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Book of Abstracts

2nd Symposium on Sustainable Energy Systems

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Book of Abstracts

of the

2nd Symposium on Sustainable Energy Systems

Editors:
Clito Afonso, Manuel Matos, João Peças Lopes, Vítor Leal,
Gil Sampaio, Fabian Heymann

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Edited by **Clito Afonso, Manuel Matos, João Peças Lopes, Vítor Leal, Gil Sampaio, Fabian Heymann**

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Clito Afonso, Chair of the Symposium on Sustainable Energy Systems

Invited Speaker

Session I - Thursday, 8th of June, 11:30h-13:00h

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

'Sustainable Energy?'

There is a rather widespread illiteracy regarding energy, even within technical professional communities, namely, of engineers dealing with energy and yet the relevancy of energy can only be absolute, as its meaning in Greek shows: the cause of the motion, meaning the cause of life.

Yet, most of the energy used by humanity so far is or has been originating, directly or indirectly, somewhere and somehow, from the Sun (solar radiation). With time some of that energy has been stored as fuel reservoirs (oil, gas and coal) as consequence of major changes of biomaterial by solar energy through millennia. Other derived energy from the Sun, in relatively stable global dynamic equilibrium, kept being under the form of mass flows associated to the water down the rivers from higher soil reservoirs or to the air under the wind generated by short-term diverse thermal conditions in different parts of the Atmosphere and the earth movement itself. And, also the energy from the biomass which, beyond the basis for the formation of the fossil fuels referred above, covered great areas of the Continents' surface with a vegetal carpet, by converting the solar radiation with an efficiency of an order of magnitude of around 1% or less. Biomass has been used for millennia to assure the fire - which discovery was a major milestone in the history of Man - to, namely, prepare meals and provide heat for comfort.

A few centuries ago, the discovery of electricity and of the thermal machines, namely the Otto and Diesel engines, led to the emergency of the designated "industrial revolution", a major step that led towards the technological and economic World of today mainly supported on the fossil fuels. Large sectors of industrial activity as well as the urban life and the explosion of mobility led to the use of the current high levels of fossil fuels. All that led to the generalization of high air pollution cases in many industrial and urban areas, a huge environmental problem of heavy consequences to health. And yet, the rising of the CO2 concentration as a component of the atmospheric air affecting the balance of solar radiation 'in' and 'out' of the Planet has created a major problem of overheating for the whole Planet, which will entrain in an associated climate change on Earth, already in course.

Once assessed that CO2 concentration in the air tends to increase as a result of the current trend in the use of fossil fuels, something had be done to find alternative ways for clean energy, namely for electricity. The planning and management of cities in general and the

promotion of new ways of converting the thermal energy from the Sun into electricity should support the economic activity and provide cities with proper mobility and general living and amenity conditions.

The solar energy is an environmentally clean energy that can also be partly used directly, for instance, by making progresses in designing buildings - one of the economic sectors with the highest energy use – to make them less 'energivores', and using solar radiation, a quite accessible vector, to take advantage of its conversion technologies into electricity, heat, and other usable forms.

Here, where we are today: a time of shifting energy resources at the Planetary scale, from fossil to renewable and, in parallel, a trend towards a more efficient use of the energy made available to the users. There may emerge economic problems associated with the change towards the new technologies in the economy since energy is a relevant factor for the economy and for the society wellbeing.

Other type of emerging problematics emerged in association to the envisaged reduction of oil or coal consumption. On the one hand, those are mineral reserves that are abundant in some regions of the Planet and which exploitation is of great economical benefit for the producing countries. On the other hand, there are also difficulties associated to nuclear energy's environmental impact and security, which end up by requiring a major technological investment without waiving the uncertainties in regards to their safety.

Yet, in the context of the energy of the Globe succinctly described above, the point here is to respond to the question of the title now into a clearer formulation: how to make the society of which we part of, converge towards a sustainable energy?

The world political leaders converged on an agreement in Paris 2016 leading to the reduction of CO2 emissions, through the so called 'decarbonization' of the economy by expressing their target result in reducing of 1,5°C the growth of Earth's temperature until 2040. For that purpose, one can expect some consistency on the development and diffusion of solar technologies and of other clean energy technologies but, also, on socio-political measures of planning and managing cities focused on buildings, mobility and economical activities in order to reduce the energy use in parallel with the substitution of fossil fuels to reach the target result.

So, sustainable energy, what?

And, the answer shall be:

To promote:

- Clean energy sources technologies, as explained above;

- Energy efficiency in all use chain from the energy resource down to the energy

service; and

- Energy sufficiency in order to reduce the ultimate energy demand without loss of

quality of services.

In our current courses at FEUP the three themes above must emerge with all evidence, the first two appealing more to the technologies themselves while the last one appealing more to soft societal behaviors, which does not necessarily mean less density and sophistication of knowledge. This branch of the sustainability through energy may include societal concerns so diverse as, comfort, health, urban planning, management and monitoring and controlling and in other different domains such as urban and landscape work, mobility and traffic management and urban quality of life (noise, air quality, traffic jams, etc.).

In conclusion, when we evoke the Paris Agreement (2016) we cannot relax on the simple substitution of the conventional energy sources thinking of the common 'imbecility' of the so called 'energy production', which, in reality does not exist… Still, a lot remains for the culture, knowledge, intelligence and professional ethics as well as for urban politicians to do regarding the link between energy and living prosperously and healthy. At the end, doing so, the energy overall will be remarkably and fatally more sustainable

Oral presentations

Financial aspect for commercial production of portable biogas plant in Pakistan

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Abstract

Biomass is one of the sustainable energy resources which is widely available in Pakistan. The research team has previously developed a modular type floating dome portable biogas plant (PBP) and published its technical results. Now, this paper describes design improvements using manufacturing cost optimization for commercial level production of the same plant. Amount of daily biogas production is 1.21 m^3/day, which is enough to suffice household need in rural area. It is preferred to use locally available material and cow dung is used as biomass source and therefore operational cost is negligible. The cost of production is reduced by using locally available pipe fittings. All the fittings and joints are made using plastic to ensure prevention from corrosion and to ensure long life. The locking mechanism is designed using slots type arrangement. It is done to avoid day to day problem to realignment of the floating dome. The result of financial studies encourages to proceed for manufacturing of this product at mass scale level as a commercial product.

Author Keywords. Biogas, Floating dome type, portable biogas plant, anaerobic fermentation, biomass, waste disposal

1. Introduction

Biogas is a renewable energy source derived from anaerobic digestion of biological wastes. The pre-treatment of waste slurries by producing biogas has become an eco-friendly and a sustainable environmental measure. Efforts have been made in establishing the technology for utilization of biogas and a modular floating dome type portable biogas plant (PBP) has been made for domestic purpose [1]. This study aims to carry forward the previous work done by same research team during development of PBP, the objective of this article is to carryout manufacturing cost optimization of PBP.

2. Materials and Methods

The floating dome type portable biogas plant is designed to have daily production capacity between 1.2 – 1.5 cubic meter of biogas. It is achieved through conversion of cattle dung obtained from two buffaloes/cows (fermentable organic matter) into combustible biogas and fully mature organic manure as byproduct. The complete assembled product has a cow dung holder (2400 liters tank) fitted with an inlet pipe to fill slurry of cow dung and water from the base of the cow dung holder. The top surface of dung in the cow dung holder is enclosed by Biogas Holder. The developed product of portable biogas plant is shown in Figure 1.

The resources available for this project are optimized considering the annual saving by consumer, production cost of the product and annual maintenance cost. The manufacturing cost optimization is done to ensure that floating dome portable biogas plant remain feasible and economical for a livestock owner. It is targeted by the authority that each product should remain below the purchasing power of each livestock owner. Linear programming optimization model is established. The objective function is formulated to minimize the manufacturing cost of the product to be paid by the consumer. The constraints are adjusted keeping in view the matters related to minimum amount saved by consumer through biogas production, daily feed of the cow-dung, capacity constraints of digester & holder tanks, constraints related to fabrication of product and expenses on daily maintenance.

