21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

CIGRE US National Committee
2017 Grid of the Future Symposium

Simulation-Based Energy Management Game

A.-L. TOBA*, N. SIANGCHOKYOO*, M. SECK, I. NGATANG
Old Dominion University
USA

SUMMARY

The use of simulation-based games for educational purposes has become more popular the recent years. Evidence suggests that experiential learning, particularly through the use of educational games and computer-assisted learning, has the potential to contribute significantly to the way students learn and process information [1], [2], [3]. This paper introduces a simulation-based energy management game aimed toward engaging young learners in utility resource management and planning.

KEYWORDS

Educational Games, Computer-Assisted Learning, Strategic Energy Management and Planning, Didactic Operation Simulation Model

*****Denotes Equal Contribution

nsiangch@odu.edu

1 INTRODUCTION

Over the recent decades, rapid technological progress has led to a drastic shift in how people consume and process information. Today's technologies and online services – technologies such as mobile phones and cloud computing – have become essential in our everyday lives. Students of the current generation have grown up with a widespread access to information and computing technology, and have years' worth of social media and game console experience. They are perpetually connected through their mobile devices and require a level of stimulation and engagement that classical lecturing and tutorials may not easily provide. Yet, the use of technology as an educational tool has been lagging and only recently become a subject of interest for researchers and educators in higher education [4].

It has been suggested that an integration of educational games in the classroom can provide a more engaging teaching and learning experience [5] [6]. Indeed, games can be used to engage students and challenge them to think critically and analytically. Whereas the traditional linear approach to teaching and learning can prove inadequate when topics are complex [1], games offer an immersive and experiential learning environment that can enhance learning outcomes by stimulating higher levels of cognitive activity, from simply memorizing and paraphrasing, to reflecting, hypothesizing, and applying.

The concept of 'serious games' has emerged recently to bridge the gap between multimedia consumption and education. Serious games are games developed to primarily focus on education rather than pure entertainment [7]. Using animations and concepts associated with other game-like designs, serious games can demonstrate topics in a manner in which students can easily relate and understand. Having engaging scenarios, with increasing levels of difficulties, intricacies, secret codes, etc. help captivate the player's mind and fuel his desire to learn. With refined graphics and interactive user interfaces, computer simulated models can be used to present complex topics in ways that cannot be achieved through traditional lecture-based formats [1]. They can be used to motivate students, keep their excitement up, have fun while acquiring, not only the necessary skills needed to progress through the different stages of the game, but also knowledge about the theme the game is built upon.

Educational games have been successfully used in various domains such as biology, chemistry, engineering, and physics [1] [3]. There are currently few options available in areas related to utility management and planning. Two of the best-known games in this area are (1) *'2050 Vision: Energy Challenge,'* created by Duke Energy[a], and (2) *'Energy City,'* created by JASON Digital Lab Project[b]. Although very innovative in their own rights, these games lack the level of details to make them a useful tool in teaching about a power grid and energy management at the higher educational level. This paper introduces a simulation-based strategic energy management game currently under development. In doing this, we wish to propose a developmental framework to provide an opportunity for improvement as well as to encourage developers to move into more realistic 'serious gaming' domains of utility management and planning. We hope to stimulate new ideas to help draw newer generations of learners to become more excited about the utility sector. More importantly, we hope this framework can inspire future works to help raise awareness of the importance of power grid and utility operations for future generations to come.

2 SIMULATION AND LEARNING

A simulation is inherently linked to a model. It is the operation of the model as time evolves [9]. Simulation is therefore a means to observe and perceive how the behavioral trends of the model unfold. This perception would constitute inference and confer knowledge as to the properties of the behavior of a real system, through experiments conducted in a systematic manner, and results interpretation. Moreover, simulation constitute an efficient and effective way to learn as it helps foster learner's motivation [9]. Unlike games, simulations reflect evolving situations of a reality and thus can be used to encapsulate relationships among several variables that enable processes or phenomenon. Sauve et al. [10] describes simulation as a "simplified, dynamic, and precise representation of reality defined as a system." Learning through simulation is a good way to funnel expertise [11]. That is, it can be used to improve skills in resource planning through rules and roles, as well as to enhance understanding of grid functioning through the contents of the game.

Learning through simulation-based games can take place in several ways. As Alessi [12] noted, “studying by using a simulation is quite different than studying a book, listening to a lecture, or doing a computer drill. In a scientific discovery simulation, for example, the learner is performing experiments, varying input variables in a systematic fashion, observing and recording output, and reflecting on the results” [6]. Simulation games can facilitate learning by providing a virtual environment for students to interact and manipulate different variables and see how their actions could lead to different results. Learning also takes place in a safe environment, where failure can be part of the learning process. Students can learn what to do, what not to do, and how his or her actions could impact the virtual environment. The role of the player extends then, from a mere role-playing, aiming to win, to a bona fide role, aiming to address the issues, threats, or problems in reality, arising in the simulation [13].

