Department of Electrical and Computer Engineering

University of Victoria

ELEC 399—Design Project I

Interim Report

Title:	Automated De-Icing Control System of a Bridge
Supervisor:	Dr. Panajotis Agathoklis
Group ID:	8
Members:	Coleton Denninger Nathan Hardy Tyler Jukes Wesley Keim David Turcios

Contents

Tables

1.0 Introduction

1.1 Description

As part of the curriculum for ELEC 399, and as per the requirements of the Department of Electrical Engineering at the University of Victoria, we found ourselves with the opportunity to collaborate on a technical project focusing on any given area within the realm of electrical engineering.

The focus of our project is the *automated de-icing of a bridge* with the aid of a *control system*. Development of our project will be split into three separate stages: research, design, and theoretical implementation. Throughout each stage, the scope of the project will be limited to:

- The control system
- The power system
- The heating system

1.2 Work Plan

The man-power dedicated to the development of each individual system will be divided as depicted in *Table 1*, below.

Table 1: Division of project work

The Control System	The Power System	The Heating System
Nathan Hardy *Coleton Denninger*	*Wesley Keim* *Tyler Jukes*	*David Turcios* *Tyler Jukes*

Table 2, below, depicts the dates selected as deadlines to present finalized project material.

Table 2: Summary of project milestones

October 2, 2012	Interim Report
November 18, 2012	Schematic diagrams, program code, functional block diagrams
December 2, 2012	Final Report and Website

It is important to note that, although not mentioned in *Table 2*, above, there are additional design criteria that will be handled as they arise.

1.3 Deliverables

Our expected deliverables for the project are the following:

- Schematic diagrams for the control system
- Schematic diagrams for the electrical system
- C source code for the micro controller
- Simulations for the control system
- Final report and project website

2.0 Development

2.1 The Heating System

The heating system refers to the execution of the de-icing process. While researching methods for transferring electrical power to heat we concluded there are two optimal methods: conductive concrete and embedded resistive elements.

2.1.1 Conductive concrete

Traditionally concrete has used flyash as an additive. A major source of flyash is coal-fired generating stations, where it's removed from the boiler outlet air using bag-houses or electrostatic precipitators before the air is released up the stack. When the Clean Air Energy Act was passed in 1990, it mandated generating stations to significantly reduce the carbon emissions they release into the air. As a result, the air particulate removal systems at these generating stations began removing flyash with a much higher carbon based content than before. An indirect result of this high carbon content was that it produced highly conductive concrete when it's used as an additive. Other methods for conductive concrete are to add metal impurities. The specific mix of additives and metal impurities determines the resistivity properties (and therefore the heating properties) of the concrete as well as the workability of the material.

Conductive concrete has been used in applications that are safe for pedestrian use and has been deemed safe for direct contact up to 240V. This application has been designed to use a 208V 600A 3Ph power supply. This gives a maximum power available of 124.8kW (the bridge slabs are single phase but will use the line to line voltage). A rule of thumb for de-icing applications is that a system should deliver between $200 - 500W/m^2$to be effective. For this project, the goal is to achieve a power density of at least $300W/m^2$.

Given the desired power density and the available power supply, the dimensions of a bridge are limited by these parameters to ensure acceptable performance. The average lane width on BC highways is 3.7m. Therefore a typical 2 lane highway bridge over a river would be approximately 8m wide. The power density (P_D) is calculated as:

$$P_D = P \div (Width * Length)$$

Therefore the maximum practical length of the bridge for this system can be determined as:

$$Length = 124800W \div (8m * 300W/m^2) = 52m$$

The bridge size for this design should not exceed 52m to maintain performance requirements, therefore a length of 50m will be focused on.

