Creation of CERID: Challenge, Education, Research, Innovation, and Deployment

"in the context of smart MicroGrid"

Masoumeh EBRAHIMI[1], Amleset KELATI[1,2], Emma NKONOKI[2], Aron KONDORO[1,3], Diana RWEGASIRA[1,3], Imed DEN DHAOU[4], Ville TAAJAMAA[2], Hannu TENHUNEN[1,2]

[1]*KTH Royal Institute of Technology, Sweden*
[2]*University of Turku, Finland*
[3]*University of Dar es Salaam, Tanzania*
[4]*Qassim University, Saudi Arabia*

Email: mebr@kth.se, smleset@kth.se, emma.nkonoki@utu.fi, kondoro@kth.se, dianasr@kth.se, phd.imed.benhaou@ieee.org, Ville.Taajamaa@utu.fi, hannu@kth.se

Abstract: The iGrid project deals with the design and implementation of a solar-powered smart microgrid to supply electric power to small rural communities. In this paper, we discuss the roadmap of the iGrid project, which forms by merging the roadmaps of KIC (knowledge and Innovation Community) and CDE (Challenge-Driven Education). We introduce and explain a five-gear chain as Challenge, Education, Research, Innovation, and Deployment, called CERID, to reach the main goals of this project. We investigate the full chain in the iGrid project, which is established between KTH Royal Institute of Technology (Sweden) and University of Dar es Salam (Tanzania). We introduce the key stakeholders and explain how CERID goals can be accomplished in higher educations and through scientific research. Challenges are discussed, some innovative ideas are introduced and deployment solutions are recommended.

Keywords: knowledge and Innovation Community, challenge-driven educations, smart microgrid, innovation and business models.

1. Introduction

Many rural communities in Tanzania do not have access to reliable and affordable electricity. According to World Bank Statistics, only 17% of the rural population in Tanzania has access to electricity [1]. This is a critical problem since access to electric power is a key requirement for development of these communities.

With growing electricity demands, the conventional top down approach of delivering electricity from large and far away sources is insufficient. It takes time and cost to build the infrastructure to reach the whole population. Thereby, there is a need for other innovative solutions, preferably localized. In this regard, some techniques have already been proposed in [2][3][4][5][6].

Low Voltage Smart Microgrid is one of the most attractive and feasible solutions [6]. It allows rural communities to take advantage of local available energy resources to satisfy their energy demands in an efficient way. Distributed Energy Resources (DER) are coordinated together with different energy storage technologies to produce and distribute clean power to individuals and businesses. Microgrids can be AC or DC-based depending on the situation. AC-based microgrids can be easily integrated with existing infrastructure which is already mostly AC-based. However, DC-based microgrids have started to gain more attention due to their higher energy efficiency and simpler control structure.

Systemic research and technology driven innovation has been widely recognized as gateway to prosperous societies [7]. On the other hand, science, technology and engineering connect and influence each other while they are also influenced by society. Thereby, another dimension on innovation is open-ended, context driven and wicked challenges that are often based on human needs. There is a need that scientists investigate, determine, and research on the issues which are based on the real societal challenges. There is a need for innovative and cost efficient solutions that can tackle these challenges. Thereby, a more multidisciplinary and holistic approach is required where the role of open innovation and educational innovations come into play [8].

Toward this goal, challenge-driven educations (CDE) [9] try to incorporate societal needs into university education through projects. In this model, usually a group of students with interdisciplinary competence work on real-world challenges. Such activities have been implemented for example between Sweden and Tanzania [10]. However, these activities hardly lead to innovations or new businesses.

On the other hand, currently there are diverse attempts to bring together businesses, research centers and universities through activities called KIC (knowledge and Innovation Community) [11]. These efforts aim to strengthen the cooperation between businesses and higher educations to produce new products or to start new companies [11]. However, in the KIC model, the challenges do not necessarily come from societal needs and they might be solely technology or business oriented.