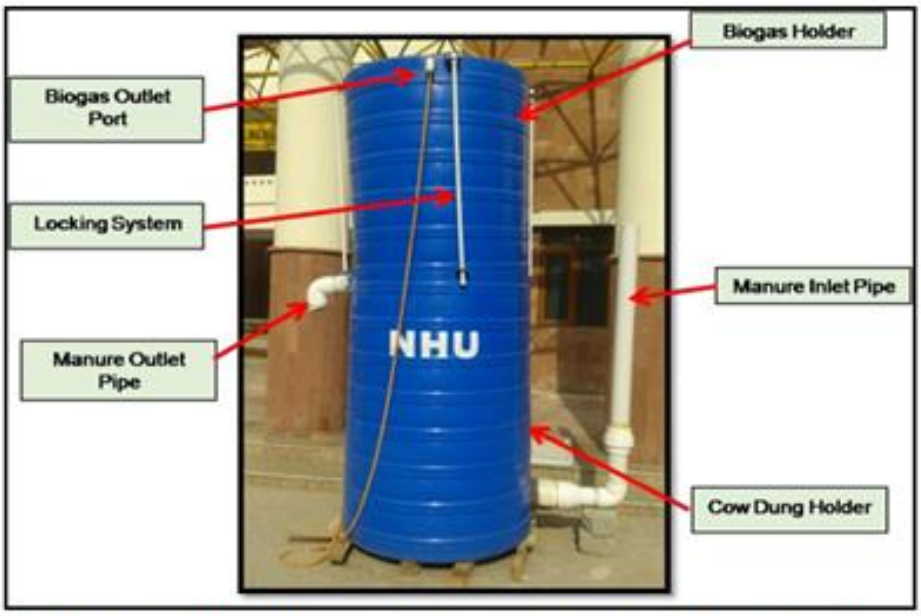

Figure 1 - Assembled floating dome type biogas plant for domestic purpose after design improvements and currently in operation in Karachi, Pakistan

3. Results & Discussion

Amount of daily biogas production is 1.21 m^3/day, which is enough to suffice household need. It is preferred to use locally available material for construction of biogas plant. Cow dung is used as biomass source and therefore operational cost is negligible. The cost of production is reduced by using locally available pipe fittings. Pipe fittings used are plastic having long life. All the fittings and joints are made using plastic to ensure prevention from corrosion and to ensure long life. The comparison table between the previous cost and optimized cost is given in Table 1.

Table 1 - Comparsion of optimized result with previous cost

Amount Spent	Previous Cost	Optimized Cost	Units
Cow dung holder tank (1000 Ltr)	200	169	US$/1000 L
Gas-holder tank (1000 Ltr)	300	274	US$/1000 L
Pipe fitting	30	25.72	US$/Set
Product fabrication	25	20.81	US$/product
Daily feed of cow dung	2	0	US$/kg
Monthly maintenance & Labour Cost	90	60	US$/month

4. Conclusions

Biogas technology offer unique set of benefits, it is sustainable source of energy, benefiting the environment and provides a way to treat and reuse various landfill wastes. The portable biogas plant design presented in this paper is tested and experimental results proved that this portable floating dome type biogas plant is beneficial for its long life, light in weight. It has capacity to sufficiently produce biogas to suffice the requirements of population living in rural areas which do not have access to electricity and natural gas resources but they have livestock. The result of optimization studies encourages us to go for manufacturing of this product at mass scale level as commercial product.

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Primary Frequency Control in the ELECTRA Project

António Coelho[1], Filipe Soares[1], Carlos Moreira[1], Bernardo Silva[1]

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Abstract

This work presents a new approach for primary frequency control in interconnected power systems. This approach is built upon the traditional control, but explores the capabilities that future network components may have, like faster communications and improved computing capacity. Specific control functions were developed aiming at solving frequency deviation problems generated in a control area by using locally available resources. The work presented in this abstract is integrated in the FP7 ELECTRA project, where a new power system architecture – the Web-of-Cells concept – is being developed, together with innovative management and control functionalities to explore the full potential of distributed energy resources.

Subject Headings. electrical energy, energy resources, electricity supply, renewable energy
Author Keywords. Primary Frequency Control, Frequency Containment Control, Power-Frequency Characteristic, Web-of-cells.

1. Introduction

European Union's goals to reduce CO2 emissions and to increase the integration of Renewable Energy Sources (RES) will have a direct impact in power systems, as they will become more decentralized, instead of nowadays centralized system. Several other problems may also arise due to the intermittence and uncertainty associated with those resources. The ELECTRA project aims at developing new approaches for frequency and voltage control with the purpose of solving local problems locally considering the problems that RES impose.

2. The Web-of-Cells Concept

The main concept of ELECTRA is the Web-of-Cells (WOC), which is a group of interconnected cells that makes the systems more stable and secure. A cell is a group of generators, loads or Distributed Energy Sources with a control center that aims at solving local problems by exploiting local resources' flexibility. The cell is controlled by the Cell Operator and can be integrated in different voltage levels. The functions used in the WOC for balance control are Inertia Response Power Control (IRPC), Frequency Containment Control (FCC), Balance Restoration Control (BRC) and Balancing Steering Control (BSC) where the last three are the equivalent of the traditional Primary, Secondary and Tertiary Frequency Control. The IRPC was developed to emulate inertia since Synchronous Generators will be getting out of the system and with this, there would be a lack of inertia, which these generators naturally provide. The focus of this work is the FCC, which will be explained in the next section.

3. Primary Frequency Control in the Web-of-Cells

The core idea of this control scheme is originated from the classic droop control extended and applied to various other resources, including DER and loads. The controller of the devices should interact with higher level functions at cell level for contributing and managing the

overall Cell Power Frequency Characteristic (CPFC), which is a WOC related concept similar to the Network Power Frequency Characteristic. The novelty of the FCC approach is that the CPFC can be adjusted in the moments subsequent to a disturbance affecting the power-frequency control mechanism, depending if the incident occurred inside or outside a cell. At an initial stage, all cells contribute to the problem. Then, when the steady-state is reached, it is evaluated where the problem occurred. If the incident that lead to the FCC activation occurred outside a given cell, the CPFC is adjusted on those cells such that they stop contributing to the power imbalance mitigation and only the cell where the problem occurs has to contribute.

4. Scenarios and Results

The functions developed were tested in a High Voltage grid with 3 cells, composed by Synchronous Generators, Wind and Solar Farms, Loads and Capacitor Banks. Four simulation scenarios were created: in scenario 0, a loss of a generator in each area; in scenario 1, a loss of a generator in area 3 with reduced capacity of the synchronous generator in that area to provide reserves; scenario 2 is similar to scenario 1 but with some adaptions in the models of the FCC control functions, so that, when an area is not able to solve the problem locally, the neighbor cells start contributing again; in scenario 3, the loss of a generator in area 3 with half of the load in the system to test different values of the NPFC.

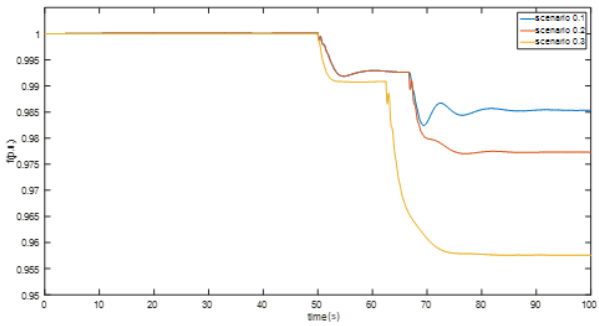

Figure 1: Frequency (Scenario 0)

Figure 1 shows the behavior of the frequency for scenario 0. We can see that the frequency had a first drop, due to an imbalance, and then it stabilizes as the generators in all cells are compensating for the imbalance. Then, after the stabilization, another drop in the frequency occurs because now, only the generators in the cell where the problem occurred contribute to the mitigation of the problem. In scenario 1, it was simulated a situation where the cell where the problem occurred did not have enough reserves to overcome the problem and so, the frequency kept decreasing without reaching the steady-state. To overcome this problem, in scenario 2, it was necessary to make some modifications to the models so that when a cell does not have enough reserves, the other cells contribute again to mitigate the problem. In this scenario, the frequency could reach the steady-state again. In scenario 3, it was studied the response of the system to different values of the NPFC. It was possible to observe that with actualized values of the NPFC, calculated according to the actual conditions of the system instead of a reference incident, the frequency problems were mitigated using less reserves.

