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ECE 445 SP22

I-Bottle Project Proposal

1. Introduction

Problem

Heating up liquids is often a cumbersome process involving the use of pots or kettles to heat the liquid, and the annoying transfer of that liquid to a bowl or thermally insulated container. These processes take more energy and effort from an individual and require many different tools.

Say you wanted to heat up a can of soup. This requires at least four things: a stove to heat the pot, a pot to cook the soup, a bowl to hold the soup, and a spoon to eat it. Not to mention the mess you have to clean up after. If one were to get very technical with the process of cooking soup, it would be ideal to measure the temperature of your soup as it was cooking, as well as the volume of soup being heated. Let's also note the potential hazards of burning yourself while you cook the liquid, transfer the liquid, or consume it (given the use of a traditional gas or electric stovetop).

There are no solutions that integrate these concepts into a single container that could perform these tasks efficiently, especially on a smaller and portable scale.

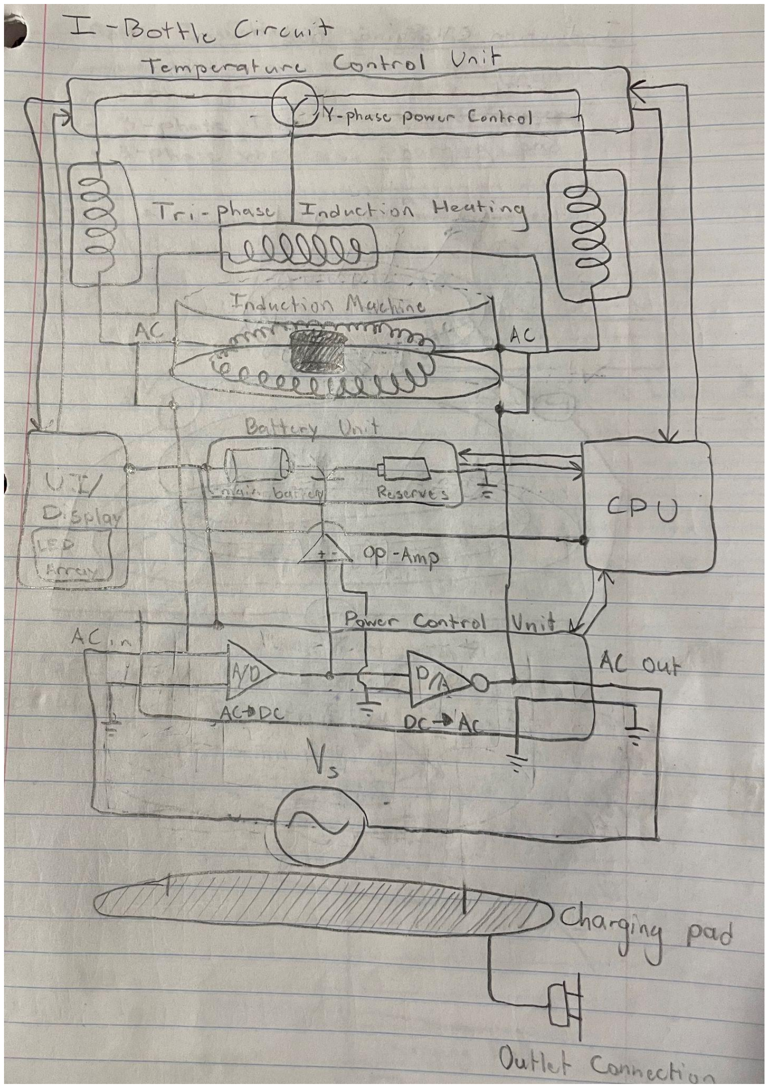
Solution

Imagine having a bottle that could control the temperature of whatever liquid was in it. It would look like a normal water bottle, but have a compartment at the bottom of the bottle containing the electronic components that measure and control the temperature of the liquid. The bottle would heat liquids with induction technology to eliminate the need for a hot surface that heats the bottle.

Instead, we will start with creating a base plate that will house our induction generator, battery, and user interface for controlling and displaying temperature metrics. The user will then place their custom bottle that works with induction technology on the base plate to heat their liquids.

Visual Aid

These are rough notebook sketches on some of the more complex areas of design for the project. These will improve and get more specific with time, and eventually be transferred to online circuit design, 3D modeling, and PCB design software.

