

# Predictive Model of Household Consumption in Conjunction with Complementary Electricity Generation

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**Abstract**—The growing importance of decentralized energy sources and the concept of community energy present new challenges in predicting and optimizing electricity consumption. This work builds on previous research and focuses on enhancing predictive models of electricity consumption by incorporating photovoltaic systems (PV) in residential homes.

**Index Terms**—energy consumption prediction, community energy, electricity sharing,

## I. INTRODUCTION

To effectively plan and optimise energy supply, it is essential to use predictive models of electricity consumption that allow for more accurate estimation of energy needs under different conditions. This work focuses on extending and improving existing models with an emphasis on the integration of PV in single-family houses and the development of a simple Graphical User Interface (GUI) in MATLAB environment [1].

## II. DEMAND DIAGRAM MODEL

The model of the consumption diagram, which was developed and detailed examined in the framework of the thesis Household consumption diagram model [2], that is a probabilistic model that takes into account the number of people and their occupancy and uses probabilistic approaches to model energy consumption with 1-second granularity, taking into account the number of occupants and their presence in the household. Emphasis has been placed on the use of freely available data and to account for socio-economic factors, allowing for a better understanding and prediction of energy consumption behaviour.

In developing the model, current methods of creating household consumption diagrams were analysed and their advantages and disadvantages were identified. Subsequently, a methodology was proposed that allows the simulation of energy consumption with high accuracy. A key requirement for this data was a high sampling rate, which is important to ensure sufficient simulation accuracy. The simulation results were verified and compared with reference data.

### A. Input data

The input data for this model are a combination of freely available datasets and reference measurements that include information on individual appliance consumption, demographic characteristics of households, behavioural patterns, and time trajectories of energy consumption. The emphasis is on transparency and reproducibility of the model. The combination of different data sources allows to simulate not only the consumption of individual appliances but also the total household consumption.

### B. Model verification and data validation

For verification and validation of the model results, data obtained from PREdistribuce are used, which include measurements of medium voltage (MV) and low voltage (LV) MV/NV transformer outlets from panel houses and measurements of consumption of individual flats in Prague. Measurement data from German households are also used to refine the results and increase their accuracy. These data have a high sampling rate, which is in the order of minutes, which allows improving the quality of the simulated household energy consumption predictions. The combination of these different metered data provides higher accuracy when compared to real consumption.

TABLE I  
COMPARISON OF DATASETS TO VALIDATE RESULTS

Datasets name	File name	Sampling frequency
German household	nemecko.csv	1 minute
PREdistribuce	predi.csv	5 minutes

### C. Demand model

The model developed takes into account various aspects of household consumption, ranging from basic constant consumption to the complex interactions between occupant behaviour and appliance operation.

For better clarity, the model can be divided into two main parts. In the first part algorithm and code structure of the

model, which includes two classes containing all the necessary attributes and functions to simulate consumption. This part provides the basic functionality of the model, including the definition of the appliances and their functions for the consumption simulation. In the second part is the file that runs each part of the classes and controls the flow of the simulation. This file modifies the simulation parameters, allows interaction with the user and ensures that all simulated scenarios

### III. SIMULATION OF PV POWER GENERATION WITH PVLIB LIBRARY

The PV\_LIB library is intended for analysis, simulation and design of photovoltaic systems. It uses to model the performance of PV systems, which includes the prediction of energy production, estimating panel efficiency and evaluating the effect of factors such as illumination, temperature and panel orientation. The library was originally developed for the Python language and was ported to the MATLAB environment [3]. The mathematical models for simulating the performance of solar panels are adapted to be able to provide results similar to the real ones. Thus, the models account for climatic and operating conditions.

#### A. Prediction of energy production based on TMY

PV\_LIB allows the prediction of energy production based on historical solar radiation data, temperatures and other factors. This data is contained in typical meteorological data Year (TMY) files [4]. To obtain them, it is possible to use the online tool PVGIS (Photovoltaic Geographical Information System). Developed by the Joint Research Centre of the European Commission, which provides information and data for analysing the performance of photovoltaic (solar) systems [5].

#### B. Outputs of PV model

One of its main functions is to calculate the electricity production from photovoltaic panels. This calculation is based on a geographical location entered by the user, which determines the amount of solar of solar radiation available in a given area.

PV\_LIB also allows different configurations of PV systems to be simulated in order to determine which setup is the most advantageous. The user can test different tilt angles and orientations of the panels, and the tool will automatically calculate the optimal values that maximize production energy [5].