References

ELECTRA - European Liaison on Electricity Committed Towards long-term Research Activity Integrated Research Programme (http://www.electrairp.eu)

-This work was developed under the "ELECTRA IRP" Project, which is supported by the European Commission under the Seventh Framework Program (FP7/2007-2013). (Grant Agreement No. 609687)

Project GReSBAS, initial installation of a test site

Antonio Barbosa[1], Filipe Joel Soares[2], José Pedro Iria[3], António Coelho[4], Fernando Cassola[5]

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Abstract

The GReSBAS project is a European project that aims to achieve a set of consumer responses through serious games between homeowners or users of a single building using the last technologies.

The main objective is to make users aware of a more efficient use of electricity while maintaining the same levels of satisfaction and comfort. This can be achieved either by reducing consumption or by relocating it to other periods. These periods may be when energy is cheaper (in case of purchase of energy in the market) or for a period in which there is a surplus of electric energy (for example in the case of micro-generation).

Three test sites will be created for this project, one of which is located in the headquarters building of INESC TEC (replicating a service building) and other two locations in Turkey, more precisely in Istanbul (representing a residential building and a set of germinated houses).

Author Keywords. Gamification, Demand Response, Sub-metering, Automation.

1. Introduction

The testing site in Portugal consists of two contiguous buildings built at different heights, which despite having a similar structure, have different technologies.

Both building have six floors, one of which is below ground. In this concrete floor, we can find some laboratories of the centers associated with the institution. In the floor of architectural quota are the entrances and two auditoriums (one in each building). In the newer building, we can also find a bar/cafeteria. In the four upper floors, we can find most of the 400 employees that make daily use of INESC TEC installation to develop new solutions and new technologies.

In order to obtain a better plan of the energy costs of the building, several consumption meters have been installed that allow the obtainance of a set of information in a predefined time frame. These devices are measuring all the differentials and some more relevant circuit breakers. To safeguard this information, a server will be installed that will allow this data to be stored in a persistent and more accessible way to be used in the various activities of the project. In order to perform the communication between the meters and the server there was necessary to acquire gateways, to make use once the system is fully operational.

2. Materials and Methods

Due to the electrical panels being three-phase, it was necessary to acquire an equipment that makes it possible to collect this information. To do so, the sub-metering equipment uses a set

of three current transformers (one for each phase) that are connected directly to the meter. This way, the gateway will collect this information (throw the various meters) and forward in to the server where it will allow storing the information in a persistent way.

The meters communicate with gateways using PLC (all being in phase R) and later will communicate with the server through TCP/IP in its own VLAN and separated from the other networks communications already existing in the building.

About 170 meters, 12 gateways and 1 server compose the measurement system. Theoretically, the system would work with only one gateway, however, to allow the equipment to communicate its information at most 5 times per second, there was a need to put a more comprehensive infrastructure bottlenecks.

The server will run a MySQL database and a JAVA plugin that communicates with the gateways an also will run a virtualization software to take better advantage of features and ensure more security and redundancy in the date.

The following diagram (Figure 1) represents the assembled system.

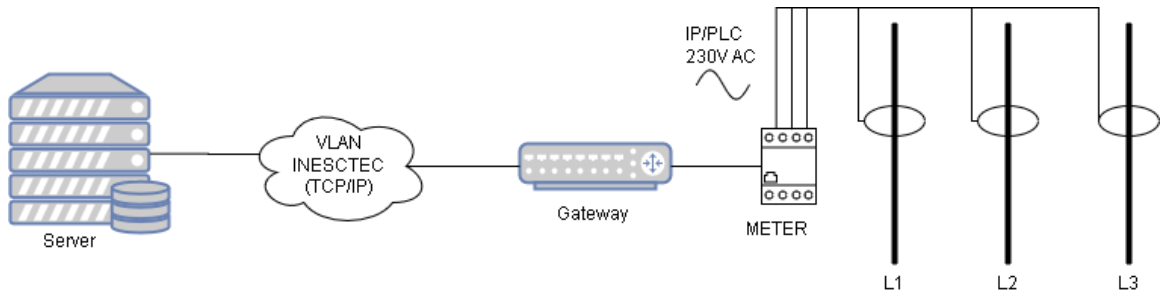

Figure 1: Diagram representing the sub-metering system

3. Expected Results

At this moment, there is no possibility to present actual results because the system is not completely assembled (we are currently working in the software of gateways). However, the information collected is expected to achieve two objectives. The first (and most important in the project) is to create a baseline to be able to have a starting point. The second is the possibility that the building managers can have a more real image of what the building consumes and can act to improve its efficiency.

4. Conclusions

In energy efficiency projects have a great focus on hardware and the possibility of consuming less energy. However, consumers and their behavior carry out an important part of consumption and this is where this project tries to be differentiating in order to alerting and educating the users to the importance of changing habits and cultures for a sustainable energy market.

References

More information can be found at www.gresbas.eu

This work was supported by Fundação para a Ciência e Tecnologia (FCT) under the framework of the GReSBAS project (ref. SmartGP/0003/2015).

Integrated Spatial Load Forecasting for Distribution Network Planning

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Abstract

Spatial load forecasting deals with the anticipation of load changes and is fundamental to distribution grid planning. Increasing use of distributed energy resources require a redesign of established load forecasting routines, considering neutralizing grid impacts by generation and demand as well as technology diffusion dynamics. The presented approach developed a first attempt towards an integrated spatial load forecasting paradigm, predicting the impact of electric vehicle charging to the distribution grid. The work uses open-source geodata and applies the developed toolbox onto a real-word case.

Subject Headings. Electrical energy, energy consumption, energy distribution.
Author Keywords. Spatial load forecasting, Diffusion Theory, Geoinformation.

1. Introduction

The prediction of future electricity consumption and knowledge on its spatial patterns are fundamental inputs for an efficient planning and operation of electric power delivery systems. Spatial load forecasting (SLF) was defined as a process which aims to reduce uncertainty in grid planning by estimating the magnitude and hotspots of future load growth. It is therefore an important part of distribution grid planning (X. Bai et al., 2012). First attempts to spatially predict load growth date back to the 1950's. In the past decades, many works expanded available SLF approaches through the integration of new concepts such as fuzzy inference and evolutionary heuristics (V. Miranda and C. Monteiro, 1999; E. M. Carreno et al., 2010).

With the rising capabilities of Geographic Information Systems and the increasing availability of big data and urban sensing, this is now fundamentally changing. Publicly accessible information does include highly detailed geo-information such as census data-sets, infrastructure and land-use information derived from high-resolution satellite imagery.

2. Materials and Methods

In the planning of electrical distribution grids, new challenges occur with the appearance of distributed energy resources (DER) such as rooftop integrated solar photovoltaics, small-scale combined heat and power plants (CHP) and additional loads such as electric vehicle (EV) charging or electrified heating devices. The dynamics of the adoption of these technologies is not uniform, thus clustering might occur which aggravates the technologies grid impact already under light adoption rates (E. M. Rogers, 1995; M. S. Elnozahy and M. M. A. Salama, 2014). The presented research integrates these new influencing factors which are combined with available locational information of energy consumption trends, land-use changes and technology diffusion dynamics. The integrated spatial load forecasting incorporates several

recent and future energy technologies and applies a highly granular geographic information resolution of 30m to assess load growth while considering HV/MV grid constraints. The table below (Table 1) demonstrates the advances of spatial resolution in load forecasting, showing a clear trend to increasing granularity, reaching cell sizes down to 0.001 km^2 per cell.

Table 1: Spatial resolutions of spatial load forecasting.

Typical resolution of traditional SLF	Resolution in presented research
0.1 – 0.5 km^2	0.001 – 0.01 km^2

3. Discussion

First attempts to build integrated spatial load forecasting focused on the effect of EV charging on HV/MV distribution grid in Porto municipality. The developed methodology extended traditional spatial load forecasting while adding diffusion theory elements to analyze the spatial patterns of future EV charging demand. The case study relied on open-access data on HV/MV substations and geo-referenced census data. Developing a deterministic framework to forecast spatial EV charging patterns to Porto municipality, first outcomes suggest that EV adoption hotspots might occur, which would surpass the installed transformer capacities for EV penetration rates of 25% and above considering a charging rate of 7.4kW.

