DCE 19 3rd DOCTORAL CONGRESS IN ENGINEERING

Doctoral Congress in Engineering

Book of Abstracts

Symposium on Sustainable Energy Systems

U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

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of the

Symposium on Sustainable Energy Systems

Editors:
Clito Afonso,
Manuel Matos,
João Peças Lopes,
Vítor Leal,
Eduardo Oliveira Fernandes,
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from Faculty of Engineering,
University of Porto.

Porto, Portugal
June 2019

Preface

This volume compiles the papers presented at the symposium on Sustainable Energy Systems (SES) within the scope of the 3rd Doctoral Congress in Engineering (DCE19) that was held in FEUP, Porto, Portugal on the 27th and 28th of June 2019.

The conference was organized by the Faculty of Engineering (FEUP), University of Porto, in close coordination with different Symposia according to Doctoral and Master Programs outlook, organized into parallel sessions.

DCE19 provided an opportunity to share and disseminate ongoing work or results of PhD or Master's thesis with particular focus on different fields involving sustainable energy system; encouraged the discussion with leading academic scholars and researchers, regarding the future avenues for sustainable energy systems.

Acknowledging the multidisciplinary of sustainable energy systems context, the SES Symposium welcomed the submission of abstracts that included relevant themes within the Energy and Sustainability scope, namely: Sustainable Cities, People and Built Environment; Advanced Electric Networks and Energy Planning, Market regulation and Environmental Policies.

Furthermore, The Symposium Scientific and Organizing Committee would like to thank all the authors and reviewers involved for their valuable contribution and for making this edition of DCE19 a successful event.

Clito Afonso
Chair of the SES Symposium

Title: Book of Abstracts of the Symposium on Sustainable Energy Systems at 3rd Doctoral Congress in Engineering 2019.

Edited by Clito Afonso, Manuel Matos, João Peças Lopes, Vítor Leal, Eduardo Oliveira Fernandes, José Luís Alexandre, Daniela Calderón Padrino, Maria de Fátima Lima, Kashif Mushtaq

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WELCOME

On behalf of the Organizing committee of the SES Symposium, we are pleased to welcome you to the 3rd edition of the Doctoral Congress in Engineering (DCE19).

The SES Symposium is focused on enabling and promoting the exchange of knowledge in the field of Sustainable Energy Systems. We hope to provide students, scholars and researchers with a favorable environment for sharing ideas regarding their ongoing research work.

We hope that you will enjoy this year's edition having reputed keynote speakers and workshop sessions.

Porto, June 2019

SES Symposium Organizing Committee

CONTENTS

COMMITTEES

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Chair: Clito Afonso, FEUP

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Célia Couto, FEUP

PROGRAMME

Session I (27th June, 10:30h-13:00h)

Opening Speaker (10min + 5min discussion)

Clito Afonso, Chair of the Symposium on Sustainable Energy Systems.

Invited Speaker (20min + 5min discussion)

Eduardo de Oliveira Fernandes, Emeritus Professor of the University of Porto

Topic: "Sustainable Cities, People and Built Environment"

Invited Keynote Speaker for Workshop I (20min + 5min discussion)

Adelio Mendes, Full Professor (FEUP), Senior Researcher and Coordinator at LEPABE

Topic: "Emerging research pathways for Sustainable Energy Systems"

Oral presentation of abstracts (10min + 5min discussion) - Session Moderator: Clito Afonso

- Micael Simões, Gil Sampaio, André Madureira and Ricardo Bessa, "Monitoring and predictive control of LV networks".
- José Gouveia, Carlos Moreira and João Peças Lopes, "Grid forming inverters integration in islanded power systems with low synchronous inertia"
- Shabnam Pesteh, Hamed Moayyed and Vladimiro Miranda, "Robust state estimation in power systems with generalized correntropy interior point method (GCIP)".
- Kashif Mushtaq, Asad A Zaidi and Adelio Mendes, "Impact of flow-fields on the performance of vanadium redox flow battery".

Session II (27th June, 14:30h-16:30h)

Invited Keynote Speaker for Workshop II (20min + 5min discussion)
Vitor Leal, Assistant Professor, Director EASSE, MIT Portugal Program, University of Porto

Topic: "Emerging research pathways for Sustainable Energy Systems"

Oral presentation of abstracts (10min + 5min discussion) - Session Moderator: Vitor Leal

- Kamel Mohamed Rahla, Luis Bragança and Ricardo Mateus , "How can circular economy be implemented in residential buildings? – An exploratory research.
- Arsenio Mindu, Jo Capece, Armando Oliveira and Rui Araujo, "Renewable energies policies impact in Mozambique".
- Fátima Lima, Paula Ferreira and Vitor Leal, "The relevance of household and sociodemographic factors on household energy and health expenditures".
- Daniela Padrino and Clito Afonso, "Energy rehabilitation measures in historic buildings from Portugal: Application in Porto's Historic Center".
- Rebeka Maria Sotero Silva, Ana Paula de Oliveira Medeiros, Antonio Rodrigues Albuquerque Filho, Beatriz Nascimento Ko Fontenele and Daniel Barboza Guimarães, "Willingness to pay and consumers' ecological behavior: An applied study on the green building field". (Oral + Poster)
- Nabeel Ahsan, Kashif Mushtaq and Asad A. Zaidi, "Numerically simulated performance assessment for integration of PEM Fuel Cell Stack into an automobile".

KEYNOTE SPEAKERS

Clito Afonso

Opening Speaker, Chair SES Symposium

FEUP

Session I

Clito Afonso, Course Director of the Specialization in Thermal Engineering, and associate professor in the mechanical engineering department from the Faculty of Engineering in the University of Porto, Portugal. In 1978 obtained his Engineering degree, in 1986 finished his Master in Thermal Engineering and his PhD in Mechanical Engineering in 1989. In 2004 began his career as a professor, has dedicated his career as a researcher teacher and industry consultant at DEMec, IDMEC (Pólo FEUP) and INEGI. Responsible for several research projects national as well as international. Part of the council for OCP "Organismo de Certificação de Pessoas" from Centerm "Centro Tecnológico para a Indústria Térmica, Energia e Ambiente". Course director for the Specialization in Thermal Energy in 2011, Member of the Scientific Committee for the PhD and Executive Master in Sustainable Energy System, additionally in the Mechanical Engineering and Environmental Engineering Integrated Master[1].

Manuel Matos

Opening Speaker, Chair SES Symposium

FEUP/INESC Porto

Born in Porto (Portugal) in 8 April 1955, graduated in Electrical Engineering in the Faculty of Engineering of the University of Porto - FEUP (1977), and completed his PhD in Power Systems in 1988, also from the University of Porto. Honored with the aggregation title from the University of Porto in 1996. In 1978 I joined the Department of Electrical Engineering of FEUP, where he is Full Professor since 2000. In the period 1990-98, he was also the Director of the Library of FEUP. In the period 2001-08, he was the director of the MSc program on Information Management, and he is presently the director of the PhD program in Sustainable Energy Systems, integrated in the MIT-Portugal program. He is a member of the Senate of the University of Porto since October 2009. [2]

Eduardo de Oliveira Fernandes

Invited Speaker

Eduardo de Oliveira Fernandes, Emeritus Professor from FEUP

Session I- Topic: "*Sustainable Cities, People and Built Environment"*

Eduardo De Oliveira Fernandes, Emeritus Professor on the Mechanical Engineering Department at the Faculty of Engineering, University of Porto, Portugal. Over 40 years working on the cross roads of Energy and Environment both as 'life resources' and as 'Comfort and Health' critical parameters in the Built Environment. In the more recent years, focusing on a) clarification/exploitation of the role of 'climate & building location' on the priority to be given to the energy sufficiency as criteria before energy efficiency in buildings for temperate climates' and b) due air ventilation rates indoors based on health and 'source control' criteria. With over 700 research items and involved in over 30 projects related to engineering. [3]

Adélio Mendes

Invited Keynote Speaker for Workshop I

Adelio Mendes, Full Professor (FEUP), Senior Researcher and Coordinator at LEPABE

Session I- Topic: *"Emerging research pathways for Sustainable Energy Systems"*

Adélio Mendes is a chemical engineer and full professor at the Faculty of Engineering of the University of Porto (FEUP)[4]. It combines the innovativeness of a scientist with the pragmatism of a businessman, two forked worlds in his research career. The awards come in cascade, as exemplified by the award of the Technological Innovation Trophy by the UP. He has patents of pioneering technologies, mostly linked to the development of clean energy, including the most expensive intellectual property traded in Portugal, sold to the Australian company Dyesol for five million euros. With the intellectual record of over 20 innovations, Adélio Mendes is one of the most successful national researchers. He was responsible for Super Bock's first non-alcoholic beer and the creator of the most expensive patent sold in Portugal for five million euros[5].

Vítor Leal

Invited Keynote Speaker for Workshop II

Assistant Professor, Director EASSE, MIT Portugal Program, University of Porto

Session II- Topic: *"Emerging research pathways for Sustainable Energy Systems"*

Vítor Leal, obtained his degree in physics engineering from the technical University of Lisbon Portugal in 1996, finished his Master in mechanical engineering branch of thermal engineering faculty of engineering University of Porto Portugal in 1999 and his PhD in engineering Science from the same faculty in 2006. Currently course Director in the MIT-Portugal Executive Master Program in Sustainable Energy Systems and chairman of the scientific committee since February 2015 and Assistant Director of the MIT Portugal Doctoral Program in the University of Porto, Portugal. Also, worked at the superior school of technology in management Polytechnic Institute of Viana do Castelo[6].

References:

1. https://sigarra.up.pt/feup/pt/noticias_geral.ver_noticia?p_nr=13448
2. https://www.inesctec.pt/pt/pessoas/manuel-matos
3. https://www.researchgate.net/profile/Eduardo_De_Oliveira_Fernandes2
4. https://lepabe.fe.up.pt/a_mendes.html
5. https://expresso.pt/sociedade/2017-11-22-E-dele-a-patente-mais-cara-vendida-em-Portugal.-E-tambem-criou-uma-cerveja-nacional-sem-alcool
6. https://web.fe.up.pt/~vleal/

ORAL PRESENTATIONS

Willingness to Pay and Consumers' Ecological Behavior: An Applied Study on the Green Building Field

Rebeka Maria Sotero Silva[1], Ana Paula de Oliveira Medeiros[1], Antonio Rodrigues Albuquerque Filho[1], Beatriz Nascimento Ko Fontenele[2], Daniel Barboza Guimarães[3]

[1] Programa de Pós-Graduação em Administração e Controladoria, Universidade Federal do Ceará, Brasil (rebeka@ufc.br)

[2] Departamento de Engenharia Civil, Faculdade de Engenharia, Universidade do Porto, Portugal, (up201809193@fe.up.pt)

[3] Programa de Pós-Graduação em Administração e Controladoria, Universidade Federal do Ceará, Brasil (barbozadan@hotmail.com)

Abstract # 149

The consumer market has put a lot of pressure on the private companies for the adoption of more sustainable conducts. In this context, civil engineering sector has identified an opportunity to improve its sales through green building. The general objective of this study is to analyze the relation between the consumers' environmental awareness and their willingness to pay for green buildings. Data was collected from a sample of 225 consumers living in Fortaleza, capital of Ceará, who took a survey. Descriptive statistics, confirmatory factor analysis and multiple linear regression were used for quantitative analysis. The results point out that increased consumers' environmental awareness means increased consumers' willingness to pay for green buildings – more specifically 5% or 6% above, according to this study. Finally, the study points out that age and education are extremely relevant on the level of consumers' environmental awareness.

