Modelling and techno-economic analysis of microgrid applications

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Abstract

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98 Z REE N°3/2017 LES MICROGRIDS (PARTIE 2) DOSSIER 2 Defining microgrids Microgrids are local, small scale groupings of generating sources, storage systems and loads, capable of operating in parallel with or independently from the main grid, as shown in figure 1. The main drivers are: generation such as solar and wind, to meet local demand; reliability, by local control of supply; in terms of cost savings by means of energy savings and avoiding costly transmission/distribution infrastructure investments. Microgrids in general display the following characteristics and requirements. They are capable of islanded operation and parallel operation with the grid. They are governed by autonomous control systems, both in terms of power (short term stability: transient effects, voltage and frequency control) and in terms of energy (long term stability: energy balancing, secondary and tertiary frequency control). They normally have a single point of interconnection with the grid, which enables bidirectional power flow from and to the microgrid. They generally include more than one generating source of different types, and rely on storage technologies. There are different key types of microgrids: - gating existing on-site generation with multiple loads that are co-located in a campus setting (e.g. hospital, university). The main drivers for such microgrid Modelling and techno-economic analysis of microgrid applications *IHFE GO SR XJS W TINMG TVSNIGXW Siebert Bressinck1, Stijn Uytterhoeven2, Baptiste Rossi3 Tractebel ENGIE Lab Grid Simulation1, ENGIE Lab, Laborelec2, ENGIE Lab, CRIGEN3 In today’s rapidly changing energy economy, microgrids are capable of dealing with higher
renewable shares, integrating new technologies and providing complete multi-fluid energy solutions. Therefore the ENGIE Labs have set up an important programme to develop several microgrid case studies and to investigate their application domains. The goal of the programme is to get more insight on the modelling, techno-economical and sociological aspects of microgrids and to gather instructive in-the-field return of experience. This paper provides two specific case study examples: the remote off-grid Princess Elisabeth Station in Antarctica and the REIDS demonstration project in Singapore. ABSTRACT Les micro-réseaux (ou microgrids) sont particulièrement efficaces dans l’intégration des énergies renouvelables à grande échelle grâce à l’utilisation des nouvelles technologies. Ils permettent de fournir des solutions énergétiques multi-fluides complètes. Dans ce cadre, les ENGIE Labs ont créé un programme clé pour développer plusieurs études de cas des micro-réseaux afin d’investiguer leurs domaines d’application. Le but du programme est de mieux comprendre la modélisation, les aspects techniques, économiques et sociologiques des micro-réseaux ainsi que de collecter le plus de retours d’expérience sur le terrain. Cet article présente deux études de cas spécifiques : la sta- tion isolée de Princesse Elisabeth en Antarctique et le projet de démonstration REIDS à Singapour. RÉSUMÉ Figure 1: Smart microgrid schematic. REE N°3/2017 Z 99 Modelling and techno-economic analysis of microgrid applications implementation are an easier manage- ment and the avoidance of regulatory barriers (such as connection fees) and - grids never connect to the main grid and instead operate in island mode at all times. Due to the lack of transmission or distribution systems, their main driver is to reduce fuel consumption of local die- sel generators by using renewable gene- ration. Military base microgrids are being deployed as a measure to increase reliabil- ity of power supply. This includes also mobile military microgrids for forward operating bases. Various new types of commercial and industrial microgrids are maturing and developing very quickly, must be noted that this last type does the industrialised world, Europe will be the region with the largest growth in - ter sectors will most likely be the health-care/hospital, government (military and regions of the world where microgrids are expected to develop are the rapi- dy developing countries and areas with remote rural communities as micro- grids will enable energy access to meet both local and regional electricity supply Case Studies Princess Elisabeth Station in Antarctica The Princess Elisabeth station in set up from 2009 up to 2012, by the station is home to scientists in the aus- tral summertime, and provides them with the facilities and required comfort levels. Figure 2 depicts a view of the sta- tion in operation. The main characteristic of the base is operation with zero-emissions. The sustainable technical concept is based on three main pillars. Distributed energy generation together with electrical and thermal storage systems provide power, heat and water to all inhabitants (see figure 3 showing the microgrid con- figuration of the station). The electri- cal grid is developed as a stand-alone smart microgrid that is able to keep the water produced in the base is purified and recycled to drinking water. Snow is Figure 2: View of the Princess Elisabeth Station in Antarctica. Figure 3: Configuration of the station’s microgrid. 