4. Conclusions

The transformation towards distribution grids with high shares of DER and additional kW-intensive appliances require new tools to assess the impact these technologies will impose to the electricity networks. Integrated spatial load forecasting provides these capabilities, taking advantage of open access geoinformation with high cellular resolutions up to 30m.

Acknowledgement

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Performance assessment of wastewater treatment plants using Data Envelopment Analysis

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Abstract
This research describes a performance assessment of wastewater treatment plants (WWTPs) using the Data Envelopment Analysis technique. The procedure proposed can have a key role in supporting utilities activity. It enables a comprehensive understanding of utilities performance, helping managers to fast detect and monitor efficiency degradation and prioritize technical interventions. The study includes the estimation of the potential for improvement of the inefficient facilities independently of the contextual conditions. The potential performance improvements are provided in terms of resources' utilization (energy and labor), considering the amounts of pollutants removed and the volume of wastewater treated. The applicability of the performance assessment framework developed is illustrated using the WWTPs of a Portuguese water company, Águas do Centro Litoral (AdCL).

Subject Headings. Energy, Environment, Business and Competition.
Author Keywords. DEA; wastewater treatment plants; performance assessment.

1. Introduction

WWTPs have significant impacts on the environment and society, as they influence the entire water cycle by preventing pollution of surface water. However, they are energy-intensive facilities due to the nature of processes conducted. The main purpose of this study is to guide improvements in the overall performance of WWTPs through the evaluation of the utilities' technical efficiency levels. The focus of the analysis is the optimization of the levels of resources used (energy and labor). In particular, energy is a critical resource for the company and its excessive consumption may be avoided by the implementation of cost-effective operational practices. The novelty of the study is the application of DEA methodology to address the challenges involving the achievement of operational excellence. It also contributes to the identification of the most important drivers of good performance in the water sector.

2. Materials and Methods

DEA, first introduced by Charnes et al. (1978), is a linear programming technique for comparing the efficiency of a relatively homogeneous set of organizational decision making units (DMUs) in their use of multiple resources (inputs) to produce multiple outcomes (outputs). DEA derives a single summary measure of efficiency for each DMU (water utilities in our study), based on a comparison with the achievements observed in other DMUs in the

sample analyzed. DEA identifies the subset of efficient DMUs that represent the benchmarks. Further details on the DEA technique can be found in Cooper et al. (2007).

The efficiency analysis using DEA can be followed by a second stage analysis to study the impact of the context in DMUs performance. Our study used a truncated linear regression as the second stage methodology. The objective is to estimate the real potential for improvement, i.e., the potential achievable independently of the contextual conditions.

The study used a sample of 41 WWTPs operating with activated sludge technology for the secondary treatment. The data analyzed corresponds to the year of 2015 and was provided by the company. The DEA model was specified with 2 input indicators (energy balance and number of full time equivalent workers), and 3 output indicators (organic matter measured as chemical oxygen demand, total suspended solids and the volume of wastewater treated). The contextual factors considered were plant size, percentage of utilization of the installed capacity, sewage biodegradability, type of secondary treatment technology, plant age, the existence of tertiary treatment and nutrients removal.

3. Discussion

The analysis conducted assumed that WWTP operates under variable returns to scale. The mean efficiency value was 66%, with a standard deviation of 24%. Only 8 plants achieved a score of 100% in the DEA model. The potential for improvement identified was a reduction, on average, of 34% in the energy indicator and a reduction of 38% in the labor indicator. Regarding the impact of the operating context on efficiency results, it was found that the scale size is a critical factor affecting performance, with the largest plants achieving the highest efficiency levels. Other factors statistically significant in explaining some of the inefficiency detected were the percentage of utilization of the installed capacity and the existence of a tertiary treatment. The former indicates that the plants with a higher utilization of the installed capacity tend to be more efficient. The latter indicates that the plants conducting a tertiary treatment tend to exhibit lower values of efficiency, as could be expected given the fact that this process is demanding in terms of energy consumption. It was concluded that the greatest potential for performance improvement lies in internal actions leading to operational improvements. The implementation of best practices observed in benchmarks could lead the company towards operational excellence. Furthermore, the information obtained can also help defining priorities in asset management actions and policies design.

4. Conclusions

The study highlights the applicability of quantitative performance assessment methods in the pursuit of operational excellence. In particular, the use of DEA as a decision support tool for public utilities management was demonstrated using a real world case study consisting of WWTPs from a Portuguese company. The potential for efficiency improvement was identified using as reference the best practices observed within the company, such that improvements can be promoted by sharing knowledge and information among peers.

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Development of natural fiber reinforced polymer composite as construction material for thermal insulation application

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Abstract

The development of low cost polymeric reinforced composites and decline in harmful destruction of ecosystem leads the researchers towards the production of natural fiber reinforced composites which are entirely green. The use of natural fibres as reinforcement in composite materials has amplified enormously. Application of composite materials to structures has presented the need for the engineering analysis; the present work focuses on the fabrication of polymer matrix composites specifically for thermal insulation usage by using natural fibers which are abundant nature. Natural fibers including bamboo, jute, coir, cotton & sugarcane were selected and matrix material (Epoxy) were used to make composite. Vacuum assisted Resin Transfer Molding (VaRTM) method was selected for the development of composite material and sample with all natural fibers have been prepared. Thermal conductivity test was performed on prepared samples for thermal insulation capacity. Later, hardness and tensile tests were implemented to find mechanical properties of composite material.

Author Keywords. Natural Fiber, Sustainable, Reinforced Composite, VaRTM

1. Introduction

Natural fiber as a replacement to synthetic fiber in polymer matrix is the focus of many scientists and engineers. The reason for focus on natural fiber reinforced polymer matrix is because of its low cost, low effect on environment and it shows good mechanical properties compared to polymer resins [1]. Extensive work has been carried out on natural fiber reinforced composites and when compared to the research on mechanical properties of natural fiber composites, the analysis and evaluation of thermal properties is left a step behind [2]. Therefore, the focus of this work is to investigate the thermal properties of composite by considering some natural fibers which are not explored so far. In that aspect the thermal conductivity characterization of bamboo fiber, coir fiber, jute fiber, sugarcane fiber and cotton fiber reinforced polymer composite have been investigated. Objective of the research was to make a composite material for construction purpose which provides thermal insulation properties in conjunction with good mechanical properties.

2. Materials and Methods

Vacuum assisted resin transfer moulding (VaRTM) is composite manufacturing process with its distinguishing characteristic being the replacement of the top portion of a mold tool with a vacuum bag and the use of a vacuum to assist in resin flow. The process involves the use of

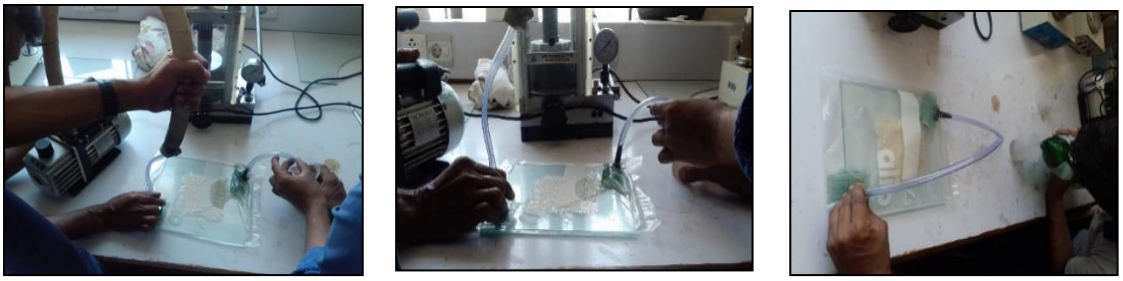

Figure 1: Vaccum assisted resin transfer moulding setup

a vacuum to facilitate resin flow into a fiber layup contained within a mold tool covered by a vacuum bag. After the impregnation occurs the composite part is allowed to cure at room temperature with an optional post cure sometimes carried out. VaRTM setup is shown in figure 1.

3. Results & Discussion

The samples prepared were in accordance with the ASTM Standards. The standards used for the test were ASTME1225 for Thermal Conductivity test, ASTM D3039 for Tensile test and ASTM 785 for hardness test. Table 1 shows Thermal conductivity test results for prepared samples. Table 2 shows Break Load, Tensile Modulus and UTS Values of prepared Composites. The Results of Rockwell Hardness Test has been shown in Table 3.