Author Keywords. Environmental awareness, green building, willingness to pay.

Introduction

Several researches investigate the relation between ecological awareness and the acquisition of consumption products or immediate consumption (BISWAS, 2016; COLARES; MATTAR, 2016). However, it was identified that few of them investigate this relation regarding long durability products that demand considerable investments, such as the properties. Dwaikat and Ali (2016) point out that studies that focus on issues related to the cost of green buildings are still limited and that the reduced existent literature does not reflect the problem's significance. In this context, the current study aims to answer the following question: what is the relation between consumers' ecological awareness and their willingness to pay for the acquisition of a green building? The hypothesis is that the consumers with more ecological awareness are more willing to pay for green buildings.

Materials and Methods

The population analyzed in the current study was made up of consumers who are over 18 years old from Fortaleza, a Brazilian city. Data was collected through the application of a survey, composed of three sections. The first one refers to the scale that measures ecological awareness; the second section has items related to the willingness to pay for green buildings; and the last one refers to the sociodemographic profile of consumers. The scale used to measure the ecological awareness was changed to the Brazilian standard by Lages and Neto (2012), based in the Ecologically Conscious Consumer Behavior (ECCB)

scale (Straughan and Roberts, 1999). The survey was attended by 225 people. First a descriptive analysis was carried out to identify the respondents' profile. Then, a factor analysis was developed, dimensions were detected and the averages of the items of each dimension of the scale were calculated. Thus, a multiple linear regression was applied in order to analyze the influence of sociodemographic variables on ecological awareness.

Discussion

The survey results showed that the level of schooling was relevant in all models, indicating that the higher the level of schooling, the higher the level of ecological awareness. The family income as well as the number of children were not statistically significant in any model, which diverges from Belz and Peattie (2009) that have affirmed that there is a positive correlation between eco-friendly consumption and the family income, and from Melo and Freitas (2018) that have proved that the number of children positively affects the level of ecological awareness. 85,8% of the respondents said they were willing to pay for additional taxes for green buildings while 14,2% are not willing to pay more. 25,3%, said they were willing to pay from 5 to 6% more in the acquisition of a green building in relation to a traditional one.

Conclusions

Analyzing the survey results, it was shown that the increase of individuals' ecological awareness means an increase in the willingness to pay more for the acquisition of a green building. It is relevant to point out that the results may guide the analysis and decisions of regulatory bodies responsible for the development of certifications which promote and foster sustainable constructions. It is important for the organizations to develop marketing strategies to educate people regarding environmental issues and to stimulate green buildings trade.

References

Belz, F. M., Peattie, K. "Sustainability Marketing: A Global Perspective". 2009.

Biswas, A. "A Study of Consumers' Willingness to Pay for Green Products". Journal of Advanced Management Science 4, no. 3 (2016).

Colares, A., Mattar, P. "Produtos verdes: análise das características potencialmente influenciadoras dos consumidores sustentáveis". Revista de Administração, Contabilidade e Sustentabilidade, 6, no.1 (jan./abr. 2016): 37-55.

Dwaikat, L., Ali, K. "Green Buildings cost premium: A review of empirical evidence". Energy and Buildings (2016): 396-403.

Lages, N. S., Neto, A. V. "Mensurando a consciência ecológica do consumidor: um estudo realizado na cidade de Porto Alegre". ENANPAD, 26. Anais...Salvador (2002).

Melo, F. V. S., Melo, S. R. S., Freitas, A. A. F. "Consciência ecológica do consumidor e sua predisposição a pagar mais por destinos turísticos que adotam práticas de sustentabilidade". ENANPAD, 42. Anais... Curitiba (2018).

Straughan, Robert D., Roberts, James A. "Environmental Segmentation Alternatives: a look at green consumer behavior in the new millennium". Journal of Consumer Marketing 16, no. 6 (1999): 558-575.

How can Circular Economy be implemented in Residential Buildings? – An exploratory research

Kamel Mohamed Rahla[1], Luis Bragança[1], Ricardo Mateus[1]

[1] Department of Civil Engineering, University of Minho, Guimarães, 4800-058, Portugal (k.m.rahla@civil.uminho.pt)

Abstract # 243

Up to now, the Sustainability approaches have supported eco-friendly constructions to preserve and enhance the environment while keeping economic prosperity and social welfare. Still, the focus was merely put on the end-of-life of the buildings to close the construction loop by reusing and repurposing materials and components. The Circular Economy (CE) is a new approach that came into practice within the housing sector to overcome the current linear model of extract-construct-demolish, to foster resource efficiency, system thinking, closed-loop systems, and restorative and regenerative design. This study attempts to outline a framework covering the main CE key-strategies to be implemented in residential buildings based on the principles of this concept.

Keywords: Circular Economy, Built Environment, Residential Building, Key-strategies.

Introduction

The building industry plays a substantial role in the global economy by providing the necessary built environment for a prospering society. However, around 40% of materials and wastes, and 33% of all global emissions are related to the building sector (Ness and Xing 2017).

The new Circular Economy (CE) paradigm has been thoroughly investigated by scholars, professionals, and policymakers as a novel pathway to reduce material consumption, and retain the value of components as long as possible with a system thinking and a life cycle perspective (Ghisellini, Cialani, and Ulgiati 2016). Although the CE approach could offer to the European construction sector over 300 Billion Euros of benefits (Adams et al. 2017), applying CE principles in the housing sector is still in the early stages, which is mainly due to all the hurdles ahead in the development of a new business model and also to the necessary changes in the mindset of designers and stakeholders.

The current research attempts to concisely outline a framework for embedding CE in residential building as an exploratory research covering the main strategies that could be adopted to promote the shift to CE residential buildings.

Methodology

This short paper is an exploratory research about the CE in Residential Buildings and could be considered as the first milestone for future research (Kothari 2004). In this context, the present study will introduce the key-strategies to induce further research on Circular Buildings.

Discussion

This section introduces key-strategies to embed CE in residential buildings within six dimensions, Environmental, Economic, Social, Governmental or Institutional, and Cultural (Figure 1), while taking into account the building's life cycle stages and putting an

emphasis on the end-of-life by discussing adequate design strategies, rather than demolition, which will eventually allow to reuse/repurpose different materials, components, and systems. Needless to say, that the ultimate aim of Circular Buildings is to achieve higher levels of Sustainability by re-thinking the end-of-life scenario and optimally use physical resources (preferably local resources) to prevent dire environmental consequences with higher economic value (increasing profitability) and social comfort (getting user's approval).

- **Selection of Circular Materials:** The choice of materials is crucial to ensure closed-loop cycles in the construction and rehabilitation process while maintaining humans' well-being. The selection will be done based on predefined criteria such as acceptability for different circular design strategies, healthy environments for humans, low carbon and embodied energy, and components with high recycled/reused content and no or minimal levels of critical materials.
- **Green Energy**: Circular Buildings should be designed in a way that they require minimum energy to reach optimal functionality. Additionally, the energy supply will be based on local renewable energy.
- **Smart water management:** The water should be managed in a circular way through the reuse and recycling of grey and rainwater while recovering nutrients.
- **Waste mapping:** Whether it is construction or household waste, adequate mapping should be carried out to set up a local waste flow and extract value from it.
- **Safety, comfort, and wellbeing:** By avoiding indoor pollution and enhancing user's safety and indoor environmental quality by establishing light, acoustics and thermal comfort, good air quality, and appealing aesthetics.
- **Circular design strategies:** Nowadays, Circular Economy pushes designers to shift their mind-set to encompass a whole system thinking in buildings and rely on different Circular design strategies such as Regenerative design, Design for Flexibility, Design for Adaptability, Design for Disassembly, among others. Furthermore, minimum resources (materials, energy, and water) should be used with increased consideration to durability to "get more with less".
- **User awareness:** The users' awareness is a key feature to unleash the CE potential by becoming more technologically and environmentally wise which can cut down energy consumption, wasting water, and to incite sorting out waste to facilitate value extraction.
- **Legal frameworks:** The role of the government is critical in developing a policy framework to provide a pathway to all actors in the buildings industry.
- **Business models:** Implementing CE in Buildings also relies on innovative Circular Business Models to cut costs and increase competitiveness. It is worth mentioning that the current CE business models, mainly, focus on closed-loop supply chains, resource recovery, extending product's life and increasing its durability, and by keeping the ownership of a product by selling it as a service. These approaches could be scaled up to residential buildings and encourage CE.
- **Digitized information:** Digitizing information and sharing it in common platforms between stakeholders is another strategy that needs to be implemented in order to ensure access to all data related to resource flows at all building's life-span.

- **Conservation of Natural and Human Capital:** It is crucial to point out that the natural and human capital i.e., biodiversity and human culture, need to be preserved and enhanced by stimulating local ecosystem and social diversity.

Conclusion

There is still a lot to do to implement circular economy models in the construction sector. Every stakeholder, e.g. government, private or public institutions, contractors, owners or even the building occupants play an important goals in this paradigm shift. This new philosophy gained rapid approval among academia and industry and it is being considered as a future fast-track approach to sustainability. The proposed framework requires further developments to holistically set up the CE in residential buildings.

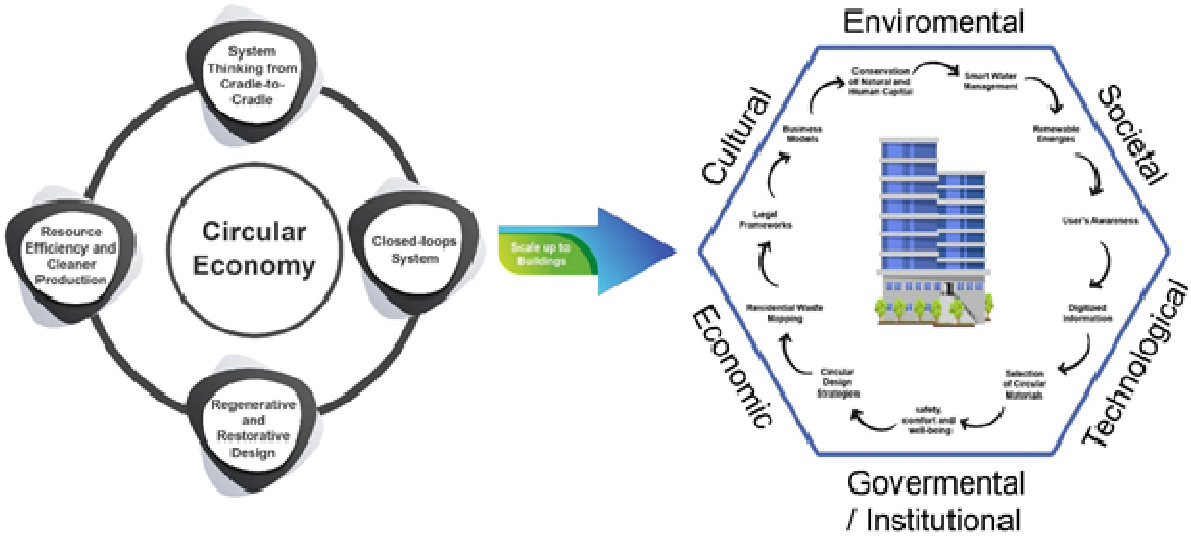

Figure 1*:* Key-strategies to implement CE in residential Buildings.

