We developed GridSpice, a scalable open-source simulation framework for modeling, design, and planning of the smart grid. GridSpice seamlessly integrates existing electric power simulation tools to enable modeling of large electric networks that blur the boundaries between generation, transmission, distribution, and markets. This is achieved via a cloud based architecture that allows for parallelizing large simulation jobs across many virtual machines using a pay-as-you-go model. GridSpice simulations can be managed through a REST API or through a python library, allowing users to run simulations programmatically and interface with disparate data inputs, external simulation tools, and post-processing tools. These capabilities make GridSpice an ideal tool for the development and testing of new grid control and optimization algorithms. GridSpice also provides an easy-to-use browser-based interface to allow novice users to begin without any setup or configuration on their local PC.

The electric power grid, comprising utility companies, power system operators, market players, and other agents, is undergoing rapid change. Centralized generation is being complemented with renewable energy sources and storage systems. A prevalence of electric vehicles, unexpected consumer reaction to demand response programs, distributed energy resources (DER), and simply a higher rate of power consumption, all add further stresses on an aging grid architecture. As such, grid operators have become more proactive about replacing outdated components with more technologically advanced ones, adding sensing devices, such as smart meters, and using sophisticated control systems to accommodate these changes. There is a high cost associated with reforming an asset such as the electric power system, a cost measured not only in dollars but also in terms of power disruption due to unintended consequences of upgrading large portions of the grid. These high costs can be somewhat ameliorated by simulation—modeling the grid as accurately as possible and using these models to develop and implement optimized control systems. This task is becoming more difficult, however, due to the increasing interdependencies between generation, transmission, distribution, and end-use loads. Existing electric power simulators provide well-proven point tools for simulating either transmission, or distribution networks. No mainstream tool supports co-simulation of both systems. High penetration of distributed generation, storage, and controllable loads increase the elasticity of electricity demand with respect to price. It is not feasible to model such scenarios independently. In addition, existing simulators run on standalone workstations, use proprietary input formats, and exhibit dependencies on particular operating systems or 3rd party libraries. These limitations makes it difficult to integrate new tools into existing planning and operations processes to address emerging smart grid scenarios.

GridSpice is a cloud based simulation platform that addresses the aforementioned limitations of existing simulation systems. GridSpice remedies these problems by creating a flexible framework that wraps industry standard simulation tools and runs them as separate but synchronized processes. Each part of the network runs in a simulator designed for that purpose while GridSpice synchronizes the boundary state of these loosely coupled processes. Since GridSpice can run each of these processes on separate
nodes on a cluster, it is possible to simulate a transmission network with hundreds of connected
distribution networks on a sufficiently large cluster. Furthermore, GridSpice allows users to specify
different levels of simulation granularity for different nodes in the transmission network. For example,
an engineer may use an abstracted aggregate load forecast for some load serving entities (LSEs) while
running a full distribution simulation for other LSEs on the same transmission network.

GridSpice allows engineers to parallelize simulations on a cluster in two different ways using pay-as-you
go compute capacity on Amazon Elastic Compute Cloud (EC2). First, independent simulations can run at
the same time on separate compute nodes. This allows users to quickly perform iterative grid
architecture optimization by simultaneously simulating potential changes to the grid. Second, large
networks are split into multiple loosely coupled processes that run on separate cluster nodes. This
makes it possible to simulate large systems involving multiple interconnected networks that would be
too large for a single workstation.

The GridSpice framework allows users to edit models and control simulations through a secure REST API.
Since the REST interface is based on HTTP requests, users may control the system through the language
of their choice and automatically synchronize their models with energy management systems (EMS),
distribution management systems (DMS), supervisory control and data acquisition (SCADA) systems. For
user convenience, the client side of this REST API has been implemented in Python to provide the user
with a ready-to-use scripting tool to perform tasks such as iterative grid architecture optimization.

GridSpice eases adoption into existing work flows by providing an easy-to-use browser-based graphical
user interface (GUI) with features including a GIS editor, project explorer, object editor, and a wizard for
importing projects from other systems. New users can become familiar with the features of the system
through the GUI before using the programming interfaces, and advanced users can use the GUI to
perform visual sanity checks on their models. This makes GridSpice ideal for academic courses and
professional training.