Hybrid Energy inspired DC Micro-grid System using Machine Learning

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Introduction

A smart grid is an electrical grid including various operations and energy measures, including advanced metering infrastructure, smart distribution boards, load control switches, and energy efficient resources. Artificial intelligence can be integrated with smart grids to facilitate energy demand forecasting and output prediction to ensure minimal electricity wastage. Also, renewable energy sources, having an intermittent nature, can be integrated into such a system. Hence, our project is aimed at building an energy management system software that uses machine learning to control and regulate renewable and non-renewable energy modules in a DC microgrid to minimize outages and maximize the output of the system by efficient use of energy demand forecasting.

Problem Statement

We must gradually shift our focus to integrating non-polluting renewable energy sources with the conventional grid system to harvest renewable energy economically while ensuring minimal wastage of electricity generated conventionally. In traditional thermal power plants, the Demand and Generation of electricity are matched using a manual process - the grid operators convey the power demand of the users (using their meter readings) to the power plant operators, who in turn control the power output of the plants. This process causes time delays and wastage of electrical energy. Hence, a smart hybrid energy management system is necessary to override the communication latencies for minimum wastage of electricity while controlling the integration of various energy sources.

Motivation

Most smart grid projects focus on controlling the management of the energy that is already generated, whereas our idea aims to automate the generation aspect in real-time. If such a system is deployed in thermal power plants, the wastage of electricity can be minimized, helping the electricity manufacturing companies by reducing their manual labor and time delays. Thus, we intend to build an energy management system to control the power output of the sources according to the energy demands of the users.

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Objectives of Work

1. Predict the power output generated by renewable energy generators using illumination and wind-speed sensors.
2. Predict the load demand of the users in the grid using their previous power usage readings, according to their observed behavior, by measuring the voltage drop and line current at their end over an extended period of time.
3. Switch and regulate the energy sources based on the load/consumption of the users as per the estimates. For uncertain demands, make use of a battery backup module.

PROPOSED METHODOLOGY

The proposed system architecture diagram, shown in Figure 1, illustrates the flow of data between the modules of the system comprising the sensing, aggregation, preprocessing, machine learning, and switching phases of the system.