References

Adams, Katherine Tebbatt, Mohamed Osmani, Tony Thorpe, and Jane Thornback. 2017. "Circular Economy in Construction: Current Awareness, Challenges and Enablers." *Proceedings of the Institution of Civil Engineers - Waste and Resource Management* 170 (1): 15–24. https://doi.org/10.1680/jwarm.16.00011.

Ghisellini, Patrizia, Catia Cialani, and Sergio Ulgiati. 2016. "A Review on Circular Economy : The Expected Transition to a Balanced Interplay of Environmental and Economic Systems." *Journal of Cleaner Production* 114. Elsevier Ltd: 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.

Kothari, Chakravanti Rajagopalachari. 2004. *Research Methodology: Methods and Techniques*. New Age International.

Ness, David A., and Ke Xing. 2017. "Toward a Resource-Efficient Built Environment: A Literature Review and Conceptual Model." *Journal of Industrial Ecology* 21 (3): 572–92. https://doi.org/10.1111/jiec.12586.

Renewable Energies Policies impact in Mozambique

Arsénio José Mindú[1], Jó Capece[1], Armando Oliveira[2], Rui Araújo[2]

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[2] Universidade do Porto, Portugal

Abstract # 274

Mozambique, a Southern African country with a total estimated population of about 28 million, has a diversification of sustainable energy sources, which are approximately 2206 kWh/m2/ year in global solar radiation, 18 GW in potential of hydroelectric power, 4.6 GW of wind potential and 2 GW of Biomass Projects potential, with the solar resource being the country in abundance, totaling a potential of 23 GW, according to the Atlas of Renewable Energy Mozambique, published in 2013.

However, only a third of the population has access to electricity from the public grid, most of which live in urban areas. The majority of the Mozambican population lives in rural areas and uses biomass as their primary source of energy to meet their needs, such as lighting, food preparation, heating, among others.

This reality contrasts with the energetic "wealth" that characterizes the country, as well as with the policies that were designed about 10 years ago. The main issues that policies have set out to address are: (i) to convert traditional technologies, such as biomass and human and animal power, into modern energy technologies, using new and renewable sources that are more efficient and of higher quality and (ii) encourage the diversification of energy supply systems through the integration of more efficient and sustainable energy systems. These goals are intended to meet energy needs in different sectors, such as the residential, public, commercial, industrial, transport and agriculture sectors.

Taking into account that the Policy for the Development of New and Renewable Energy (Resolution 62/2009 of 14 October) and the Energy Strategy (Resolution 10/2009 of 4th June) call for access to and use of renewable energy sources as a means of poverty reduction through the provision of energy in its various forms, and considering that these goals have a 2020 deadline, the number of projects implemented falls short of meeting the previously defined objectives.

The setback in the expectations drawn by the Government in relation to Renewable Energies has as one of the main reasons the tariffs that are imposed on those who intend to explore the energy market based on renewable energies. For example, the Regulation on the New and Renewable Energy Tariff Regulations (REFIT), Article 8 a), establishes that for solar power plants with an installed capacity of 10 kW, the tariff value is 13.02 Mt / kWh), while those with 10MW of capacity, the tariff to be applied is 7.91 Mt / kWh. Paradoxically, the higher the installed power plant, the lower the price of the tariff.

In contrast to Solar Power Plants, Article 7 (a) refers to 4.81 Mt/kWh for a hydroelectric plant with installed capacity of 10 kW , the tariff applied is 2.29 Mt/kWh for 10 MW This bipolarity of tariffs does not encourage entrepreneurs and singular persons to invest in the

energy market based on renewable sources and in particular on photovoltaic solar energy. It should be noted that solar projects would have their greatest impact in rural areas where the level of poverty is high, as the main subsistence activity is small-scale agriculture.

On the other hand, one of the factors that undermine the access to electric energy is the almost successive increase in tariffs that are applied by the National Entity of Electricity - Electricity of Mozambique (EDM). Evaluating the increases that are carried out by EDM from 20012 to 2016, it is verified that the increase exceeded 100%, from 2105 to 2016, the tariff increase was 73% in the domestic tariff (where we find the largest number of consumers).

Based on these facts, it appears that the legislation *vs*. national policies in the area of Renewable Energies do not favor its use, which would serve as an alternative to the diversification of the energy matrix, which is basically leaned in Hydro plants with particular focus to Cahora Bassa Hydroelectric Plant.

In this case, the article seeks to analyze the various instruments related to Mozambican government policies related to and to assess the extent to which they contribute to the massification or attraction of projects related to Renewable Energies with particular emphasis on the solar source.

Key Words: *Mozambique's Policies, Renewable Energies, Renewable Energy Tariff*

Grid Forming Inverters Integration in Islanded Power Systems with Low Synchronous Inertia

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Abstract # 280
The large scale integration of inverter-based renewable generation in isolated power systems is posing stability concerns, where the integration of energy storage systems (ESS) operating as grid-forming is mandatory in order to ensure the transient system stability. Therefore, in this paper it is performed a transient stability analysis of a medium-size island power system endowed with a large share of renewable generation, where it is considered the simultaneous operation of grid-forming inverters and synchronous machines (SM).

Author Keywords. Grid-Forming, Virtual Synchronous Machine, Dynamic Stability, Islanded Power Systems.

Introduction

In recent years, environment and economic concerns are leading to the decarbonisation of insular power systems, encouraging the large scale integration of renewable-based generation, which pose significant challenges, since isolated networks are intrinsically prone to instability (Vasconcelos 2015). In this sense, the displacement of the conventional SM will require the integration of ESS operating as grid-forming units, in order to assure the network control capabilities (Beires 2018). So, recently has emerged the concept of virtual synchronous machine (VSM), consisting in a control feature which allows inverters to emulate SM characteristics (Zhong 2011). Thus, this paper aims to assess the transient stability of an isolated power system, considering an operating scenario with a large integration of renewable generation and with a low share of SM, where it was considering installation of an ESS operating as a VSM, in order to allow the direct integration of renewable generation.

Grid Forming Modelling and Control

The implemented grid forming followed a VSM control approach, which consisted in the adoption of a simplified model of the SM. Therefore, a block diagram illustrating the VSM control is illustrated in Figure 2 (a), where H and D correspond to the virtual inertia and damping respectively (since the inverter has no physical mass of inertia their values can be parametrized), P and P_{ref} are the measured and reference active power, and P_{FR} corresponds to a modulation term given by the virtual speed governor. Since inverter have very limited overcurrent capability, a transient virtual impedance (TVI) method was employed in order to achieve current limitation during faults, Figure 2 (b), where the virtual impedance Z_{VI} is enabled when the current value i_{abc} surpasses a predefined threshold limit i_{th}.

Case Study and Results

A medium-size island power system was studied, where it was considered a typical noon operating scenario. Therefore, the system is operated with a combined solar and wind power injection of 20 MW, and with a 15 MVA diesel unit is providing 5 MW in order to fulfil the load demand of 25 MW. Additionally, a 12 MW battery power plant (BPP) was installed, where it was implemented the control approach presented in section 0. Thus, the test system was fully modelled in the Matlab/Simulink simulation platform, where a 200ms three-phase fault was simulated at 10s of the simulation.

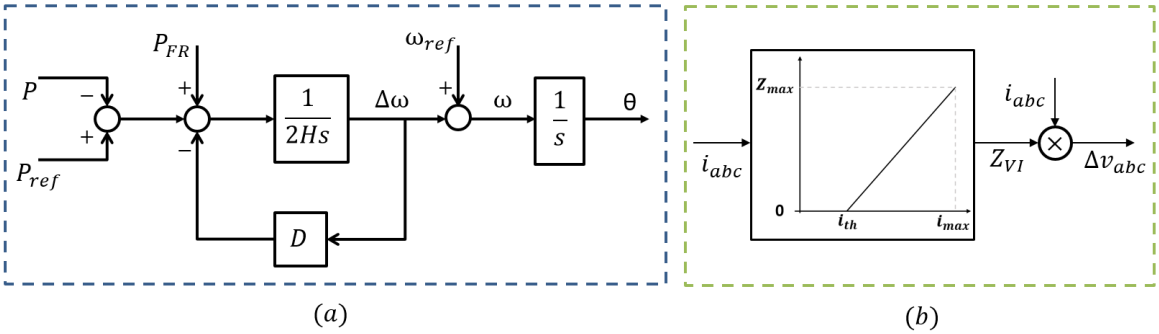

Figure 2: Schematic view of the grid-forming control: (a) Virtual synchronous machine control loop; (b) Transient virtual impedance control.

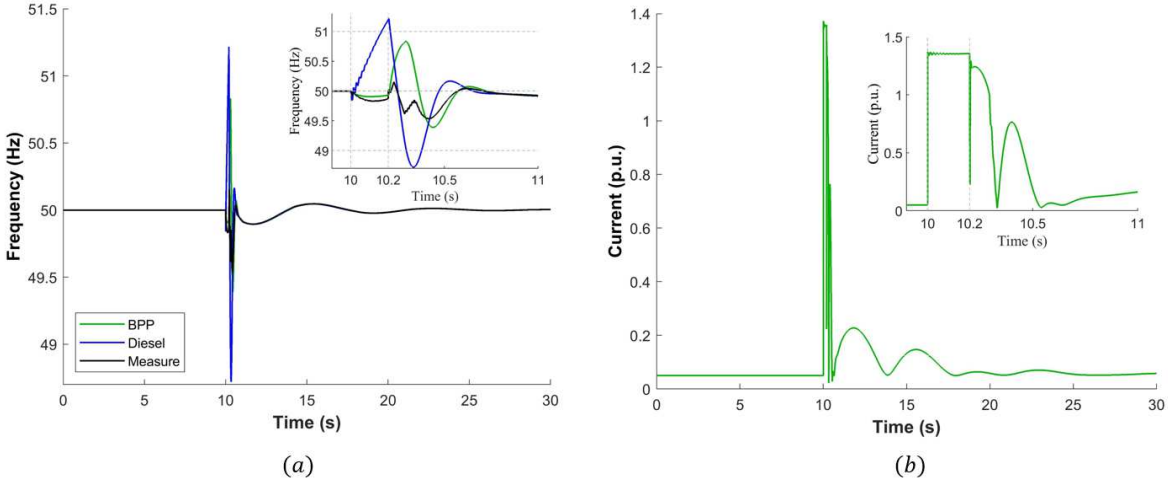

Figure 3: Simulation results: (a) Diesel, grid and BPP frequency; (b) BPP current.