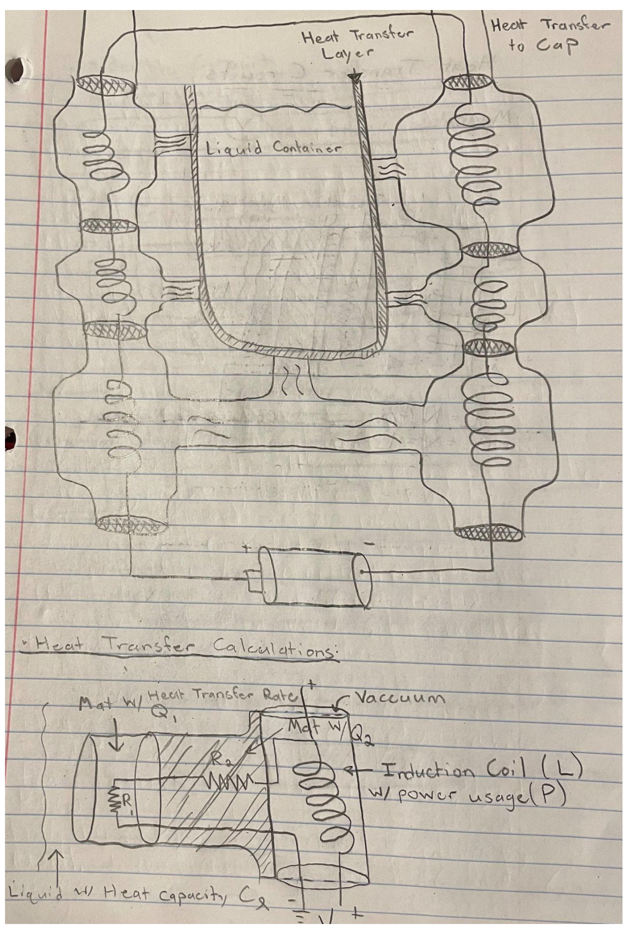


High-level requirements list

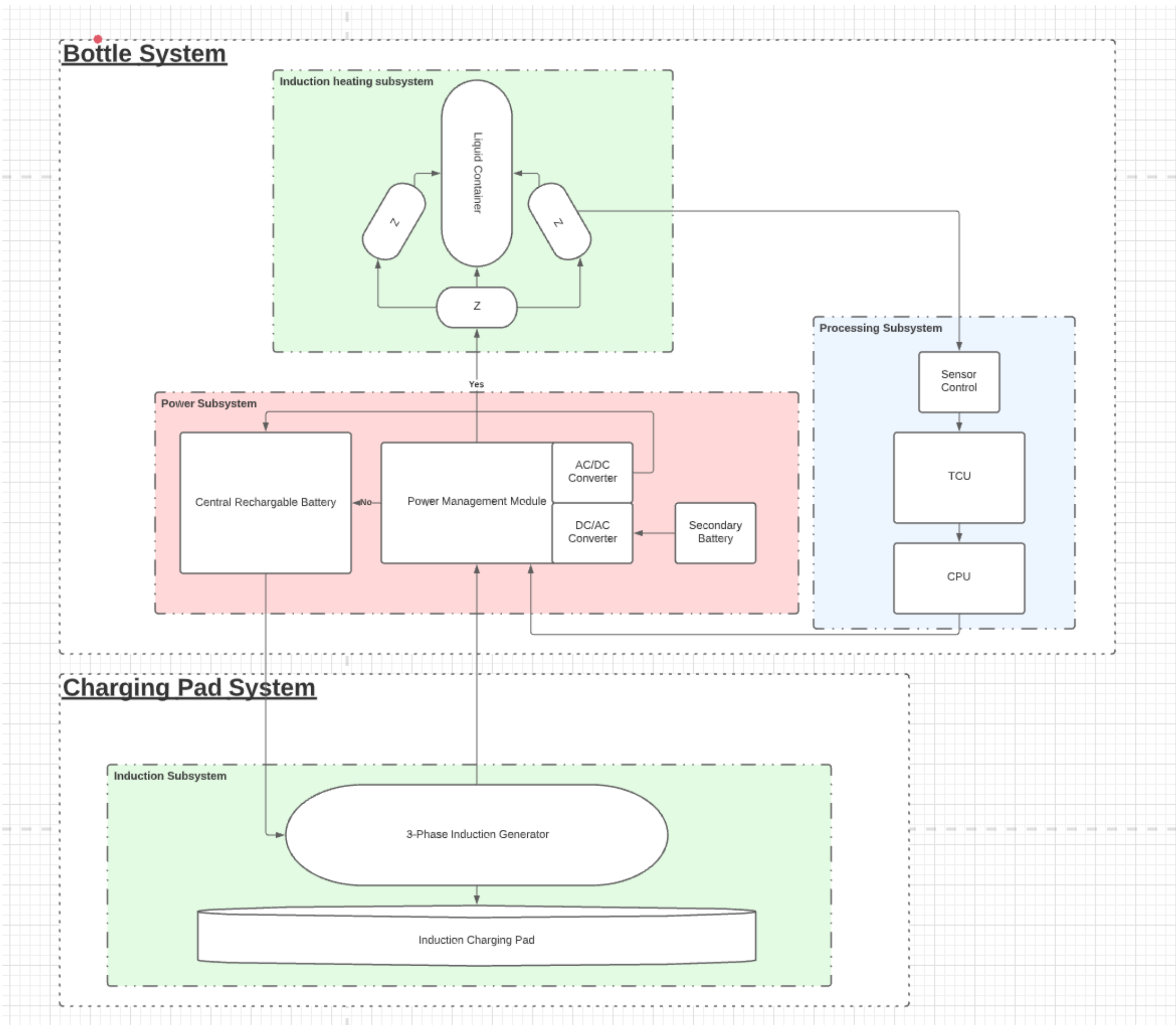
1. Temperature control
    a. The device must be able to monitor the current temperature of the liquid and also heat this liquid to a desired temperature. These metrics will go hand in hand with our user interface system that will display the metrics.