100 Z REE N°3/2017 LES MICROGRIDS (PARTIE 2)DOSSIER 2 melted to replenish consumed water by the human body. Diesel generators are present on site and are expected to be used in emergency situations only. The electricity grid comprises nine wind turbines of around 6 kW, photovol- taic panels are dispatched on the roof-top of the buildings with a total peak power of around 60 kW. Next to that, a battery storage system is installed with a total peak power of around 60 kW and a storage capacity of 380 kWh, the total available power capacity many times. The availability of power produc- tion is estimated to be around 40 kW on average due to the fact that the whole power production is not available in the same time. To cope with the mismatch of power production and consumption, a smart load control system is implemented, which ensures grid stability at all times. The load control system includes a continuous measurement of consumed power, combined with an algorithm to assess the available reserve power to be consumed if needed. Users can apply to the system for a demand for consumption by pushing a button next to the power socket. The state of a blin- king led tells them if they have access to power or not, if deemed feasible for the coming 15 minutes by the system - néd by priorities throughout the sta- tion, both determined by time and by location. The kitchen has a high priority during lunch hours, while the priority is reduced at other times. The medi- cal cabinet and fire safety systems have of low power availability, power priority is given to applications that meet most urgent needs, in a logical way. These rules were not easily accepted by the inhabitants in the beginning for the following reasons: - mited) power at all times; the operation principles and operating limits of the electrical system. This led to frustration and even tam- pering with the system rules when pos- consumption habits progressively chan- ged to match with the availability of power especially at the time of the day the end, by progressive integration of the system use constraints, congestions were avoided and the system was used even with limited power generation and thanks to a thorough load control, sys- tem stability is ensured while offering the initially expected level of comfort for the users. REIDS (Renewable Energy Integration Demonstrator) With increasing exposure to fossil 2 emission reduction targets, the need for higher renewable energy shares in smart city grids and cleantech hubs is increasingly important. Microgrids are key to properly integrate these renewables into the smart grid. with the Nanyang Technical University - - prises an experimental microgrid to develop smart grid systems that can successfully run on variable renewable energy sources and storage technolo- gies, for remote offgrid microgrids. Within that frame, an Energy Mana- gement System (EMS) is being deve- lopment of microgrids integrating ren- ewable energy, batteries and H2 based storage. The developed EMS will be plugged to a Power Management System (PMS), a number of small islands using die- sel for power generation; moreover it also hosts industrial sectors gene- rating big carbon footprints. The key challenges of that region are to imple- ment micro-grids, while striving for the energy efficiency of industrial sectors, and to integrate gas (storage) technolo- gies in the energy mix to further reduce 2 emissions, all combined under the form of decentralised energy system Figure 4: View of the Semakau Island. REE N°3/2017 Z 101 Modelling and techno-economic analysis of microgrid applications solutions adapted to the specific needs of the end-users. Pre-feasibility study - ject, a pre-feasibility study assessed the techno-economic viability of different business scenarios for the microgrid. The main objectives of the study were to model the system and to identify the most economically viable sustainable energy investments for the energy sup- ply on the island whilst developing inno- vative tools and methodology suitable for evaluating the complete value chain.