3 POWER GRID

A power system is an interconnected network of components for the supply, delivery and consumption of electricity [14]. It consists of generation stations to produce electrical power, transmission lines to transport electricity from distant sources to demand centers, and distribution centers to provide power to end users [15]. The system should be able to balance supply and demand of power whenever, wherever and in whatever quantity necessary, in an environmentally responsible and least costly manner [16]. Yet, reliably maintaining this balance has become increasingly difficult considering the growing penetration of renewable energy sources, the diversity of supply and technology options available, and environmental constraints [17]. Utility companies go through a decision process called Integrated Resource Planning (IRP) to weigh the options to meet future power demand while balancing cost, reliability and sustainability [18].

Simulation-based gaming is an effective way to introduce the complex subject of power system planning.

4 LET’S PLAY

The game under development will allow decision makers to perform four functions: *Review*, *Forecast*, *Plan*, and *Execute*.

The *Review Function* provides output metrics for the player. Indicators to measure operational (e.g. transmission and plants utilization rates, hourly dispatch, expected loss of load), financial (e.g. locational marginal price of power, generation costs) and environmental (e.g. carbon dioxide CO_2, nitrogen oxides NOx, and sulfur dioxide SO_2 emissions) performances are provided. The player can observe current performance levels to see how he or she is currently doing.

The *Forecast Function* includes data for future power demand, technology costs, and fuel prices. The player can look at the future projections of key environmental variables to determine future courses of action.

The *Planning Function* allows the user to interactively construct a portfolio. Based on his current performances and the forecasts indicated, the player can decide to alter the current grid.

The *Execute Function* allows the player to put the plan into motion. The player's decisions are embodied in a power system simulation to compute the resulting performance. The engine is based on a discrete-event simulator developed in the DEVS formalism [19] and implemented in the Python programming language.

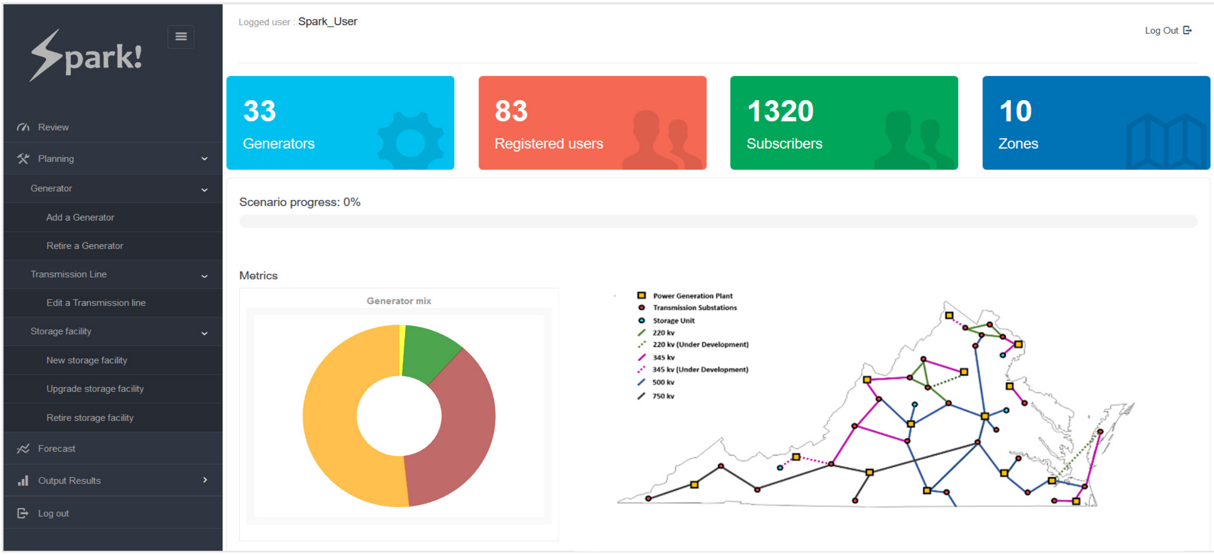

Figure 1: Game interface

Figure 1 displays the game interface. The player has the ability to log in and out using personalized data. Boxes at the top provide general information about the current situation of the grid (e.g. number of generator and zones), as well as the number of registered users (other players) and subscribers. The panel on the left lists the options available to the player as mentioned in the previous section. Under the tab *planning* the different actions are showed, namely add new constructions, retire and/or upgrade generation and transmission assets, including storage units. Each change in the grid is reflected on the map on the lower right corner. The pie chart in the metrics box displays the generation mix. This mix shows the percentage of each available technology generation type that compose the total supply used to meet the demand in the whole network (technology include wind, coal, solar, etc.). For example, 30% of the total supply come from coal, 25% from wind, etc., with the total adding up to 100.

