellin Lang-Gillming  
710 W A st  
Moscow, ID, 83843  
Email: lang8631@uidaho.edu

Education

Senior Electrical Engineering Undergraduate Student, University of Idaho  
Graduation Date: December 2005

Experience

Summer 2004: Internship with Jet Propulsion Laboratory in Pasadena, CA which consisted of design verification for the Mars Polar Lander electronics systems for future missions.

Relevant Coursework

   Electronics I, II  
   Energy Systems I, II  
   Power Electronic Circuits  
   Digital Logic  
   Microcontrollers  
   Signals and Systems Analysis I, II
Michael R. Frost
222 N. Lieuallen St. Apt. #3
Moscow, ID, 83843
360-969-1992
Email: fros5802@uidaho.edu

Education

Senior Electrical Engineering Undergraduate Student, University of Idaho
Graduation Date: December 2005

Experience


Relevant Coursework

- Electronics I, II
- Energy Systems I, II
- Digital Logic
- Microcontrollers
- Signals and Systems Analysis
5. Schedule

Tasks for Spring 2005 Semester:

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Mar '05</th>
<th>Apr '05</th>
<th>May '05</th>
<th>Jun '05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional Project Description</td>
<td>25 days</td>
<td>Mon 2/21/05</td>
<td>Fri 3/25/05</td>
<td>20</td>
<td>27</td>
<td>9</td>
<td>13</td>
</tr>
<tr>
<td>Design Review Presentation</td>
<td>5 days</td>
<td>Mon 3/21/05</td>
<td>Fri 3/25/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts for Small Model</td>
<td>5 days</td>
<td>Mon 3/21/05</td>
<td>Fri 3/25/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterization of Lamps</td>
<td>10 days</td>
<td>Mon 3/21/05</td>
<td>Fri 4/1/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Model Construction</td>
<td>10 days</td>
<td>Mon 3/23/05</td>
<td>Fri 4/6/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software for Model</td>
<td>10 days</td>
<td>Mon 4/4/05</td>
<td>Fri 4/15/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototyping/Demonstration</td>
<td>6 days</td>
<td>Mon 4/13/05</td>
<td>Mon 4/26/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Report I</td>
<td>28 days</td>
<td>Mon 4/4/05</td>
<td>Mon 5/9/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts for Full Sized Model</td>
<td>5 days</td>
<td>Mon 5/2/05</td>
<td>Fri 5/6/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Division of Labor for Spring 2005 Semester:

<table>
<thead>
<tr>
<th>Team Member</th>
<th>Kellin</th>
<th>Matt</th>
<th>Mike</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact / Potlatch contact</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Project Description</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Review Presentation</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Order Parts for Small Model</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Characterization of Lamps</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Model Construction</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Software for Model</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prototyping/Demonstration</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Final Report I</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Order Parts for Full Sized Model</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Tasks for Fall 2005 Semester:

<table>
<thead>
<tr>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Sep '05</th>
<th>Oct '05</th>
<th>Nov '05</th>
<th>Dec '05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sized Model Construction</td>
<td>7 days</td>
<td>Thu 9/1/05</td>
<td>Fri 9/8/05</td>
<td>26</td>
<td>4</td>
<td>11</td>
<td>18</td>
</tr>
<tr>
<td>Software Simulation and Testing</td>
<td>21 days</td>
<td>Mon 9/12/05</td>
<td>Fri 9/17/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development of Final Design</td>
<td>39 days</td>
<td>Mon 9/26/05</td>
<td>Wed 10/5/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts for Final Design</td>
<td>19 days</td>
<td>Mon 10/3/05</td>
<td>Fri 10/14/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardware Implementation</td>
<td>23 days</td>
<td>Mon 10/17/05</td>
<td>Wed 11/16/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Software Implementation</td>
<td>23 days</td>
<td>Mon 10/17/05</td>
<td>Wed 11/16/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Testing and Debugging</td>
<td>19 days</td>
<td>Mon 11/28/05</td>
<td>Fri 12/9/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Report II</td>
<td>15 days</td>
<td>Mon 11/28/05</td>
<td>Fri 12/16/05</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Division of Labor for Fall 2005 Semester:

The division of labor for the fall 2005 semester will be determined at a later date.
6. **Budget**

A. **Personnel:**

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Time</th>
<th>Wage</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matthew R. Harvey</td>
<td>Student Designer</td>
<td>350 hrs.</td>
<td>$ 25/hr.</td>
<td>$ 8750</td>
</tr>
<tr>
<td>Kellin M. Lang-Gillming</td>
<td>Student Designer</td>
<td>350 hrs.</td>
<td>$ 25/hr.</td>
<td>$ 8750</td>
</tr>
<tr>
<td>Michael R. Frost</td>
<td>Student Designer</td>
<td>350 hrs.</td>
<td>$ 25/hr.</td>
<td>$ 8750</td>
</tr>
</tbody>
</table>

B. **Equipment / Supplies:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamps and Fixtures for Model Array</td>
<td>$ 1000</td>
</tr>
<tr>
<td>Mounting Hardware and Structure for Model Array</td>
<td>$ 300</td>
</tr>
<tr>
<td>Controller and Associated Development Tools</td>
<td>$ 1000</td>
</tr>
<tr>
<td>Thyristors, Heat Sinks, Gate Drivers, etc.</td>
<td>$ 3000</td>
</tr>
<tr>
<td>Printed Circuit Boards</td>
<td>$ 300</td>
</tr>
<tr>
<td>Presentations and Documentation</td>
<td>$ 100</td>
</tr>
</tbody>
</table>

**Subtotals:** $ 5700 $ 26,250

**Total:** $ 31,950

7. **Safety**

The portion of the design process in which safety will most be an issue is the use of the large scaled model of a Compact IR dryer. This model will contain approximately 70 100W light bulbs, creating a 7 kW system. The model will use voltages of 120 V<sub>rms</sub>. Thus, care will need to be taken when reconfiguring, taking measurements, and performing tests on the model. Also, while the actual Compact lamps are being characterized, heat will be an issue as the lamp temperatures are high enough to cause serious injury. Other safety concerns will be those associated with all electrical experimentation.

Once the design in complete, safety will continue to be an issue. Due to the high temperatures and high voltages used by the system, as well as the industrial setting in which it will operate, there are numerous safety concerns in regards to the use of the final design. To the greatest degree possible, these issues will be accounted for with an error handling procedure included in the final design.
APPENDIX A