IST-Africa 2018 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2018
ISBN: 978-1-905824-59-5

CDE for ICT Innovation Through the IoT Based iGrid Project in Tanzania

Diana RWEGASIRA[1 2], Aron KONDORO[1 2], Amleset KELATI[1 5],
Imed BEN DHAOU[3 6], Nerey MVUNGI[2], Hannu TENHUNEN[1 5]
[1] KTH Royal Institute of Technology in Stockholm, P.O.BOX 229, 16440 (SWEDEN)
[2] University of Dar es Salaam, P.O.BOX 5555, 14113 (TANZANIA)
[3] College of Engineering, Qassim University, P.O.BOX 6677, 51452 (SAUDI ARABIA)
[5]University of Turku, P.O.BOX 20014, 20500 (FINLAND)
[6]University of Monastir, P.O.BOX 56, 5000 (TUNISIA)
Email: dianasr@kth.se, phd.imed.bendhaou@ieee.org, kondoro@kth.se,
smleset@kth.se, nhmvungi@udsm.ac.tz, hannu@kth.se

Abstract: The research projects in ICT need to embrace new dimensions. Traditionally, research group work in an isolated manner and is conducted in a purely academic way. This type of research is outdated and needs to be more innovative, engaging and address societal challenges from the local perspective. Quadruple-helix model is a concept that ties together government, academia, industry, and society to promote innovation in education. Challenge drive education is a graduate course that aims to solve societal problems in the quadruple-helix model. This paper summarizes the key idea of challenge driven education to design an intelligent dc microgrid for rural areas of Tanzania.

Keywords: Challenge Driven Education, ICT, Internet-of-Things, smart energies and iGrid project.

1. Introduction

Electricity is the greatest discovery in humankind history, which is the enabling power for the innovation in our daily life. ICT infrastructure, industry, society, and the like rely on stable, affordable and continuous electricity. Utility companies have been created many countries with the aim to generate, transmit and distribute electricity to residential areas, factories, governmental buildings, and cities. Conventionally, electricity was produced using fossil fuel, nuclear generators, hydraulic turbine.

The growing concern on the climate changes coupled with the need for clean and affordable energy have forced the government, industry, and non-governmental organizations to integrate renewable energy into the existing grid. Smart-grid is a new gird architecture that adds two-way communication along with distributed energy generation to the legacy grid [1].

The success of the smart-grid depends to a greater extent on the ICT infrastructure and the strength of the adopted security. The grid has been classified as a critical infrastructure and the widespread uses of smart devices along with the public wireless system have paved the way for cyber-physical attacks. Recent topics on the smart-grid have been identified in several reports [2] [3].

Tanzania is an African country with a total population that exceeds 58 million. According to the World Bank, 36% of Tanzanians have access to electricity [4]. iGrid is a research project financed by SIDA (Swedish International Development Agency) and operates by the Royal Institute of Technology (Sweden) and University of Dar es Salaam (Tanzania). The research project aims to design an intelligent dc-microgrid through the involvement of graduate students with concrete real local challenges.

2. Objective

The objective of this work is to demonstrate on how Challenge Driven Education (CDE) [9] (https://www.kth.se/) has been used to conduct the research under the iGrid project through ICT innovation.

3. Challenge Driven Education Approach

Our societies are experiencing complicated challenges in various sectors such as healthcare, education, energy, environment, etc. Recently, there has been a growing interest in improving the education system to address the societal problems. University is a place to gain knowledge and skills in different areas of studies and expected to work closely with the societal problems through applied research projects. Challenge Driven Education (CDE) is an innovative methodology in graduate education that aims at creating skills and knowledge to address several challenges in the community [5], [6], [7]. It involves design thinking method as well as open ended discussions with stakeholders, students and university instructors [8], [9].

The CDE approach is designed around the following steps:

i. The external stakeholders should define the real-life problems and challenges in a specified sector.
ii. Students should be assigned to address those challenges in accordance with their skills and expertise. This can be done with the help of their instructors until the best solutions are proposed.
iii. Students should team-up to propose solutions to the defined problems.

