Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 198 (2017) 366 – 374

Procedia Engineering

www.elsevier.com/locate/procedia

Urban Transitions Conference, Shanghai, September 2016

Towards generalized co-simulation of urban energy systems

Kunpeng Wang[ab], Peer-Olaf Siebers[b], Darren Robinson[b*]

[a]*Austrian Institute of Technology, Giefinggasse 2, Vienna, 1210, AT*
[b]*The University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom*

Abstract

Maximizing energy conservation, improving energy efficiency and integration and control of renewable energy sources are critical in order to achieve a low carbon future. An integrated modelling system is needed to evaluate and improve energy performance of urban energy systems' design and operation, from both financial and environmental perspectives.

To this end, this paper presents an urban energy co-simulation framework. It is based on co-simulation standard Functional Mock-up Interface (FMI) and CityGML-based semantic 3D city model and utilized programing packages, like PyFMI, FMILibrary, and mosaik, which is capable of orchestrating the execution of dynamic simulation models supporting the for co-simulation. To demonstrate the proof of concept, two simulation tools are coupled in the first instance: EnergyPlus and No-MASS. Based on the two use cases, the principles and workflow of the framework and results from its application are described. Results from use cases show that synchronization and interaction between our urban energy co-simulation framework and coupled co-simulation components works as intended. The paper concludes by discussing strategies to tackle more complex and multiscale energy systems.

Peer-review under responsibility of the organizing committee of the Urban Transitions Conference

Keywords: Urban Energy Systems; Co-Simulation; Functional Mock-up Interface; Functional Mock-up Unit

1. Introduction

Nowadays, 54% of the world's population live in urban areas, which is predicted to increase to over 66% by 2050 [2]. Cities are the source of the majority of energy consumption in many industrial and high population countries. The International Energy Agency (IEA) estimates that more than two-thirds of primary energy in the world is consumed by cities that correspondingly results in approximately 71% of global CO2 emissions [3]. By improving the efficiency of urban energy usage and using low-carbon energy sources, cities can play an active role in climate change mitigation [4]. Due to complex energy characteristics of cities, understanding and managing energy usage in

Peer-review under responsibility of the organizing committee of the Urban Transitions Conference
doi:10.1016/j.proeng.2017.07.092

cities is critical to achieve this target. To commit new policy initiatives or infrastructure investments, urban planners need appropriate urban energy modelling tools to provide scientific analysis.

Over the last few decades, a number of high quality domain specific simulation tools have been developed to simulate dynamic system behavior of urban energy systems [5]. They are able to help to understand related problems in a certain domain. However, less effort appears to focus on creating integrated modelling systems to couple energy simulation models at various temporal and spatial scales from different domains within the urban energy systems modelling community.

In this paper, a standards based urban energy co-simulation framework is presented to address such gap. The modularity design of this framework enables it to integrate different urban energy simulation tools encapsulated in Functional Mockup Unites (FMU) with minimum effort and cost. The corresponding urban energy modelling system developed by using this framework can provide an integrated representation of urban energy usage. Simulation results from such system are able to provide a comprehensive solid basis of scientific analysis to facilitate urban planners and policymakers in planning and decision-making process.

The remainder of this paper is structured as follows: Section 2 provides an introduction of key technologies used by the framework and its implementation; Two case studies are presented in section3, which are used to validate functionality of the framework and demonstrate workflow from data collection to co-simulation; Section 4 concludes the work and discussion regarding some planned improvements is given.

2. Background

- Co-simulation

Integrating models of multiple aspects of urban energy system such as demand models, supply models, agent-activity models and urban energy supply network models is complex to analyze and implement. To tackle such challenge, co-simulation (co-operative simulation) approaches were adopted by a number of researchers such as [6-10].

Co-simulation is an approach for joint simulation of phenomena modelled by different tools. In this approach, existing domain-specific energy modelling tools, each with its own expertise, are coupled in a way that enables a dynamic multi-physics simulation of a hybrid system. Co-simulation can be implemented using different strategies. From the coupling point of view, the implementation can be done using either tight coupling (onion) or loose coupling (ping-pong) as indicated in Figure 1 [1, 11]. Tight coupling requires an iterative solution among involved simulators to satisfy a predefined convergence criterion in each step. In loose coupling, simulators only use data from preceding step, which can have their own iterations, and there is no iteration required between the coupled simulators.

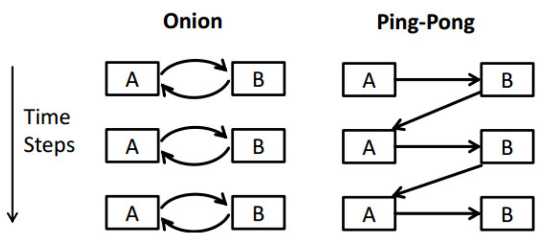

Figure 1: Data exchange scheme of tight coupling (onion) vs loose coupling (ping-pong) [1]

Currently, the co-simulation framework presented in this paper adopted loose coupling strategy. Within which, data exchange between coupled simulators is restricted to discrete communication points, which is orchestrated by master algorithms. Between two communications point, coupled simulators solve their own internal iterations.

- Functional Mockup Interface

FMI is a tool independent industry standard [12] to support both model exchange and co-simulation of dynamic models.

The co-simulation part of the FMI specification defines essential interfaces enable diverse simulation tools to interoperate, covering all stages of the co-simulation process including instantiation, initialization, configuration, access, modification and manipulation, in the form of C functions (FMI APIs). The calling sequences of these functions must follow the state chart shown in Figure 2.