Table 1: Thermal conductivity test results

Composite	Break Load(kg)	Tensile Modulus (N/mm^2)	UTS(N/mm^2)
Cotton	9.513	5136.27	280.25
Coir	3.1	3822.5	94.913
Bamboo	14.313	2277.23	50.641
Jute	5.832	4589.68	123.01
Hybrid (Coir + Jute)	8.503	4285.20	65.302

Table 2: Break Load, Tensile Modulus and UTS Values of prepared Composites

Polymer Matrix Composite	Indenter Used	Load in Kg	RHN
Coir			85C
Cotton			72C
Bamboo	Diamond Indenter	150	66C
Jute			42C
Hybrid (Coir + Jute)			74C
Coir			73B
Cotton			81B
Bamboo	1/16 ball indenter	100	67B
Jute			79B
Hybrid (Coir + Jute)			77B

Table 3: Results of Rockwell Hardness Test

Name of Sample	Results (KW/m.K)
Sample J (Jute Fiber)	0.48
Sample B (Bamboo Fiber)	0.39
Sample C (Coir Fiber)	0.40
Sample CT (Cotton Fiber)	0.46
Sample H (Hybrid[Coir + Jute])	0.37

4. Conclusions

The prepared samples underwent tensile tests, hardness tests and most importantly thermal conductivity tests. Hybrid sample (Coir + Jute) shows best thermal insulation properties moreover the sample also restrained better mechanical properties as compared to other thermal insulation material for building and construction purpose.

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Potential of Demand Flexibility to Enhance Distribution Grids Operation

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Abstract This paper presents a study about the influence of Distributed Energy Resources' flexibility on the operation of a Medium Voltage network, in a Smart Grid environment. An AC multi-temporal Optimal Power Flow (OPF) tool was developed and used to simulate the impact of the DER flexibility (including electric vehicles (EV), controllable loads and micro-generation) in distribution network operation. Some simulations are presented, demonstrating the impact that DER flexibility can have on solving operation problems namely in terms of voltage limits.

Subject Headings. Distributed energy resources, Load shifting, Multi-temporal OPF, Smart grids.

1. Introduction

A new paradigm in power system has been the theme of discussion due to the increasing integration of distributed energy resources (DER) (Madureira et al., 2013). This new paradigm increases the complexity of network operation process and creates new and interesting challenges that should be further investigated, such as the optimal management of resources' flexibility and their utilization in enhancing network operation. The integration of DER in distribution networks is already known to bring some problems related to voltage and branch limits violations, principally in the peak load periods. However, the integration of such resources also increases the network's overall flexibility, as it will demonstrate in this paper.

2. Problem formulation

A multi-temporal OPF tool was developed based on the MatPower OPF formulation (MatPower, 2016). The objective function is simply a summation of individual polynomial cost functions of real and reactive power injections (f^P and f^Q) and is given by (1). In addition to the classic OPF constraints, (2) to (4), some others are considered, related with inter-temporal dependencies (e.g. the state of charge EV) or related with load shifting.

$$\min_x \sum_{t=1}^{n\_period} \sum_{i=1}^{n\_generators} (f_{it}^P(P_{it}^g) + f_{it}^Q(Q_{it}^g)) \tag{1}$$

$$\sum_{k=1}^{n\_gen\_in\_i} \mathrm{P}_{ik}^g - \mathrm{P}_i^{load} = \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{V}_i \mathrm{V}_\mathrm{j}[\mathrm{G}_{ij}\cos\theta_{ij} + \mathrm{B}_{\mathrm{ij}}\sin\theta_{ij}] \tag{2}$$

$$\sum_{k=1}^{n\_gen\_in\_i} Q_{ik}^g - \mathrm{Q}_i^{load} = \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{V}_i \mathrm{V}_\mathrm{j}[\mathrm{G}_{ij}\sin\theta_{ij} - \mathrm{B}_{ij}\cos\theta_{ij}] \tag{3}$$

$$S_{ij}^{\min} \le S_{ij} \le S_{ij}^{\max} \tag{4}$$

$$x_i^{\min} \le x_i \le x_i^{\max} \tag{5}$$

$$SoC_{et}^{\min} \le SoC_{et} \le SoC_{et}^{\max} \tag{6}$$

$$tan_{lt}(\varphi) * P_{lt}^g - Q_{lt}^g = 0 \tag{7}$$

$$\sum_{j=0}^{24} \left(-\varepsilon_e^{cons} * P_{et}^{cons} - \frac{1}{\varepsilon_e^{inj}} * P_{et}^{inj} \right) = p * SoC_e^{\max} \tag{8}$$

$$\sum_{t=1}^{n\_periods} \left(\mathrm{P}_{lt}^{increased} - \mathrm{P}_{lt}^{decreased} \right) = 0 \tag{9}$$

The constraint (6) imposes the limits of state of charge of the device *e* - SoC_{et} -, where *e* represents the EV batteries. (7) assures that active and reactive power, P_{lt}^{g} and Q_{lt}^{g} in the remaining load, at time t, maintains the same proportion as the original load. Restriction (8) assures that the EV batteries' state of charge is at a certain percentage, *p*, of its maximum capacity at the time of disconnection, 100 % for the following studies. ε^{cons} and ε^{inj} are the EV's charging and discharging efficiencies. Lastly, (9) assures that the entire decreased load, $P_{lt}^{decreased}$, is replaced in some other period.

3. Discussion

A network based on a real 15kV Portuguese network was used to test the proposed model. In order to access the DER flexibility impact in the network operation, two different scenarios were compared in an hourly basis. Scenario 1 represents a situation with a high DER integration, but no flexibility, presenting two problems: the inversion of power flow around 10 a.m. and the violation of the minimum voltage around 9p.m, Figure 1. Scenario 2 assumes the possibility of DER flexibility operation. The proper operation of the flexible resources results on a new voltage profile, free of violations. Furthermore it also decreased the network power losses, by relieving the network power flows on peak hours, softening the consumption profile.

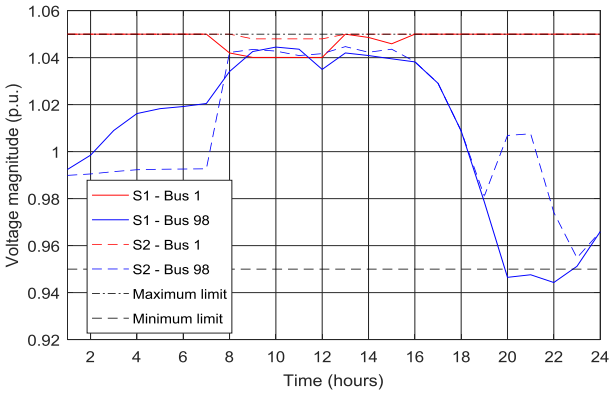

Figure 1: Voltage profiles in two extreme buses, for both scenarios.

4. Conclusions

Some of the problems DER integration can bring to the network operation were observed, namely voltage violations, during peak hours, and reversed power flows, during high production hours. Although DER integration bring such problems, it also increases the network overall flexibility. If one aims at maximizing the DER integration, the way to deal with these problems may be by exploiting the DER flexibility. The proposed model presents an efficient way to define daily operations load shifting, solving problems related with voltage violations, decreasing the network losses and avoiding reverse power flows.

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Profitability of Variable Speed Pump-Storage-Power in Frequency Restoration Reserve

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Abstract
Traditional fixed speed pump storage units typically operate in the day-ahead (DA) market to perform price arbitrage. Variable speed pump storage can not only participate the DA market but also contribute to frequency restoration reserve, given their ability to control its operating point in pumping mode. This work does an extended analysis of a complete bidding strategy for Pumped Storage Power, enhancing the economic advantages of variable speed pump units in comparison with fixed ones.