Thereby, in Figure 3 (a) it is presented the frequency behaviour during the simulation, where it is made a comparison between different frequency measures, namely the frequency measured at the network, the frequency synthetized by the BPP and the frequency provided by the diesel unit, being noticeable a more oscillatory behaviour by the diesel unit, reaching approximately 51.2 Hz after the fault clearance. In addition, Figure 3 (b) shows that the BPP inverter current is successfully limited below its maximum admissible value of 1.5 p.u..

Conclusions

In this paper it was showed that the power system stability was ensured for the presented operating scenario, while grid-forming overcurrent limitation was successfully achieved.

References

Vasconcelos, H., C. Moreira, A. Madureira, J. P. Lopes and V. Miranda. 2015. “Advanced control solutions for operating isolated power systems: examining the Portuguese islands”. In *IEEE Electrification Magazine,* vol. 3, no. 1, pp. 25-35. Accessed March 2015.

Beires, P., M. H. Vasconcelos, C. L. Moreira and J. A. Peças Lopes. 2018. “Stability of autonomous power systems with reversible hydro power plants”. In *Electric Power Systems Research*, Vol. 158, pp. 1-14. Accessed May 2018.

Zhong, Q. and G. Weiss. 2011. "Synchronverters: inverters that mimic synchronous generators". In *IEEE Transactions on Industrial Electronics*, vol. 58, no. 4, pp. 1259-1267. Accessed April 2011.

Numerically simulated performance assessment for integration of PEM Fuel Cell Stack into an automobile

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Abstract # 292

This study is focused on the integration of fuel cell stack (FCS) for the automotive system. The paper discussed different input parameters such as temperature, pressure and humidity for the optimum working of the FCS to power a medium sized car. A numerical simulation was carried out in which FCS of 132 hp was analyzed by varying the input parameters. In order to evaluate the performance of the system, several assumptions were made before running the final program. Graphical representations show the comparison between FCS and the overall system which signifies that the system should be designed to have 6.8% more power output in order to meet the actual requirement of the system after catering the system losses. Simulation results highlighted that the critical pressure and temperature are 4.2 bar and 92^{o} degree celsius respectively. Although, the system is close enough to a real world fuel cell based automotive system, but sensitivity error analysis further help to assess the criticality of the components.

Author Keywords. FCS (fuel cell stack), humidity, net power, temperature, pressure, efficiency.

Introduction

The automobile industry is one of the leading sectors which contribute to the carbon emission into the environment. As fuel cell based car is considered an environment friendly vehicle, therefore it is a topic of interest for the researchers working on sustainable cities. There is still gap for further investigation for design optimization of primary and secondary components of the fuel cell based system especially for the air and fuel management system. Air compressor is one of those core components in a fuel cell based system which plays a vital role in the overall system performance and efficiency.

Materials and Methods

The type of FC used in the system is the Proton Exchange Membrane FC (PEMFC). The FCS size is modelled to produce 132 hp (98 KW) which is equal to the horse power of a medium sized car. Figure 1 shows the working mechanism including the minimal components required for a FC system. In order to obtain simulation results following

assumptions are taken into consideration. Constant specific heats and ideal gases are assumed, no change in the air and fuel properties within the operating range, no pressure drops in the flow channel except across the FC.

The simulation is done by using code in MATLAB. The code is used to simulate the FC system with the turbo compressor and give system efficiencies and other output such as pressure and mass flow operating lines to give the highest FC system efficiency. There are several programming loops in the program such as current-loop, pressure-loop and temperature-loop. The equation for determining the power required by turbo compressor is given by equation 1 [5].

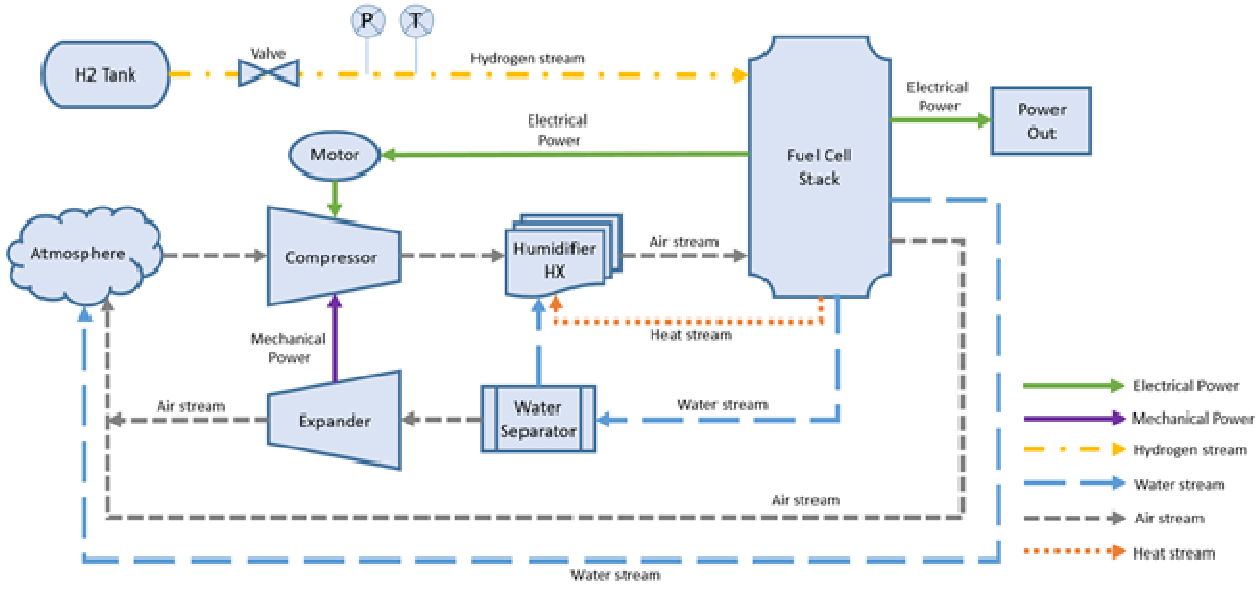

Figure 1: Schematic diagram of PEM FC system

$$Pwr\_c = \frac{\left[\frac{matr1}{Ma} + \frac{mvap1}{Mh2o}\right] * 8314 * T1 * \frac{k}{k-1} * \left\{\left[\frac{P2}{P1}\right]^{\frac{k-1}{k}} - 1\right\}}{\text{eff\_overall} * \text{nm}} \qquad (1)$$

where; *mair1* and *mvap1* are inlet flow rate (kg/s) of dry air and water respectively. M_a and M_{h2o} are molecular masses (kg/kmole) of air and water respectively. *T1* is ambient air temperature (K) and k is specific heat ratio. *P1* and *P2* are inlet and outlet pressures (atm) respectively. *nm* and *eff_overall* are efficiency of compressor motor and adiabatic efficiency of compressor.

Results and Discussion

In order to develop the highly efficient FC system, it is important to analyze the operating parameters and their impact on the system performance. The ideal operating conditions for minimum and maximum currents are 5A and 475A respectively. Desired input and output temperatures of stack are 358K and 363K respectively.

However, the turbo compressor with an expander has higher efficiency, except for low FC load where the efficiencies are approximately the same. The FCS maximum efficiency is 70.8 percent, whereas, the approximate maximum efficiency for each system is

comparatively lower than the FCS which is 62.4 percent for the turbo compressor systems (with and without expander) at low stack load.

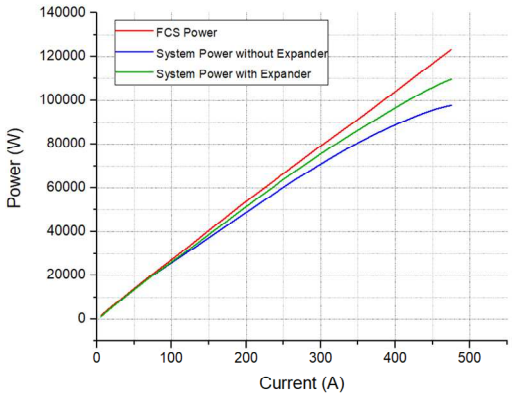

Figure 2: Power curves of FCS and overall system

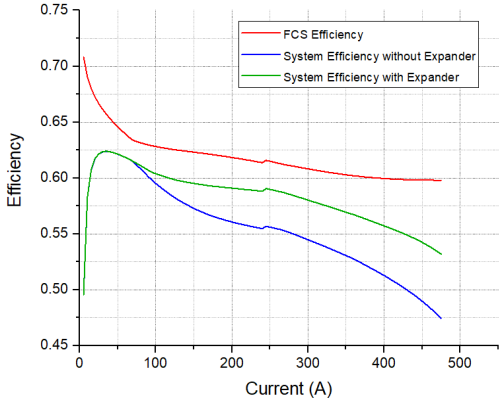

Figure 3: Efficiency curves of FCS and overall system

Conclusions

From the above simulation results it can be concluded that the FCS efficiency increases as the stack size increases. However, the stack power is a little lower than the designed power due to energy losses in the system. Therefore, the system should be designed to have 6.8% more power output in order to meet the actual requirement of the system after catering the system losses. The results also prove that using an expander has a significant impact on the overall system performance. The simulation results also provided the operating range and critical limits of temperatures and pressures for the stack performance. The critical pressure and temperature are 4.2 bars and 92 degrees Celsius respectively. Crossing the upper limit may damage the proton exchange membrane of fuel cell stack.

References

[1] David Joshua Friedman, Reform Ate FCS Characteristics and System Interactions, 35th Intersociety Energy Conversion Engineering Conference, 24-28 July 2000/Las Vegas, Nevada.

[2] Wan Yu, Xu Sichuan, HuaiSheng Ni, Air Compressors for FC Vehicles: An Systematic Review, SAE Int. J. Alt. Power. 4(1):2015, doi:10.4271/2015-01-1172.

[3] R.M. Moorea, K.H. Hauerb, D. Friedmanc, A dynamic simulation tool for hydrogen FC vehicles, Journal of Power Sources 141 (2005) 272–285.

[4] Dongdong Zhaoa, Liangcai Xua, Yigeng Huangfua, Semi-physical modeling and control of a centrifugal compressor for the air feeding of a PEM FC, Energy Conversion and Management 154 (2017) 380-386.

