UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Revolving Gardens: An Installation in UBC's Student Nest Building

Sonia Taylor, Eli Nemtin, Raymond Desjardins, Keith Bystrom, Mallory Josephson

University of British Columbia

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Abstract

Revolving Gardens is a living installation located in the AMS Student Nest Building. The project was sponsored by UBC SEEDS in partnership with AMS Sustainability and was designed, built and installed by UBC Mechanical Engineering Students. The purpose of the installation is to bring beauty and plant life to the Great Hall foyer space within the Nest and to promote sustainability. The final design as installed is comprised of seven wooden pods over which tropical hanging vines grow. The design also includes a solar powered mechanical system to rotate the pods when direct sunlight is present, and a self-watering irrigation system to minimize maintenance requirements. The project was installed in March 2017, using a total of $11,200 of the available $13,750 budget.

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1.0 Objectives

The Revolving Gardens project is a UBC Mechanical Engineering Capstone Design project sponsored collaboratively by UBC SEEDS and AMS Sustainability. The objective of the project is for the team of Mechanical Engineering students to design, build and install a living wall to fill one of the 20ft by 10ft window bays of the AMS Student Nest Great Hall foyer.

The attributes of the final design must align with the sustainability goals of SEEDS and AMS Sustainability; the project is intended to embody and inspire interest in sustainability within the UBC community. It must also be aesthetically pleasing and enhance the Great Hall Foyer by bringing plant life and artistic design to the space. It has also been identified by SEEDS and AMS sustainability that it is desirable for the final installation to showcase the design skill of the team by including interesting mechanical features.

AMS sustainability will be responsible for coordinating maintenance of the installation. It is important for the installation to require minimal maintenance in terms of both time and cost. The minimum lifetime of the installation should be three years, however if the design is successful and robust it may be retained for a longer period.

The total available budget for the project is $13,750, broken down by contribution as follows:

- SEEDS: $6000 + $2000 Contingency
- AMS Sustainability: $5000
- Mechanical Engineering Department: $750

2.0 Design and Testing

2.1 Design

Figure 1 shows the completed Revolving Gardens installation. Thirty-four plants cascade over 7 wooden pods which rotate in sunny conditions using solar power. The design can be divided into 3 subsystems, Structural and Aesthetic, Mechanical and Solar, and Irrigation. The major components and function of each subsystem are described below.

Figure 1 - Revolving Gardens Installation

2.1.1 Structural and Aesthetic

The aesthetic design of the pod form and composition is intended to complement the aesthetic of the Great Hall foyer. The oblong shape of the pods plays off the geometry of the light fixtures while the cascading layout of the pods within the window bay brings a sense of movement to the space.

The exterior texture of the pods is achieved using maple edge-banding while the inner structural pieces of the pods are made of water-jet cut ply-wood. The plants selected are several varieties of Pothos as well as Purple Jews. These species were chosen due to their suitability for the light conditions in the foyer, their natural beauty, and their robustness.

Clamps drilled through the two columns support two beams from which the pods are suspended. This structural design is designed by the student team and has been signed off on by RJC Engineers. Details of the load calculations and Finite Element Analysis (FEA) on the components can be found in Dossier 11.

Each pod is supported by a steel pipe with welded tabs to which the pod is bolted. The pipes thread together to form the three columns. Each of the three columns is tethered to an anchor in the concrete floor to prevent gross lateral movement.

2.1.2 Mechanical and Solar

Two photovoltaic solar panels are located at the southernmost window bay to maximize sun exposure. The solar panels are connected in series and connected to a 12V 18Ah battery with a charge controller that protects the battery from both overcharge and overdischarge. The solar panels produce an average of 2.2W on a sunny day, while the columns require a combined total of 1.8W to rotate.

Each column is powered by a 12-volt DC gear motor capable of delivering 187 in-lbs of torque. Power is transmitted through a chain drive utilizing a self-lubricating Polyvinylidene Difluoride

(PVDF) chain with a 16:13 gear ratio. The control circuit utilizes a light-dependent resistor (LDR) incorporated into a voltage divider to drive three transistors that regulate the voltage across the gear motors. A potentiometer allows for fine-tuning of the light intensity required for activation, determining the ambient light conditions under which pods will rotate. An in-line fuse protects the circuit in the event of motor stall due to mechanical fault.

2.1.3 Irrigation

In alignment with the clients' desire for the installation to require minimal maintenance, an automated timed irrigation system is used to deliver water and nutrients to the plants. The system originate at the 3rd floor Janitor's Closet (Room number 3407) where it taps into the building Domestic Cold Water Line. A backflow prevention device is also installed in the line to prevent fertilizer from entering into the building water when it is present in the system.

