HET – REU Electrical Engineering Project
Summer 2004

Theory of Operation

The louver system at HET consists of 14 separate louver banks, each controlled by a directional 120V AC motor. Each motor has an open (forward) and close (reverse) connection. Motor direction is controlled by providing power between a neutral motor terminal and either the forward or reverse terminals. There are a set of relay contacts that control power to each terminal. Control is required to be such that the system cannot provide power to both forward and reverse motor terminals simultaneously.

The current controls of the louvers have a switch to either a master mode of operation or an individual mode of operation which engages coils that control relays.

In the master mode, there is an open and a close button. Each button closes a switch that engages coils to control the appropriate contacts to open or close all of the louvers together. There are timers that disengage the coils after 20 seconds to ensure that motor power is removed after adequate time has passed to permit the motors to open or close. Limit switches at each motor determine when each is either fully opened or closed.

In the individual mode, there are 14 individual switches that can engage either the open or closed terminals of the motor. Each terminal of these switches is in parallel with relay contacts whose coils are driven when the master/individual switch is in the master mode. A schematic of the current system is included as Schematic 1.

A new remote control system is required to be interfaced with the current system. It is meant to provide a method to control the position of the louvers from a computer-generated signal. This signal will initially be generated by the user, but in its final implementation will be controlled by a computer depending on wind direction and speed, temperature, and precipitation. Phase 1 of this project is the initial implementation documented in this report. Phase 2 will be completed later and consists of the final implementation using a weather computer and a louver position measurement system to control louver position. Figure 1 is a block diagram of how the system will work with the remote control project, Phase 1, shown in a box.

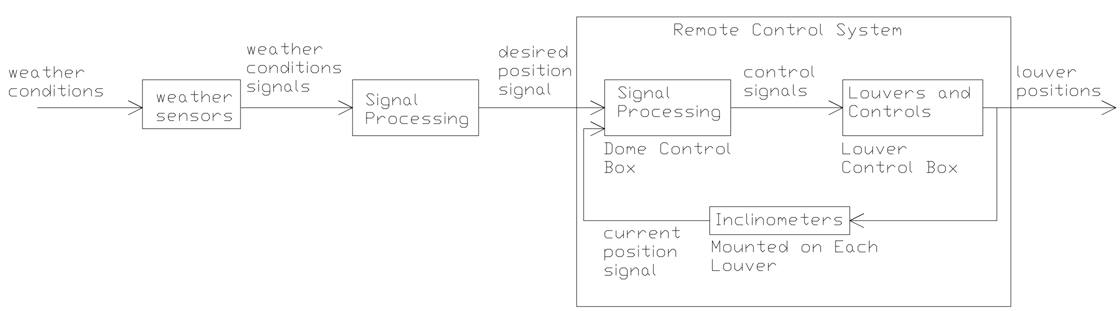

Figure 1: Block diagram of the system with details of the Remote Control System

System Requirements

Interface: There will be a new switch that will control the local/remote mode of operation. When the switch is in the local position, a contact will be closed that will power the present system. When the switch is in the remote position 12V DC power will be available to power the remotely actuated control relays.

An EMO function will be added. During normal operation a coil will be energized that closes normally open contacts in series with the 120VAC power to each louver. If an EMO is asserted, the coil will be de-energized and the contacts will open, disengaging the motors regardless of any of the other controls, remote or local. Figure 2 shows a schematic of the EMO override switch.

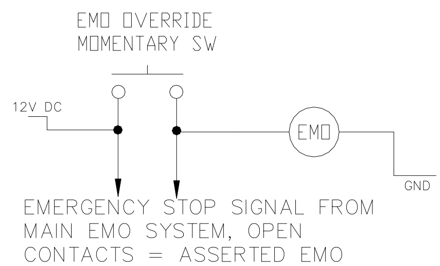

Figure 2: EMO override switch in parallel with emergency stop signal from main EMO system controlling the EMO coil across 12V DC

Inclinometers: An absolute inclinometer will be used to convert the angular position of the louver to an electric analogue signal. This signal will be read by a PMAC through an ADC accessory. There will be fourteen inclinometers, one mounted on each louver, so there will be fourteen signals input to the PMAC through the ADC.

The inclinometers should have an angular range of more than 90° in order to detect the position of the louvers if there should be a problem being opened or closed too far.