[5] EG&G Technical Services, Inc., FC Handbook, Seventh Edition, U.S. Department of Energy Office of Fossil Energy, National Energy Technology Laboratory Morgantown, West Virginia, 2004.

[6] Galen W. Kulp, A Comparison of Two Air Compressors for PEM FC Systems, Master's Thesis, Department of Mechanical Engineering, Virginia Polytechnic Institute and State University, USA, 2001.

The relevance of household and sociodemographic factors on household energy and health expenditures

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Abstract # 293

This paper is an initial approach to relate health expenditures, energy expenditures and sociodemographic features of households. Research findings were based on household budget survey microdata database, with particular attention to energy and heath expenditures in relation to a given household size and type. This paper aims to contribute to existing discussion, by focusing on the interplay between health and energy expenditures within the household context, and by doing so, promote future research pathways to establish a better understanding between these factors through a modeling approach that considers also housing characteristics.

Author Keywords. household energy and health expenditures, sociodemographic and housing factors.

Introduction

Increasing attention has been given to household sector regarding its potential role in the context of energy and climate change. This focus has been primarily directed towards the potential for emission reduction of this carbon intensive sector, though additional co-benefits have been reported for other sectors, such as health, resorting to household energy efficiency.

It has been estimated, that during 2017, the building sector accounted for nearly 36% of global final energy use during construction and operation phase, and almost 39% of carbon dioxide (CO2) emissions (International Energy Agency and the United Nations Environment Programme, 2018). Simultaneously, and almost seeming contradictory, the building sector has also been considered one of the sectors with greatest viable energy efficiency potential. According to (IEA, 2014) about 80% of building's energy efficiency is still untapped or latent.

As a result, there has been recently an upsurge of studies looking to characterize the interaction and determine the main drivers of energy consumption and expenditures at household level. Within this scope (Besagni & Borgarello, 2018) have resorted to coupled statistical model analysis to ascertain the relationship between residential energy expenditures, building factors and sociodemographic and appliance ownership in Italy. Results have emphasized the relevance of both sociodemographic and building factors for electricity and thermal energy expenditures, respectively.

Meanwhile (Longhi, 2015) sought to study whether the changes in household economic circumstances implied changes in energy expenditures in UK. It was found that socioeconomic characteristics have a moderate impact comparatively to housing and household features, with greater changes in energy expenditures being associated to changes in household size.

When studying the socioeconomic, dwelling and appliance influence on domestic energy consumption (Jones, Fuertes, & Lomas, 2015) review enabled to identify a total of 62 factors that affect (significantly or not) household electricity use, among which less focused factors related to appliance ownership and use and require further research.

In addition to traditional sociodemographic and building characteristics (Huebner, Hamilton, Chalabi, Shipworth, & Oreszczyn, 2015) studied the influence of occupant's attitudes and behavior, in UK. The study results show that dwelling characteristics have a greater explanatory power than other variables considered, including sociodemographic and behavior factors. However, it is recognized that behavioral factors need further research to become more accurately represented.

In spite of this, although bottom up models seem to be more inclusive of additional variables in order to explain energy consumption and expenditures at household level, these studies have scarcely focused the possible interconnection to health. Yet, the deployment of envelope level energy efficiency measures, such as wall insulation, seem to be associated to positive outcomes regarding energy savings and/or for health and wellbeing.

For instance, (Poortinga, Jones, Lannon, & Jenkins, 2017) reported that housing upgrades resorting to multiple energy efficiency measures (e.g. new windows and doors, wall insulation, among others) have been associated to positive social and health outcomes, comprising greater thermal comfort, improved household finances, household satisfaction, as well as, improved mental, respiratory and general health outcomes.

Hence, a more in depth knowledge regarding household and sociodemographic features and the way they relate to energy and health expenditures may be useful for policymakers that aim to develop cross-sectional policies, with wide-ranging breadth, covering buildings, climate change, energy and health issues.

Materials and Methods

This paper will then analyze the relationship between health expenditures, household related energy expenditures, and socio-demographic variables at country level, resorting to the development of regression models using Eurostat microdata databases, namely the Eurostat's Household Budget Survey (HBS).

This strict access database, is characterized by data collection at household level, enabling to promote an in depth analysis of household expenditure dynamics. Currently the database covers a wide range of countries at EU level (a total of 26 Member States), and is collected every 5 years (Eurostat, 2018).

A brief summary of featured (and relevant in bold) categories of consumption expenditure is illustrated in (**Error! Reference source not found.**).

Table 1: Focal consumption expenditures and sociodemographic features of HBS (sources: (Eurostat, 2019))

Database: Consumption Expenditure of Private Households (HBS)	
Focal Expenditures	
Consumption Expenditure according to the Classification of Individual Consumption by Purpose (COICOP):	
CP01	Food and non-alcoholic beverages
CP02	Alcoholic beverages, tobacco and narcotics
CP03	Clothing and footwear
CP04	**Housing, water, electricity, gas and other fuels**
CP05	Furnishings, household equipment and routine maintenance of the house
CP06	**Health**
CP07	Transport
CP08	Communications
CP09	Recreation and culture
CP10	Education
CP11	Restaurants and hotels
CP12	Miscellaneous goods and services
Sociodemographic Features	
Age; gender; household size; household type; income and education level	

Expected Outcomes

Thus, this paper aims to contribute to existing discussion, by analyzing the relationships between variables and determine the impact different household factors have on per capita family energy and health expenditures.

The developed analysis could contribute towards a better understanding of the effect that different nature factors have on expenditures and therefore support the development and design of health inclusive energy policies, adjusted for the Portuguese household context.

This initial approach also contributes to open future research pathways to establish a better understanding between these factors through a modelling approach that considers also housing characteristics.

References

Besagni, G., & Borgarello, M. (2018). The determinants of residential energy expenditure in Italy. *Energy*, *165*, 369–386. https://doi.org/10.1016/j.energy.2018.09.108

Eurostat. (2018). Household Budget Survey: Description of the HBS Scientific-Use Files. Retrieved from https://ec.europa.eu/eurostat/web/microdata/household-budget-survey

Eurostat. (2019). Consumption expenditure of private households (hbs)- Reference

Metadata in Euro SDMX Metadata Structure (ESMS). Retrieved from https://ec.europa.eu/eurostat/cache/metadata/en/hbs_esms.htm

Huebner, G. M., Hamilton, I., Chalabi, Z., Shipworth, D., & Oreszczyn, T. (2015). Explaining domestic energy consumption – The comparative contribution of building factors , socio-demographics , behaviours and attitudes. *Applied Energy*, *159*, 589–600. https://doi.org/10.1016/j.apenergy.2015.09.028

IEA. (2014). *Capturing the Multiple Benefits of Energy Efficiency Capturing the Multiple Benefits of Energy Efficiency*.

International Energy Agency and the United Nations Environment Programme. (2018). *2018 Global Status Report- 2018 Global Status Report: towards a zero emission, efficient and resilient buildings and construction sector*.

Jones, R. V, Fuertes, A., & Lomas, K. J. (2015). The socio-economic , dwelling and appliance related factors affecting electricity consumption in domestic buildings. *Renewable and Sustainable Energy Reviews*, *43*, 901–917. https://doi.org/10.1016/j.rser.2014.11.084

Longhi, S. (2015). Residential energy expenditures and the relevance of changes in household circumstances. *Energy Economics*, *49*, 440–450. https://doi.org/10.1016/j.eneco.2015.03.018

Poortinga, W., Jones, N., Lannon, S., & Jenkins, H. (2017). Social and health outcomes following upgrades to a national housing standard : a multilevel analysis of a five-wave repeated cross-sectional survey, 1–15. https://doi.org/10.1186/s12889-017-4928-x

Impact of flow-fields on the performance of Vanadium Redox Flow Battery

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Abstract # 295

Possibility to increase the performance of Vanadium redox flow cell (VRFC) by tuning operational condition and by using optimized components is evident through our published article [1]. This work reports that current density and energy efficiency of VRFC can be improved by modifying the plain graphite foil to impregnated graphite bipolar plate having flow-fields. Interdigitated flowfield performed better than serpentine and conventional flowfields. This study suggested that an efficient way is to decrease the pressure drop by using flow-fields instead of keep on increasing flowrate.

Keywords. Vanadium, VRFB, Redox Flow Battery, Redox Flow Cell, Flowfields

Introduction

The increment in the performance of Vanadium redox flow cell (VRFC) by tuning operational condition and by using optimized components is evident through our published article [1]. This work reports the improvement in current density while maintaining the efficiency and reduction in pumping flowrate of VRFC by utilization of flowfields. The performance comparison between conventional, interdigitated and serpentine flowfield will help researchers to further optimize the design of flowfields. The plain graphite foil as used in our previous experiments [1] is replaced with impregnated graphite bipolar plate having flow-fields as shown in figure 1. All of the other components are used as per the recommendation of previous experiments [1].

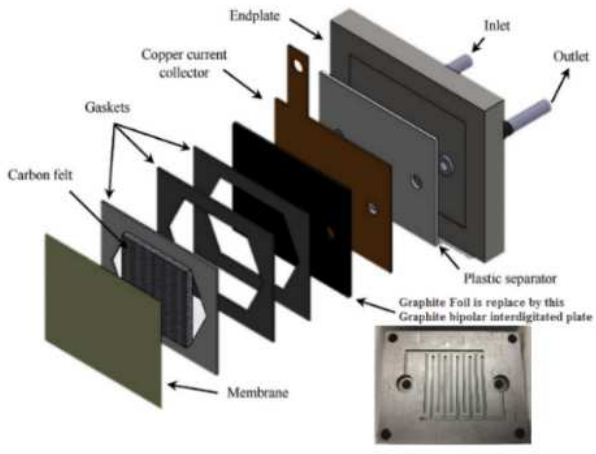

Figure 4 - Schematic of vanadium redox flow cell [1]

Results and Discussion

Charge discharge cycling was done at 40ml/min, starting from 40mA cm^{-2}, to 155mAcm^{-2}. The experimental data helped to calculate the efficiency and capacity of the VRFC at varying conditions as shown in Figure 2. Intergitated flowfield gives better performance in terms of capacity and energy efficiency as shown in Figure 3. However, the loss in columbic efficiency is due to crossover which can be avoided by use of fresh membrane. The flowrate is also significant alongwith choice of flowfield as shown in Figure 4. Electrochemical impedance spectroscopy (EIS) is carried out to measure the contribution of area specific resistance (ASR) at 40 ml/min for conventional, interdigitated and serpentine flow-fields, which is 1.49 Ωcm^2, 1.36 Ωcm^2 and 1.39 Ωcm^2 respectively. Impedance of membrane has major contribution in ASR and values are similar because of same type of membrane used in all experiments.