At KTH, CDE has been applied for global impact as shown in Figure 1, to build mutual Innovation Capacity (MIC) through a project. At UDSM, CDE is involving in the iGrid project which focuses on Capacity Development and Enhancement in Tanzania research training program intended to develop human technical and scientific capacity to facilitate implementation of automation on monitoring, evaluation, analysis, control and management of electrical power system (smart grid) in order to improve delivery efficiency and to optimize operational costs in the electrical power system in Tanzania within the area of Microgrid.

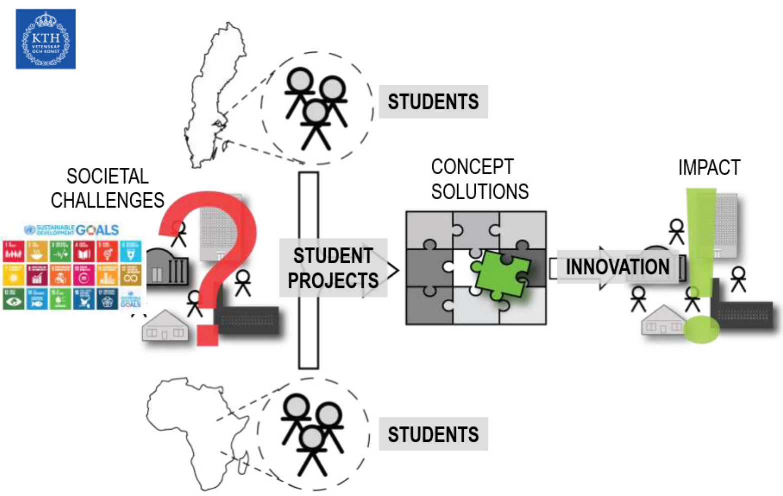

Figure 1: Infrastructure of CDE for global impact at KTH [9]

4. iGrid Project Description

The iGrid project is a joint SIDA-funded project between two Universities: The Royal Institute of Technology (KTH) in Sweden, and the University of Dar es Salaam (UDSM) in

Tanzania. The goal of the project is to design and implement autonomous solar-powered DC smart microgrid that can satisfy the energy demands of small local rural communities. Using state of art Information and Communication technologies such as IoT and agent-based architectures, the project aims to design solar-powered microgrid that is more efficient, reliable, autonomous and self-sustaining.

To achieve this goal, the project involves bya large team of multi-disciplinary experts. The team consists of a number of Masters, Ph.D. and Postdoc students working on different aspects of the microgrid trying to solve existing research challenges. They focus on developing solar based power solutions that are more efficient, reliable and autonomous than existing solutions. Different tasks will be described under this section.

4.1 Communication and Security Problems

One of the promising approaches in the implementation of the ICT systems for powering micro-grids and smart-grid has been the use of Internet-of-Thing (IoT) technologies [10]. The integration of the technologies has offered many opportunities and advantages. By embedding communication IoT components in nodes making up the power system, the whole process of power generation, transmission, distribution, consumption, and management has been made more efficient and intelligent. These intelligent nodes can perform better by making autonomous decisions and adapting their behaviors based on the context and predicting the near future based on the previous history. In addition, they can also communicate with each other and coordinate their activities in order to achieve system-wide goals more efficiently.

As IoT devices also continue to become smaller, more powerful and consuming less power, the number and variety of functions that can be implemented in power systems can only increase. The technology has already been transforming the power grid in China turning it into a smarter system [10]. In another example, the integration of an IoT platform in a DC-based grid allowed the creation of a power system that is flexible and adaptable. This resulted in a system that is easily upgradeable and where innovative applications can be implemented easily [11].

The traditional electric power system is generally divided into three main sections depending on the main function that is performed: transmission, distribution, and customer [12]. In all these parts, IoT technologies have already been implemented with positive results. In the transmission domain, IoT has been used to improve the reliability and stability of transmission lines. By deploying small wireless sensors throughout transmission lines and towers, the technology can allow for the sensing and monitoring of different adverse conditions that can occur in power transmission lines.

