Introduction

Problem

Unstable power for electric machinery is a common problem in the industry. Unstable power causes power outages or fluctuations which could be harmful to the machinery and the people around it. In a large factory, for example, a power outage can cause hours of downtime and thousands of dollars to be lost. This problem is vital as it could cause permanent damage to both the machinery and the people using it.

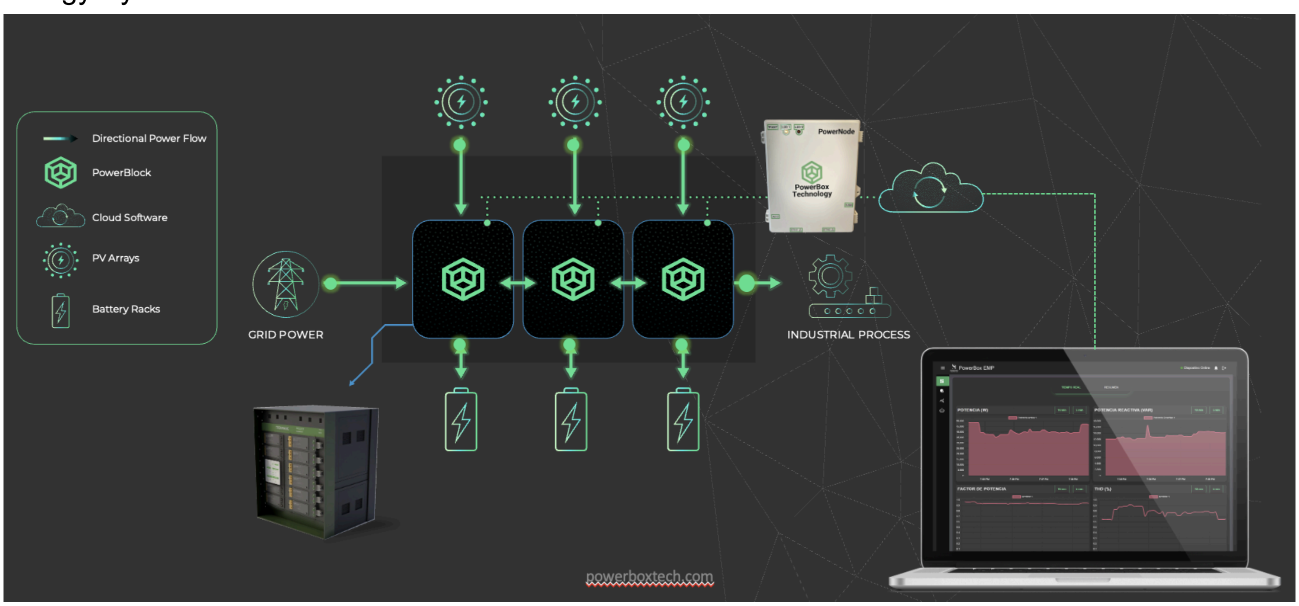
Solution

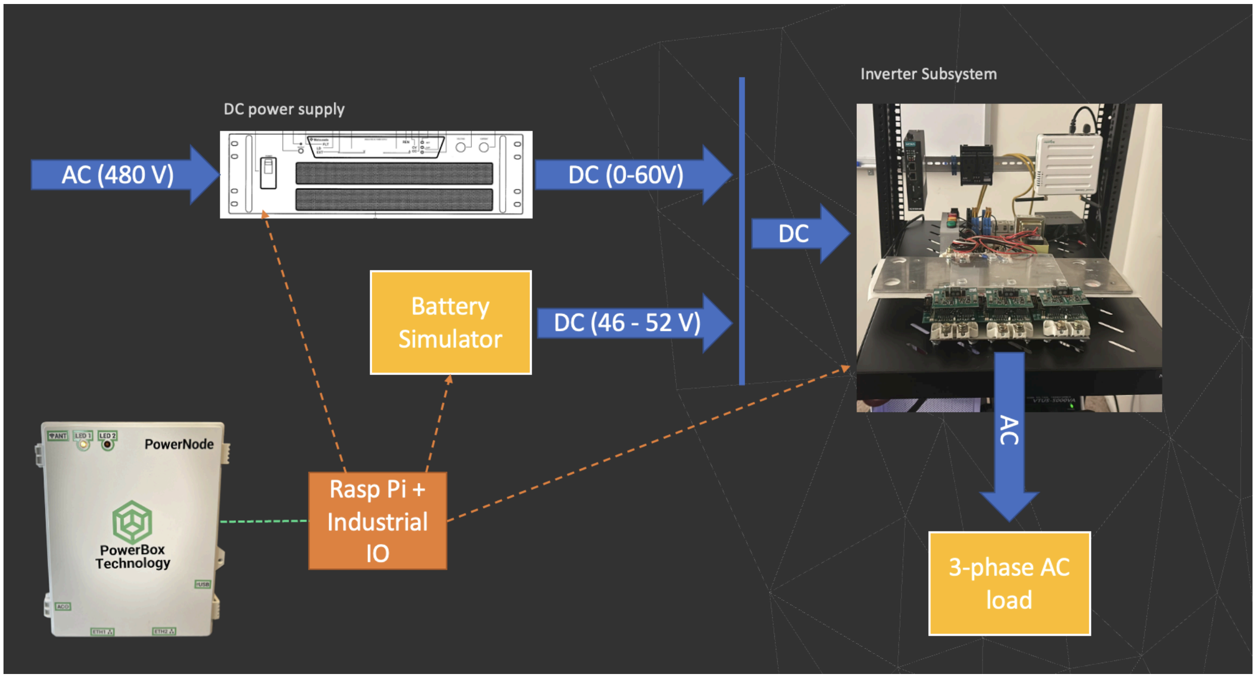
This team will work under the supervision of Oscar Azofeifa, the founder of PowerBox Technology, in order to create a power meter for the PowerBlock. This power meter is to be used in an industrial setting, ensuring that the high-power machinery receives a consistent, clean source of energy.

This power meter will connect to the 3-phase output of an inverter and will be used to measure the 3-phase RMS current / voltage, real power, reactive power, and apparent power. The voltage/current will also get stepped down and outputted to be used as an instruction signal for a DSP. All of our data will be recorded for use in optimizing power delivery to the machinery that requires it.

Visual Aid

PowerBox Technology helps modernize factories' electrical systems through the PowerBox Energy System.





The PowerBlock includes the DC power supply, Rasp Pi + Industrial IO, inverter subsystem and our power meter. In a real setting, the battery simulator would be the battery racks shown in the picture above.

