ECO-DISTRICTS: ENGINEERING GREEN CITIES OF THE FUTURE

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Introduction

In 2018, it was found that buildings consume over 40% of the energy produced in the US. Eco-districts, the connection of multiple buildings into one sustainable energy unit, provide a way to greatly reduce the energy consumed by buildings. This project was devised by Seattle City Light as a study to determine the feasibility of implementing Eco-districts to help meet the goals set by the City of Seattle's Climate Action Plan. This Action Plan calls to eliminate the use of fossil fuels and achieve carbon neutrality by 2050.

In this project we design a concept for a completely electrified, fossil fuel free, and off-grid eco-building-district that utilizes thermal and electrical storage systems, on-site energy generation, and renewable source district heat exchangers.

Requirements

- Analyze building thermal load data to determine min/max loads throughout the year and how the load differs throughout the day
- Select equipment for the central plant that considers energy efficiency, cost, size and compatibility with the district
- Specify equipment parameters such as size, cost, COP, capacity, min/max flow rates, ingoing/outgoing temperatures, etc.
- Create a CAD drawing of the one-line diagram
- Draft a control sequence for the system
- Determine the layout in which our storage systems will operate and integrate with one another.
- Conduct solar simulations and determine the projected energy and cost savings.
- Conduct a cost analysis on electrical equipment and determine specified size, capacity, degradation rates.

Recommendations

We recommend that in the near future the university create smaller eco-districts utilizing GSHR technology as a primary, sustainable source for energy. However, looking further into the future we recommend that a sewage heat recovery system (SHR) be used as the source of heating and cooling for the entire university district. The nearby sewage system has a capacity of around 40MW compared to the mere 4MW this eco-district would consume. A connection point can be made for all existing eco-districts that would make the retrofitting of a SHR system simpler.

We also recommend that instead of investing to utilize just one type of battery storage system to fit every need, the university instead invest in a couple. Our recommendation is to interconnect the usage of redox flow and lithium ion batteries. The combination of these systems allow a more efficient design based on cost, degradation, and size.

Implementation

Figure 1: Diagram of chosen eco-district location and buildings shown on the UW Master Plan. Depicting the location of the central heating and cooling plant (CHCP)

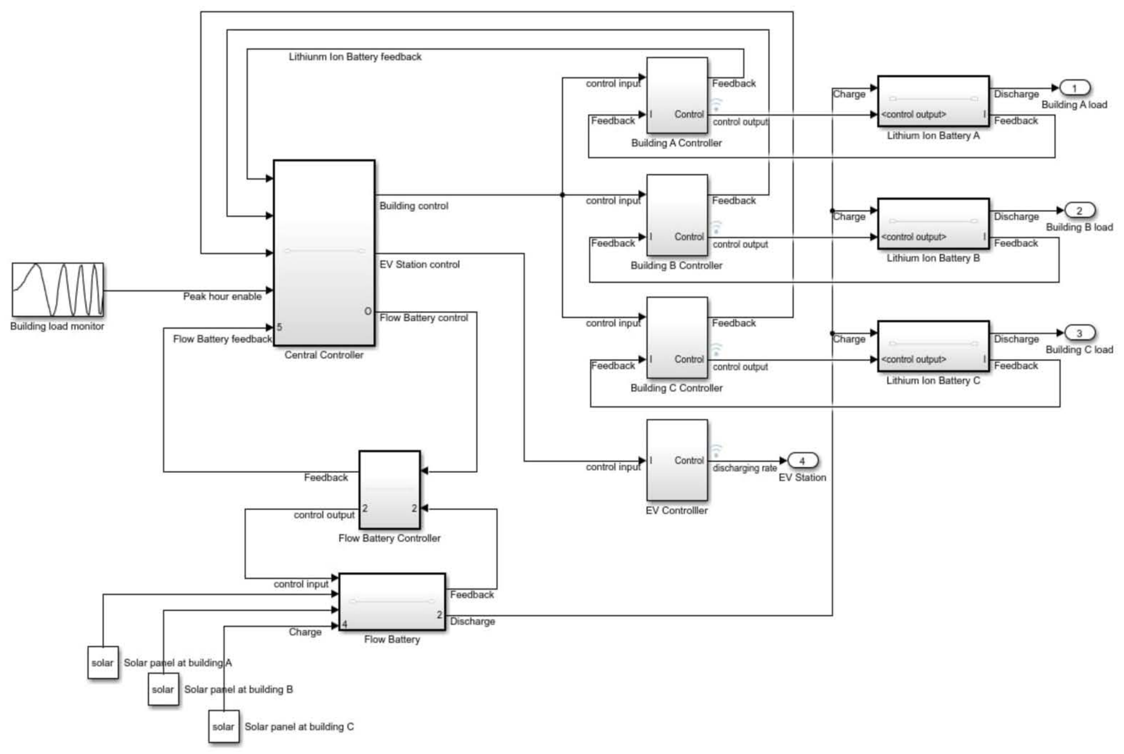

Figure 2: Eco-district system control sequence design of the entire system and its interconnections. Instead of relying on one type of battery storage system, two different systems are used to utilize to maximize efficiency.