Signal Processing: The signal processing will be done with a PMAC. The PMAC will use a desired position input by the user and the current position input through the ADC from the inclinometer to calculate and produce 28 output signals through a digital I/O accessory. Each of the 14 louvers will have an output signal for open and an output signal for close. The output is an open collector transistor connected to a controlled coil, whose other terminal is connected to 12 V DC. Asserting this transistor shorts it to ground providing a path to ground and energizing the coil.

Louvers and Controls: The 28 signals will engage or disengage coils to control relay contacts that control the motors. Figure 3 shows the schematic for one signal driving one coil. Each coil will control one normally open and one normally closed contact that will be connected to the motors as shown in Figure 4. This system provides a lockout feature that prevents both forward and reverse motor terminal from being powered at the same time. When the relay controlling the forward contact is asserted, it opens a contact in series with the reverse contact.

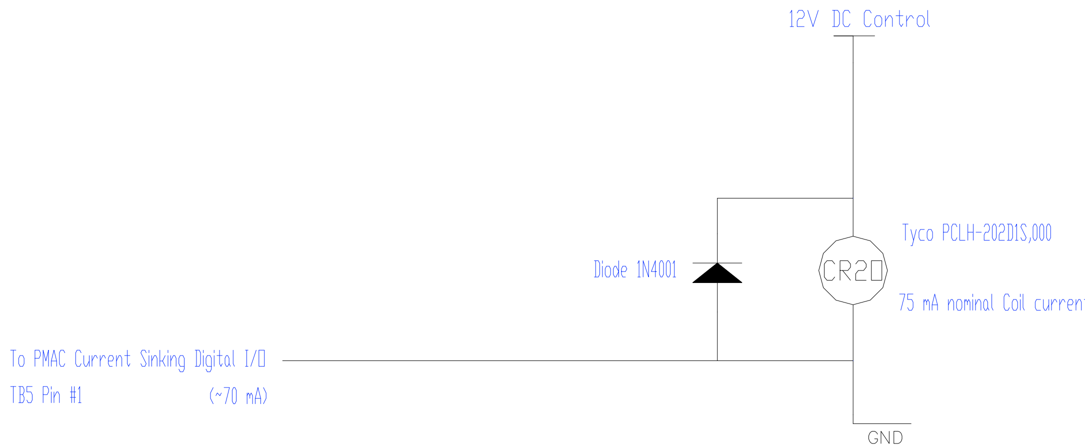

Figure 3: One control signal from PMAC driving a relay coil

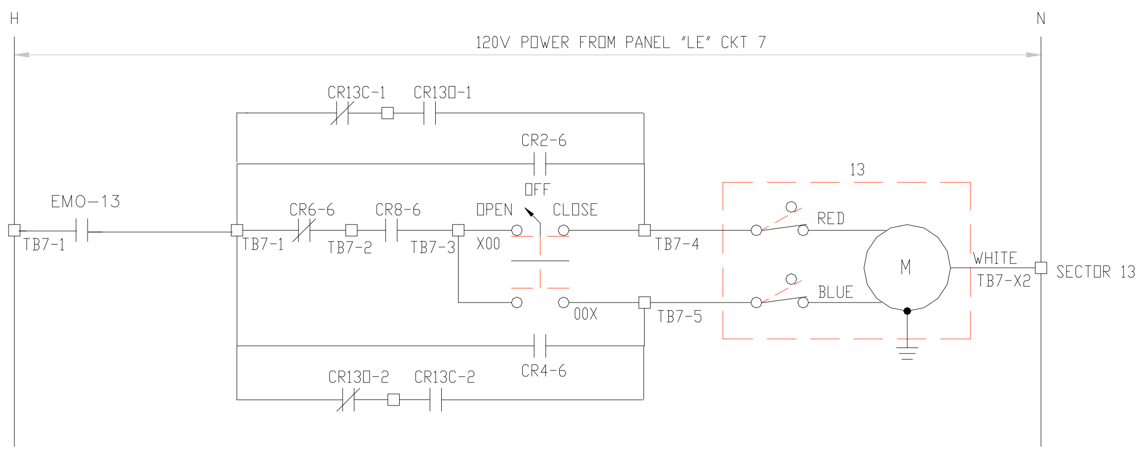

Figure 4: Contacts to control one motor. Note: The EMO (EMO-13) contact will be closed as long as an EMO signal has not been asserted or the EMO override button is pushed. CR2 and CR4 are controlled when the system is in Local → Master mode. CR6 and CR8 are controlled when the system is in Local → Individual mode. CR13C and CR13O are controlled when the system is in Remote mode.