In the customer domain, IoT has also been applied to seamlessly integrate nodes in homes and buildings into the power system, [13] propose utilizing an IoT platform that allows home devices to be embedded with computational and communication abilities. The architecture of the system which consists of sensor and actuator networks, an IoT server, and user interfaces for visualization and control, provides a mechanism for data collection, processing, and monitoring by leveraging existing devices in homes. This use of existing devices minimized the complexity of the deployment and helped with user acceptance.

To follow a similar approach, the communication system powering the proposed micro-grid prototype in the iGrid project will also depend on IoT technologies. The architecture will consist of small low-powered devices with sensing and processing capabilities. These devices will allow for easy integration of intelligence in the power generation and distribution process. In addition, the use of off-the-shelf IoT devices will to reduce the overall cost of the whole infrastructure. This will facilitate the deployment of the prototype in poor and rural areas of Tanzania where it is most needed. Figure 2 shows the proposed design of the micro-grid with the underlying IoT based communication system.

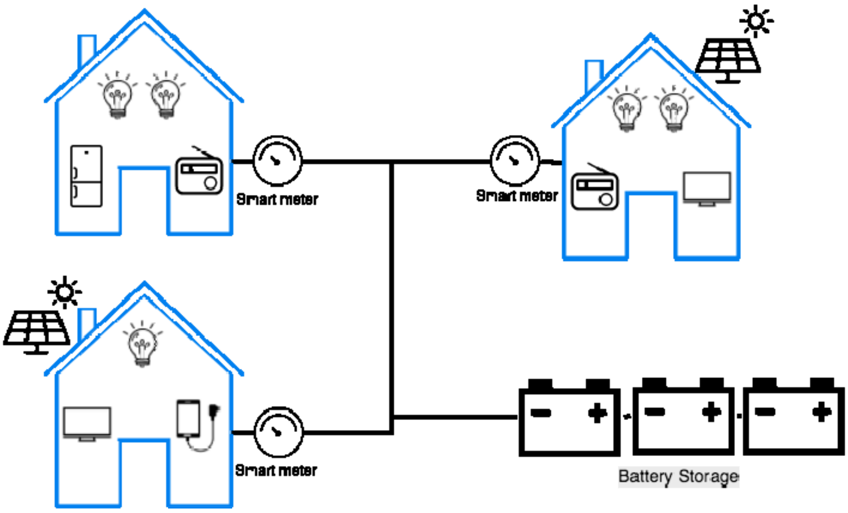

Figure 2: Communication with IoT in Smart Grid

It consists of smart meters connected via data network running on IoT based protocols such as CoAP and MQTT. The smart meters are designed using Raspberry Pi and Arduino platforms. Arduinos are used to create smart end devices such as smart plugs that can sense environmental variables such power consumption, and actuators that can receive commands and take action. Raspberry Pis are used as processing platforms that offer computational services in a compact and power efficient manner. They execute the intelligent algorithms that monitor and control the operation of the micro-grid autonomously.

4.2 Control and Monitoring Problems

In Tanzania, smart grid has not yet much implemented especially in the control and monitor customer's side. The Tanzania Electric Supply Company (TANESCO) which is the sole supply company of the electricity in Tanzania, the transmission side is the part which has been implemented in the process of monitoring and controlling with smart grid and lesser extent to the primary distribution side of the grid system. These raised the issues of fault detection capabilities, lack of self-healing and self-discovery in the system.

The need for the automation process in the control of electric power so as to increase efficiency in all aspects of the electric power system, optimize cost to consumers and reduce human power and errors is crucial. Also, the use of renewable energies such as solar and the wind are more valuable in the utilization and provision of electricity in places without access to the national grid or supplement at the local level the national grid itself.

The use of control and monitoring processes in the electric power distribution are fundamental aspects in the smart grid. Different attributes, systems and mechanisms are required in handling activities from transmission, distribution and consumer side of the electrical network based on advanced technologies. One of the famous approaches on the control and management of distributed energy systems is the deployment of agent-based systems in smart grid [12].

