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OPTIMIZATION APPLIED WITH AGENT BASED MODELLING IN THE CONTEXT OF URBAN ENERGY PLANNING

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ABSTRACT

The inherent complexity of urban energy systems, and related decision making on system configuration and system operation strategies requires appropriate energy modelling, simulation and optimization means and tools. Due to its character, optimization applied with agent based modeling can be used to tackle problems whose nature is distributed and complex. In this work we present the insights gained through the optimization model building process in the area of urban energy planning, which deals with multi-scale, domain transversal and largely heterogeneous systems. Optimization is applied to urban energy infrastructure planning and energy system operation planning.

1 INTRODUCTION

Infrastructure planning as part of urban energy planning deals with decisions concerning the choice and dimensions of distribution technologies to supply the electricity, thermal or gas needs of an urban area. Operation planning answers questions about generation dispatch, demand-side measures, storage control, network operations in the energy systems. Optimization problems in energy system usually aim to achieve an optimal system configuration as well as an optimal operation strategy with optimization criteria falling on cost effectiveness or environmental friendliness. Energy system components can be modularized as a set of agents characterized by their attributes, and interact each other though the definition of system operation rules via system networks. Agent-based models help to represent these systems in a disaggregated, multi-scale and multi-layer way, benefitting from the inclusion of interactions at individual levels and the representation of emergent phenomena as an implicit characteristic of these models.

2 OPTIMIZATION ON MULTIPLE SCALES

A model that represents a urban energy system shall be able to simulate local energy generation, demand, storage, distribution and optionally demand side management. Energy carriers including electricity, heat, cooling and gas, usages including lighting, air conditioning, heat radiator, etc., and building functions including office, residential, shopping mall, etc. shall be optionally considered depending on simulation purpose and data availability. Optimization tasks are detected on different scales of an agent based model. They exist within different energy carriers, energy distribution levels, or energy sectors.

Lack of both demand and generation data is usually the first obstacle when building an energy model, furtherly, optimization that are applied on the developed model is as well limited. Furthermore, an optimization of all the individuals forming system is not possible for large scale system, as we would go beyond an acceptable computational time and effort, when considering e.g. a whole district including thousands of buildings and a consequently high number of entities and optimization variables. This is why we apply an interactive, multi-scale optimization method to deal with lacking of detailed data and computing capacity in the task of optimal urban energy system planning.

For instance, at the early stage of an urban planning task, master plan of a district is made. Land use of different building functions can be obtained, but further data on level of distribution network or buildings is unavailable. The optimization can start on an aggregation level, in this case, on building function level, to obtain an optimal system configuration with assuming all the individual agents of generation, demand and storage following the same simple operation rules, respectively. Once the optimal system configuration is obtained, it will be disaggregated into a lower scale, so that optimization on system operation of each agent can be further conducted. At the end, the optimal operation strategy can be applied to calibrate with optimization of infrastructure planning on the aggregation level.

3 MODULE SIMPLIFICATION

Considering the modularity of agents, agent based modeling can divide the global problem into small “local” problems. Large-sized optimization problem can be handled better when the sub-model presents its characteristics simply and yet correctly. This way, reducing the size of sub-problems could help to achieve better optimization performance. The overall system optimum should then emerge through the interaction of the sub-problems as an aggregation of local optima. Take a model of battery management system as an example, one may model it with 4 variables to define battery daily charging starting time, charging period, discharging starting time and discharging period. Or one can alternatively design the control model with only one variable to present charging/discharging threshold over electrical demand, which charging/discharging power of a battery shall not exceed. In this case, more autonomy is given to the individual agent (the battery management system), and at the same time, the complexity of the agent is reduced to the “outside” by only having one variable to be optimized. Optimization on large scale energy system with distributed storages or demand side management is gaining more and more attention in urban energy planning, a storage control model with only one variable to optimize reduces considerably the system optimization effort. The simplified module can further be described inside the agent by more variables, and be broken down at system level after the optimization, if needed.

4 SENSITIVITY ANALYSIS

Sensitivity analysis is of one of the most interesting area in optimal urban energy planning. Many attempts are conducted to investigate the optimization problem behavior when input data changes, which is useful to make a proper system planning considering the trend of future improvement of technology and cost. For example, gas boiler, electricity-driven CHP and utility power gird are intended to supply heat and electricity of an area. Due to the cheap price of grid electricity, CHP is not suggested for this system by optimization result. Interest will be gained to investigate how optimization result will be influenced by CHP price drop and utility electricity price increase in the future years.

5 CONCLUSION

In this paper, we propose a combined optimization approach for largely distribute agent-based model in order to solve both problems in energy planning and operation, using an interactive approach not only limited to classical mathematical optimization. Simulation (by agent-based models) is used as objective function, which, due to its complexity, demands a reduction of the time for simulation runs, especially when several optimization experiments are needed to provide sensitivity analysis. And yet meaningful results can be achieved through determining the objective of each run. By dynamically adapting the aggregation level at different stages of the process, and applying metaheuristic optimization method at different levels, a combined technique is presented which benefits both from the strengths of optimization and simulation, and especially their synergies, in a joined energy system model.