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A SIMULATION TOOL THAT FACILITATES THE PLANNING AND THE DEVELOPMENT OF MICRO SMART GRIDS

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1 INTRODUCTION

Electric mobility has gained much attention over the last years. The reason for this popularity is the hope that the electric powertrain may—one day—replace conventional combustion engines; including all the problems they cause. At first glace, this hope seems to be justified, on second thought, however, electric vehicles (EVs) do not appear as environment-friendly as they are supposed to. The problem is electricity. Studies (Icha and Kuhs 2015) show that in Germany, the production of 1 kWh entails the production of 569 g of CO_2. Having in mind that that modern electric vehicles consume roughly 20 kWh per 100 km, we arrive at a CO_2 fingerprint of roughly 11 kg for every 100 km that are driven with an electric vehicle.

There were several attempts to improve this situation, e.g., to increase the utilization of renewable energy. In Germany, most electricity is produced by coal-fired power plants. These are mainly responsible for the extremely bad CO_2 fingerprint of energy that comes from the grid. Much work was done to improve technologies that produce energy from renewable sources, e.g., wind turbines or photovoltaic facilities. Yet again studies (Steuer et al. 2013) showed that the approach was not applicable since the energy-grid is not able to transport energy from where it is created (mostly off-shore) to the places where it is mainly required. As a consequence, much of the sustainably produced energy remains unused.[1]

The latest approach to decrease the "effective emissions" of electric vehicles is to relocate energy production from the remote coastline directly to our cities. The approach is implemented by means of so called *Micro Smart Grids* or *MSG*s (Freund et al. 2012).

MSGs are small to medium-sized infrastructures with office and living buildings, all of which connected to a state-of-the-art electric grid network. The distinguishing characteristic of MSGs, however, is the fact that these infrastructures are able to consume the energy they are producing. Thus, MSGs usually comprise energy-producing devices, e.g., wind turbines, photovoltaic systems, combined heat and power plants, or geothermal power plants, to name but a few. In order to buffer surpluses of energy, MSGs frequently apply stationary batteries or electric vehicle fleets with *Vehicle-to-Grid* capability.

Setting up MSGs became a profitable business in Europe, yet, setting up MSGs is extremely difficult due to lacking experience in this area. In order to support the planning and the implementation of MSGs, we developed a consulting tool (Lützenberger, Küster, and Albayrak 2014), which we present in this demo. The tool allows to configure and to simulate fictitious MSG infrastructures and thus helps stakeholders to determine the requirements (e.g., the required amount of energy-producing or storing devices, the required size of the electric vehicle fleet, the required amount (and capacity) of stationary batteries, etc.) of their construction project. The tool applies an agent-based simulation model and was field-tested at the *European Energy Forum*[2], or *EUREF*.

[1] Electric grids are based on the concept that the amount of produced energy has to equal the energy demand.
[2] European Energy Forum website: http://www.euref.de/de/

2 THE TOOL

The tool evolved from a software (Lützenberger, Küster, and Albayrak 2014) that was originally written to control the charging of EVs (and stationary batteries) in MSG architectures. The software was designed to determine charging schedules (start-time(s), end-time(s), current over time, etc.) that are optimal in terms of selectable optimization criteria, e.g., maximal utilization of renewable energy, minimal CO_2 consumption, fastest EV availability, etc. Optimization is based on *evolution strategy*, such that an initial charging schedule is randomly created and respectively: simulated (next 24 h), assessed, and mutated until it's quality converges. Our optimization system has access all kind of data that is required to maximize the performance of the MSG. The MSG's consumption, for instance, is forecasted by using historic consumption data (available for roughly 2 years), including an "adaption factor" that we calculate based on the consumption of the last 24 h. Energy production is estimated by using location-tailored and highly precise weather forecasts (radiation, temperature, and wind) that are provided by *MeteoGroup*[3].

The optimization system is implemented as a multi agent system, each fundamental functionality encapsulated by a JIAC V software agent. A graphical frontend allows users to configure MSG architectures, to select utilization schema for the installed EVs and to send these "simulation scenarios" to the simulation software. We extended this frontend to serve as a professional consulting tool.

This was done by adding an additional agent, namely the *Simulation Agent* to our existing multi agent system. The agent was designed to receive MSG configurations and data that is required for the simulation (weather and consumption reports) and to create a corresponding set of time-discrete events from these input values. The approach allows us to examine the impact of each input value (the MSG itself, the consumption, the energy production, the charging efficiency, etc.). Created event objects are identical to the objects that are created by the MSG itself (in reality), so from the perspective of the optimization system it is no difference whether an MSG is being simulated or a real MSG is being optimized (the optimization software is deployed at EUREF's IT infrastructure). The tool allows to analyze the impact of all relevant MSG parameters, thus, we hope that it helps decision-makers to assess the impact of constructional extensions (e.g., a larger PV system, a more efficient wind turbine, an additional stationary battery or a larger EV fleet). The tool also allows to add time-depended energy tariffs (including tariffs for energy provisioning). This feature helps decision-makers to assess their MSGs in terms of economic efficiency (even before it is built). We hope that this simulation-based prototype convinces more and more industrial stakeholders to invest and to participate in the trendsetting and promising Micro Smart Grid business.

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[3] *MeteoGroup* website: http://www.meteogroup.com