1. Introduction

Reversible hydro power plants with reservoir (Pumped Storage Power - PSP) are the most mature storage technology. Typically, fixed speed PSP participates in the day-ahead (DA) electricity market for price arbitrage and, in specific cases, provision of downward replacement reserve (RR). Due to technical limitations, the current fixed speed PSP technology does not participate in the frequency restoration reserve (FRR). In contrast, variable speed PSP units cannot only participate in RR but also in FRR, given their flexibility to quickly change the generating/consumption operating point. In this paper it is presented an extended analysis of the complete bidding strategy previously presented in [1] for operating a PSP unit in the DA market, by performing price arbitrage, but also bidding in the ancillary services market. Compared to [1] the present paper has the following original contributions: a) the possibility to operate either with one or two groups of machines and b) a fairer economic analysis, by comparing two PSP that bid in both markets, one with a fixed speed and the other variable.

2. Bidding Strategies Framework

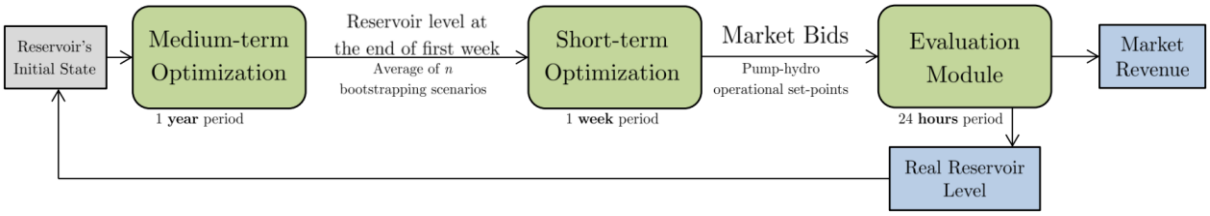

***Figure 1** – Architecture of the Optimization Framework*

Figure 1 depicts the overall bidding strategy framework for the participation of a PSP unit in the DA and FRR markets, which is divided into three modules. As it is clear from the interpretation of Figure 1, the strategy implementation is cyclical. After calculating the updated level in the reservoir, this value is then used as the initial state and the strategy restarts.

The medium-term optimization model uses the concept of water value to find the optimal allocation of the water resource throughout the year, considering weekly periods (i.e., 52 weeks).

The short-term optimization is responsible to optimally define the operating set-points of the PSP. The formulation of this optimization model presumes that it is not possible to determine *a priori* the amount of electrical energy that will be activated used from the available reserve band. Thus, the revenue for the FRR is represented in the objective function only for the reserve capacity price. Following the same logic, the amount of reserve band made available to perform FRR does not affect

the rate of discharge/pumping water flow or the amount of water available in the reservoir. To avoid situations where the energy used in the FRR would result in the violation of a reservoir level it is assumed that a portion of the reservoir is allocated solely for the purpose of FRR. In order to define the set-points the algorithm relies on a set of forecasted data, such as DA and FRR market prices and natural water inflows, as well as the technical characteristics of the unit. The objective function aims to maximize the revenue of the system in both markets, DA and FRR, for a period of one week.

To assess the performance of the bidding strategy an evaluation module emulates the real operation, by applying the markets bids determined by the optimization problem to real market conditions. Since FRR remuneration is made in two fractions, reserve band and energy activated, it is necessary to estimate the latest based on the ratio of the overall energy used and the total amount of FRR reserve contracted. The amount of energy used is also relevant to update the level of the reservoir, since, the use of the PSP unit to perform downward regulation results in more water stored in the reservoir. The detailed description of this framework can be found at [1].

3. Case Study

To accurately represent the conversion between water flow and power, we applied a methodology adapted from [1] to the s-shape characteristic curves (normalized for the point of max efficiency and fixed head, for all the gate openings, provided by the manufacture of the machine. An economic analysis (Table 1) was made by comparing the revenues of variable speed PSP with a fixed one, as well as comparing the operation with just one group of machines versus two groups, in the Iberian Market environment. As expected, with variable speed PSP the revenue from the DA market suffers a small decrease, but it is largely compensated by the revenue from the FRR market. The overall revenue of a PSP with variable speed achieves an increase of 12% in comparison with a fixed one. Additionally we can observe that doubling the amount of machines does not guarantee a proportional gain in terms of revenue, predominantly due to the limited size of the reservoir. Since the amount of energy used from the reserve band was not considered in the short-term optimization model, it is possible that during the operating day the reservoir level could be above or below its technical limits. Furthermore, forecasting errors on the natural water inflows could also result in discrepancies between expected and real amount of water stored. In this case study, the real reservoir level is, rarely, greater than the expected, while the opposite is frequent. However, during all the simulation, only 1.9% of the hours registered a real reservoir level bellow its minimum. This deviation indicates that if we increase the minimum reservoir level by 1.5hm^3, it is expected that the technical constraints would not be violated.

	Single Group Mach.		Two Groups Mach.	
	Fixed Speed	Variable Speed	Fixed Speed	Variable Speed
Day-ahead	33.1	31.34	40.28	36.27
Frequency R.R.	37.45	44.01	63.68	80.03
Total	**70.55**	**75.35**	**103.96**	**116.3**

Table 1 *– System Revenue from DA and FRR, cosidering pumping with variable and fixed speed*

4. Conclusions

In [1] was demonstrated the validity of the bidding strategy as well as the economic benefit of adding the FRR to the PSP market portfolio. In this paper the same strategy was applied with two added features: representation of losses, both hydraulic and electrical, and the possibility to operate with one or two groups of machines. It was shown that a PSP with a variable pump unit could increase its revenue by 12% in comparison with a fixed unit. Furthermore, the amount of groups of machines does not led to a proportional gain in revenue, since it is constraint by the stasis of the storage capacity. It was also concluded that the consequences arising by discrepancy between expected and real reservoir level could be mitigated by increasing the reservoir's minimum level constraint by 1.5hm^3.

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Defining Planning and Operation Guidelines for European Smart Distribution Systems

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Abstract
During the last decades, the planning and operation procedures of power distribution grids have been changing, being one of the main reasons the high penetration of Distributed Energy Resources (DER). However, distribution grids, which have been designed to supply customers through unidirectional power flows coming from the transmission network, may not be able to overcome technical issues brought by the inclusion of DER. *SmartGuide* is a research project which main objective is to tackle these issues through the development of improved and generalised planning and operating guidelines for European smart distribution systems, considering RES and the demand-side that arise from smart market applications.

Subject Headings. energy policy, energy resources, electricity supply, renewable energy, energy technology.
Author Keywords. Smart grids, guidelines, planning of distribution systems, operation of distribution systems.

1. Introduction

Future electrical distribution systems will come across many modifications mostly due to new paradigms both at conceptual and technical levels. The integration of RES in existing European energy distribution systems all over Europe is being promoted following the climate and energy 20/20/20 targets of the European Union (EU). Smart Grid (SG) technologies are important to ensure cost-effective expansion of distribution systems. Naturally, the use cases may vary from country to country depending on country specific regulatory and legal parameters as well as historical and geographical conditions, which lead to different grid topologies and operation principles. *SmartGuide* is an on-going project aiming to identify the current solutions in use and the nearby tendencies allowing tackle the possible gaps that persist in the operation/planning of distribution systems through the analysis existence practices of four European countries (Portugal, United Kingdom, Norway and Germany).

2. Scientific approach

SmartGuide is building upon existing knowledge on operation and planning of distribution networks through the review of current state-of-the-art on distribution network planning and the existing practices in the countries involved in the project as well as the potential smart grid business models. Then the mains focus will be on developing simulation skills that permits capturing smart grids control instruments and inserting them in the network planning actions. Figure 1 shows the planning methods and tools intended to be produced within this project.

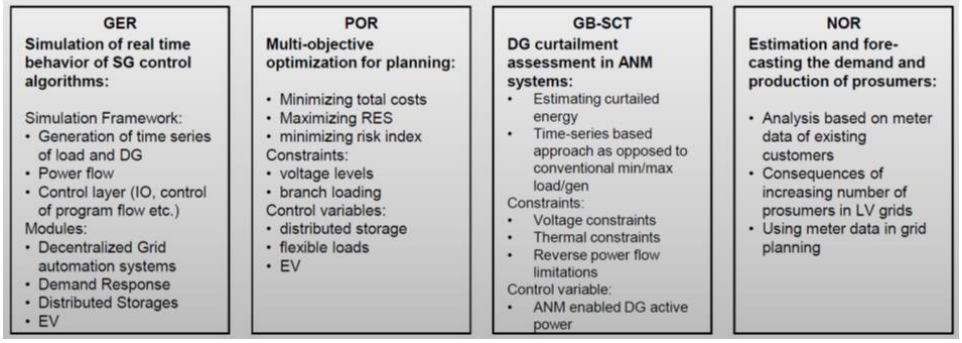

Figure 1: Planning methods and tools of SmartGuide project.