By combining the roadmaps of KIC and CDE, in this paper, we discuss the whole cycle from identifying challenges to deploying solutions which are achievable by research and innovation in higher educations. Fig. 1 shows the roadmap that includes five major parts as challenge, education, research, innovation, and deployment. We call the five parts as CERID. We investigate the whole cycle through the iGrid project which is established between Sweden (KTH Royal Institute of Technology) and Tanzania (University of Dar es Salam) and financed by SIDA (Swedish International Development Agency).

The iGrid project follows the bottom-up approach of a smart microgrid. It aims to design and implement an autonomous solar-powered DC smart microgrid that provides electric power to small off-grid rural communities. It uses new developments in Information and Communication Technologies such as Internet-of-Things (IoT), agent-based control mechanisms, and fog-computing to build more efficient, reliable, and autonomous power systems. This new paradigm shift also introduces the concept of prosumers where end users can produce and sell excess power to others. In this paper, we suggest innovations and deployment solutions on top of the smart microgrid.

Fig. 1. From identifying challenges to deploying solutions

2. Objectives

The objectives of the paper are as follows:

- To investigate the complete deployment cycle which include: identifying challenges, challenge-driven education, scientific research, high-tech solutions, and innovations in deployment. We thoroughly investigate this cycle in the context of the iGrid project.
- To suggest the learning outcomes of students that reflect the perspectives of all stakeholders: government, society, students, university faculty, and industry.
- To suggest new innovative and deployment solutions on top of the smart microgrid.

3. Developing CERID in the iGrid Context

3.1 Identifying Challenges

The project has been started by having meetings and site visits with different stakeholders regarding the electricity issue in remote rural areas. The purpose of the meetings was to brainstorm and identify a concrete challenge to solve. The stakeholders were from electric company (TANESCO) [12], the renewable energy agency (REA) [13], professional instructors in the field of electricity, some selected students and the representatives from community/society. The raised challenges were poor infrastructures, the aging of electricity infrastructures, theft and tampering with the infrastructures, etc. The selected challenge was to provide power to rural areas in a smart way with little human interventions.

After identifying the challenges, the students visited Kisiju, Pwani village which is about 50 km southeast of Mkuranga District headquarters, Pwani region. This is the village which was used in [14] to provide electrification process in the household consumers, streets, and commercial centers, schools, hospitals, etc. The project was meant to serve approximately 70 customers.

The challenges were defined as using renewable energies to produce power by utilizing microgrid. The design and implementation of the microgrid involves the solar panels, converters (AC to DC power), storage batteries, power switches, main sockets, and loads as illustrated in Fig. 2.

Fig. 2. Microgrid overview at Kisiju Pwani

3.2 Education

Through the iGrid projects, students with interdisciplinary competence are working together with the challenges. The learning outcomes of the project are defined in a way that satisfies the standpoints of all key stakeholders: government, society, students, university faculty, and industry. The learning outcomes of students are: 1) they will be able to identify the real societal challenges; 2) they will be able to formulate the research questions that need high-tech solutions; 3) they will be able to tackle the research questions by forming inter/multi disciplinary competence groups; 4) they will be able to work on business models; 5) they will learn how to find finance sources and deploy the solutions.

3.3 Research

Within the iGrid project, new technical challenges with regard to smart microgrids are identified which are summarized in Table. 1.

Table. 1. Technical challenges of smart microgrids in Kisiju Site

	Challenge	**Effect**
1	Capacity of solar generation is limited	-The usage of high-power appliances is limited. -“Switching off” electricity in the daytime and “switching on” during night hours.
2	Manual process of fault detection and restoration	-Time consuming, e.g. manual checking of 120 battery banks. -Inaccuracy and inconsistency.
3	No smart meter infrastructure	-Flat rate approximation of power consumption used for consumers (Tsh.15,000/= for users and Tsh.20,000/= for commercial users).
4	Manual control and maintenance process	-Poor cleaning of the solar panels, batteries, etc. -Poor energy management.
5	Rigid infrastructure	-Not easy to add new customer. -Not easy to control the supply and demand. -Not easy to forecast the power production.
6	Higher expertise requirements on users	-Infrastructure cannot be efficiently utilized.