Agent-based distributed system has been seen to work successfully which involves the use of artificial intelligence and autonomous actions during the operations and controlling activities. Therefore, in this manner, the generated model based on REPAST simulation tool [14] for solar driven DC microgrid will be demonstrated to show features of control and monitoring the grid including load shedding technique and demand responses based on pricing. The main focus will be on control and optimization techniques, algorithm development, simulations and innovation and business model. Furthermore, the design of the prototype based on the stated features will be performed by smart devices such as smart sensors.

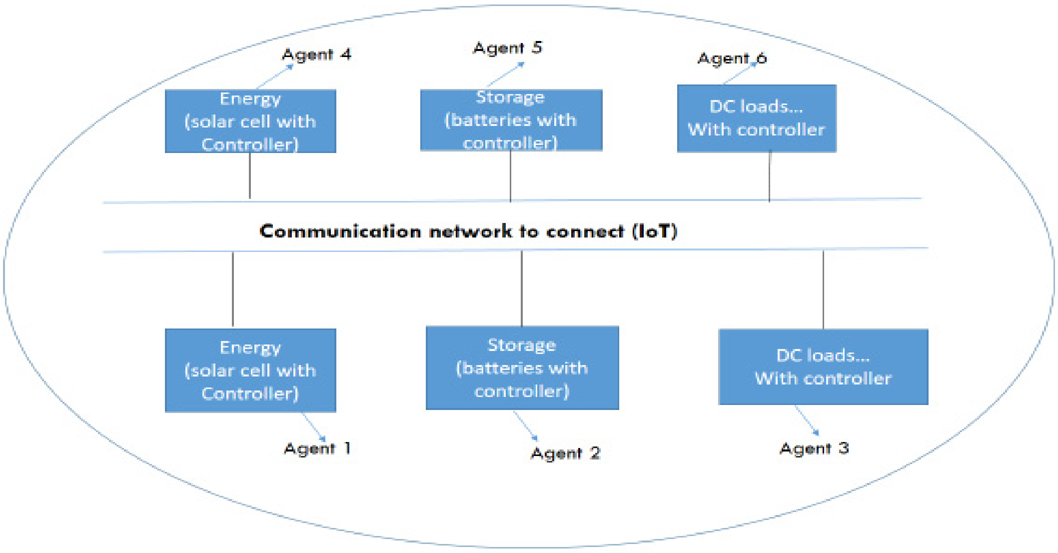

Figure 3: An agent-based system with solar driven DC microgrid

5. Results

The goal of the iGrid project is to design and implement a smart autonomous solar-powered DC-based microgrid using state of the art information technologies such as the Internet of Things (IoT), Innovation, wireless communication, distributed architectures and new sustainable business models. CDE is the approach which has been used to solve the problem associated with our surrounding environment. It includes students from UDSM, instructors from both UDSM and KTH. Several researchers and experts are also involved from different universities including Qassim University, Turku University and Brunel Universities towards solving the challenges. Also, stakeholders from electricity markets in Tanzania where involved at the initial stages towards the formulation of the challenges. These are Tanzania Electric and Supply Company (TANESCO), Rural Energy Agency (REA) and the community participated in Power Electrification at Kisiju, Pwani.

5.1 iGrid Portal Development

This was the initial phase product of the project. It is an open science platform with several features including (i) to provide tools and mechanisms to facilitate coordination and collaboration among different stakeholders involved in the project, (ii) to easily integrate all the different research tools used to solve challenges met, (iii) to share raw research results and facilitate the involvement of other teams in the research process and (iv) to offer a stage to share progress and results to the public and the intended community of practice in particular. The portal is now hosted at KTH () and different activities have been posted and still used such as a paper published and presentations and the progress of the ongoing activities. Moreover, discussion and forum tools available on the portal have also used on coordinating site visits based on pilot sites for exploring the world.