The individual conclusions obtained in these processes can be compared and European-wide guidelines can be established using the resemblances found and local challenges and overall gaps will be clearly identified.

3. Innovative content

This project aims to define new guidelines that will face the challenges of RES integration and consider the possibilities of smart grids and Active Network Management (ANM). DSOs could choice appropriate technologies and build smart grids with less effort using the mentioned guidelines. This will clearly instigate the market acceptance process of smart grid technologies in MV and LV grids. Country specific planning guidelines could be carried to different European countries, so that they are replicated, enhanced and scaled-up to business as usual.

4. Expected impacts

This project will be encouraging the standardization of EU-wide policies and confronting the specificities of each DSO through the definition of clear planning and operation rules, as well as a proper regulatory framework. Also, it will contribute to best practices when introducing DER in the MV and LV grid, and knowledge sharing between countries. Improved and generalized planning and operation guidelines will exist, which can be used by DSOs to adopt existing grids considering future demands of smart markets and integration of decentralized, RES. The project will contribute to increase the rollout of smart technologies as well as the development of new smart technologies and applications (DSOs are afraid to invest too much in flexibility if the investment is not covered by their regulated activity).

5. Conclusions

By endorsing smart grids, the project will be promoting renewables and carbon free grids in Europe. Moreover, the project results will have an impact on society at large by optimizing existing capacity usage by making smaller investments in SG and by reducing the countries energetic dependence in foreign fuel sources. So far, in spite of the different states of integration by the solutions/technologies in each country, it is possible to see a global common transition to a smarter, more interoperable and standardised distribution power system throughout Europe.

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Integrated energy solutions towards sustainable isolated communities

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Abstract
Since any activity requires energy, access to energy is an essential means for all. Especially isolated communities in developing countries often have no or limited access to affordable energy resources. Despite the use of premier resources such as wood and dung, the minimum level of energy needs can frequently not be reached. Plus, these resources cause indoor air pollution and health problems.
An integrated approach for isolated communities to improve access to energy and increase the level of health and well-being in housing will be presented. Housing and other physical elements and conditions of such communities will be analyzed so that sustainable livelihoods can be achieved. Thereby the needs and opportunities for the enhancement of housing and living in general have to be balanced. In the end, planning for sustainable livelihoods requires an integrated framework to guarantee sustainable development and growth.

Subject Headings. Renewable energy, energy resources, energy technology, energy consumption, use of energy
Author Keywords. Energy access, sustainable livelihoods, isolated communities

1. Introduction

The motivation of this research is to respond to the "energy for all" leitmotiv and discuss the problematic of how to conceive integrated energy solutions at isolated village-level. Merit is placed on an 'integrated concept' to support local decision makers with more adequate solutions to provide energy to fulfill both electric and thermal needs, based on available local resources and taking advantage of the recent technology developments.

The concept is intended for isolated communities with poor financial conditions that are unlikely to be grid connected due to the enormous distances among them and limited access to modern fuel. At the same time, the lack of literacy and the high poverty levels force most inhabitants of these areas to use whatever resources and conversion devices are available. Sustainability and the attenuation of current indoor pollution problems have to be addressed in this context. This research is an attempt to discuss proposals on a topic where many opportunities are waiting for decision makers to take the most appropriate decisions.

2. Energy Issue and Sustainable Development

The energy issue is a widely discussed theme that is associated with a wide variety of problems as, for instance, availability of resources, conversion technologies, security of supply, cost, environmental impact etc. Though, three basic aspects have to be assessed in the context of energy issues: the energy resources which are itself an integral part of the environment; the purpose of the energy which is to aim for well-being and sustainable development; and the technology capabilities to exploit the natural energy resources converting them into affordable final and useful energy products.

3. Proposed Approach

A conceptual framework, representing the overall energy system within the objectives of the energy triangle (economic, energy access and environmental sustainability) will be discussed. A village (basically any isolated community) simplifies the core of this framework. In the first phase the current energy carriers in use shall be identified. Then the conditions in and around the village have to be assessed, whereas village demography, topography and resource availability are key aspects. Critical reflection should also be placed upon the availability of land, the influence of extreme weather events (i.e. if annual monsoons lead to local floods) or the possibilities of connecting to the outside world. Especially the latter aspect can demonstrate a village's reliance on certain imported energy sources (i.e. kerosene, diesel or paraffin). Additionally, the evaluation of resource conditions requires an assessment of the availability of abundant resources. Certainly, there would be no interest to assess the possibilities of a wind turbine, if wind is not available for longer periods during the year. Similar accounts for hydro power, which in most cases is scarcely available all around the year and, thus, may compete with other uses such as agricultural activities.

The second phase focuses on social elements, which include stakeholders, local government and businesses as well as production activities. All of those elements contribute in shaping the physical conditions of the village. Hence, the acceptability and adaptability of modern energy systems within the village have to be analyzed. Opposition against modern technology or the favoring of a specific technology solution can become a considerable obstacle for the implementation of some systems. Consequently, education about and an introduction to modern technologies becomes a key factor before any implementation.

The framework continues with a focus on boundary constraints. As such, physical and social elements limiting the performance against the energy objectives have to be assessed. Commonly analyzed constraints should include: land, water, wind, wood, solar radiation, availability of energy reserves, geographic setting and climate, security of supply, economic growth in the community, etc. All of the boundary constraints fall under the umbrella of the energy triangle, whereas it is intended to provide and increase energy access considering economic development in an environmentally sustainable manner.

Along those elaborations the conceptual framework sets the scene when planning to improve energy access in isolated communities. It is clear that not all aspects can be evaluated or assessed. Nevertheless, decision makers can be supported in understanding the complexity of making decisions and how to select modern energy technologies to supply the respective energy requirements. Thereby, emphasis is placed on designing solutions that improve the performance of the overall community, rather than a specific household or service. Only with the diversity of supply alternatives threatening indoor air pollution and health issues can be overcome.

4. Conclusions

This work illustrates the completeness and richness of an integrated process when searching for energy solutions for isolated communities with no or limited access to energy networks from national grid systems or others. It highlights the importance when dispersed or decentralized energy systems have to be considered appealing to the combination of intermediate and renewable energy technologies at different sizes and scales. This integrated approach appears to open up a compromise between the difficulties of financing infrastructure of large areas of the globe where over 1 or 2 billion people still rely on premier resources and the need to respond in a reliable, economic and sustainable manner.

Designing and fabrication of a portable water purification system for remote regions and disaster affected areas

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Abstract

Water is an essential element for human and domestic life, yet millions of people throughout the world do not have adequate drinking water. Therefore, the human driven water purification system is designed to address the difficulties of accessing clean and safe water in remote regions, as well as the developed urban areas of country where access to clean water is not possible for the residents. The Water Purification System is also designed for natural disasters (flood, earth quake, etc) affected areas, as contaminated water is the main and the most severe issue. Even in developed cities like Karachi, many citizens face challenges securing water free from contaminants such as bacteria, viruses, and dissolved impurities. The Human Powered Water Purification System is designed to reduce pathogenic contaminants along with dissolved salts from source water using a membrane technology. The design utilizes pedal power to drive the membrane filtration process. The main force of membrane technology is the fact that, this is a low energy intake technology which works without additional chemicals, on top of easy and well-arrange processed conductions. The system has been designed in a way that only one individual is required for its operation. The system achieves a level of purification as fine as 0.2 microns. The system is capable of being powered using human pedal power, can produce 1 L of potable water after 6 minutes of operation, can remove all existing levels of Coli forms, bacteria and E. Coli from water, weighs 35 kg and comes out to enclose a volume of 1 m^3. The cost to construct the final prototype was USD 400.