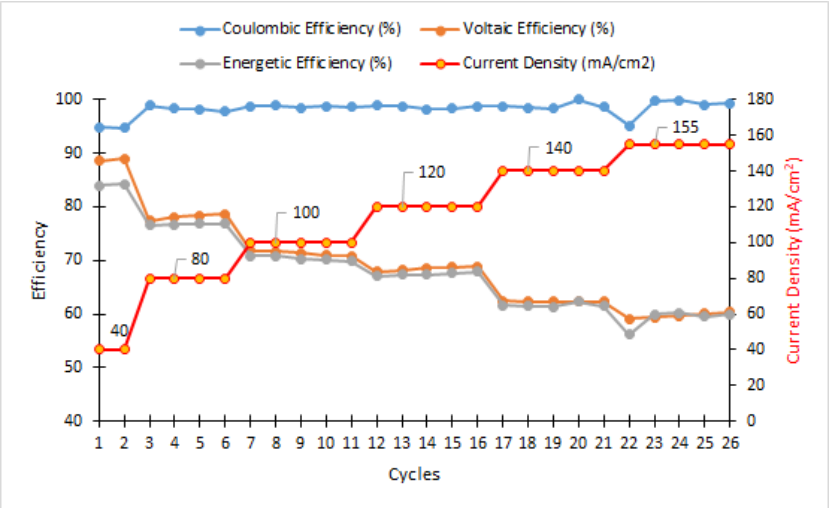

Figure 2 – Impact of varying current density on efficiency of the VRFB having interdigitated flow-field with flowrate of 20ml/min

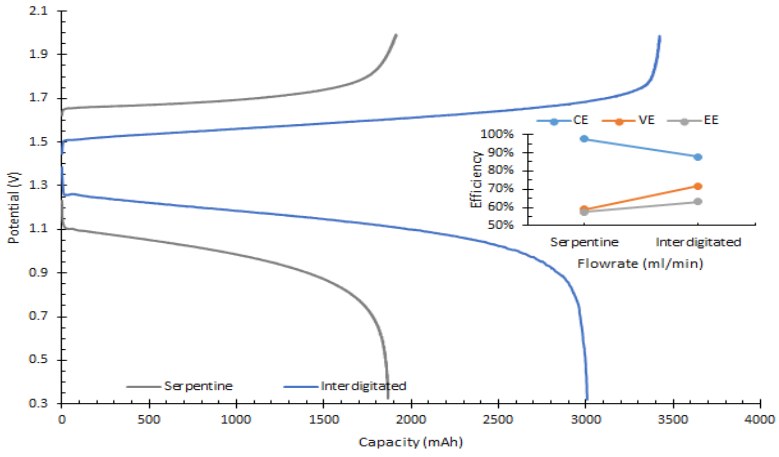

Figure 3 - Impact of flowfield on the capacity & efficiency of VRFB using 120 mA/cm^2 at 20ml/min

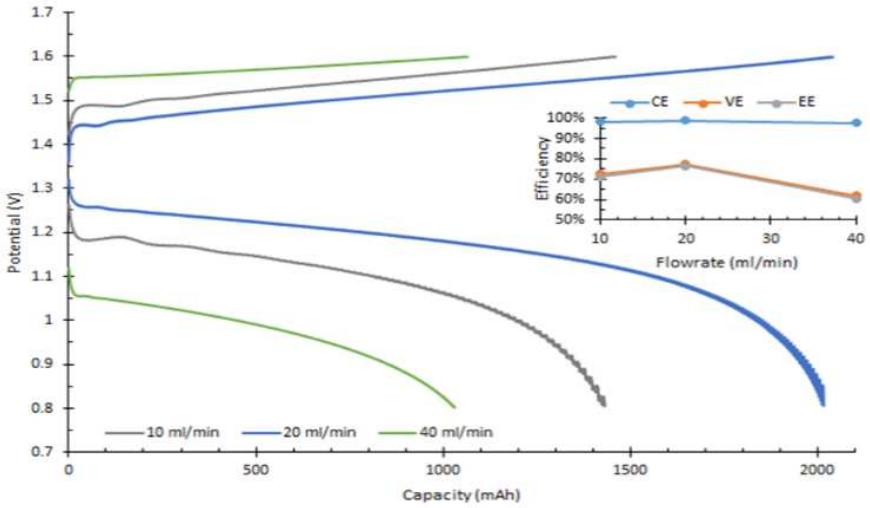

Figure 4 - Impact of varying flowrate on the capacity & efficiency of VRFB using interdigitated flowfield at 80 mA/cm^2

Conclusions

As per the previous article [1], in the absence of flowfields, it was observed that increase in flowrate is feasible to increase the energy efficiency. But, current study suggested that an efficient way is to decrease the pressure drop by using flowfields instead of keep on increasing flowrate. This approach helps to reach higher current densities at much lower requirement pumping flowrate.

References

[1] R. Monteiro, J. Leirós, etc., "Insights into all-vanadium redox flow battery: A case study on components and operational conditions," *Electrochimica Acta,* vol. 267, pp. 80-93, 2018.

Robust state estimation in power systems with generalized correntropy interior point method (GCIP)

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Abstract # 296

Nowadays, each TSO may be, at times, operating its own network close to the limits with more and more corrective actions in a context of higher uncertainties due to renewable energy sources and increased interactions between neighboring networks. Furthermore, the eclectic power systems are continually growing with the addition of many interconnected transmission networks and emerging new technologies. As a nucleus module of the online security analysis of power systems, state estimation (SE) is a major part of modern energy management system. SE acts like a noise filter, between the raw measurements received from the system and all the application functions that require the most reliable database for the current state of the system. And there may be instances when these raw measurements do not arrive in the control center due to communication problems or might be contaminated with one or more multiple simultaneous gross errors (GE).

As a robust nonlinear similarity measure between random variables, Correntropy has given growing attention as a SE criterion. Correntropy employs Gaussian kernel, which is indeed only one among other kernel choices. Kernel shape, however, may have impact on the ability of procedures to compute correct solutions. We propose a robust state estimator based on Generalized Correntropy Criterion that adopts the Generalized Gaussian density function as the kernel. GC can obtain additional flexibility by dint of GC parameters, which control the performance of the induced metric, and demonstrates a remarkably better robustness than Correntropy.

A recently introduced method by the authors called Generalized Correntropy Interior Point method (GCIP) answers to this problem in a very efficient way. GCIP is based on Generalized Error Correntropy instead of traditional Least Squares (LS) and on an interior point method (IPM) instead of the conventional Gauss-Newton algorithm. The proposed technique also introduces an innovative technique to identify outliers based on a very important feature occurring in IPM central path (arc of strictly feasible points that plays a vital role in the theory of IPM algorithms). Experimental results show the efficiency of GCIP compared to traditional largest normalized residual test (LNRT) which employs LS as objective function and Gauss-Newton search algorithm.

Energy rehabilitation measures in historic buildings from Portugal: Application in Porto's Historic Center

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Abstract # 300

Historic buildings concentrated in urban areas, form spaces of core importance in cities, greatly appreciated due to their historic relevance. Consequently, the UNESCO has recognized the significance of several historic centers in Portugal. Specifically in Porto, Portugal, this recognition motivated a set of guidelines and rehabilitation initiatives in the sites selected by UNESCO. This has opened the opportunity for a profound analysis about the impact of the rehabilitation measures currently applied in residential buildings from the Historic Center of Porto, which could potentially facilitate a deeper understanding and characterization of historic centers from the Mediterranean. Measures from other energy rehabilitation interventions in Portugal were reviewed, these measures could be used as basis to start a deeper analysis of rehabilitation interventions in the Historic Center of Porto, which could potentially serve for other areas within the Mediterranean.

Author Keywords. Energy rehabilitation, Historic buildings, Comfort, Energy in buildings, Portugal, Emissions.

Introduction

Residential buildings from the Mediterranean region allocate similar resources and techniques of construction, including the materials used in the construction process. This resemblance could be due to their shared climatic conditions, the temperate climate allows flexibility in the ways of achieving comfort conditions indoors. Additionally, the opportunity to preserve an elevated amount of energy in the residential building, a relevant characteristic of the Mediterranean area in the context of energy rehabilitation, where potential improvements could be achieved.

In this same manner, the construction and energy sector could benefit from the current state of the art of thermal insulation in the field of aerospace, potentially able to provide innovative measures toward reductions in energy consumption. Given that the innovative materials used for aerospace could be implemented for insulation in the commonly aged built environment from countries such as Italy, Portugal, Spain and Greece. Regardless of these possible improvements in energy savings, specific concerns surfaced from the energy rehabilitation interventions, currently taking place, these challenges include various technical, cultural, economic, social and environmental aspects further explained in the following sections.

As to better understand the motivation behind the energy rehabilitation interventions, it should be noted that since the beginning of human settlements continuous change and growth has been the norm (E. de O. Fernandes 2016). Currently in cities, this continues to be the case, with tendencies towards modernization, in increasing new developments with

the historic and cultural values at risk, considering the growing weight of rehabilitation in the total of concluded works (INE 2016b).

The aim is to provide a framework to develop innovative strategies that would support on the implementation of the energy rehabilitation interventions. Additionally assist in the resolutions of the existing challenges, such as the issue of the impoverishment of the historic and artistic heritage. This deterioration a possible consequence of a lack of maintenance may be causing the acute loss and ageing of population, as well as the improvement of the esthetical and safety perception of the city. Although the undergoing energy rehabilitation interventions could be motivating the recent touristic boom (Gregório and Seixas 2017).

The rehabilitation of spaces in historical and culturally important sites has been on the agenda for intervention in cities, particularly around Europe, China and many other places around de World. Yet from the last decades of the 20th century, energy rehabilitation became a current concern, especially for developed countries, evidenced with the Kioto agreement 1992 and the Bruntland report in 1987. The concepts for urban rehabilitation from the current Mediterranean regulations presented on the following paper act as the conceptual base, in the process of understanding energy rehabilitation and draw attention to the factors involved in the rehabilitation process. Justifying the need for an integrative approach, with the aim of improving the current energy rehabilitation process, taking place in different cities within the Mediterranean region.

Conclusions

The result of the literature review provided a further understanding of the energy rehabilitations in the Historic Center of Porto, currently taking place and the studies analyzing the measures carried out during the interventions. The assessment of certain challenges presented along this article, such as the greenhouse gas emissions, the gentrification and possible effects of the current rehabilitation interventions, calls for the harmonious integration of social, economic, cultural and environmental aspects as general concern. To identify measures with the highest impact, in terms of comfort, energy performance, socio-economic benefits, while preserving the value of the Historic buildings, it is important to analyze the benefits of choosing such measures.

References

Alexandri, Georgia. 2011. "The Struggle to Belong The Breeder Feeder : Tracing Gentrification in Athens City." *International RC21 Conference 2011 Session 2: Social Consequences of Gentrification*, no. July: 27.

Almeida, Celeste Maria Nunes Vieira de. 2013. "Paredes de Alvenaria Do Porto Tipificação e Caraterização Experimental." Universidade do Porto.