5.2 CDE Practice Towards Exploring the Research Problem

In order to have realistic outputs of the research, literature reviews and site surveys have been done to get different views, problems from stakeholders, and find research gaps. Ideally, the site should be a small off-grid community of about 10-100 households that is not under any short-term plan, to be connected to the main power grid. The first meeting was held in 11th January- 2016 with the management and technical people from REA which is an autonomous body under the Ministry of Energy and Minerals of the United Republic of Tanzania dealing with promoting and facilitating improvements on access to modern energy services in rural areas of mainland Tanzania. The meeting was focusing on identifying potential areas in Tanzania in which iGrid project could offer as a solution and several sites in Ngorongoro-Arusha and Kisarawe-Pwani where identified. Moreover, another meeting was done on 27th September-2016 with stakeholders who participated in the project [15] piloted at Kisiju, Pwani. This project involved in photovoltaic based minigrid for electrification of remote areas in Tanzania. The output of this meeting resulted in a number of challenges towards operations and maintenance of the microgrid system. Basically, this is the site we are using in the iGrid project to solve the community problem.

Furthermore, to understand the extent of smart grid implementation in Tanzania, several meetings with stakeholders were done at TANESCO, Head Quarters and SCADA at Mikocheni in March 2016. These provided the clear insight of the stages which have been done towards achieving smart grid systems in Tanzania. Several achievements include automatic meter reading to read data from customers with high power consumptions, remote configurations of the new sites and automatic detection of faults in the distribution sites. Other explorations which have been done to achieve the challenge driven education include attending the Gotland smart grid workshop in Stockholm, Sweden to understand the application of smart grid in utility sectors and visiting the microgrid lab at KTH for equipment analysis, identification and evaluation with respect to our requirements in the iGrid project.

5.3 Agent-based Control Approach

The use of the REPAST simulation tool has added much value to this project. The modeling part based on an agent-based distributed system with several features have been developed. The tool makes use of JAVA programming language to develop agents and simulate in a step running model. The results in [16], the work mainly focused on the solar driven DC microgrid targeting the static loads. In this case, the critical and non-critical loads were able to be distinguished and the results were able to perform the load shedding technique. The model was tested with 3 houses.

Another work was in [17] whereby this was the extension of the previous work. The idea was to use dynamic loads and provide a framework with load shedding techniques as well as demand response scheme. Two ways of simulations based on PV systems and the solar panel where the focus of this work. The model also described the algorithm for the solar panel, storage battery and loads and then describe the agents' collaboration on the framework. Furthermore, the modeling of the system with demand response based on pricing issues was developed and the simulation was demonstrated with three houses as seen in Figure 4 showing the parameters whereby the user can insert before simulating the microgrid and Figure 5 showing the step by step simulation. Also, the model provides the individual load to sell/buy electric power into the grid based on its preferences. Figure 6 shows the simulation on the solar panel based on the power generated and supplied to the storage and loads. Also, Figure 7 shows the extra power obtained when individual load supply to the solar panel.