Author Keywords. Human Powered, Instantaneous, Purification

1. Introduction

It has been estimated that water, sanitation and hygiene related diseases cost Pakistan's economy about Rs.112 billion per year, in terms of health costs and lost earning. While the filtration plants installed in the federal capital are supplying highly unsafe water contaminated mainly with microbial contamination. Situation is even worse for the rural areas of the country where 88 percent of the population lacks access to safe drinking water. Due to climate changes, Pakistan has been facing natural disasters like floods more frequently, which results in the clean drinking water crisis. Therefore, access to potable water is an exceedingly urgent issue in which action should be taken immediately. In response to such a need, this idea of purifying water by means of human power is taken into consideration and successfully implemented.

2. Materials and Methods

Considering all aspects of cost, weight, operating and maintaining requirement authors came up with a model as shown in figure 1. The designed system has crankshaft assembly (having pedal crank assembly and intermediate sprocket assembly), pump drive assembly and process flow (filtration membranes).

Pedal crank assembly was used to extract human power, than transmit it to intermediate sprocket assembly where the provided angular speed was amplified and transferred to the pump to provide required head. Multiple filtration Membranes were used to clean the contaminated water from pathogenic and all undesirable compounds. The membranes used

in our system are ceramic filter, Activated Carbon filter and musaffa filter. A process flow diagram of the final system is shown in Figure 2 below:

Figure 1: Human Powered Water Purification System

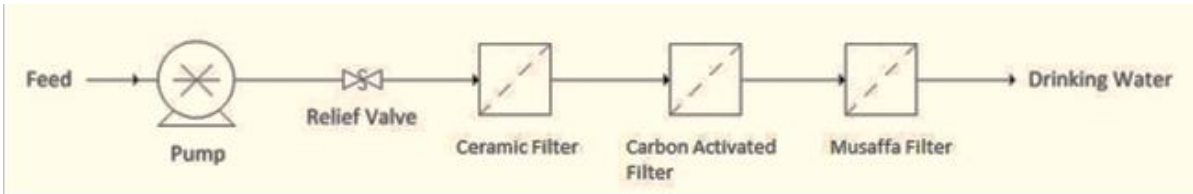

Figure 2: Overall process flow diagram

3. Results & Discussion

To measure the effectiveness of the system in improving the water quality, water tests were performed on different samples of water (e.g. prepared in lab as well as natural flood water). The water quality testing was performed at Pakistan Council for Research in Water Sources (PCRWR) lab for Water. The samples were tested by PCRWR Laboratories in Karachi, Sindh Pakistan and found as per the standards of World Health Organization (WHO) and Pakistan Standards Institution (PSI).

4. Conclusions

The system is economically very sustainable; it has been designed keeping in mind an average earning of Pakistani family. Its maintainability cost is 20 times less than the other drinking water purification systems.

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State Estimation Based on Smoothing Techniques

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Abstract
Power systems are becoming more complex and the need for increased awareness at the lower voltage levels of the distribution network requires new tools that provide a reliable and accurate global image of the system. In this paper is presented an innovative state estimation approach for LV networks that searches for similarities between a snapshot comprising a small amount of real-time information and complete system states present in historical data. Real-time voltages are then obtained smoothing the closest past snapshots with a methodology that do not resorts to network topologies. The results show impressive low estimation errors, even in the scenario of strong penetration of microgeneration.

Author Keywords. Distribution State Estimation, Smoothing Methods.

1. Introduction

The drive for the development of a state estimator stems from the need of going beyond the power flow calculations by considering the uncertainties involved within the acquisition of measurements, which are caused by meter and communication errors, incomplete metering, errors in mathematical models, unexpected system changes, etc. Nonetheless, different challenges are now present in particular at the distribution network, such as the growing penetration of renewable resources and storage devices, including electric vehicles, demand-side-management strategies, the establishment of microgrids with independent controllability and islanding capabilities and the massive deployment of smart meters.

On the other hand, taking advantage on the huge amounts of data provided by smart meters it is possible to identify patterns in such a way that even having a small set of real-time sources, a quite accurate state of the system can be obtained. Moreover, LV network are many times found bereft of topology and equipment characterization. In this sense, having a state estimator that is based exclusively on historical data and requires a small amount of real-time data is of considerable importance.

This work is inspired in the developments accomplished in (Lobo and Sanchez, 2012), where smoothing techniques are used to predict aggregated power generation from a historical of wind speed predictions.

2. Smoothing Methodology

The proposed methodology uses a set of explanatory variables, for each node n, to compare the present state (instant t) with past occurrences (instants h), namely:

- Hour and week of the day ($Hcos_h$, $Hsin_h$, $Wcos_h$, $Wsin_h$);
- Irradiance (I_h);
- Voltage magnitude of the R nodes ($V_{1,h}$, $V_{2,h}$, … $V_{r,h}$) with real-time meters;
- Voltage magnitude of node n at the h-24 instant ($V_{n,h-24}$);
- Voltage magnitude of node n at the same instant in the previous week ($V_{n,h-168}$).

New updates to the historical of voltages are assumed to be obtained every 24 hours representing complete system states of every 30 minutes of the previous day.

When running, the state estimator searches for similarities, for each node n, computing a Kernel regression as (1), where the estimated voltage for the current instant, $V_{n,t}$ is obtained as a weighted average of past observations.

$$V_{n,t} = \frac{\sum_{h=1}^{H} V_{n,h} \cdot w_{n,h,t}}{\sum_{i=1}^{I} w_{n,h,t}} \tag{1}$$

The smoothing coefficients $w_{n,h,t}$ are in this work addressed considering: i) the distance ($d_{n,h,t}$) between the explanatory variables in this instant and each instant of the past; ii) the bandwidth (tuned by the user) that defines the selection window of data according to the distances; and iii) a function that weights the past instants according to distances and within the bandwidth ((2) where α is a tuning parameter and μ is the center of the distribution of distances). The objective is to give largest weights to the nearest observations.

$$w_{n,h,t} = \exp\left(-\frac{\alpha}{\mu} \cdot d_{n,h,t}\right) \tag{2}$$

3. Tests and Discussion

The methodology was tested on a 33-bus LV network with heavy penetration of renewables, estimating the voltage magnitudes at all nodes' phases for a horizon of 4400 instants (new estimation every 30 minutes). In Fig. 1 are compared the real states with the estimations for the phase *a* of node 7 during the last 400 instants. It is possible to visualize the great accuracy achieved by the proposed method with the major discrepancies occurring at peaks. As time goes by, more historical is available and thus more information can be used to estimate voltages. Fig. 2 proves it showing the evolution of the weekly absolute average error.

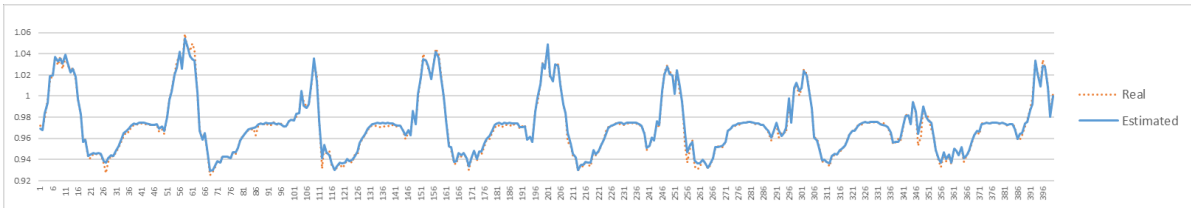

Figure 1 - Real and estimated voltage magnitudes for the last 400 instants of the simulation at phase a of node 7

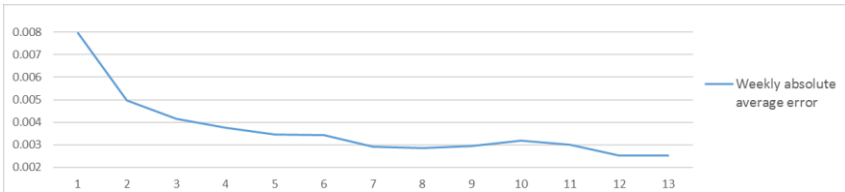

Figure 2 - Weekly absolute average error evolution

4. Conclusions

The growing dynamics observed and expected at the distribution networks require approaches different from the ones applied to the transmission systems. In particular, the topology of LV networks is usually erroneous, not updated or even inexistent. This works explores the subject of state estimation overcoming the traditional requirements for this analysis, taking advantage of the historical information provided by smart meters.

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Best oral communication award for the Symposium on Sustainable Energy Systems

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