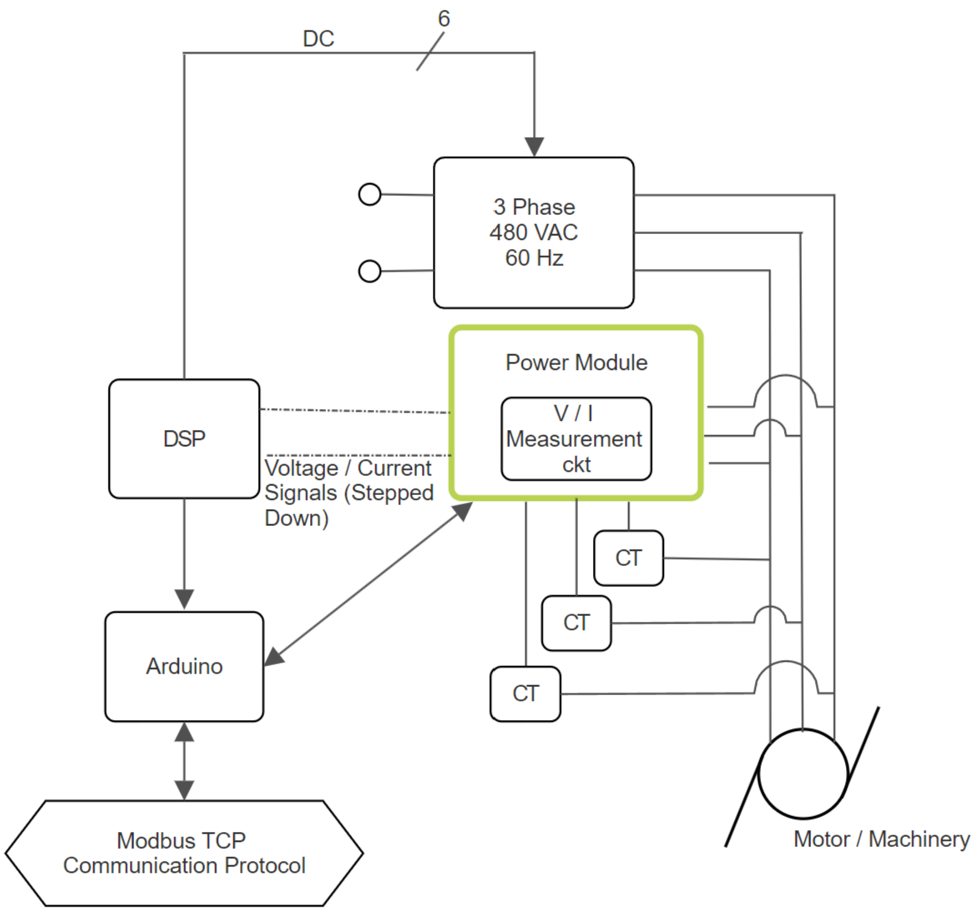
High-level Requirements List

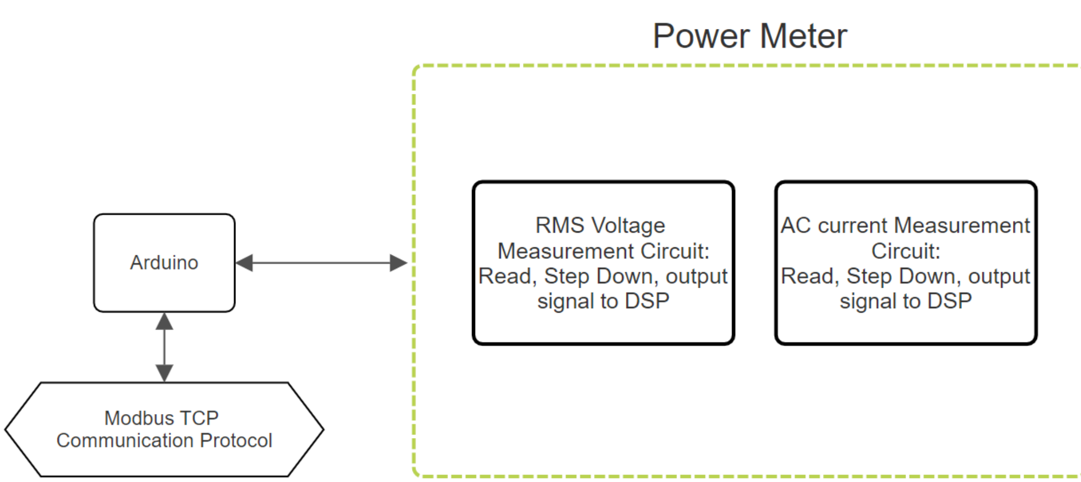
- The Power meter will receive the following information:
  - Three phase voltage readings of the system.
  - Three phase current readings of the system.
- The Power meter will output the following information:
  - Three analog current and voltage signals which have been stepped down from the inverters high voltage/current readings.
  - Real Power of the system.
  - Reactive Power of the system.
  - Per phase voltage readings of the system.
  - Per phase current readings of the system.
- The current analog outputs should be within +-1% of the actual value. This can be checked using the rated current.
- The voltage analog outputs should be within +-1% of the actual value.
- The real power should be within +-1% of the actual value.

This is according to the IEC accuracy standard and is what is expected from PowerBox Technology.