### IV. IMPLEMENTING MODELS INTO THE APPLICATION

The application will implement scripts for simulating household and photovoltaic systems, it will export the simulated data and display them in a user-friendly interface. Furthermore, the application will allow aggregation of data to different time intervals, on a per second basis, minute and 10-minute periods, thus ensuring flexibility in analysis and visualisation results. One of the core features of the application is its ability to aggregate simulation data across different temporal resolutions — namely, 1-second, 1-minute, and 10-minute intervals. This

functionality provides a high degree of flexibility for both visualization and analysis. The use of 1-second intervals is particularly advantageous when detailed system behavior is of interest. Such a high-resolution time base allows for the precise capturing of fast dynamics in household consumption patterns or PV system outputs — including sudden power spikes, voltage fluctuations, or inverter reaction times

#### A. Application graphic section

The AppDesigner tool is responsible for the functioning and design of the application, the first step of this process is to create a basic application environment that will contain all the necessary controls for effective interaction with the user. The application controls are systematically divided into three main groups, allowing for clear organization and easy navigation between the different functions of the application.

- General Settings - this group is focused on setting simulation parameters, rendering graphical outputs and selecting the month for simulations,
- consumption Simulations - this section is used to select the period and the number of households,
- PV simulation - this group sets the GPS (Global Positioning System) coordinates, inclination and azimuth, etc.

Each of these groups focuses on specific tasks provided by the application, such as household simulation, data visualization, and simulation parameter settings, among others.

#### B. General settings

This group focuses on the configuration of basic simulation parameters that are common for multiple elements of the application. The user can set several parameters here. The exact elements are month selection, interval length, rendering of simulation progress, plotting of graphs.

#### C. PV simulation

The last group of components contains the PV plant simulation setup and basic information for obtaining TMY data. The parameters in this control are panel selection, inverter selection, number of panels in series, number of strings, panel angle and azimuth settings.

#### D. Consumption simulations

This group includes components for controlling, setting and adjusting the simulation of household consumption. The period selection element is a control that allows to set the period for which the electricity consumption will be generated. The user can choose between two modes. Weekday, where the simulation adapts its algorithms to match the typical behaviour of people and appliance usage on weekdays. And Weekend, where the simulation algorithms are optimized for the weekend when people's behavior is different.

Furthermore, a content component to select the number of iterations that the accuracy of the simulation.

The last component of this page is a numerical selector for the number of households for which to simulate the resulting consumption.

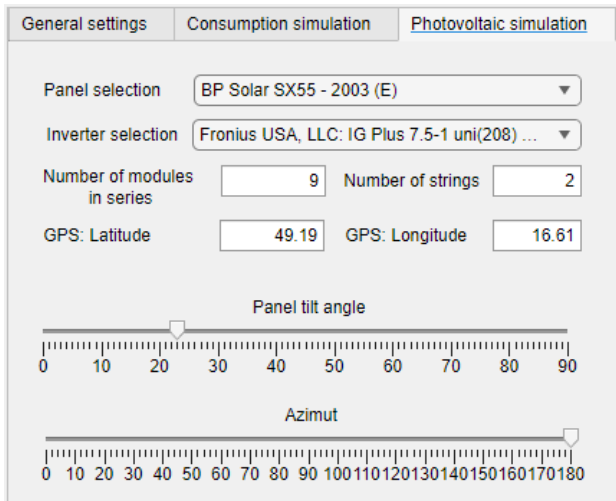


Fig. 1. Designed GUI for setting up a photovoltaic power plant

### E. Application control

The last important part of the GUI is the ability to save to .csv. For this purpose, a Save to .csv button is created that downloads the data from the simulation and prepares it for export in CSV format.

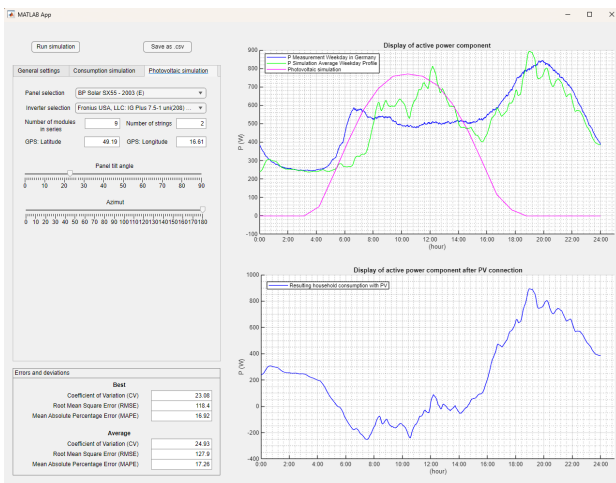


Fig. 2. Overall designed GUI applications

## V. APPLICATION OPERATION

After pressing the Run Simulation button, all variables are restarted to ensure a clean start of the simulation. This is followed by saving all user options and finally the progress\_bar function is run to coordinate the execution of other parts of the application (e.g. the nemecko.m script for the simulation, plotting graphs, etc.).