Schematics

The first schematic shows the current system:

Schematic 1: Elementary Diagram

Schematics 2-3 show the revisions reflecting changes to the system. The first page (Schematic 2) shows the addition of the Remote/Local switch, the EMO-override pushbutton, the EMO relays, and the additional contacts to control the motors. The second page (Schematic 3) shows the coils for the additional relays to control the motors and shows how they will be configured with the PMAC I/O board.

Parts/Vendor List

Interface: A DPDT switch will be needed for the Remote/Local switch.

A pushbutton switch will be needed for the EMO-override button.

A PCLH-202D1S,000 relay will be used as a main EMO controller. The coil will be energized by the main EMO contacts in the control room. The main EMO contacts in the control room are rated at 3A, and the 12V rating for the coil of the PCLH-202D1S,000 is 75mA. The contact of the PCLH-202D1S,000 will control coils for two Allen-Bradley 700S-P710A1 relays. Each of these relays has seven normally open contacts that will be in series with the 120VAC supply for each of the louvers. (There is also one normally closed contact on each Allen-Bradley 700S-P710A1 that will not be used.)
http://www.ab.com/industrialcontrols/products/relays_timers_and_temp_controllers/industrial_relays_and_timers/700s-specification.html
http://relays.tycoelectronics.com/datasheets/PCL-PCLH.pdf

Inclinometers: The SPECTROTILT Radiometric Electronic Inclinometer is an absolute, single-axis inclinometer with a ±70° range and is fully signal-conditioned. It will run on +5 to +15V DC at nominally 0.5mA. When powered with 12V DC the output signal is 60mV/degree in the linear range, which is ±60°.
http://www.spectronsensors.com/datasheets/SDS-119-4203.pdf

Signal Processing: PMAC Accessory 36P is a 16-channel 12-bit ADC board that will interface with PMAC. The signals from the inclinometer can be converted from analogue to digital so that PMAC can process them.

PMAC Accessory 34AA is an Opto 32-bit Input/32-bit Output board that will be used to interface PMAC with the louver controls. The output is driven with a Darlington array of transistors that will act as a current sink rated up to 100mA, sufficient to drive a coil for a PCLH-202D1S,000 relay at 12V.

Louvers and Controls: Twenty-eight PCLH-202D1S,000 relays will be used to control the louvers. Fourteen 1N4001 Diodes will be required to ensure that current is not sent back to the source as the coil is energized. The contacts are rated at 10-15A and the coils can be energized by 12V DC. Each coil has two contacts that can be configured to be normally open or normally closed.
http://relays.tycoelectronics.com/datasheets/PCL-PCLH.pdf

Power Requirements: There will be a 12V source added to the system. This source will have to power the 29 coils of the PCLH-202D1S,000 relays (28 for the louver controls and one for the EMO system). Each PCLH-202D1S,000 coil draws 75mA max (0.9W), so the total power that can possibly be drawn from the source due to the PCLH-202D1S,000 relays is 2.175A (26.1W).

The source will also supply power to the 14 inclinometers. Each inclinometer draws 0.5mA, so the total power that will be drawn from the source due to the inclinometers is 7mA (0.084W).

The total possible draw from the 12VDC source will be 2.182A (26.184W). An Omron #S82J-05012D DIN rail mounted supply from Newark Electronics (Newark #89C3211) will supply up to 4.2A at 12V, which will satisfy this requirement.

Total Price of Parts: A new DPDT paddle switch for the Remote/Local switch will cost about $40.

A new pushbutton switch will cost about $20.

There will be two Allen-Bradley 700S-P710A1 relays, each costing $197, totaling $294. Each mount will be approximately $15, totaling $30, making the total cost for the relays $324.

There will be fourteen inclinometers, each costing $140, totaling $1960.

