Reflection Paper:
Smart Energy System for a Micro-Grid Incorporating Autonomous Vehicles

Group III

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1 Introduction

The problem statement which shall be solved during the course of this semester leads to the following general approach. A Smart Energy System for the TU Berlin micro-grid will be developed on the basis of a machine learning model forecasting data and of a multi-objective optimization method. The goal is to assure an ideal management of the power flow according to the users needs. General problems are stated, objectives are defined and implementation ideas are roughly described.

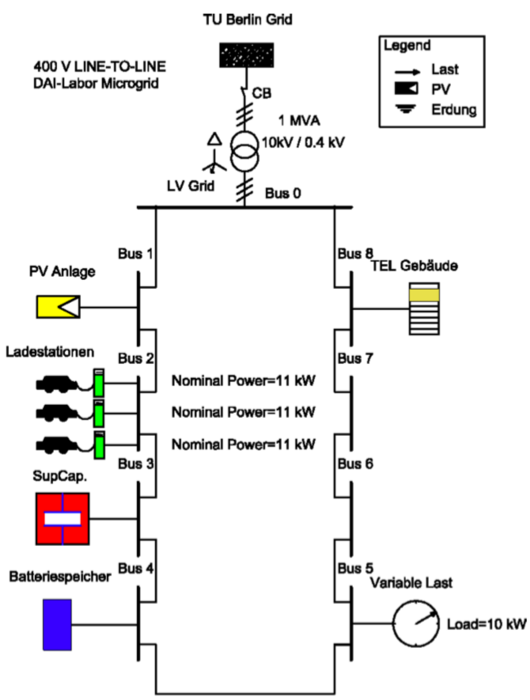

Figure 1: DAI-Labor Micro-grid

In the following, an overview over the underlying energy infrastructure and a problem statement of the issues within the setup is given. Next, possible objectives which were discussed are introduced and lastly, implementation ideas are introduced.

1.1 Micro-Grid Model

The following elements are relevant for the examined Mirco-grid shown in figure 1:

- External grid
- PV generator
- Batteries
- Autonomous electric vehicles
- Load: Tel Building

The direction of energy flow differs for the listed elements. The connection to batteries, vehicles, as well as the external grid is bi-directional, whereas the PV-system only generates and the TEL building only consumes energy.

1.2 Problem Statement

PV generated energy is always time-varying and fluctuates, i.e. non consistent with the consumption and thus leading to economical and ecological disadvantage. Further, the time and load of consumption of the building is strongly dictated by the time of day, more specific working hours with the exception of special events and state holidays. This assumption might also hold for the autonomous vehicle charging station. For example, workers might plug-in their car when arriving at work.

Therefore, depending on influences like weather condition and building activity, different settings must be applied to satisfy users' needs . If the energy production exceeds the consumption, the possibility to sell extra energy could also be considered, if selling prices offer an advantage. Lastly, the building activity might also influence the use of the electric vehicle charging station, such that electric vehicles get directly plugged in during arriving times without considering the energy source or cost.

2 Objectives

The electrical energy generation, usage and purchase will be optimized according to the users needs. On this basis the following objectives are defined:

- Minimize economic expenses
- Minimize CO_2 production
- Maximize customer comfort

The first objective is drawn from the assumption that one goal of a potential user could be to reduce overall cost. General energy consumption should be kept low, except if enough solar energy is generated. The cost of buying external energy should be reduced. Here, also the time of charging electric vehicles might be critical to reduce overall cost, for example charging could be scheduled during lunch time when solar energy production is high.

The second objective considers an environmentally aware user group. Here, the overall goal is to minimize CO_2 production, for example by examining precisely when or if at all external energy should be bought. Generally, an autonomous micro-grid running on solar energy could be a user's main goal. Here, it might be important to supervise overall energy consumption to keep it low if few energy is produced. This might lead to a shortened charging duration for electric vehicles, meaning that vehicles get only charged partly. When considering cost or CO_2, charging electric vehicles should rather take place during sunny phases or when batteries are loaded with PV energy, rather than automatically start the charging process as soon as an electric vehicle gets plugged in.

Lastly, another user group is considered where the users' aim at maximal comfort without regarding environmental aspects or cost, meaning that energy should always be available in sufficient amounts. Still, cost and usage can be optimized. Using the electric vehicle example this means that a vehicle should be charged as soon and as fast as possible without considering the energy source. The importance (i.e. weight) of each objective will be adjustable via a user interface.

3 Implementation Ideas

The foundation of a good model, especially in machine learning, are the data from which it learns. For this use case historical generation and load data will be provided as a basis to decide all further steps. Here, the provided data will be encoded as numerical values. Depending upon the data available the appropriate encoding algorithm will be chosen. The resulting feature vectors can be passed to the model. Machine learning problems are mainly classified into four types - classification, regression, clustering and rule extraction. As a next step, the model which serves the purpose best will be chosen. For example, regression could be used for forecasting. The learned model should then be able to predict future energy consumption or production.

3.1 Forecasting

The model from part one should be able to forecast future energy consumption and production. The output of the model can then be further utilized for the optimization task. This output data can then help to find the best solution for the end user. As an example, PV production heavily depends on the weather, while charging is a static consumption for a closed period of time. Estimating PV energy production can help to decide when its best to charge an electric vehicle according to the given constraints.

3.2 Optimization

Once the machine learning model is obtained the optimization task can be implemented. Here, data from the model can be used as input in combination with the gridmodel data. Then, multi-objective optimization is applied to obtain the best scheduling of loads and generators. The output data can be fed to the pandapower model to simulate the micro-grid with the new schedule. Finally, the resulting schedule can be presented to the user or directly applied to the micro-gird.

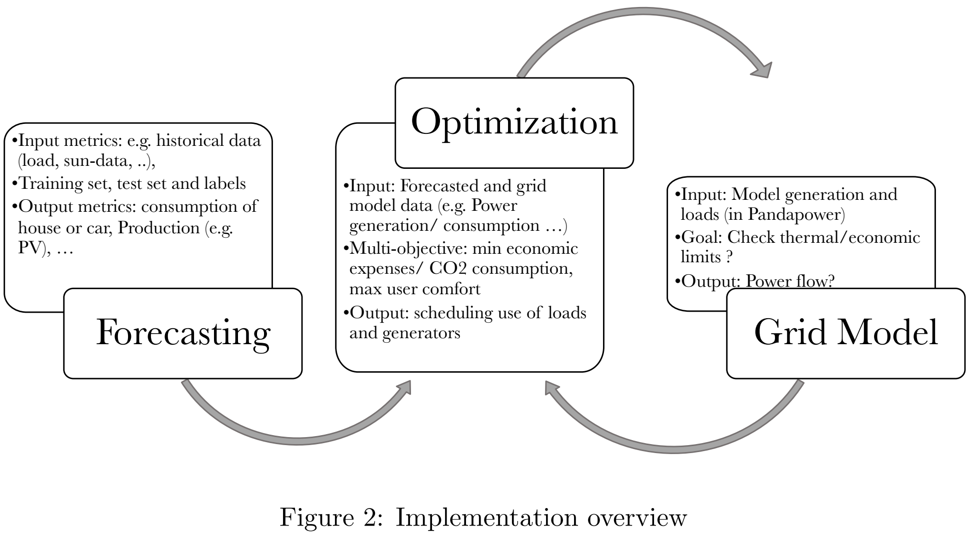

Figure 2: Implementation overview