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Agent based Modeling and Simulation in Power and Energy

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Abstract: *Simulation is a process that allows the user to observe an operation without performing that operation. In order to simulate a system first a model of the same should be developed. Simulation and modeling is helpful in application where experimenting with the actual system is difficult due to various reasons. In the smart electric grid it is highly useful to develop a model and simulate it to observe the results before implementing the actual system as it is expensive, inconvenient and sometimes hazardous to do experiment using the real system. Simulation tools ease the development of models and simulation, by providing easy to use interface and powerful simulation engines, which saves time of the developer. Agent based modelling and simulations(ABMS) are where each entity within a model is considered as an agent which is reactive and proactive. The agents within a system will interact with one another and with the environment to form a simulation pattern. This paper discusses the advantages of using ABMS tools over the traditional modelling tools. It also discusses the various applications for which different ABMS tools are used in the power and energy sector. The ABMS tools AnyLogic, REPAST, Simulink, JADE and GridLabD are explored in detail along with the applications built. Finally it identifies GridLab-D as the most prefered ABMS tool for power sector as it provides built-in modules for the components in power simulation and it has already been successfully used in a number of simulation systems.*

1. INTRODUCTION

Any and energy are so closely related to our day to day life that even a minor change in these will have a significant impact on us. So continuous studies and research are going on in these areas for the betterment of life. But experimenting with the real world system is not advisable in these areas as any minor defect may affect the common people and it can be hazardous. In such situations modeling and simulation, where in a representation of the system is made to imitate the working of the system. Nowadays computer simulation, in which the model is a software, is considered as one of the fastest, safest and cost effective form of modeling and simulation. A variety of tools are available which helps in modeling the power and energy systems in a computer simulation.

Power and energy sector has become smart with the use of intelligent systems for various purposes. Smart grid, smart power, smart energy, smart meter, all these are now part of power and energy. Smart here means capable of sensing various factors and making suitable decisions based on these inputs. These smart devices can even communicate with one another, through messages, in such a way that the decision of one device can have an impact on other devices. When devices start making their own decisions and act upon those decision the behavior of the whole system will be the combined product of these actions. The modeling and simulation tools based on mathematical formulas and equations are not flexible enough to model this kind of system. This is where the relatively new approach of Agent Based Modeling and Simulation(ABMS) comes in.

ABMS also known as Multi-agent Systems (MAS), is an approach to modeling a system where each component is designed as an intelligent agent. Each agent has certain characteristics like being proactive, that is to act on its own, can communicate with other agents, can interact with the surroundings, and can react upon certain situations. The inherent flexibility of the system makes it suitable for modeling smart grids. Since each component here is an agent and each agent has to be designed to implement all characteristics of the component, the system can be reliable. ABMS systems also help to analyze the emergent behavior of a system which is a result of interaction among the agents. [12]MAS are used for studying distributed problem solving, cooperation and coordination in an organization, communication, fault-tolerance, negotiation, multi-agent learning, and robotics, because of its characteristics such as learning and adaptation. MAS have been suggested by several authors as a potential technology for energy management and improving comfort in buildings [15]. Oliveira, Pedro, et al. [19] proposes a modeling and simulation platform called MASGrip that models the internal operation of smart grids.

Here we are discussing certain tools that support ABMS. The sections are organized as follows. Section-2 of this paper gives a list of some traditional tools that are being for modeling the power and energy systems. Section-2.1 discusses why there is a need for advanced tools. Section-3 details five ABMS tools that are put to use in power and energy and compares them.

2. MATHEMATICAL TOOLS VS SMART TOOLS IN MODELLING AND SIMULATION

All The conventional power system were modelled using the mathematical modelling tools like MatACDC, 4DIAC, THYME, PowerSystems, SimPowerSystems, libIEC61850, OpenIEC61850, OpenETran, UWPFLOW, MatPower, DCOPFJ, InterPSS, PSAT based on MatLab, MatDyn, etc. These tools successfully modelled the functions of the power system, and since they were based on well-known and tried out formulas and equations, it was easy to use these tools with a little or no concern about the underlying platform or code. The power and energy engineers could themselves work on these tools to build their models and test them without much help from the developers or sometimes even without much programming background. These tools acted as a powerful platform in which research and studies were carried out.

Need for Smart tools

The growth of computers, Internet and communication technologies brought about tremendous change with them, which affected the power sector as well. When communication and intelligence got incorporated into the electric grid, the whole system emerged as the smart grid, with smart appliances, smart sensors, smart monitors and so on. The smart grid technology in now an ever evolving technology, much like any other systems related to the computers and internet. So the model of a smart grid needs to have intelligence, be adaptive, proactive, social, reactive, flexible and extensible. Most of the mathematical modelling tools were incapable of providing many of these features. This was the point where Agent Based Modelling and Simulation gained importance because of its inherent features that support almost all the needs of a smart grid modelling platform.

3. AGENT BASED MODELLING AND SIMULATION PLATFORMS

When systems became smart with the advent of technology, new paradigms for modelling these systems also emeged, ABMS being one of the most widely used among them. Here the whole system is represented as an environment which provides some static components and houses numerous intelligent agents. The agents are the dynamic components of the system to which intelligence is integrated by some rules governing their behavior in such a way that the agents try to achieve their goals by interacting with other agents and the environment. The interactions may include sensing the environmental conditions, communicating with other agents though messages or signals, and changing some of the properties of the environment in the process. The characteristics of an ABMS system, also called a Multiagent system(MAS) make them a preferable platform for modelling the smart power and energy.