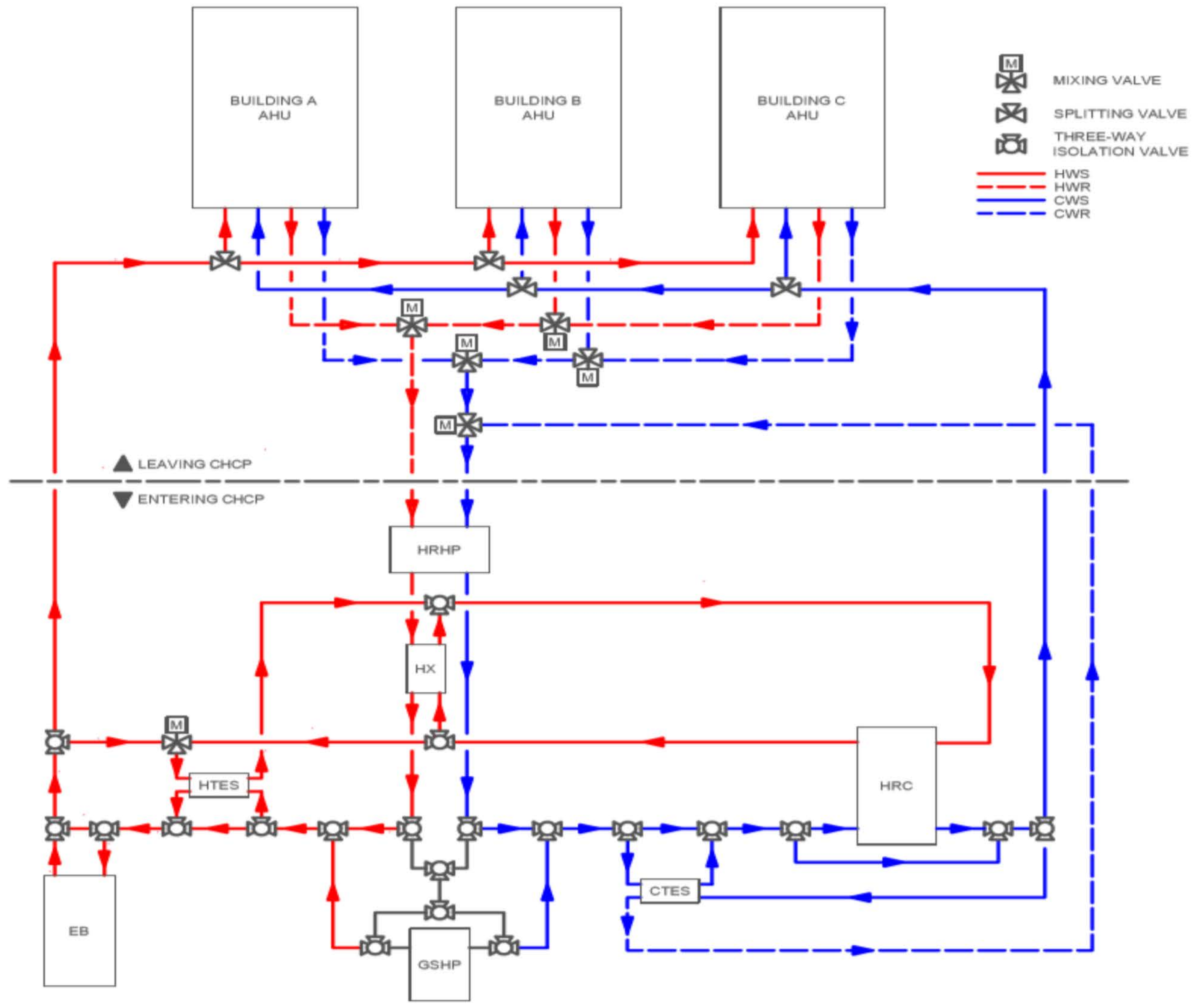

Figure 3: Eco-district system one-line diagram design. Featuring the chosen equipment: heat recovery heat pump (HRHP), ground-source heat pump (GSHP), electric boiler (EB), heat recovery chiller (HRC), heating thermal storage (HTES), cooling thermal storage (CTES)

Results

Equipment Cost Breakdown

	Capacity (kW)	Quantity	Total Cost
HRHP	132	49	$19,610,500
GSHP	83	52	$21,993,050
EB	1050	4	$260,000
HRC	528 - 5012	1	$312,650
CTES	3517 - 5979	1	$86,000
HTES	435	3	$56,550

* including GSHP bore cost of $1,136,750 in total cost

Figure 4: A cost breakdown of all selected mechanical equipment. Showing capacity of each unit, quantity of units needed to satisfy the heating load and total cost.

Equipment Cost Breakdown

	Capacity	Quantity	Total Cost
Panels	604 kW	1887	$1,787,248
Inverters	530 kW	22	$132,325
Redox Flow	179200 kWh	1	$17,920,000
Lithium Ion	2180 kWh	3	$436,000

Figure 5: A cost breakdown analysis of all selected electrical equipment to show the capacity and quantity of each unit needed to satisfy energy and storage needs per our recommendations.

Conclusion

The goal of this project was to design an eco-district concept that is completely electrified, fossil fuel free, and as off-grid as possible. Our final design incorporates renewable energy technology, such as heat recovery and ground source heat pumps to greatly reduce fossil fuel use. It uses thermal storage systems to reduce the amount of energy being produced on a daily basis. Finally, solar energy, as well as energy storing technology, can be utilized to reduce the reliance of the district on a grid connection. This project only explores the basis of an eco-district design for the University but is intended to show that an eco-district is an effective and feasible solution for the University to reduce its energy footprint.

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