The game offers different scenarios, in which the player is presented with a given situation and is confronted with a specific problem. The scenario progress bar on Figure 1 tells how far in the scenario the player is. The player can only launch the simulation once a year. If a scenario is ten year long, every simulation will count for 10% in the scenario progress bar. In this scenario, the grid is divided into 10 zones, composed of 33 plants, with generation technology including natural gas, biomass, solar and coal. Besides the energy source mix, the player can appreciate the financial and environmental output of each his actions.

Figure 2 displays all the costs involved in the electricity production, including fuel costs, operation and maintenance costs, capital costs as well as fixed costs. The player can thus gauge the profitability of the grid at the end of each year. In figure 3, the player assesses the carbon dioxide (CO_2) emissions, based on the generation technologies used in the network. These metrics provide an overview of the state of the grid and help guide the actions of the player.

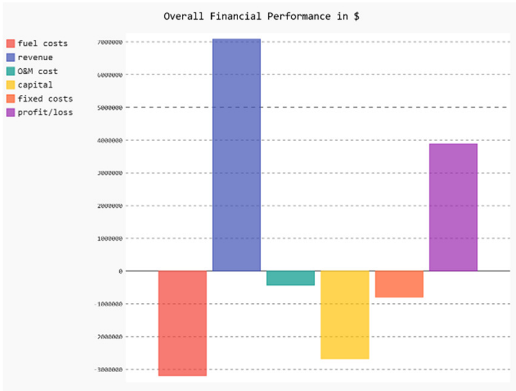

Figure 2: Grid Financial Performance

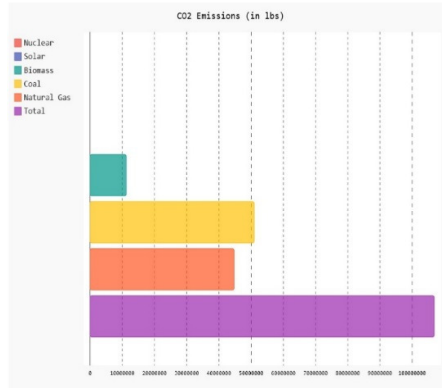

Figure 3: Grid CO_2 Emissions

5 DISCUSSION AND AREAS FOR FUTURE WORK

This paper examined the concept of 'serious games' and showed the example of a simulation-based energy management game in higher education. Simulation-based games can be useful in helping instructors teach complex topics related to utility management and planning. When integrated within a well-developed curriculum, serious games can be used as a teaching tool to illustrate the different components of a power grid and their interrelationships and operations. Simulation-based game should be designed to not only attempt to engage learners but to also offer a more serious representation of an electric grid and its key metrics. In providing an overview of our simulation-based game, several key aspects of the game design were discussed. Gaming also has a potential for actors in the power sector to communicate on their challenges and opportunities, achieve policy advocacy, and even to discover and recruit talented prospective employees.

Future work includes a more systematic evaluation of simulation-based gaming in energy systems education. Particularly, a specific undergraduate-level course curriculum to teach engineering and management students about strategic energy management and planning will be developed. We will also evaluate the impacts of our game with respect to teaching and learning. To accomplish this, several metrics will be considered: (1) transfer of knowledge from serious games to real-world situations, (2) comparison of knowledge acquisition between game-based learning and traditional learning methods, (3) amount of time students spent studying and learning on their own, (4) amount of engagement both inside and outside of the classroom, and (5) learning enjoyment through game-based learning compared to traditional learning examples.

6 CONCLUSION

The use of simulation games has shown great promises in engaging students in the learning process [20]. Despite the recent surge in popularity of game-based learning, very few games have been developed to focus on topics related to utility resource planning and energy management. With increasing demand for energy, challenges associated with energy supply, and concerns over environmental constraints, there is a clear need for institutions to ensure that future generations of students gain a holistic understanding of concepts relating to energy management. Students should also know how to interrelate the various concepts, trade-offs, and resource constraints in order to be able to maximize the transfer of knowledge gained in the classroom to practical use in the industry [1].

We hope that this work will inspire other researchers and industry actors to adopt simulation games as a way to inform newer generations about the societal and technical complexities of the energy domain.

NOTES

[a] *2050 Vision: Energy Challenge* Game: http://energychallenge.duke-energy.com/
[b] *Energy City* Game: http://gated.jason.org/digital_library/cfy/8239.aspx

BIBLIOGRAPHY

[1] A. Deshpande and S. H. Huang, “Simulation games in engineering education: A state□of□the□art review”, *Computer Applications in Engineering Education*, vol. 19, no. 3, pp. 399-410, 2013.