The accessories for the PMAC must be purchased. Accessory 36P (ADC board) will cost $979 and Accessory 34AA (I/O board) will cost $528. The total cost for the PMAC accessories will be $1507

There will be twenty-nine PCLH-202D1S,000 relays (twenty-eight for the louver controls and one for the EMO control), each costing $5.40, totaling $156.60. Each relay will have a mount, each costing $8.39, totaling $243.31. The cost of the relays with their mounts will be $399.91.

The Omron 12V power supply will cost $85.21.

The total cost of the remote control system will be $4336.12.

Test Procedures

Interface: The interface will be included in Phase 2. The Remote/Local switch will be installed when all the louvers are installed with the remote control system. The EMO will be also be implemented in Phase 2.

Inclinometers: Some preliminary testing was done on the inclinometers. Data was taken of the voltage of the signal coming from the inclinometer as the louver was opened. Figure 5 shows this data, which was taken in a peak detection mode. It shows that the voltage when the louver is closed is 2V and the voltage when the louver is open is 7.5V. It also shows that the inclinometer signal is linear with respect to the angle of the inclinometer and that the slope is about 60mV/°. More accurate data will be taken for Phase 2 of the project.

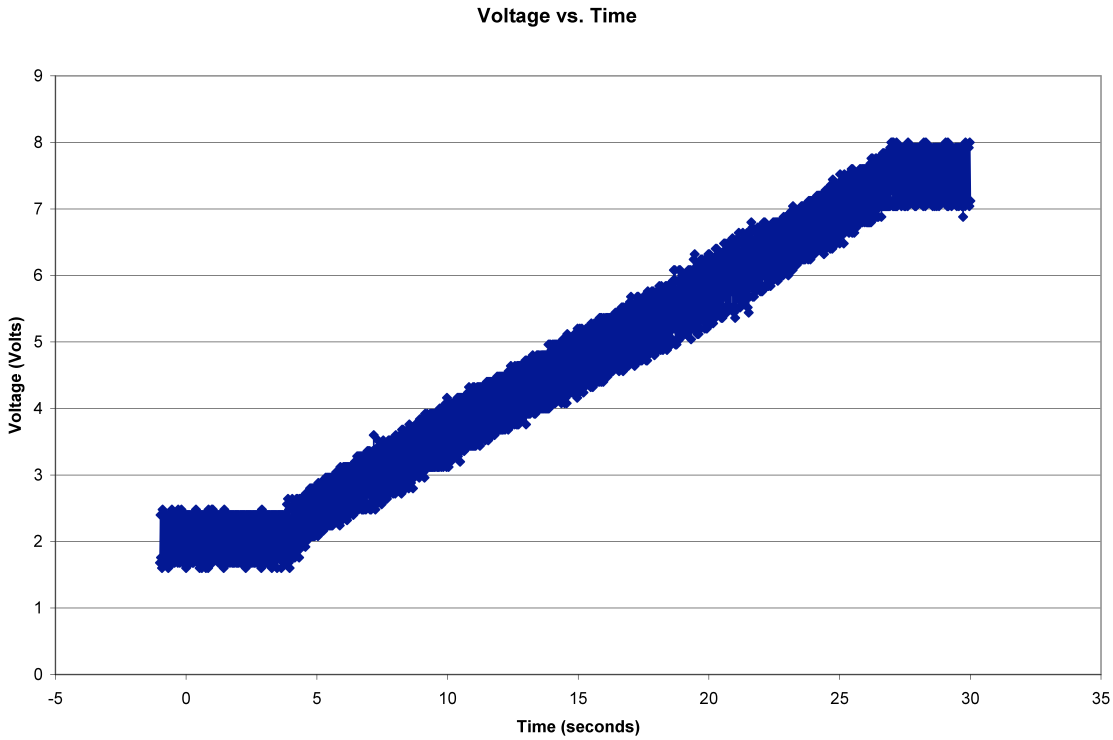

Figure 5: Plot of Voltage vs. Time as the louver opens. The voltage when the louver is closed is 2V and the voltage when the louver is open is 7.5V. As the louver opens the voltage increases linearly at a slope 60mV/°.

Signal Processing: The PMAC output ports were modeled using a signal generator and n-FETs in the sinking configuration described below when testing the louvers and controls.