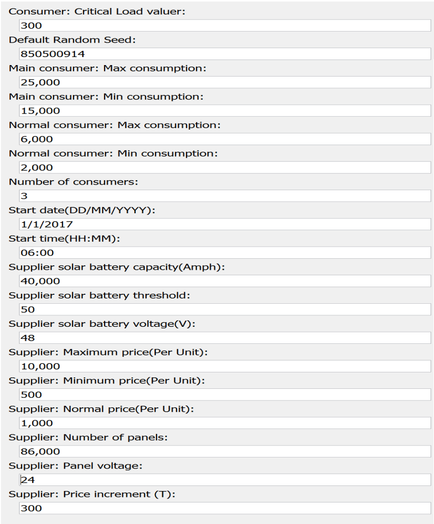

Figure 4: Parameters for simulation

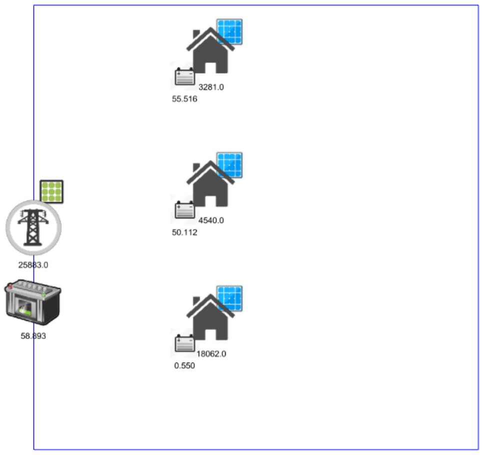

Figure 5: Step by step simulation

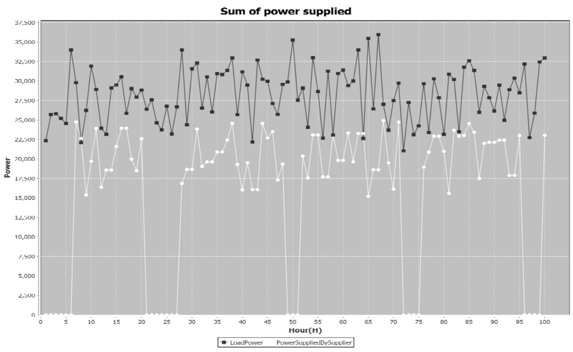

Figure 6: Power supplied and generated

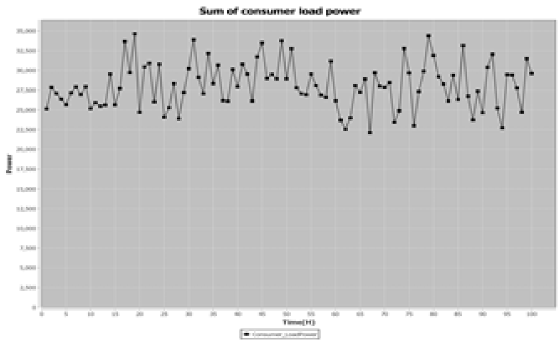

Figure 7:Power generated from loads

5.4 Communication with IoT Capability

Smart grid communication and security technologies, applications, challenges, and threats have been deduced in the work [3]. This was the mirror towards the implementation of smart grid communication as several challenges and open issues were clearly addressed. Among the listed issues are security and privacy, interoperability and efficiency in the smart grid whereby further research needs to be done. Security and privacy have dominated and many researchers are focusing on due to the benefits it provides in the smart grid such as wireless sensor network, trusted platform module and network, database, crypto-analysis, IoT, cryptographic algorithms, data security, web-design, and cloud & fog computing. In most cases, security solutions target to discover the following subjects: smart-meter authentication, security protocols for advanced metering infrastructure, secure demand-response scheme, homomorphic encryption, lightweight authentication protocols, a secure vehicle to grid communication, real-time & data transmission, and interoperable security architecture.

Starting with security and privacy issues, the research has focused on the simulation model which analyzed the attacks of the Advanced Metering Infrastructure (AMI) in the microgrid. This was achieved through the use of the Network Security Simulator tool (NeSSi2), (http://www.nessi2.de/).

Moreover, to address the interoperability issues in the AMI, IGRID researchers are studying two middlewares: KAA and LEGOS. The initial findings show that there are still challenges and open isses in the middleware for the smart meter that can handle the various communication protocols, securities and hardware platforms.

6. Conclusions

Combining research, innovation and creativity are the factors which bring development in the community. The approach of distributing tasks based on the comments and views from stakeholders and instructors is more valuable. So far the CDE approach has been seen to work successfully in the iGrid project. The project is still on-going. In this paper, we described how the CDE approach has provided the impact in the society based on the applied research and innovativeness ideas. The ongoing activities are:- (i) Continuation of communication and security aspects on our microgrid (ii) development of the prototype based on the features stated earlier with devices such as on Arduino, raspberry pi and smart sensors and (iii) analysis of the complete system.

Acknowledgment

Our gratitude goes to the iGrid project, which through their financing and technical assistance keeps on facilitating the implementation of the CDE approach. iGrid is a joint Sida-funded project between Royal Institute of Technology (KTH) in Sweden and University of Dar es Salaam (UDSM) in Tanzania.