### VI. 1 ST. SIMULATION AND PV SYSTEM CONFIGURATION

The simulation was carried out for a representative group of 200 households based on the model described in [2]. The simulation was performed for the month of July, which was

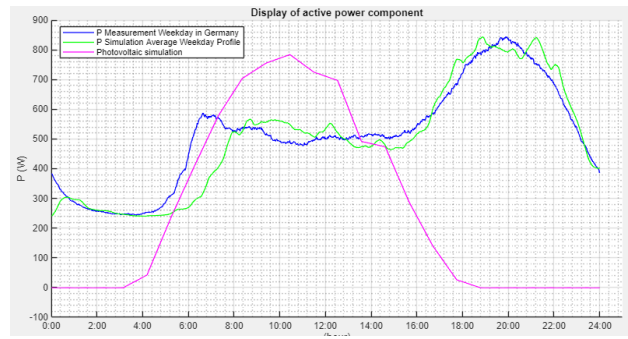


Fig. 3. Displayed active power of all components in 1 st. configuration

chosen to represent the period with intense solar radiation. The number of iterations for this simulation was set to 10 in order to improve the stability and accuracy of the results. The PV plant model included two stringers, each containing nine panels of the BP Solar SX55 - 2003 type. The output energy was further processed by a Fronius IG Plus 7.5-1 uni(208) inverter. A more detailed configuration of the PV system can be found in Fig. 1 IV-C.

### VII. 1 ST. SIMULATION RESULTS AND ANALYSIS

The resulting waveforms of both simulations are shown in Fig. 3 V, where they are compared with real measured data from Germany. The plot shows only a minimal deviation between simulated and real values, which is confirmed by the following error bars: CV = 21.18, RMSE = 108.6, MAPE = 14.23. Bottom figure on Fig. 2 IV-E further shows the resulting course at the level of the whole object, i.e. the consumption point. It shows that the PV plant designed in this way is optimally sized - it minimizes the energy overflows to the distribution grid while covering its own consumption. The main advantage of the proposed application is the possibility to efficiently estimate the appropriate size of the PV system with respect to the number of load points, while maintaining high simulation accuracy.

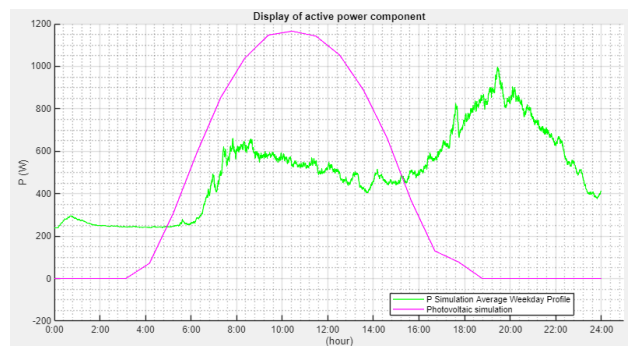


Fig. 4. Displayed active power of all components in 2 nd. configuration

### VIII. 2 ND. SIMULATION AND PV SYSTEM CONFIGURATION

For the second test, a Sharp ND-187U1F panel was used in combination with a HiSEL Power – HiSEL-K 4000 inverter

(208V), responsible for processing the generated energy. The panel configuration consisted of four strings, each with two panels. The consumption simulation was again performed for 200 households, but this time with six iterations and using a higher time resolution with 1-second intervals.

## IX. 2 ND. SIMULATION RESULTS AND ANALYSIS

From the plotted results, it is evident that reducing the time step to one second significantly improved the accuracy and variability. Thanks to the probabilistic model described in [2], the resulting load curve exhibits a distinctly different shape, more accurately capturing realistic variations in household behavior.

## X. DATA VALIDATION

The data validation for the household consumption model is thoroughly described in [2]. Validation for the photovoltaic model is available in [3]. This application utilizes their original source codes and integrates their functions into a unified user interface, offering users convenient access to both models within a single environment.

## XI. CONCLUSION

The practical implementation combines the theoretical knowledge explored in an earlier master thesis in the field of energy consumption modelling with energy production modelling using PV\_LIB supported by the PV\_GIS library.

The application is developed in the AppDesigner environment in MATLAB. Both graphical and computational aspects have been considered in its development, while the adjustment of the calculations focuses on data aggregation. The graphical part of the application is designed to be user-friendly and intuitive, allowing easy interaction with the different modules and visualization of the results. The application also includes a data export option. The application includes an integrated reporting system to help users avoid errors in their work.

The result is a link between the prediction of PV generation and the estimation of consumption based on the behaviour of the household users. The generated values are then merged to produce the resulting waveform shown in Fig. 2 IV-E. This graph illustrates how the consumption of a customer site changes after the integration of a PV plant.

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