ENERGY MANAGEMENT PLATFORM BASED ON AUTOMATED MACHINE LEARNING

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Abstract:

With the emergence of renewable energy sources, such as solar collectors, wind turbines, etc., electricity management has become more complex. To solve this problem, we have created *Smarticity*, a software platform that provides renewable energy users with a reliable digital twin of their micro-grids, relying on machine learning predictive models. In addition, the platform offers a micro-grid operation optimization, based on evolutionary algorithms that can help them to find an optimal pattern of energy production and consumption in terms of efficiency, environmental protection, safety, and profit. To validate the effectiveness of the *Smarticity* platform and underlying methodology, we have conducted an experiment on the virtual prosumer. The results obtained from the simulations have clearly shown that the operation plan optimized by the *Smarticity* significantly outperforms other strategies.

Keywords: AutoML, evolutionary algorithms, renewable energy, optimization

1. Introduction

With the introduction of easily accessible renewable energy sources, every household will become not only a consumer, but also a producer of electricity. The balance between supply and demand in such systems, with billions of producers and consumers, is necessarily a complex task. This complexity forces distribution systems operators (DSOs) to switch from energy transmitters into orchestrators of renewable energy grids. Such grids can vary in scale from even one household, through residential building or area, to state-wide distribution network. Regardless of the scale, the problem of managing energy production and consumption is essentially the same and requires adequate software solutions.

In previous years, many authors have used machine learning to solve these problems. Some find artificial neural network (ANN) technique as a very appropriate tool to predict the performance of solar collector systems [1]. XGBoost is considered the best performing ML algorithm for household electrical energy (EE) consumption prediction [2]. Genetic algorithm (GA) has been used for the optimisation of renewable energy systems, especially in cases where different multi-objective functions are considered [3]. An integrated genetic algorithm (GA) and artificial neural network (ANN) have also been used to estimate and predict electricity demand using stochastic procedures [4].

Our solution for these challenges is Smarticity, a comprehensive software platform that provides renewable energy users with optimal operation plans continuously, considering all important natural and social factors. Based on private and publicly available data, Smarticity automatically generates predictive models of the production and consumption processes within the facility, enabling simulation of the energy data chain and evaluation of different operation plans under various conditions. By taking meteorological forecasts and the expected social factors into consideration, operation plans are optimised on a daily basis, employing the obtained models as a digital representative of the building as a micro-grid. To make sure that the generated predictive models are always genuine digital twins of the installed equipment and the residents' habits, the models are recreated periodically, thus evolving together with the building and the environment.

2. Platform description

2.1 Smarticity concept

As a prerequisite for the optimisation of the operation plans, Smarticity automatically generates machine learning models of the internal energy production and loads, based on data acquired during the energy system exploitation. These models are improved by using publicly available data on weather, working and non-working days, specifics of renewable energy incentives, etc.

To create and maintain these models, Smarticity employs Blackfox, our Cloud service for automated generation of optimised machine learning models, based on Deep Neural Networks, Random Forest and XGBoost. Blackfox performs genetic algorithm (GA) optimisation of all elements of the machine learning model with the aim of generating a model that best describes input data.

Generated predictive models are used for the simulation of the energy data chain and evaluation of a number of hypothetic operation plans under given conditions. The optimal operation plan is obtained on a daily basis through simulation-based optimisation performed on our portable cloud service OSICE - Optimization as a Service in the Cloud Environment. Thanks to its microservice design and inherent scalability, OSICE performs complex evolutionary algorithm (EA) based optimisation efficiently.

2.2 Software implementation

Thanks to its microservice architecture, Smarticity is a cloud-native solution designed from the ground up to fulfil security and scalability requirements. Its key components have been successfully deployed in various computing environments, such as HPC clusters, on-premises Docker-compose and Kubernetes, AWS ECS/EKS and Google Compute Engine. All services are deployed in a separate VLAN, for the sake of security. Most of the underlying services are available through asynchronous and well documented REST API, ready to be exploited by any other energy management tools. All microservices are developed in the way to support containerised technology, so that the setup of the entire platform is simple and can support cloud-native implementation. High manipulation speed over the datasets is achieved by using the Hadoop cluster along with Spark. Training and optimisation processes are done simultaneously by using Elastic Kubernetes Cluster (EKS) and if the load rises above a certain value, EKS can automatically add a new node.

3. Validation

To verify and validate the Smarticity platform and the underlying methodology, we have conducted an experiment on a virtual prosumer, based on the data acquired from the relevant internet database – pecan street [5]. The prosumer is equipped with:

- 1 solar collector (nominal output power: 20 KW)
- 1 air-conditioning system (cooling power: 6 KW)
- 1 electric vehicle charger (charging level: L1, max. output power: 2 KW)
- 1 battery (capacity: 50 KW/h, max. charg. power: 20 KW, max. out. power: 20 KW)

The entire system is connected to the electricity micro-grid that enables two-way power exchange at the equivalent prices in both directions. Energy exchange prices are harmonised with the market prices on an hourly basis.