References

[1] R. Bayindir, I. Colak, G. Fulli and K. Demirtas, "Smart grid technologies and applications," *Renewable and Sustainable Energy Reviews,* pp. 499-516, 2016.

[2] X. Fang, S. Misra, G. Xue and D. Yang, “Smart Grid – The New and Improved Power Grid: A Survey,” *IEEE COMMUNICATIONS SURVEYS & TUTORIALS,* vol. 14, no. 4, pp. 944-980, 2012.

[3] I. B. Dhaou, A. Kondoro, A. Kelati, D. S. Rwegasira, S. Naiman, N. H. Mvungi and H. Tenhunen, “Communication and Security Technologies for Smart Grid,” *International Journal of Embedded and Real-Time Communication Systems,* vol. 2, no. 8, pp. 40-65, 2017.

[4] The world bank, “Increasing Electricity Access in Tanzania to Reduce Poverty,” The world bank, 6 December 2016. [Online]. Available: http://www.worldbank.org/en/results/2016/12/06/increasing-electricity-access-in-tanzania-to-reduce-poverty. [Accessed 22 1 2018].

[5] Kolb, D., (1984), Experiential learning. Experience as the source of learning and Development, Englewood CliÚ s, NJ

[6] Kolb, A. Y. & Kolb,D A., (2005), Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education, Academy of Management Learning & Education, 2005, Vol 4, No. 2, 193-212

[7] Dewey, J., (2012) How We Think, Renaissance Classics, 2012

[8] Mulgan G., Townsley O., Price A., The challenge-driven university: how real-life problems can fuel learning, NESTA, 2016

[9] Magnell M., Högfeldt A-K., Guide to challenge driven education ECE Teaching and Learning in Higher Education no 1, KTH, 2014

[10] Jianming Liu, Xiangzhen Li, Xi Chen, Yan Zhen, Lingkang Zeng, Applications of Internet of Things on Smart Grid in China, International Conference on Advanced Communication Technology (ICACT2011), p13-17, 2011

[11] Di Zenobio, D., Steenhaut, K., Thielemans, S., & Celidonio, M. (2017). An IoT platform integrated into an energy efficient DC lighting grid (pp. 1–6). Presented at the 2017 Wireless Telecommunications Symposium (WTS, IEEE. http://doi.org/10.1109/WTS.2017.7943547

[12] Kundur, P., Balu, N. J., & Lauby, M. G. (1994). Power system stability and control

[13] Spano, E., Niccolini, L., Pascoli, S. D., & Iannaccone, G. (2015). Last-Meter Smart Grid Embedded in an Internet-of-Things Platform. IEEE Transactions on Smart Grid, 6(1), 468–476.

[14] Bragen, M., Collier, N., Murphy, J. T., Ozik, J., & Tatara, E. (2012). http://repast.sourceforge.net/. Retrieved from http://repast.sourceforge.net/

[15] B. M. M. Mwinyiwiwa, R. T. Kivaisi, and C. Msoka, “Photovoltaic based Mini-Grid for Electrification of Remote Areas of Tanzania : The case of Kisiju-Pwani Village,” Dar es Salaam, Tanzania, 2013.

[16] Diana Rwegasira, Imed Ben Dhaou, Aron Kondoro, Naiman Shililiandumi, Amleset Kelati, Nerey Mvungi,Hannu Tenhunen, "A Multi-Agent System for Solar Driven DC Microgrid", *The 2017 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC),* 978-1-5386-1667-3/17/$31.00, 2017 IEEE Xplore

[17] Diana Rwegasira, Imed Ben Dhaoa, Anastasia Anagnostou, Aron Kondoro, Naiman Shililiandumi, Amleset Kelati, Simon Je Taylor, Nerey Mvungi and Hannu Tenhunen, "A Framework for Load Shedding and Demand Response in DC Microgrid using Multi Agent System", *Proceeding of the 21st Conference of Fruct Association Conference*, ISSN 2305-7254, 6-10 November 2017, Helsinki, Finland.