The study focused on minimizing the overall cost of the microgrid, not only by sizing the various generation assets within the - - scenarios. These are considered in paral-lel to have an overview of the optimal Scenario definition Three main scenarios were modelled: upgraded existing 200 kW diesel-powered microgrid (~1 GWh/year annual load) by integrating PV and different storage technologies (batteries, hydrogen storage); categorised as a brownfield approach (figure 5); an entirely new system consisting of preferably renewable generation sources, but with diesel generators as back-up, and different storage technologies (batteries, hydrogen storage); categorised as a greenfield approach (figure 6); a 100% renewables scenario using an entirely new system consisting in only renewable generation sources and different storage technologies (batteries, hydrogen storage); also categorised as a 100% greenfield approach (figure 7). Methodology - mic viability of each of the above sce-narios, a new methodology had to be 1. The high-level characterization def-ines the energy uses and different technology options for different com-monic data of the technology options (standardized generation profiles, - ters like the annual demand, peak load and daily load profile, existing assets characteristics and supply contracts. reality check allows ranking sever-al options in terms of their respec-t and generation profiles of roughly sized required assets and their rela-ted investments. Noteworthy invest-ment options are identified whereas uneconomic cases are excluded. The QuickSizing tool is therefore used to allow a quick assessment. 3. Refined input data is obtained by reviewing site-specific constraints together with the collection/calcula-tion of full-year hourly time series of and of non-dispatchable renewable generation. 4. The advanced optimization process is using more complex simulation tools to perform a high-resolution Totex optimization where the sizing esti-mate of sensitivity analyses of key software are then used to perform the extended simulations. 5. The last step consists in the results analysis where the Key Performance Electric), carbon intensity, self-sufficiency - an investment & replacement plan is set out. In-house tools & software during the scenarios definition, various in-house tools had to be enhanced to cover the new aspects of multi-fluid microgrids. The following software pa- Figure 5: REIDS scenario 1 – Brownfield. Figure 6: REIDS scenario 2 – Greenfield. Figure 7: REIDS scenario 3 – 100% RES Greenfield. 102 Z REE N°3/2017 Les microgrids (PARTIE 2)Dossier 2 kages were developed and used for the study at different steps: QuickSizing tool works with pre- liminary technical and economical input parameters, low time resolution load and generation profiles. Using lin-ear optimization algorithms, it pro- cesses the installed equipment, and related -nologies, storage options (electrical, thermal, hydrogen) and load types, whilst searching for the optimal sizing of the generation and storage assets under constraints related to the annual energy balance. The result is the optim- al trade-off between assets size, CleanPower provides minimal sizing and optimal dispatching at the same time taking into account the hourly annual generation profiles of a wide different load profile types (electrical, thermal, others). The tool is capable of handling user-defined multi-fluid/com-modities as well as numerous conver-sion, consumption, storage, purchase and sales parameters of a typical microgrid configuration. When evalu- ating the energy balance, a “copper-considered. SmartOperation optimal power flow software capable of simulating and optimizing the active and reactive power flows in the time domain for a given microgrid set-up representing the different production characteristics and profiles, as well as the local grid constraints on injection limits, generation curtailment, load shedding and grid losses. The tools are currently upgraded to include electrical mobility and multi-fluid networks [2]. Simulation results Simulation results revealed that in most remote off-grid situations, fossil fuel prices are quite significant in the 2 relative reduction by the integration of - Too large PV injections into the grid could cause over-voltages and result in diesel costs increase, even more when compared to configurations including storage (figure 8). Greenfield approach outcomes show- ed that it makes sense to consider install-ing a considerably sized battery storage slightly oversized renewables (400 kW), but still with (yet smaller, 150 kW) diesel generators functioning nearly half-time. - tipping point where the output of the study addressed the regulatory aspects and the way local agencies are organized. as there are over 5,000 islands and far more potential sites to be studied, local agencies will point to the best sites and business opportunities that fit in their development strategy. Hence, even though microgrids seem at first to be the key for decentralization, regulations and local policies still matter de facto, as they drive demand and lead the remote areas electrification process. National and local regulatory framework can reduce business models possibilities and microgrids global business. The regulatory framework has to evolve to create viable conditions for microgrids: state monopolies and local regulations can limit if not block the opportunities for privately operated microgrids. This is true in countries with strong and reliable grids but also for weak codes and the numerous constraints faced when connecting a microgrid to a main grid, opportunities can be stalled by the impossibility for a private company to operate a power plant within a country. - vate operators cannot operate more than a