Louvers and Controls: The PCLH-202D1S,000 relays were tested in a lab bench. The objectives were to verify design specifications of the device and to make sure the contacts would open and close as desired when controlled by a signal simulating the output of the PMAC. Finally, the system was connected to louver #13 to show that the design for the louver controls would work to open and close the louvers appropriately.

The coil was asserted with a 12V DC source with a diode across it to permit dissipation of the voltage spike that occurs due to instantly de-energizing the coil. A multi-meter was used to measure the resistance across the contacts of the relay. The multi-meter verified that the correct contacts were open and closed appropriately as the coil was energized and de-energized. The coil drew 75 mA from the power supply at 12V, but as the coil heated it drew slightly less. This verifies that the power consumption of the coil when it is engaged is 0.9 W. A schematic of this test is shown as Figure 6.

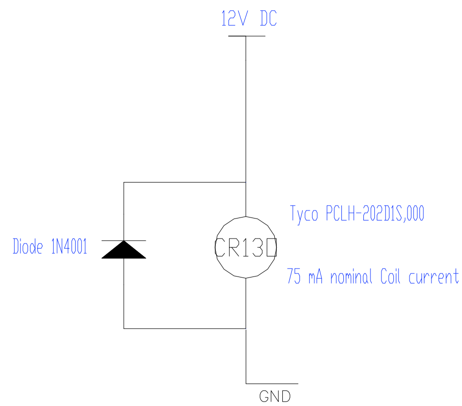

Figure 6: Test schematic of the PCLH-202D1S,000 to verify specifications and properties

Once the properties of the coils were verified, a signal generator and n-FETs were used to simulate the PMAC output to drive the coils in a sinking configuration. The gate of one n-FET was connected to 100Ω in series with a signal generator set to produce a square wave at frequency 0.1 Hz, amplitude of 2.5V, and offset 1.25V. Because of the configuration of the signal generator, this produced a square wave at 0.1 Hz, amplitude 5V, and offset 2.5V at the gate of the n-FET. The source of the n-FET was connected to ground and the drain was connected to the coil in place of the previous connection to ground as shown in Figure 7. The coil was driven adequately by the configuration.

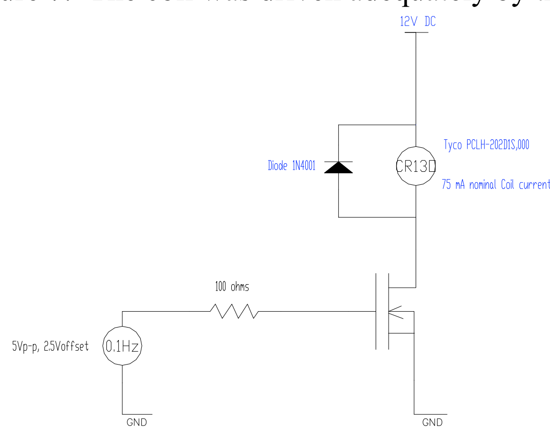

Figure 7: Test schematic to show that the PCLH-202D1S,000 coil can be driven by a PMAC (simulated with signal generator and n-FET)

Finally, a second n-FET was used to create an opposite signal to drive a second coil. The first coil would be an 'open' coil and the second coil would be a 'close' coil. This configuration is shown in Figure 8. In this configuration, the coils switched from one being energized and the other not to the one not and the other energized.