We considered three days of operations, different from the period used for the ML models training. To compare the influence of different operation plans on the total energy cost we considered two scenarios. In Scenario 1, deficiency of electric energy is compensated by the energy from the battery whenever it is possible. The rest of the energy needed is supplemented by the energy from the grid. In Scenario 2, Smarticity determines in which hours the deficiency of electric energy is compensated by the energy from the battery and when from the grid.

Since the production of solar collector and consumptions of air-conditioner and EV charger do not depend on the required operation plan, the predicted production/consumption of these appliances based on the given input data was the same in each of the scenarios. The amount of energy produced by the solar collector, the energy taken from the battery and the energy taken from the grid in two scenarios are shown in Figures 1 and 2. Negative values of the energy taken from the grid mean that the energy is sold to the grid in those hours.

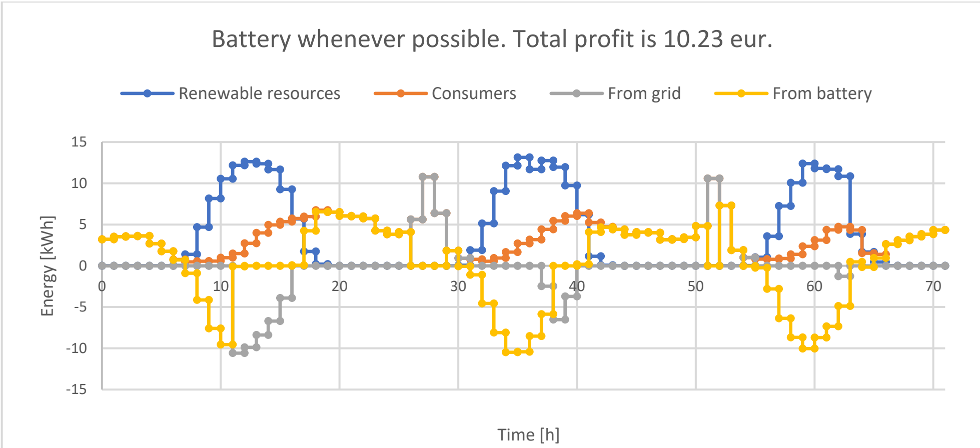

Fig. 1. Scenario 1 - Battery whenever possible

In Scenario 1, the battery is used to compensate for the lack of energy in the hours when the solar collector worked at low intensity. Due to the limited battery capacity and output power, in some hours the lack was compensated by the energy from the grid as well. Using such rule of operating, the profit achieved by the system was 10.23 EUR.

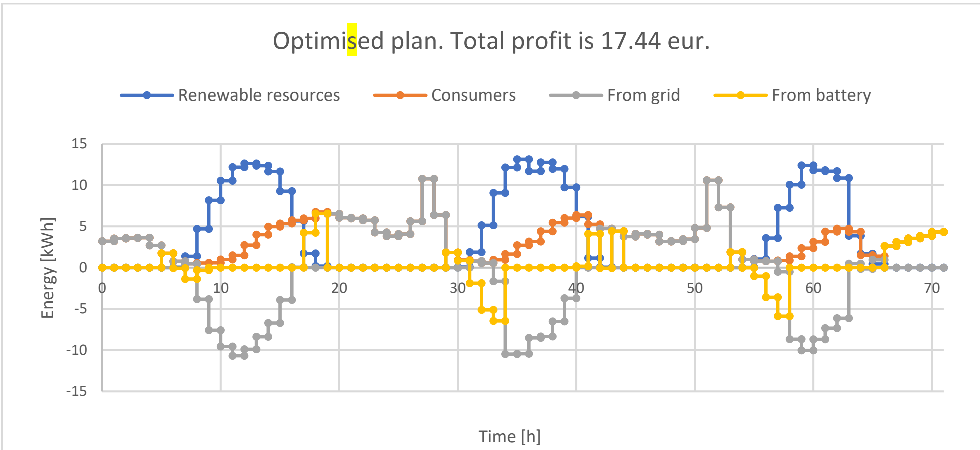

Fig. 2. Scenario 2 - Optimised plan

In Scenario 2, Smarticity was improving the plans until it achieved the best operation plan, which generated the maximised profit of 17.44 EUR.

4. Conclusions

In this paper we presented Smarticity, the energy management platform based on AutoML and GA, that continuously provides renewable energy users with optimal operation plans. To verify and validate the Smarticity and the underlying methodology, we conducted an experiment on the virtual prosumer. The data used had been acquired from the relevant internet databases. We performed simulations of two different operating scenarios and compared the profits achieved by each of them. The results clearly showed that the operation plan optimised by the Smarticity significantly outperformed the greedy one.

In order to improve this platform, our future work will be directed towards the implementation of Physically Informed Neural Networks (PINN), which in cases where the available data is known to comply with a particular physical law, require significantly smaller amounts of data to be trained.

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