2. Induction system
    a. The device will need an induction generator to supply energy to the coils that will then create a magnetic field. This magnetic field is what actually heats up the bottle and eliminates the needs for a hot cooking surface.
    b. The device will also have a housing unit for the bottle or we will design a custom bottle. Either of these options will have coils powered by the induction generator that create the magnetic field around the bottle, therefore heating the bottle and also whatever is touching the heated bottle.
3. User Interface
    a. The device will need to display metrics such as current temperature, desired temperature, battery level, and time to heat to desired temperature.
    b. On the mini version of our device (the custom bottle we will design), we will integrate bluetooth into the bottle device to be controlled by your phone, which would eliminate the need for a display on the bottle device and base plate device, since these metrics could be displayed on a mobile device like an application.
    c. Other metrics that could be added as extra include pressure (for capped bottle, aka closed system state), water volume, plastic saved by using our bottle (already exists in some smart bottles).

2. Design



Block Diagram



Main Systems:

Bottle System

Induction heating subsystem:

- Liquid Container
    - Material will be magnetic to allow for induction heating
- 3-phase Induction heating coil load
    - These induction coils will have temperature data read by temperature sensors and sent to the processing subsystem

Power subsystem:

- AC/DC and DC/AC converters for Bidirectional power flow
- Routing circuitry from Charging system to rest of control system
- Contains the central rechargeable battery alongside the power converters for easy recharge
- Secondary battery in place for emergency use
- The Power Management Module will be a system of transformers and diodes to construct a proper power upscaling/downscaling system in addition to the AC/DC converting bridges
    - Other possible components of the power management module include:
        - BiPolar Junction Transistors (BJT)
        - Zener Diodes
        - Frequency Filters (RLC systems)
        - Temperature Sensors and control systems
        - Operational Amplifiers
        - LED systems for operation control
        - Physical Buttons/Switches for manual interrupt signals
        - Mechanical Mechanism for connection to induction generator
- Frequency management is critical for distribution of AC current, and Band-Pass filters along other frequency controlling systems can ensure a consistent 60Hz across system

Processing subsystem:

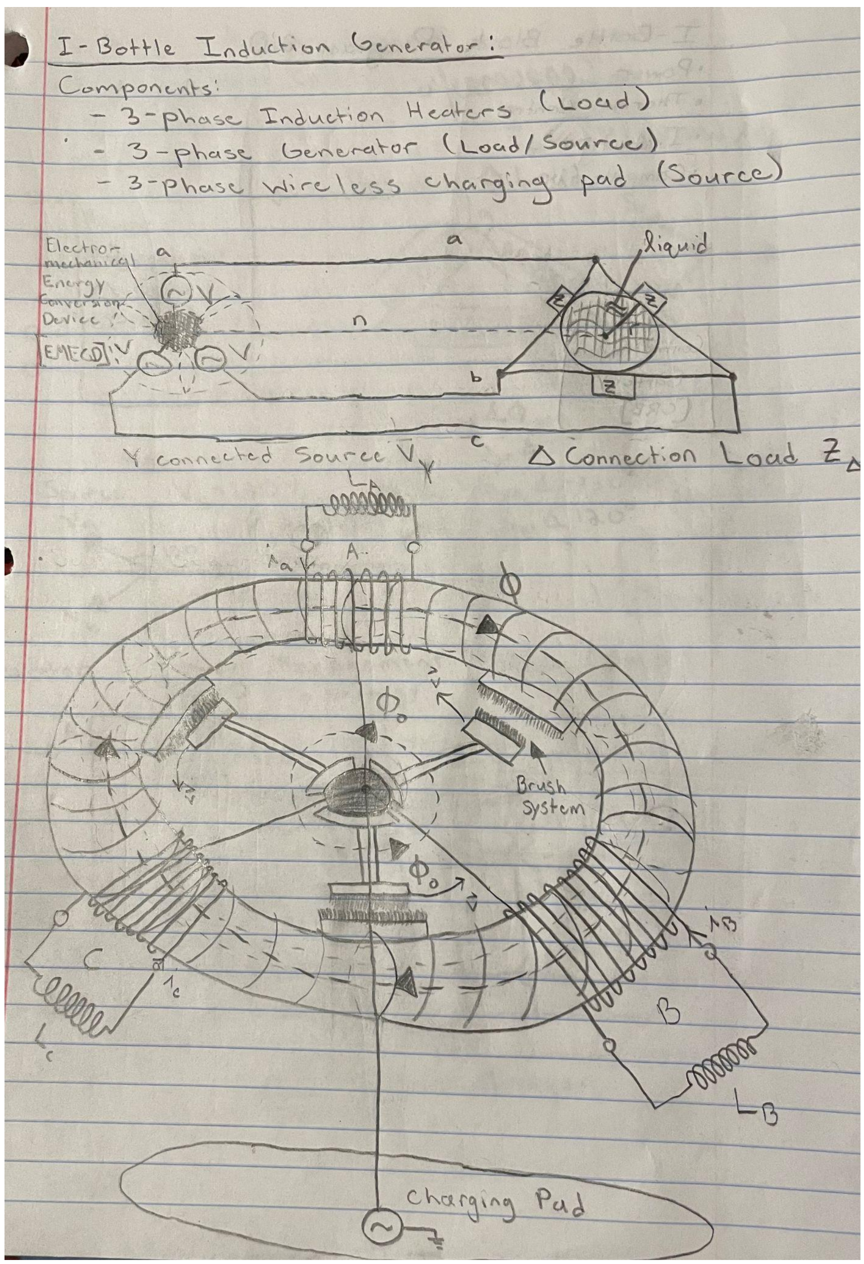
- Central computing unit (microprocessor) handles system to system control
    - Focuses on signaling induction generator runtime
- Temperature Control Unit (microcontroller) to monitor bottle system temperature, humidity, pressure, etc
- Sensor Control Module to gather data from a variety of sensor devices around bottle system

Charging Pad System

Induction Subsystem:

- Induction Generator
    - Responsible for creation of power to be distributed to
        - Liquid heating induction coils

        - Rechargeable Battery
        - Processing Subsystem
    - Direct connection to power management module, which will distribute AC current to 3-phase induction heating coils, or convert to DC current for all other subsystems
- Induction Wireless Charging Pad
    - Outlet plug providing 120V at 60Hz, allows induction transfer to the generator of the bottle system via wireless magnetic induction of current
    - Designed to encapsulate the Induction generator for ideal wireless connection.
        - Generator will have physical connections to the Bottle System, and ideas for mechanical mechanisms to attach and detach the generator can be implemented.



Subsystem Requirements

Bottle System:

- Induction Heating Subsystem:
    - Must be able to raise to and maintain a constant liquid temperature, controlled by user
    - Must optimize power consumption to run on generator or battery systems, and have the ability to transfer between the two
    - Must communicate with processing system smoothly to functionally control temperature
- Processing Subsystem:
    - CPU must processes and route data to power management system, alongside using data from temperature control unit
    - TCU must take data from temperature sensors and interpret this data into signals the CPU can use with the power management module
    - The sensor control must operate multiple temperature sensors and send accurate data to the TCU for processing
- Power Subsystem:
    - Power Management Module (PMM) is responsible for routing and converting AC and DC current throughout systems
    - The Central Rechargeable Battery must be able to withstand the current and power requirements of the Induction heating system,the power management module, and the processing subsystem when in mobile mode.
    - The secondary battery is for back up use and must be able to cover extra power consumption when the main battery fails