given (low) total threshold of power, which hinders various business models around microgrids. Local ecosystems have to be created around economically competitive microgrids solutions appetite, there are many cases where energy access enables direct economic growth and local well-being. The following points are important to keep in mind: solutions have to be affordable first and competitive with their main competitor: diesel generators. Economy around those microgrids is key: a diesel generator is easy to use, to LES AUTEURS Siebert Bressinck graduated as - Tractebel shortly afterwards. He was involved in the development of large onshore and offshore wind farms and PV farms located in Belgium and worldwide. Since 2016 he is working as Project Manager & Smart Energy Systems Expert in the Energy Transition department. His focus is on the techno-economic assessment of microgrids and pre-feasibility studies for decarbonisation of single/multi-site industrial clients. Baptiste Rossi graduated from the has been working at Engie on various optimization problems in the field of energy, building decision help tools for intraday management of gas transmission system and lately on energy management systems in microgrids. Since 2016, he is a responsible for the Energy Manager - Stijn Uytterhoeven graduated at civil electromechanical engineer, option electrical energy. Since as an expert on electrical power joined the crew at the Princess Elisabeth University of the building of the smart microgrid. Since 2014, he is a project manager for research projects in the field of electrical grids. His main activities are in the field of electrical networks and power quality, with a focus on simulations on electrical network stability and complex measurement systems of power quality and electrical grid parameters. 104 Z REE N°3/2017 LES MICROGRIDS (PARTIE 2) DOSSIER 2 repair, to refuel. The same should also apply to microgrids. Hence, training has to be done locally, so that microgrids and renewable assets use and maintenance become a standard practice in remote isolated areas. The very challenging climatic conditions (e.g. typhoon) potentially damaging PV panels or drowning equipment (monsoon), really encountered with a small dam being quickly damaged because of lack of training of local population on how to operate or maintain it. Conclusions For remote off-site conditions, back-up fossil fuel generators are not always the desired solution (for environmental or cost reason) nor their power supply guaranteed (due to supply chain issues). This results in reduced power availability, load shedding, and consequently new way of consuming power. Therefore microgrids are utterly suitable to tackle these hurdles by integrating renewables in the energy supply mix and using different storage technologies that serve different needs (electricity, heat). The first-of-a-kind remote off-grid microgrid of the Princess Elisabeth Polar station showed that the idea of 100% renewable fed microgrids does work even under the most extreme conditions. When scarcity of supply is present, intelligent load control proves to be a powerful way in controlling battery storage and maintaining grid stability, while ensuring maximum comfort for the users. The key sociological aspect is the understanding of the electrical system by the users, in order to allow the system to function optimally and avoid power shortage. This in-the-field experience at the forefront of the microgrid applications showed that a new microgrid business model is technically viable. From a techno-economic point of view, several factors come into play: sizing of the various generation assets and optimization of their load flows have to be considered simultaneously. Therefore high-level global evaluation tools as well as more advanced state-of-the-art mathematical (non-)linear simulators with high-resolution time-domain models are needed to handle all these factors together at once. - case study, amongst others, resulted in new insights on how to translate the urbanisation, environmental concerns and digitalisation trends into innovative distinct need for expert tools. The importance of assessing the sociological aspects of microgrids by studying the local environment has been highlighted through multiple microgrid case studies. Even though that part is often neglected, it can be quite structuring for screening and project development. Lifetime of the microgrids to ensure that the value and energy is effectively delivered over time in the most efficient manner. References [1] L. Zpryme Research & Consulting, “Power Systems of the Future: The Case for Energy Storage, Distributed Generation, and Microgrids,” IEEE SmartGrid, 2012. [2] F. Geth, S. Leyder, C. D. Marmol and S. Rapoport, “The PlanGridEV Distribution Grid Simulation Tool with EV Models,” in CIRED 2016, Helsinki, 14-15th June 2016. [3] P. Chittur Ramaswamy, C. Chardonnet, S. Rapoport, C. Czajkowski (Westnetz), G. O. Bulto (ENEL Distribuzione), R. R. Sanchez (Tecnalia) and I. G. Arriola (Tecnalia), “Impact of electric vehicles on distribution network operation: real world case studies,” in CIRED 2016, Helsinki, 14-15th June 2016. [4] P. C. Ramaswamy, S. Leyder, S. Rapoport, B. P. (UMons), Z. D. G. (UMons) and D. V. (ORES), “Impact of load and generation flexibility on the long term planning of YLPIC distribution network,” in CIRED 2016, Helsinki, 14-15th June 2016. [5] A. Traore (CI-ENERGIES), S. Ahoussou (CI-ENERGIES), S. Leyder and S. Rapoport, “Technical-economic optimal development plan of the Distribution Network of Abidjan,” in CIGRE 2016, Paris, 2016. 

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