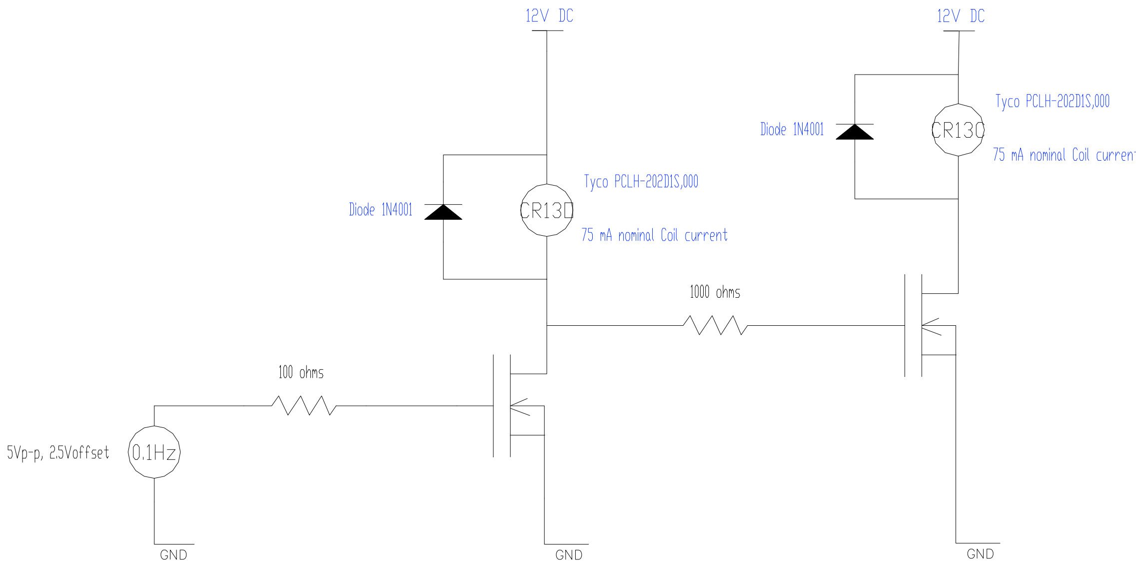

Figure 8: One open and one close coil driven by signal generator and two n-FETs to simulate a PMAC switching between an open signal and a close signal

The final test procedure was to connect the contacts of the relays to a louver. Louver 13 was used. The contacts were connected as shown in Figure 9. The louver properly opened and closed as the contacts switched according to the signal generated by the signal generator.

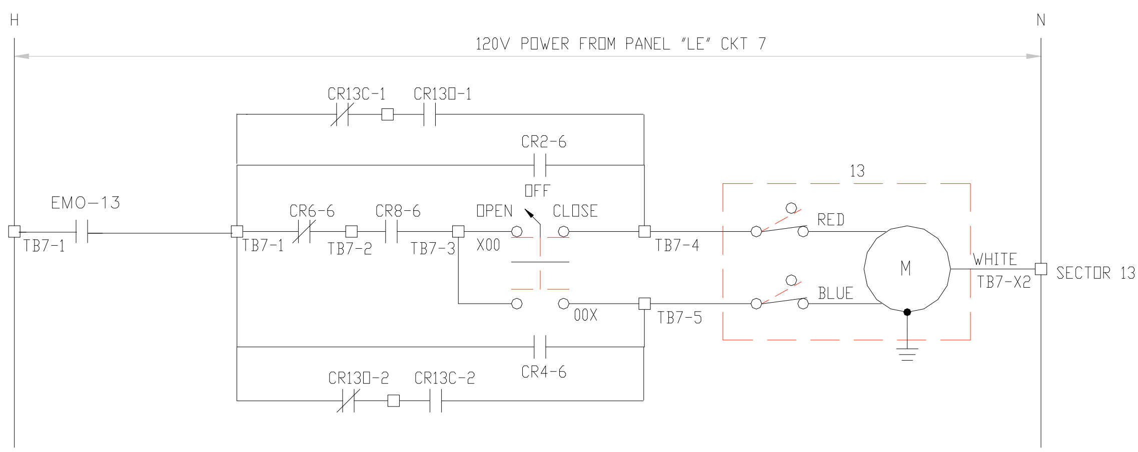

Figure 9: Control contacts for louver 13. The EMO-13 contact was not in place, but the contacts CR13C-1, CR13C-2, CR13O-1 and CR13O-2 were connected to the nodes TB7-1, TB7-4, and TB7-5 as shown in this schematic.

Implementation

14 inclinometers must be installed, one on each bank of louvers. They must be powered by the 12V supply and connected to the ADC board of the PMAC. Conduit must be run to connect signal and power wires from the inclinometers at each louver to the PMAC computer in the dome control box.

The ADC board and the I/O board for the PMAC must be connected and the PMAC programmed so that the output signals will properly control the louvers. Conduit must be installed to connect control signals from the PMAC computer in the dome control box to relays in the louver control box.

28 relays must be installed as shown in the schematics with the coils driven by the PMAC.

The EMO relays must be installed according to the schematics. The EMO-override push-button must be installed. The louver EMO relay must be wired into EMO contacts in the control room.

The Remote/Local switch must be installed.