Charging Pad System:

- Induction Subsystem:
    - 3-Phase Induction Generator:
        - Required to supply power to the three-phase induction heating coil system via the PMM, with the excess power going towards recharging the main battery and supplying energy to the computational system
        - Must operate while the device is heating the liquid, and a constant supply of electricity must be guaranteed for the system to work correctly.
        - Ideal, 120V 60Hz 3-phase signals supplying 500KW of real power, with a power factor close to 1.0
    - Induction Charging Pad:
        - Constant magnetic field voltage source optimized for wireless transfer of outlet voltage
        - Must provide a constant 120V, 60Hz signal via magnetic induction.

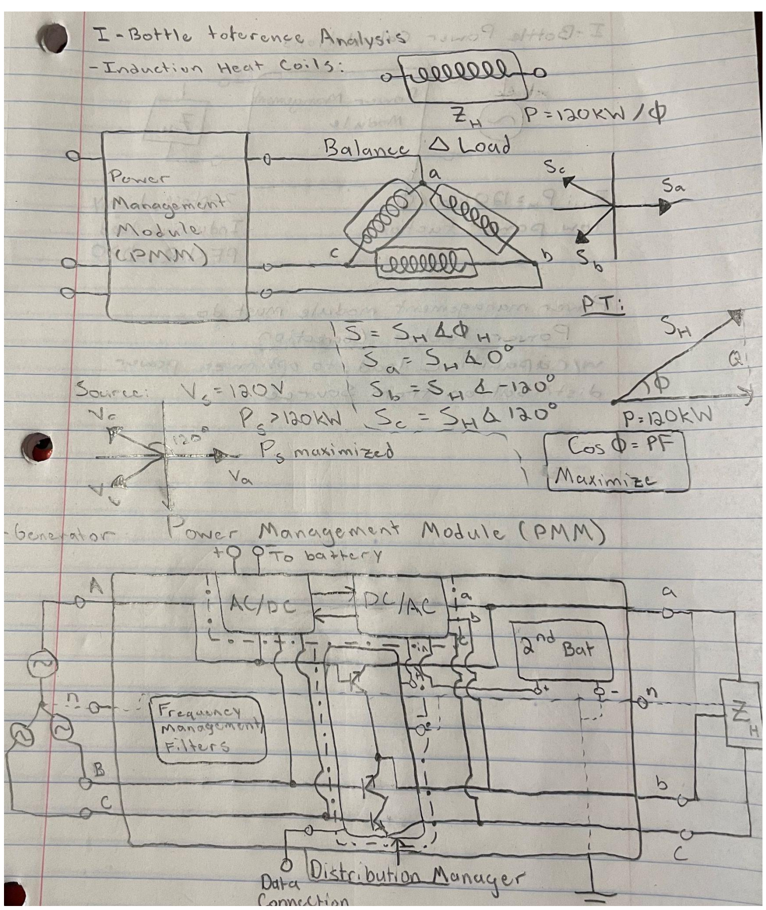
Tolerance Analysis

Developing the induction generator will be our most difficult task, as we will likely need to custom make a 3 phase generator that will be the desired size to fit on our charging pad system. We need to make sure we can supply enough power to the generator and that the generator can create enough energy to power the induction coils. We will have to determine power limits on our AC/DC and DC/AC converters to make sure we don’t damage any of our components.

Induction heating coils take a large sum of power to operate, and if we balance this load with a delta oriented, three phase connection, this will lead to a 3-phase, 120kW per phase, leading to a total of 360kW of real power required by the heating coil system. This load will be highly inductive, meaning a much higher complex power will need to be provided due to the low power factor

Using Power Factor Correction, the Power Management Module can correct the highly inductive load with a capacitive load, meaning the source will output much less reactive power and can use the excess real power to charge the battery.

The I-Bottle system will require a 500 kVA - 1 MVA source (500+ KVA to distribute the real and reactive power throughout the system. This source will be the induction charging pad and generator system. The battery will require similar tolerance stats, but will be optimized to only use the required amount of power necessary to run in mobile mode.



3. Ethics and Safety

Highly magnetic systems can be a cause for concern with most people because of the impact it may have on their other electronics and their own health, so an insulating material must be used around any magnetic structure to isolate it from the outside environment.