A copper line runs from the janitor's closet to the nearby storage closet (Room 3407) where a control box is installed. The components within the control box include a pressure reducing valve to set the system pressure, a tank and coupler for injecting fertilizer into the system seasonally, and a solenoid valve and controller for setting the watering duration and frequency.

Connecting to the copper line is a PEX pipe which runs across the Great Hall foyer ceiling to the Revolving Gardens where it branches off into three lines, one for each column. A low torque rotary union is used at the header of each column to allow water to flow to the pods as they rotate.

Flexible vinyl tubing then runs through the steel support pipes and branches off to deliver water to each plant. At the outlet for each plant a pressure compensating dripper emitter is used to maintain a uniform flow rate to each plant.

Excess water is drained through a bulkhead fitting at the base of each plant pot and runs through a flexible vinyl drain line to collect in a stainless steel basin at the base of each column. The basin should be emptied periodically (once every 4 weeks) to prevent overflow.

A more detailed description for the irrigation system design can be found in Dossier 11 along with an operation and maintenance manual.

2.4 Validation and Testing

2.4.1 Control Circuit Design and Validation

The function of the control circuit is to activate the motors when exposed to a predetermined amount of sunlight. In order to accomplish this, it was important to correctly specify the light-dependent resistor (LDR) and potentiometer to achieve the correct base-emitter voltage across the transistor.

Due to the low cost of electrical components three sizes of LDR were purchased, with various resistance ranges (8k-20k, 18k-50k, 30k-90k). Additionally, two different potentiometers were purchased with various resistance ranges (0-5k, 0-10k). Using a standard breadboard and multimeter, different combinations of LDRs and potentiometers were tested to choose a setup that would allow fine-tuning of the activation threshold around a base-emitter voltage of approximately 1.6V.

Using this method, the combination of an 18k-50k LDR and a 0-10k potentiometer resulted in a base-emitter voltage range of 0.5-3.5V when exposed to moderate daylight. Once installed, this allowed the light activation threshold to be adjusted from approximately “high overcast” to “bright sunshine”, as the exact install location of the control circuit was unknown at the time of testing. Localized variation in light intensity relative to true exterior conditions was thus accounted for using an appropriate control range.

2.4.2 Irrigation Testing

Irrigation leak testing was performed to ensure the system does not damage the installation or building. Each bulkhead fitting was sealed using a silicone gasket and the seal checked prior to installation in the pod. Once the irrigation system was fully installed, the system was pressurized without the plants installed and each connection was inspected for leaks. Several of the vinyl tubing connections were leaking on first inspection, which was corrected by tightening the gear clamps to seal the connection.

The flow rate of the pressure compensating dripper emitters was also verified by measuring the actual flow rate and comparing to the published flow rate. The actual flow rate was found to be approximately 60% higher than the published flow rate and was thus used to correct the programmed watering times. Tuning of the watering frequency and timing will be ongoing during April 2017 based on monitoring of the soil moisture and plant appearance.

3.0 Conclusions

The large scale of the installation and need to integrate multiple subsystems made this project an engaging and challenging endeavour for the design team. The installation was entirely built and installed by the students with the exception of the copper portion of the irrigation system, meaning that several hundred hours were devoted to manufacturing and installation alone. This provided the student team with excellent experience in larger scale project management that will undoubtedly prove valuable as the students enter into industry upon graduating from UBC.

Despite the logistical challenges and volume of labour required, the project was delivered on time as it was fully commissioned during the last week of March, 2017. The Revolving Gardens are operating as intended with the pods rotating in direct sunlight conditions and the automated irrigation system delivering water to each plant on a weekly basis. Furthermore, the project was completed under budget with total expenditures amounting to $11,200.

4.0 Recommendations

The installation of the Revolving Gardens has been executed according to the design of the student team and is currently operating as intended. As such, no recommendations for amendments or modifications to the design are made here. Instead the following recommendations are given to ensure the longevity of the Revolving Gardens.

1. The irrigation maintenance schedule outlined in Dossier 11 should be followed by the AMS Sustainability responsible for the upkeep of the Revolving Gardens. This includes periodic emptying of the drainage collection basins and seasonal engagement of the fertilizer injection system and refiling of the injection tank.
2. As the plants become fuller, it is possible that their watering needs may change over time. Periodic assessment of the plants' health and adjustment of the watering frequency and duration are recommended. Instructions for adjustment to the irrigation controller are outlined in Dossier 11.

3. The intended lifetime of the installation is three years. It is recommended that AMS Sustainability and SEEDS assess the condition of the Revolving Gardens at the end of this period to determine whether its life should be extended.

It is the hope of the design team that the Revolving Gardens will continue to enhance the Great Hall space and encourage students, staff and visitors to UBC to think positively about sustainability for years to come.