Asadi, Ehsan, Manuel Gameiro, Carlos Henggeler, Luís Dias, and Leon Glicksman. 2014. "Multi-Objective Optimization for Building Retrofit : A Model Using Genetic Algorithm and Artificial Neural Network and an Application." *Energy & Buildings* 81. Elsevier B.V.: 444–56. https://doi.org/10.1016/j.enbuild.2014.06.009.

Baldassarre, Fabrizio, Francesca Ricciardi, and Raffaele Campo. 2017. "Tourism Consumption and Opportunity for the Territory : Exploring the Case of Matera , 2019 European Capital of Culture." In *20th Excellence in Services International Conference*, 35–46. Verona, Italy.

Barbadilla-Martín, Elena, José Guadix Martín, José Manuel Salmerón Lissén, José Sánchez Ramos, and Servando Álvarez Domínguez. 2018. "Assessment of Thermal Comfort and Energy Savings in a Field Study on Adaptive Comfort with Application for Mixed Mode Offices." *Energy and Buildings* 167: 281–89. https://doi.org/10.1016/j.enbuild.2018.02.033.

Boeri, Andrea, Laura Gabrielli, and Danila Longo. 2011. "Evaluation and Feasibility Study of Retrofitting Interventions on Social Housing in Italy." *Procedia Engineering* 21: 1161–68. https://doi.org/10.1016/j.proeng.2011.11.2125.

Brito, N., Luís Mateus, and Manuel Carlos Gameiro Silva. 2012. "Upgrade Opportunities for Buildings in City Centres." *EPJ Web of Conferences* 33 (1): 7. https://doi.org/10.1051/epjconf/20123305008.

Câmara Municipal Porto AdEPorto- Agência de Energia do Porto. 2010. *Plano de Acção Para a Energia Sustentável Da Cidade Do Porto*. Porto.

Cellura, Maurizio, Francesco Guarino, Sonia Longo, Marina Mistretta, and Aldo Orioli. 2013. "The Role of the Building Sector for Reducing Energy Consumption and Greenhouse Gases: An Italian Case Study." *Renewable Energy* 60: 586–97. https://doi.org/10.1016/j.renene.2013.06.019.

Departamento de Alterações Climáticas - DCLIMA. 2018. "Inventário Nacional de Emissões Atmosféricas," 1–6.

Dubois, Samuel, Liesbeth Dekeyser, and Yves Vanhellemont. 2016. "Energy Efficiency and Comfort of Historic Buildings." In *EECHB*, edited by Liesbeth Dekeyser and Yves Vanhellemont Michael de Bouw, Samuel Dubois, 342. Brussels.

EDP, Energias de Portugal. 2017. "EDP Energy Outlook 2017," 1–122.

Fernandes, Eduardo de Oliveira. 2016. *Energy Perfornmance of Buildings: The Built Environment and Its Policies.* Springer I. University of Porto.

Fernandes, Francisco Barata. 1999. "Transformação e Permanência Na Habitação Portuense." Universidade do Porto.

Gregório, Vera, and Júlia Seixas. 2017. "Energy Savings Potential in Urban Rehabilitation: A Spatial-Based Methodology Applied to Historic Centres." *Energy and Buildings* 152. Elsevier B.V.: 11–23. https://doi.org/10.1016/j.enbuild.2017.06.024.

INE. 2012. *Censos 2011 Resultados Definitivos Norte*.

INE. 2016a. "Boletim Mensal de Estatística 2016." *Estatísticas Oficiais*, 1–89. https://doi.org/0032-5082.

INE. 2016b. *Estatísticas Da Construção e Habitação.*

INE. 2018. "Atividade Turística: Resultados Preliminares de 2017," 1–11.

Kim, Sunkuk, Sungho Lee, Young Ju Na, and Jeong Tai Kim. 2013. "Conceptual Model for LCC-Based LCCO2 Analysis of Apartment Buildings." *Energy and Buildings* 64 (2013): 285–91. https://doi.org/10.1016/j.enbuild.2013.05.016.

Kverndokk, Snorre, Eric Nævdal, and Linda Nøstbakken. 2014. "The Trade-off between Intra- and Intergenerational Equity in Climate Policy." *European Economic Review* 69. Elsevier: 40–58. https://doi.org/10.1016/j.euroecorev.2014.01.007.

Menezes, Paula. 2014. "Caraterização Do Setor Dos Serviços Em Portugal," 38.

Monteiro, Claudia Sousa, André Pina, Carlos Cerezo, Christoph Reinhart, and Paulo Ferrão. 2017. "The Use of Multi-Detail Building Archetypes in Urban Energy Modelling." *Energy Procedia* 111 (September 2016). Elsevier B.V.: 817–25. https://doi.org/10.1016/j.egypro.2017.03.244.

Nicol, J. F., and M. A. Humphreys. 2002. "Adaptive Thermal Comfort and Sustainable Thermal Standards for Buildings." *Energy and Buildings* 34 (6): 563–72. https://doi.org/10.1016/S0378-7788(02)00006-3.

Pires, André Manuel Chéu. 2013. "Análise de Paredes de Tabique e Medidas de Reforço Estrutural; Estudo Numérico." Universidade do Porto.

Porto Vivo AdEPorto and the Ministry of Culture. 2010. "Reabilitação de Edifícios Do Centro Histórico Do Porto: Guia de Termos de Referencia Para o Desempenho Energético-Ambiental," 64. http://www.portovivosru.pt/Guia_Termos_Referencia.pdf.

Porto Vivo and Oporto City Council. 2008. "Historic Center of Oporto World Heritage Management Plan– Volume I December 5th." Porto.

Queirós, João. 2009. "Gentrification of Porto's Historic Centre: Notes for the Future History of an <<impossible Commodity>>." *ISA Housing Conference "Housing Assets, Housing People,"* no. September: 1–16. http://www.urbanoutcastsoftheworld.net/uploads/5/9/6/7/5967617/jq2009.pdf.

Rodrigues, Carla, and Fausto Freire. 2017. "Adaptive Reuse of Buildings: Eco-Efficiency Assessment of Retrofit Strategies for Alternative Uses of an Historic Building." *Journal of Cleaner Production* 157. Elsevier Ltd: 94–105. https://doi.org/10.1016/j.jclepro.2017.04.104.

Rodrigues, Carla, Randolph Kirchain, Fausto Freire, and Jeremy Gregory. 2016. "Streamlined Environmental and Cost Life-Cycle Approach for Building Thermal Retrofits: A Case of Residential Buildings in South European Climates." *Journal of Cleaner Production* 172. Elsevier Ltd: 2625–35. https://doi.org/10.1016/j.jclepro.2017.11.148.

Roulet, Claude-Alain, Flourentzos Flourentzou, Flavio Foradini, Philomena Bluyssen, Chrit Cox, and Claire Aizlewood. 2006. "Multicriteria Analysis of Health, Comfort and Energy Efficiency in Buildings." *Building Research & Information* 34 (5): 475–82. https://doi.org/10.1080/09613210600822402.

Santos, Hugo, Paulo Valença, and Eduardo Oliveira Fernandes. 2017. "UNESCO's Historic Centre of Porto: Rehabilitation and Sustainability." *Energy Procedia* 133. Elsevier B.V.: 86–94. https://doi.org/10.1016/j.egypro.2017.09.375.

Serghides, Despina, Stella Dimitriou, Ioanna Kyprianou, and Costas Papanicolas. 2017. "The Adaptive Comfort Factor in Evaluating the Energy Performance of Office Buildings in the Mediterranean Coastal Cities." *Energy Procedia* 134. Elsevier B.V.: 683–91. https://doi.org/10.1016/j.egypro.2017.09.588.

Silva, Mafalda. 2017. "A Multi-Scale Decision Support Model to Integrate Energy in Urban Planning." Universidade do Porto.

Stellacci, S., V. Rato, E. Poletti, G. Vasconcelos, and G. Borsoi. 2018. "Multi-Criteria Analysis of Rehabilitation Techniques for Traditional Timber Frame Walls in Pombalino Buildings (Lisbon)." *Journal of Building Engineering* 16 (January). Elsevier Ltd: 184–98. https://doi.org/10.1016/j.jobe.2018.01.001.

Tadeu, S., C. Rodrigues, A. Tadeu, F. Freire, and N. Simões. 2015. "Energy Retrofit of Historic Buildings: Environmental Assessment of Cost-Optimal Solutions." *Journal of Building Engineering* 4: 167–76. https://doi.org/10.1016/j.jobe.2015.09.009.

Tavares, P. F., A. R. Gaspar, A. G. Martins, and F. Frontini. 2015. *The Impact of Electrochromic Windows on the Energy Performance of Buildings in Mediterranean Climates: A Case Study*. *Eco-Efficient Materials for Mitigating Building Cooling Needs: Design, Properties and Applications*. Elsevier Ltd. https://doi.org/10.1016/B978-1-78242-380-5.00018-2.

UNEP/MAP. 2016. *Mediterranean Strategy for Sustainable Development 2016-2025 Investing in Environmental Sustainability to Achieve Social and Economic Development*.

Monitoring and predictive control of LV networks

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Abstract # 87

This paper describes the approach taken in InteGrid project to perform the active management of Low Voltage (LV) Networks, with low levels of observability, exploiting the flexibility provided by Distribution System Operator's (DSO) resources, and private consumers through their Home Energy Management Systems (HEMS). The proposed approach defends a preventive management of the LV network, resorting to forecasts of microgeneration and load to estimate the network's state for future instants.

Introduction

The InteGrid project aims at demonstrating the feasibility of smart distribution networks, coping with a high amount of renewable energy sources (RESs), and making use of the available DERs flexibility for various functions / business cases at different levels. At the LV level, the project is developing and demonstrating a LV state estimation (LVSE) and a LV control (LVC) tool, making use of smart meter data and a complementarily of multiple technologies, offering different types, degrees and levels of flexibility, such as demand response at domestic level and energy storage (at a utility scale or domestic scale).
The interoperability of the Advanced Distribution Management Systems (ADMS) will be ensured by near- real-time and historical measurements as well as by the available flexibilities, allowing producing forecasts and setting control strategies to solve foreseen network problems. A Grid-Market Hub (trading platform) provides the interface between the different actors. Figure 1 shows the general architecture of this solution.