Students’ task was defined to research and tackle challenges on the design and development of a smart solar-powered DC-based microgrid. The possible technologies are Internet of Things, distributed architectures, and wireless communication. In another way, the idea is to propose the smart microgrid, which will be able to solve some challenges listed in Table. 1. The technical features to investigate in the iGrid project are as: energy management, advanced control mechanism and infrastructure, distributed fog-based architecture, plug and play capability. The tentative architecture is shown in Fig. 3, which includes different features of the smart microgrid.

3.4 Innovation

The digitization of the power sector along with the advances in renewable technologies have created considerable business opportunities. A number of scholars have identified and proposed new business models for the smart-grid [15][16]. Green economy is spurt out thanks to the introduction of the renewable energy where the end-consumer became prosumer. Additionally, in under-developed countries, remote communities that have no access to electricity now have the mechanism to access an affordable power, which can have a deep societal impact. The wellbeing of humans are largely dependent on the availability of electricity. Communities, which are deprived of energy, have no access to basic human needs such as education, clean water, telecommunication, and medication. Electricity is also needed to create a sustainable economy.

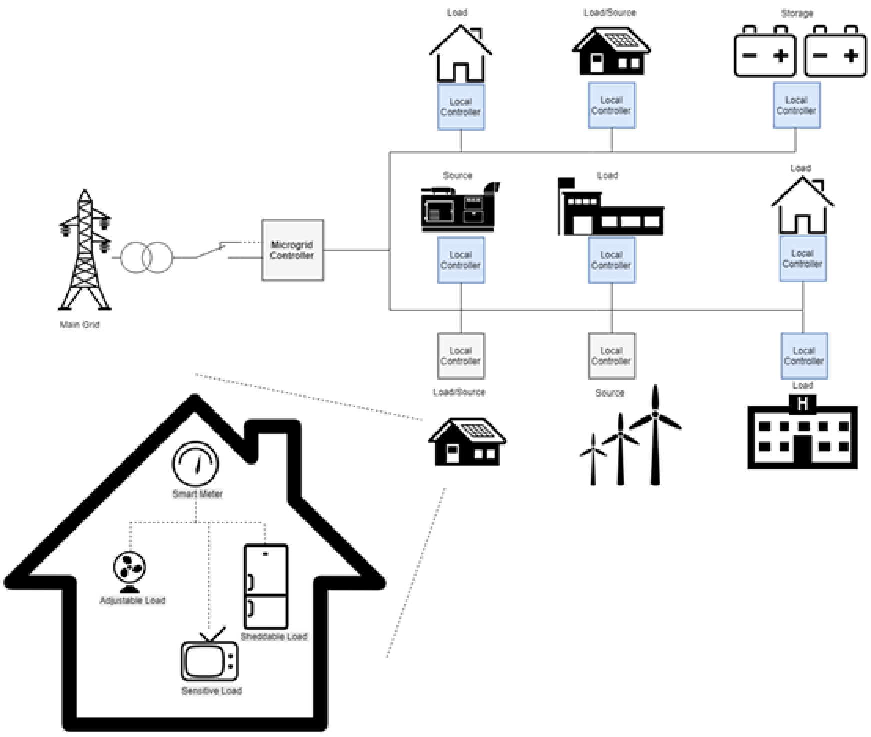

Fig. 3. The proposed smart microgrid architecture

In 2015, the united nation adopted 17 sustainable goals set for 2030. Those goals cannot be met without access to affordable and clean energy [17]. Rural electrification using off-grid microgrid is the outfitted solution that can help to achieve a green economy. In this section, we discuss several business opportunities that can be achieved with the off-grid microgid.