For even heating across the bridge deck, the heating layer should be broken up into smaller pieces. For simplicity the bridge was split in half so each piece would be 4m wide. The other dimension was fixed at 2m and the slab thickness will be 100mm. This means the bridge deck will be composed of 50 slabs (25 down each side). To select a possible concrete mixture, the resistivity was calculated for each slab:

$$P_{SLAB} = 310W/m^2 \div 8m^2 = 2480W$$
$$I_{SLAB} = 2480W \div 208V = 11.92A$$
$$R_{SLAB} = 208V \div 11.92A = 17.45\Omega$$
$$\rho_{SLAB} = RA \div l = (17.45\Omega)(0.4m^2) \div 2m = 3.49\Omega \cdot m$$

This is the required resistivity of the conductive concrete material. The type of concrete mix used could be Conducrete. (ρ =3.06-6.38Ωm)

2.1.2 Resistive elements

While researching information on the implementation of embedded resistive elements we found a Danish company that manufactures the sort of elements that we would require for our project. The company is called *SAN Electro Heat*, and the datasheet for the heating element provided by the manufacturer showed the information depicted in *Table 3*, below.

Table 3: Rated values for round heating elements

Rated Power (W)	*2000*
Rated Voltage (V)	*400*
Length (m)	*2.1*

The data depicted in *Table 3*, above, allowed us to calculate the resistance of the heating element as depicted below.

$$R_c = \frac{P_{rated}}{V_{rated}} = \frac{2000}{400} = 50\Omega$$

Equation 1: *Calculation of element resistance*

In order to maximize efficiency, we found that it would be best to employ a matrix-style configuration when implementing a system of resistive elements. This conclusion was made due to the following two reasons:

- The small length of the elements limits the size of the area that can be heated at any given instant
- Employing a "modular" approach to heating the bridge allows us to reduce the amount of power that is consumed while heating

2.2 The Control System

The control system will consist of a microcontroller with humidity and temperature sensors.. The microcontroller will most likely be a PIC MCU from Microchip. This chip will allow input/output communication between peripheral sensors and external connections.

The idea of the control system is to sense via humidity and temperature when conditions that result in the formation of ice are met. To prevent the formation of ice on the bridge, the controller will activate the heating system via a relay or other isolated device. Temperature sensors will be embedded in the heating system to provide feedback to the control system, preventing excessive temperature on the bridge deck. The control system will deactivate the heating system when the temperature of the bridge passes a certain value, or the temperature/humidity sensors deem that there is no longer viable conditions for the formation of ice.

The major deliverables of the Control System include:

- Schematic diagrams for the control system.
- C source code for the micro controller.
- Design and operation of the control system.

2.3 The Power System

The scope of the power system is to deliver the heating power to the bridge as well as power all instruments and control system devices. Initially, alternative power sources were considered such as solar and geothermal systems, however it was determined the load would be much too large and grid power was needed. For this system a standard distribution voltage of 4160V was assumed. Should the grid voltage be different, the primary voltage of the main transformer would need to be modified accordingly.

The 3 phase heating power from the transformer secondary will be connected to the bridge slabs through (25) 30A rated contactors (2 slabs per contactor). Single phase 120V power will be provided for the micro controller power supply, infrared camera power supply, and contactor control circuits. To meet these requirements the transformer ratings must be 150kVA 4160V-208/120V Delta-Wye.

The major deliverables for the power system will include:

- Providing a bill of material for all necessary equipment
- Electrical schematics of the overall system
- A cost analysis

3.0 References

Heating Elements:

http://www.san-as.com/upload/SAN/Pdf-files/Katalog/Heating_Elements.pdf

http://www.san-as.com/en/SAN-pages/Products/

Conductive Concrete:

http://www.conducrete.com/about-conducrete/#main

Log Book Group 8

September 17th 2012,

The initial group is formed consisting of David Turcios, Tyler Jukes, Coleton Denninger, and Wesley Keim.

September 18th 2012,

Ideas for possible projects were discussed. Different projects included a cell phone booster for the ECS & ELW building, pulse generators for high efficiency power generation, and other projects that would involve engineering applications.

September 26th 2012,

Finalized which project would be completed. It was decided that a system that would automatically defrost bridges in the winter would be the best project. The project would involve power systems, controls, and a heating system for a bridge.

October 3rd, 2012,

Nathan joined the group. This added more expertise to the controls side of the project.

October 10th 2012,

Supervisor Contacted. Dr. Pan Agathoklis agreed to become the project supervisor.

October 11th 2012,

The Group conducted a meeting to decide what tasks needed to be completed and established a strong grasp on the short and long term goals of the project.

October 14th 2012,

The group gathered to discuss the progress of the project for the interim report