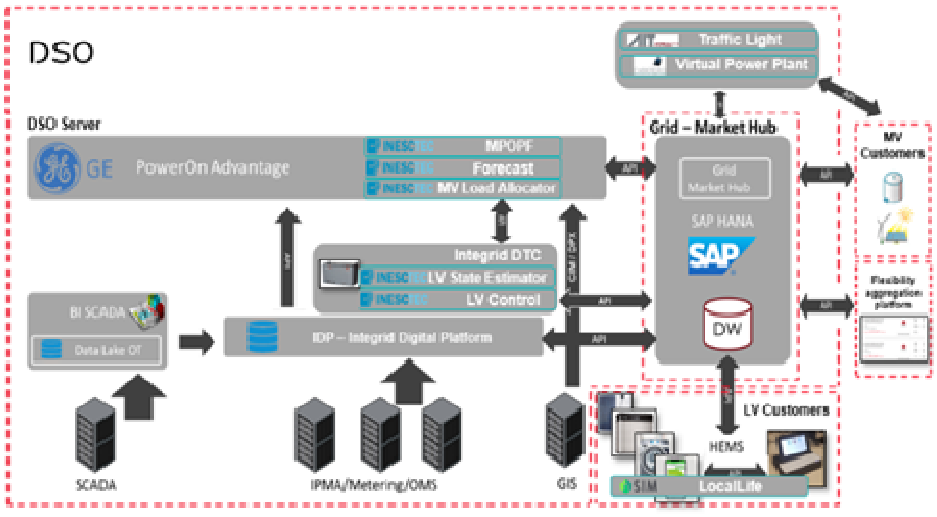

Figure 5: InteGrid Solution Architecture

Distributed Monitoring and control of LV Networks

As previously mentioned, the proposed control approach encompasses two core tools: the LVSE and the LVC. The LVSE provides a full snapshot of the LV network operating conditions (including a probabilistic characterization of the electrical measurements) and it is used to generate voltage alarms that trigger the LVC module.

The LVSE uses historical information gathered by the smart grid infrastructure along with some real-time measurements and exogenous information, like weather forecasts and calendar information (hour of the day, day of the week, etc.). In preventive mode, a few hours ahead, the LVC uses net load and PV energy forecasts as input to define a set of preventive control actions that help keeping voltage within admissible upper and lower limits. Figure 6 depicts this preventive control.

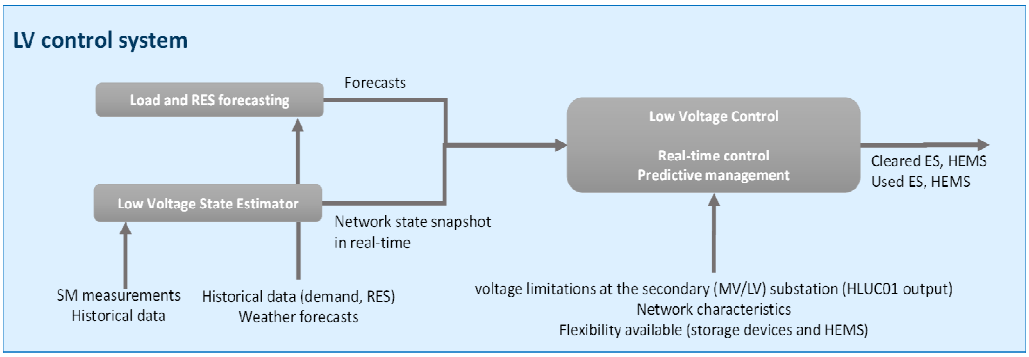

Figure 6: Monitoring and preventive control strategy for LV networks

LV State Estimation (LVSE) Tool

The LVSE is a data-driven state estimator based exclusively on historical data and on a small subset of smart meters with real-time communication of active power and voltage magnitude measurements, bringing the following innovations [1]:

a) Uses a very limited number of real-time metering points (assuming that smart meter measurements are sent every 24 hours or every week).
b) The output takes the form of quantiles representing uncertainty in the state estimation process. This enables the creation of probabilistic alarms for voltage problems, e.g. 95% probability of overvoltage in a specific node.
c) Neither topological information, nor electrical characteristics of the elements of the grid are absolutely necessary.
d) Exogenous variables can be integrated in the state estimation process.

LV Control (LVC) Tool

The LVC tool, initially developed within the framework of FP7 SuSTAINABLE project [2], and further developed in InteGrid [3], has the following innovations:

a) Exploits forecast data to run a predictive management of the available flexible resources, including customer flexibility and DSO owned resources such as Energy

Storage (ES) devices and transformers with On Load Tap Changing (OLTC) capabilities.

b) Uses pre-booked flexibility from domestic clients to manage voltage deviations.
c) Re-evaluates the conditions of the LV grid in real-time using the most recent data available.

Expected results

Monitoring of the low voltage network

Preliminary tests have been conducted to assess the capabilities of the LVSE to provide a more accurate image of the network. Snapshots of the probabilistic results obtained by the LVSE for the voltage magnitude and active power injection in a node of a test network are illustrated in Figures 7 and 8, respectively.

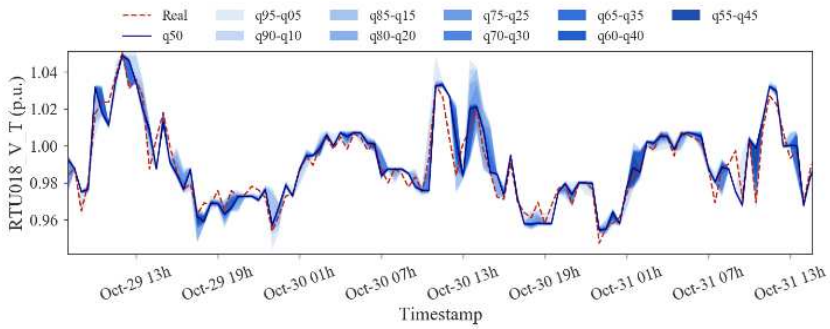

Figure 7: Probabilistic estimation of the voltage magnitude in node 18, phase T

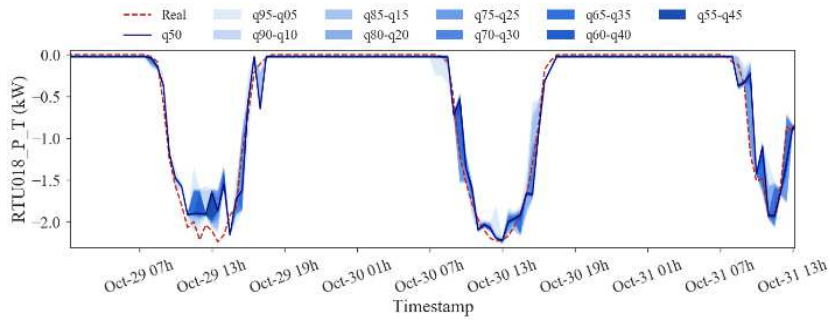

Figure 8: Probabilistic estimation of the active power injection in node 18, phase T

Preventive Control

The LVC tool has been extensively tested, both through simulation and laboratorial tests. Some of the results using a simulation network are presented next. The control variables considered for the algorithm are an MV/LV OLTC transformer, an ES connected to the secondary substation and several HEMS.

In Figure 9 it is possible to see the nodes that present voltage violations for the considered time-horizon, according to the limits established to the LVC tool. The EN 50160 limits and limits used for the execution of the LVC algorithm are also represented. Without any voltage regulation mechanism, most of the network's nodes present voltage violations for

some period. The voltage profiles for the same nodes, after the application of the preventive control LVC algorithm are shown in Figure 10.

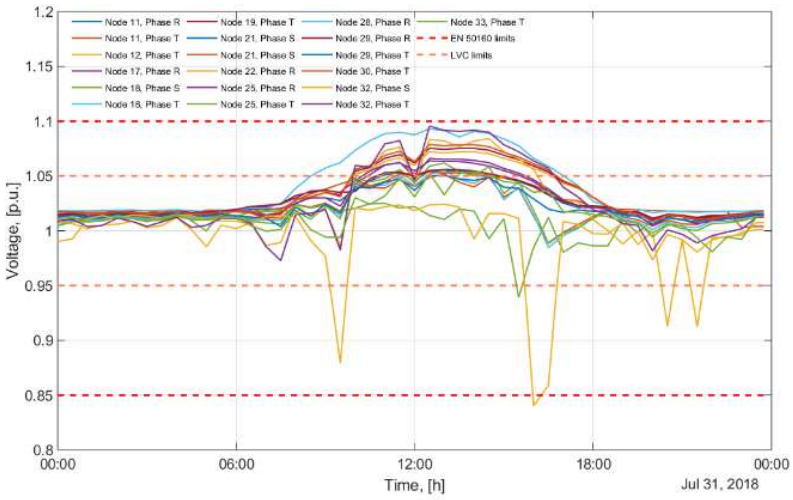

Figure 9: Voltage profiles of the nodes that present voltage violations, before the application of the LVC tool.

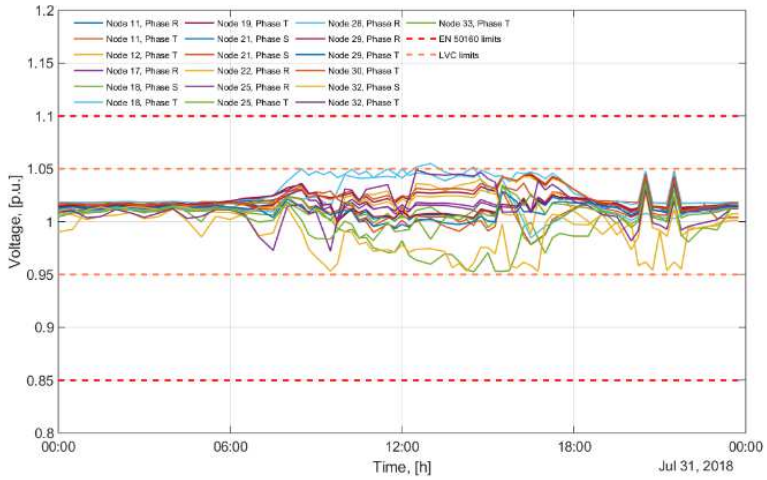

Figure 10: Voltage profiles of the nodes that present voltage violations, after the application of the preventive LVC tool

Conclusions

Both tools presented here are being tested at the INESC TEC's Smart Grids and Electric Vehicles Laboratory, and will then be deployed in a live test environment, in a smart grids pilot operated by EDP Distribuição, during the year of 2019. The pilot is intended to demonstrate the monitoring and control capabilities shown in this paper, using the smart meter infrastructure and exploiting the flexibility provided by DSO resources and private consumers, through their HEMS.

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REFERENCES

[1] Bessa, R.J., Sampaio, G., Pereira, J., Miranda, V. Probabilistic Low Voltage State Estimation Using Analog-search Techniques. *20th Power Systems Computation Conference (PSCC2018)*, Ireland, 2018.

[2] H. Costa, M. Miranda, J. Ramos, L. Seca, A. Madureira, D. A. Lopes, et al., "Voltage Control Demonstration for LV Networks with Controllable DER - The SuSTAINABLE Project Approach," *in Electrical Networks for Society and People, CIRED 2016 Workshop*, Helsinki, Finland, 2016.

[3] M. Simões, H. M. Costa, A. G. Madureira., "Predictive Voltage Control for LV Distribution Grids exploiting Flexibility from Domestic Customers," *MEDPOWER 2018 Conference*, Croatia, 2018.

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