- ***ICT Kiosk:*** "*Energy kiosks are centers for electricity production and supply of energy services, generally located in rural or peri-urban zones. It is a "pre-electrification" model, offering centralized energy production at the level of an energy kiosk/point/station/hub, in proximity to local communities.*" [18]. In this case, we talk of an ICT kiosk where people can get not only electricity but also access to information, which is an outcome of getting access to electricity. This facilitates seeking new information and techniques, moving toward a better diary services, food processing, health, etc. as shown in Fig. 4.

Fig. 4. Clean energy opens directions for development in other domains.

- ***Agriculture System:*** Agriculture is still one the main sources of income in rural areas. It is heavily dependent on livestock and crop growth. Farming in poor countries is rainfed. The access to groundwater for irrigation necessities an ECO-system that consists of energy sources for water pumping, wells, and sensors for precise irrigation. Additionally, livestock farming needs access to water for operations such as crops growing, dairy production, and drinking [19].

- ***E-health System:*** To improve the quality of life, smart microgrid can be used to manage health-monitoring system based on smart meter and load profiling. By using the information such as energy consumption, appliances' usage information and time duration of using appliances, the independent living of elderly or patients with self-limiting health conditions can be regularly monitored by caregivers [20][21].

- ***PV Leasing:*** The intermittency of the solar energy along with the unexpected shortage of power may lead people or businesses to lease PV panels, inverters, batteries, DC generator and other PV incentives for a fixed-term. This approach can also be used in a fixed location, where users with a shortage of power can direct the power generated from the leasing system to their premises [22]. The architecture of this model is shown in Fig. 5.

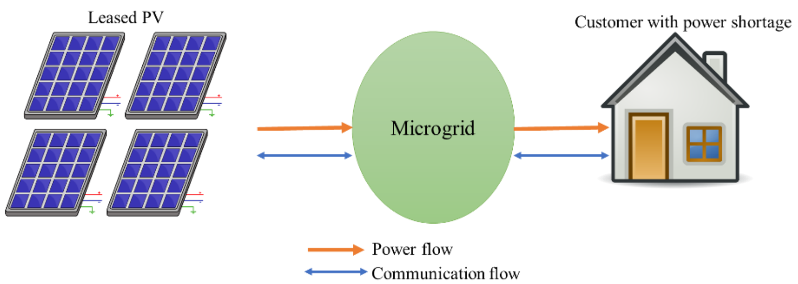

Fig. 5. Proposed system for PV leasing.

- ***Integration with Fog Computing:*** Adapting renewable energy using microgrid is nowadays deployed by fog computing. This provides a better control of the residential and industrial energy consumptions and a better performance. IoT application in fog computing is more energy efficient and has the advantage to control the data processing locally instead of sending the information to cloud that may associate with some security related issue. Therefore, in the suggested models, the power management system can be integrated with IoT gateway and fog computing [23].

3.5 Deployment

The industrial significance of the micro grid solution appears from different angles such as affordability of the service, shorter supply chain, being environmental friendly, and having a greater locality. In addition, smart micro grid solution makes the organization of the market easier where the consumers are also producers and sellers. The benefits of using a smart micro grid are significant such as enabling new businesses, providing a better education, and more importantly improving the quality of life. To summarize, it is obvious that through electricity, rural people can improve their standards of life, socially and economically. In turn, the economy of the country will increase in a positive way since even rural citizens will be able to contribute to the economic circle.

In the early phases of the deployment a joint understanding of what are the goals, what are the metrics to measure innovativeness, and what measures of action should be taken are of paramount importance [28]. The cases of KIC and iGrid projects bring about an excellent setting for launching a CDE based project focusing on taking technological possibilities and solutions created in the iGrid to the area of urban and rural grassroots innovation setting. The goal would be to facilitate and empower local people to use the iGrid technology to enhance their level of innovation capabilities through integrating new technologies with empowering education such as presented in the challenge identification model in this paper. This would also present a natural continuum to existing KIC and iGrid projects. It would allow an approach where both grassroots and more systemic innovation can be examined through different projects aimed at ecosystem level impact. Ecosystem defined as a vehicle combining university education, new technologies, surrounding society and its members, users, customers and investor profiles.