Design

Block Diagram





Subsystem Overview

RMS Voltage Measurement Circuit

The RMS voltage measurement circuit uses the output of the inverter to measure the three-phase voltage. This and the AC current measurement circuit will be used to calculate the real power, reactive power, and apparent power. This circuit will also step down the voltage and output three analog signals to the digital signal processor. This high voltage will be stepped down to a value that can be outputted as a signal through the use of a PCB step-down transformer. In order to safely do this, we will also incorporate regulators and protection circuits.

AC Current Measurement Circuit

The current for the three phases will be going through current transformers, then to the AC current measurement circuit. The current transformer is used to accurately monitor the current while not damaging the equipment with the high current flow. The AC current measurement circuit and the RMS voltage measurement circuit will be used to calculate the real power, reactive power, and apparent power. The circuit will also step down the current and output three analog signals to the digital signal processor. The current transformer is given in this project, but we will have to set the current limits. We will include circuitry that will ensure that the stepped-down values are clean and accurate. These may include precision regulators, overcurrent protection, and low-pass filters.

Power Calculation (Arduino)

This part of the interface board will take the voltage and current from the previous circuits and calculate real power, reactive power, and apparent. The power data will be recorded. This could be done with an Arduino board and the power data could be stored in registers for the other software to use if necessary. The arduino will also receive data retrieved through the communication protocol, this data is processed and stored. The arduino works as the brain of the power meter, it is connected to the circuitry of the meter in order to store and analyze voltage readings, it reads the information retrieved from the communication protocol, and it communicates this data with the DSP.

Communication Protocol

In this subsystem, we will use a communication protocol like Modbus TCP to transmit power data (real power, reactive power, and apparent power) from the power meter to the Power Node. Modbus TCP is a well-established protocol in industrial environments and provides a reliable solution for data transmission. The Arduino board (or an equivalent microcontroller) will be equipped with an Ethernet shield to support TCP/IP communication. This microcontroller will interface with the power calculation circuit to collect power data while the Ethernet connection will facilitate communication using Modbus TCP. The Arduino will act as a Modbus TCP server that regularly updates power parameters, sending data in response to requests from the Modbus TCP client of the Power Node.

Subsystem Requirements

1. RMS Voltage Measurement Circuit:

    a. The fixture must be able to measure the three-phase RMS voltage with an average error percentage of ±1% as per the IEC's standards.
    b. The high voltage output of the inverter should be stepped down using a step down inverter. These stepped down voltage values are to be used as input signals for the DSP. Voltage regulators and protection circuits will be incorporated as well.
2. AC Measurement Circuit:
    a. The subsystem should be able to measure the AC current with an error percentage of ±1% as per the IEC's standards.
    b. The current should be stepped down to a suitable value for the power meter to send analog signals to the DSP.
3. Power Calculation Circuit:
    a. The subsystem should be able to calculate the power (real, reactive and apparent) with an error percentage of ±1% as per the IEC's standards.
    b. The subsystem should be able to record the power data for other uses if necessary.
4. Communication Protocol:
    a. The subsystem should be able to transmit power, voltage and current data to the Arduino. From the arduino, this data will also be transmitted to the DSP module.

Tolerance Analysis

One critical aspect that is needed to define the successful completion of the project is the accuracy of the current measurement circuits. In an industrial setting, the ability to measure the real power, reactive power, and apparent power with precision is vital, as errors in these measurements can lead to inefficiencies or equipment failure. The measured current from the system should have at most a 1% error from the rated current value. This ensures that the build falls within the IEC's quality standards.

Ethics and Safety

One ethical issue involves the responsibility to design and implement a safe and reliable system, as outlined in the IEEE Code's principles of prioritizing the safety, health, and welfare of the public. The potential misuse of our power meter, such as improper installation, could lead to inaccurate power measurements or electrical hazards, causing harm to operators or damaging equipment. To prevent such incidents from happening, we will have comprehensive testing and documentation, ensuring that users are well-informed and can operate the power meter safely. Safety concerns that involve high voltages are also important. We will follow established safety standards at the PowerBox Technology lab, which provide guidelines and training that we have already done to protect against electrical shock, fire, and equipment damage.