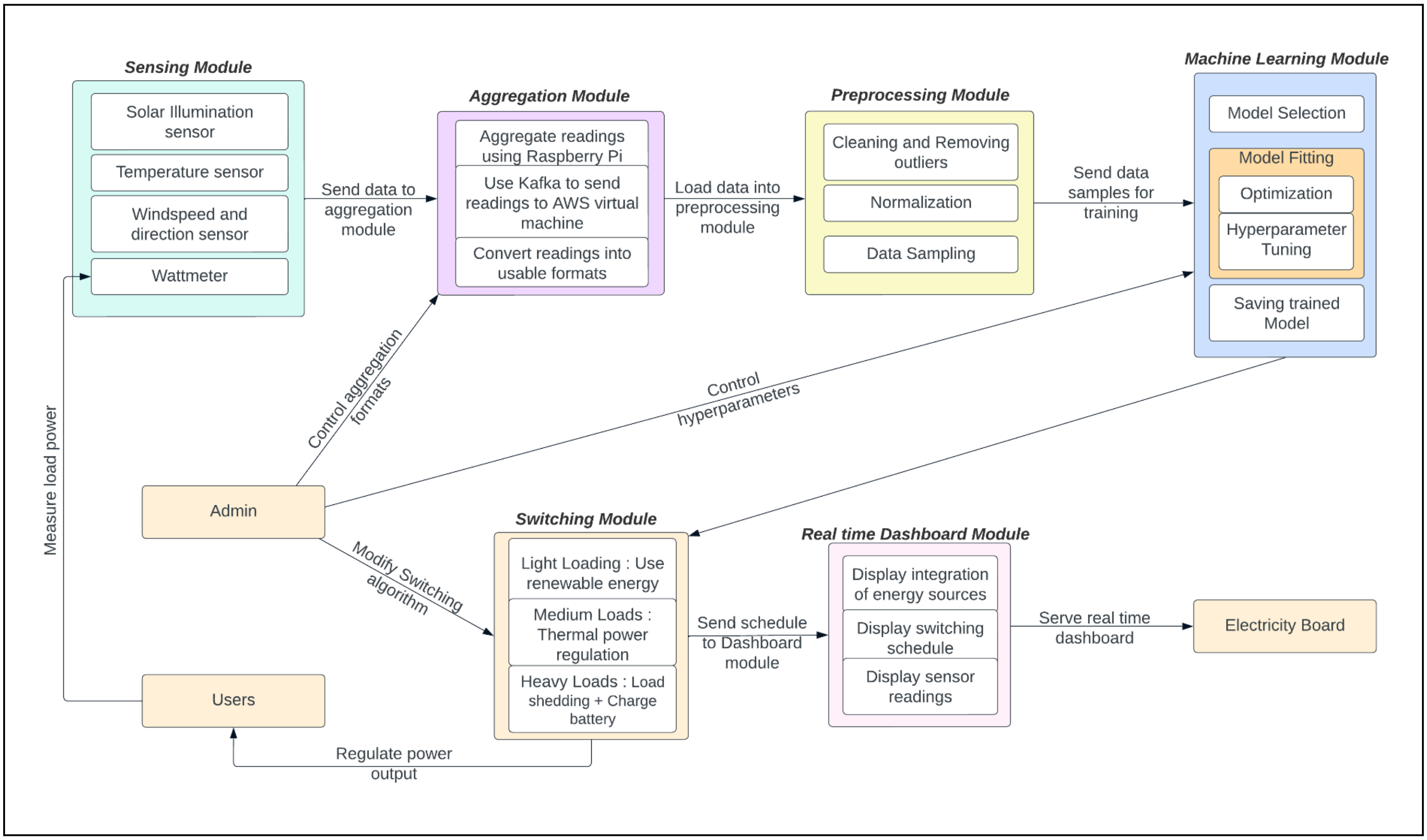

Figure 1: System Architecture

1. **Sensing Module:** The sensing module is responsible for obtaining readings for generating solar, wind, and users' power demand datasets over time to study the renewable energy generation patterns and users' power usage patterns and provide predictions.

   i. An illumination sensor is used to obtain readings of sunlight falling on the operating area of the system, along with the assistance of a temperature sensor.

   ii. To estimate the wind power generation, wind speed and direction sensors are employed.

   iii. A combination of voltmeters and ammeters embedded in the users' end will be used to obtain load demand readings to assist the energy demand forecasting.

2. **Aggregation Module:** This module is responsible for aggregating the sensed readings using a Raspberry Pi, formatting the readings, and sending them to a cloud setup - a virtual machine running on AWS's EC2 using Apache Kafka's publish-subscribe model.

3. **Preprocessing Module:** This module has the responsibility of cleaning the aggregated data - removing anomalous points/outliers, normalization of the dataset, and sampling the dataset to pass a subset of data to the machine learning module.

4. **Machine Learning Module:** This module of the proposed system will be responsible for fitting models to the aggregated and preprocessed datasets and consists of selecting machine learning algorithms, training them on the data, tuning their hyperparameters, validating the model's accuracy using MAE and MSE metrics and saving the trained model. Algorithms - SVM (Support Vector Machine) Regressor and deep learning algorithms - LSTM (Long Short Term Memory) and RNN (Recurrent Neural Network) will be made use of.

5. **Switching Module:** This module will switch/regulate the energy sources based on these operating cases :

    1) ***When Demand < Renewable Generation :***

        The system uses Renewable Power only, and extra power is used for charging backups.

    2) ***Renewable Generation < Power Demand < Power Plant Capacity :***

        Total Power Output = Renewable + Conventional Generation whose output is controlled as per the load demand estimates, and uncertain loads can be handled using power backups/batteries.

    3) ***Power Plant Capacity < Power Demand :***

        Implement load shedding in the power line connected to the intended user.

6. **Dashboard Module:** This module is responsible for displaying the aggregation of renewable power and conventional power generation by the system as a hybrid energy controller and their actual production versus the estimates provided by the trained models. This module is intended to assist electricity manufacturing companies and power plant operators.

ALGORITHM

Step 1. Sense and load the power generation and power demand datasets, clean them, and normalize them.

Step 2. Split both datasets into training and validation sets.

Step 3. Instantiate two LSTM models with initial hyperparameters. Fit the model to both training sets and fine-tune the parameters to obtain the best possible accuracy on the validation sets.

Step 4. Employ the trained models to obtain power demand estimates as well as renewable generation estimates. Use these to regulate the conventional power and divert extra power for charging backups.

Step 5. Visualize the power estimates versus actual power generation and consumption to validate the model's performance and assist the power plant operators in their daily tasks.