Microgrid deployment and management is far from straightforward. Several social, technological, economical, environmental and policy factors need to be considered and successfully addressed in order to achieve sustainable operation as a business or some other form of continuous operation over the technological lifespan of the microgrid [27]. As an example, the main economical factors that affect the financial feasibility are cost structure, tariff model, including load characteristics and anchor users, financing model and ownership structure. All of these factors are complex and crucial criteria for decision-making in microgram deployment, and need to be further analysed and optimised. For instance, cost structure consists of two main components, hardware costs (PV array, BOS, storage and monitoring, backup generation, distribution and metering) and soft costs (installation, system design, project management, capability building, permitting, financing, and transport) [28]. Stimulating the community activities for business model development as a part of deployment may be necessary, e.g. providing financing for investments of anchor users such as SMEs, machinery for agriculture or public services.

The requirements and constrains of deployment should be considered in every phase of the CERID chain as some of them are fundamental in the technological design, business modelling and operational management planning. Most notably in the challenge phase, these questions should be emphasised in addition to technological challenges.

4. Conclusion

In this paper, we explained the whole development cycle of the iGrid project, a project between KTH Royal Institute of Technology (Sweden) and University of Dar es Salam (Tanzania). The iGrid project deals with the design and implementation of a solar-powered smart microgrid to supply electric power to small off-grid rural communities. We first discussed the challenges in rural population in Tanzania with regard to electricity. Then we tried to tackle the challenges within the challenge-driven education system and by proposing scientific solutions through research. Finally, we introduced some business models for the iGrid project such as ICT Kiosk, Agriculture System, E-health System, PV Leasing, and Integration with Fog Computing. We also discussed some deployment solutions. In sum, we investigated the five main elements toward the deployment of the iGrid project. These elements are called CERID that stands for Challenge, Education, Research, Innovation, and Deployment.

References

[1] OECD, "Graph 5.A2 - Access to electricity in East African countries," Africa's Development Dynamics: Growth, Jobs and Inequalities, 2018.

[2] S. Al-Sumaiti, M. M. A. Salama, and M. El-Moursi, "Enabling electricity access in developing countries: A probabilistic weather driven house based approach," Applied Energy, vol. 191, pp. 531–548, 2017.