[2] C. Girard, J. Ecalle, and A. Magnan, “Serious games as new educational tools: How effective are they? A meta□analysis of recent studies”, *Journal of Computer Assisted Learning*, vol. *29, no.* 3, pp. 207-219, 2013.

[3] P. Rajan, P. K. Raju, and C. S. Sankar, “Serious games to improve student learning in engineering classes”, *in Proc 2013 ASEE Annual Conference & Exposition, Atlanta, GA, USA*.

[4] M. Kebritchi, A. Hirumi, and H. Bai, “The effects of modern mathematics computer games on mathematics achievement and class motivation”, *Computers & Education.* Vol. 55, no. 2, pp. 427–443, 2010.

[5] C. Girard, J. Ecalle, A. Magnan, “Serious games as new educational tools: how effective are they? A meta□analysis of recent studies”, *Journal of Computer Assisted Learning*, vol. 29, no. 3, pp. 207-219, 2013.

[6] J. J. Padilla, J. Lynch Christopher, Saikou Y. Diallo, Ross J. Gore, Anthony Barraco, and Hamdi Kavak, “Using simulation games for teaching and learning discrete-event simulation”, *in Proc 2016 Winter Simulation Conference, IEEE Press,* 2016.

[7] L. M. Miller, C. Chang, S. Wang, M. E. Beier, and Y. Klisch, “Learning and motivational impacts of a multimedia science game”, *Computers & Education,* Vol. 57, no. 1, pp. 1425–1433, 2011.

[8] J. Banks, B. L. Carson, L. Nelson, and D. Nicol, “*Discrete-Event System Simulation*”, 4th Ed., Upper Saddle River, NJ: Prentice Hall, 2001.

[9] Katherine A. Wilson, Wendy L. Bedwell, Elizabeth H. Lazzara, Eduardo Salas, C. Shawn Burke, Jamie L. Estock, Kara L. Orvis, Curtis Conkey, "Relationships between game attributes and learning outcomes: Review and research proposals", *Simulation & Gaming*, vol. 40, no. 2, pp. 217-266, 2009.

[10] Louise Sauvé, Lise Renaud, David Kaufman, and Jean-Simon Marquis, "Distinguishing between games and simulations: A systematic review", *Journal of Educational Technology & Society*, vol. 10, no. 3, 2007.

[11] M. Laura Angelini, Amparo García-Carbonell, Frances Watts, “Student perceptions of gain in telematic simulation", *in Proc 2014 Conference of the International Simulation and Gaming Association*, The shift from teaching to learning: Individual, collective and organizational learning through gaming simulation, pp. 176-186, 2014

[12] S. Alessi, “Building versus using simulations.” *in Integrated and Holistic Perspectives on Learning, Instruction and Technology,* edited by J. M. Spector and T. M. Anderson, pp. 175–196. Netherlands: Springer, 2000.

[13] Gredler, Margaret E. "Games and simulations and their relationships to learning", *in Handbook of research on educational communications and technology,* Routledge, New York, NY, 2nd Ed., pp. 571-581, 2004.

[14] A. Adegbululgbe, J. Fenhann, I. Konstantinaviciute, W. Moomaw, Hassan B. Nimir, B. Schlamadinger, J. Torres-Martínez , C. Turner, Y. Uchiyama, Seppo Vuori, Njeri Wamukonya, X. Zhang, “Energy Supply”, *in Climate Change 2007: Mitigation of Climate Change*, H. Larsen and J. R. Moreira, pp. 253 – 322, 2007.

[15] S. M. Kaplan, “Electric power transmission: background and policy issues”. *US Congressional Research Service*, vol. 14, pp. 4-5.

[16] Department of Energy, “An assessment of energy technologies and research opportunities“, US Department of Energy, 2015. [Online].

[17] Y. P. Li, G. H. Huang, and Xingquan Chen, "Planning regional energy system in association with greenhouse gas mitigation under uncertainty", *Applied Energy* vol. 88, no. 3, pp. 599-611, 2011.

[18] Tenessey Valley Authority, "2015 Integrated Resource Plan", 2015. [Online].

[19] Mamaou Seck and A. Verbraeck, "DEVS in DSOL: adding devs operational semantics to a generic event-scheduling simulation environment", *in Proc 2009 Summer Computer Simulation conference,* Society for Modeling & Simulation International, 2009.

[20] S. Tobias, J. D. Fletcher, and A. P. Wind, “Game-based learning”, *in Handbook of research on educational communications and technology,* Springer New York, pp. 485-503, 2014.