Though the ABMs systems have been used successfully for modelling the smart grid for various studies, building the ABMS system is a complex task in itself. Many platforms are available to provide help in this task most of which being free and open source. But most of the tools are domain oriented, have their own area of applicability. These include ABMS tools for education, marketing, transport, simulations, network simulations, social studies, power system simulations, etc. the differents platforms include Repast, AnyLogic, JADE, GridLab-D, Simulink, MacStarLogo, MIMOSE, AgentSheets, Oris, Beahavior Composer, StarLogo, SimPack, MASGriP, MACSimJX, etc. These tools are put to use in a wide variety of applications ranging from teaching simulation to grade the students(StarLOGO) to implementing large-scale agent-based transport simulations for DGT (Dangerous Goods Transport) (MATSim)[28][29]. MADkit (Multi Agent Based Development Kit) [2]tool is used to develop a distributed application, for decision making control in KDD(Knowledge Discovery Database)[8]. Altreva Adaptive Modeler is used for simulating a financial market models for forecasting real world market prices. [13]SMACH platform is used to study the occupant behavior of building with respect to energy consumption.Other tools include Aglets, Ascape, D-OMAR (Distributed Operator Model Architecture), Agent builder, Insight Maker, Boris, JAS, MASS(Multi Agent Simulation Suit), MASON, JCA-Sim, GAMA, A3(Agent Anytime Anywhere), JIAC, MOOSE, Swarm simulation tools, etc.[18][7]. Five tools that have already been used to build applications in power and energy are explored in detail.

AnyLogic

AnyLogic, a tool primarily intended for distributed simulations, is an open source tool, which provides a platform for building MAS based applications [10]. It has a web oriented architecture based on Java and can be used with any web browser which is Java-enabled. It is considered as a general purpose tool with applications built on it in areas like traffic simulation, building energy management and many others. In a study[1] to model the power consumption in an office building, the impact of human behaviour is analysed along with the technologies, policies and devices used for energy management . The simulation of this model was carried out to identify the different behaviour patterns that influence the energy consumption in a building and what are the measures to control these.

Repast

A free and open source platform for building and simulating agent based models, Repast (Recursive Porous Agent Simulation Toolkit) [6] provides a collection of classes for the building the agents and display of data through graphs, charts, and tables. The primary domain of REPAST is considered as Social Sciences, due to its ability to directly integrate GIS (geographical information science) data into simulations. It

has been applied for modelling a strategy for bidding in an electricity market[35]. The model was used to evaluate the environment on the basis of past experiences and pricing behaviour of opponents to obtain optimal benefits.

Simulink

The graphical programming language tool, Simulink, provides platform for building and simulating systems like MAS as a MATLAB extension[39]. It provides a convenient user interface which can be used for simulations in different domains. The differential equations representing the thermal model within a building have been implemented under a Matlab / Simulink environment. SimuLink has been used as a model for testing the model of an engine in Hardware in the loop simulations [17].

JADE

JADE stands for Java Agent Development Environment. [3]Jade is a Distributed applications composed of autonomous entities and Java-based simulation, [11]Object based models and graphic user interface. It has been used to build a model for communication of agents in an MAS within a Virtual Test Bed (VTB) based simulation[34]. In the VTB, electrical components are interconnected as in as electric power plant. The interaction between different agents in this system is implemented in JADE. This example shows that JADE can be useful in building agent based systems that links external system with the VTB. The test simulation uses a Shipboard power system(SPS) modelled over the VTB which is controlled by an agent based system.

GridLab-D

Most popular open source simulation tool is GridLab-d. [9]It is used as a power distribution simulation and analysis tool that provides valuable information to users. This a unique tool to design the smart grid .GridLAB-D is developed by Pacific Northwest National Laboratory (PNNL) in collaboration with industry Grid LAB-D is used to combines multiple domain expertise in a unique simulation environment to more effectively evaluate smart grid technologies. Grid LAB-D provides the user with the technical benefits of distribution automation technologies, device coordination and automation, feeder reconfiguration, reliability, and fault detection identification and restoration. Technologies to better guide the selection of best business practices and future investments [20]. [4]This gives several aspects of consumer participation in the smart grid. Using Gridlab-D, a smart grid simulator, a representative feeder was implemented where each residential air-conditioner is paired with a price responsive thermostat controller. The controllers have parameters that are uniquely defined for each residence that determine how price responsive that residence will be. This works explore how the feeder as a whole responds to price signals but also the effect of missing or dropped price signal packets on feeder load. [37]Gridlab-d introduced about CVR and its framework for the analysis reducing service voltage in order to reduce the energy consumption by using the GridLAB-D platform. The application shows the effectiveness of using GridLabD as powerful tool for MAS simulations.. It has also been used to simulate the electricity market based on demand response, considering the physical constraints [38]. Grid Lab-D platform has been applied to study Demand Side Management, Load Management and electricity market [14]. .

4. CONCLUSION

The applicability of ABMS systems in power and energy is emphasized by analysing the overlapping features of the today's smart electric power sector and the ABS system such as distributed nature, adaptability to changes, proactive goal oriented behaviour, interaction among components and the system, fault tolerance, robustness, etc. Different ABMS tools are compared with respect to their applicability to the power sector & electricity. Most of the tool are open source and freely available on the internet. Almost the tools have multi agent system supporting engine in its core. Multi-agent system is a system that consists of an environment with numerous interacting agents which simulate intelligence by using methodical, functional, procedural or algorithmic search. GridLAB-D is identified as one of the most preferred, tool which is high tech and can simulate different situations within a power system. GridLAB-D can help researchers and innovators on the grid as well as the industry and power system operators, by handling unusual situations accurately and is easy to integrate with new modules and third-party systems. It was observed that though there are many powerful tools that provide convenient platforms for ABMS, most of them still require the modeller to have some knowledge of the coding behind so as to have control of the whole process, and studies and researches are going on for providing better experience to the developers

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