[3] G. M. Ngounou, M. Gonin, N. Gachet, and N. Crettenand, “Holistic Approach to Sufficient, Reliable, and Efficient Electricity Supply in Hospitals of Developing Countries: Cameroon Case Study,” in Sustainable Access to Energy in the Global South, 2015, pp. 59–77.
[4] Mainali and S. Silveira, “Alternative pathways for providing access to electricity in developing countries,” Renewable Energy, vol. 57, pp. 299–310, 2013.
[5] E. Mboumboue and D. Njomo, “Potential contribution of renewables to the improvement of living conditions of poor rural households in developing countries: Cameroonʼs case study,” Renewable Sustainable Energy Rev., vol. 61, pp. 266–279, 2016.
[6] X. Lu, J. Wang, and L. Guo, “Using microgrids to enhance energy security and resilience”, The Electricity Journal, Volume 29, Issue 10, December 2016, Pages 8-15.
[7] M.Jensen, B.Johnson, E.Lorenz, B.A.Lundvall, “Forms of knowledge and modes of innovation”, Research Policy 36, 2007, pp. 680–693.
[8] D.E.Goldberg, M.Somerville, “A Whole New Engineer”, Threejoy, 2014.
[9] Magnell M., Högfeldt A-K., Guide to challenge driven education ECE Teaching and Learning in Higher Education no 1, KTH, 2014.
[10] D. Rwegasira, A. Kondoro, A. Kelati, I. Ben Dhaou, N. Mvungi and H. Tenhunen, “CDE for ICT Innovation Through the IoT Based iGrid Project in Tanzania,” *2018 IST-Africa Week Conference (IST-Africa)*, Gaborone, 2018, pp. Page 1 of 9.
[11] https://eit.europa.eu/activities/innovation-communities
[12] http://www.tanesco.co.tz/
[13] http://www.rea.go.tz/
[14] Bakari M. M. Mwinyiwiwa, Rogath T. Kivaisi, and Colman Msoka, “Implementation Roadmap of a Photovoltaic based Mini-Grid for Electrification of Remote Areas of Tanzania: A case of Kisiju-Pwani Village”, 3rd International Conference on Mechanical and Industrial Engineering (MIE), 2014.
[15] A. Shomali and J. Pinkse, "The consequences of smart grids for the business model of electricity firms", Journal of Cleaner Production, vol. 112, pp. 3830-3841, 2016. Available: 10.1016/j.jclepro.2015.07.078.
[16] A. Anderson et al., "Empowering Smart Communities: Electrification, Education, and Sustainable Entrepreneurship in IEEE Smart Village Initiatives", IEEE Electrification Magazine, vol. 5, no. 2, pp. 6-16, 2017. Available: 10.1109/mele.2017.2685738.
[17] United Nations, 2015. “Transforming our world: the 2030 Agenda for Sustainable Development” (A/70/L.1).
[18] L.Tavernier, S.Rakotoniaina, “Review of energy kiosk development projects”, 2016, pp.66-67.
[19] J. Xue, “Photovoltaic agriculture - New opportunity for photovoltaic applications in China”, Renewable and Sustainable Energy Reviews, vol. 73, pp. 1-9, 2017. Available: 10.1016/j.rser.2017.01.098.
[20] J. Liao, L. Stankovic, and V. Stankovic, “Detecting household activity patterns from smart meter data”, in Proc. Int. Conf. Intell. Environ. (IE), vol. 6. Jul. 2014, pp. 7178.
[21] H. Ghayvat, S. Mukhopadhyay, B. Shenjie, A. Chouhan and W. Chen, “Smart home based ambient assisted living: Recognition of anomaly in the activity of daily living for an elderly living alone”, IEEE International Instrumentation and Measurement Technology Conference (I2MTC), Houston, TX, 2018, pp. 1-5. doi: 10.1109/I2MTC.2018.8409885.
[22] X. Liu, E. O'Rear, W. Tyner and J. Pekny, "Purchasing vs. leasing: A benefit-cost analysis of residential solar PV panel use in California", Renewable Energy, vol. 66, pp. 770-774, 2014. Available: 10.1016/j.renene.2014.01.026.
[23] M. A. Al Faruque and K. Vatanparvar, "Energy Management-as-a-Service Over Fog Computing Platform," in *IEEE Internet of Things Journal*, vol. 3, no. 2, pp. 161-169, April 2016.
[24] A.D.Sagar, B. der Zwaan, “Technological innovation in the energy sector: R&D, deployment, and learning-by-doing”, 2006.
[25] O.Vermesan, P.Friess, “Internet of things, from research and innovation to market deployment”, 2014.
[26] R. Leichenko, “Climate change and urban resilience”, Current Opinion in Environmental Sustainability,Volume 3, Issue 3, May 2011, Pages 164-168.
[27] Akinyele, Belikov, Levron, “Challenges of Microgrids in Remote Communities: A STEEP Model Application”, Energies 2018, 11, 432.
[28] Moner-Girona, Solano-Peralta, Lazopoulou,Ackbom, Vallve, Szabo, “Electrification of Sub-Saharan Africa through PV/hybrid mini-grids: T Reducing the gap between current business models and on-site experience “, Renewable and Sustainable Energy Reviews 91 (2018) 1148–1161.