Digitalisation and Smartness in Energy Systems

Introduction

The need to address the rising levels of CO_2 in the atmosphere in order to mitigate the impacts of climate change is increasingly urgent. There is now a comprehensive range of legislation and policy at various scales which supports the development and implementation of **decentralised and digitalised energy infrastructure to reduce the consumption and reliance on fossil fuels for energy production**. Within this context, the world has embarked onto a journey for an aggressive energy transition. Greece is no exception to this rule with recent legislation being discussed at the parliament for decarbonisation within 2020s.

Digitalisation along with smart control and operation can significantly boost the transition and incumbent challenges by providing accurate information, closing the loops of the energy systems as necessary to achieve cross-sector and cross-vector operation in timescales close to real-time [1]. This trend towards greater digitalisation of the energy sector has been enabled by advances in smart controllers, sensors, communication devices and data analytics. Indicatively, these include increasing volumes of data, due to the declining cost of sensors and data storage; rapid progress in advanced analytics such as deep learning; greater connectivity of people and devices; and faster and cheaper data transmission [2]. The lifetime, efficiency and utilisation of energy infrastructure would increase by combining the elements mentioned, leading also to reduced operational costs. Additionally and more importantly, this transformation can help to break down traditional silos that dictate the separation of various energy sector participants. Consumers and producers in any sector can now actively participate across energy system operations, enhancing the flexibility with which the system can cope with changes in supply and demand, and reduce the cost of integrating new technologies like distributed generation, energy storage or electric vehicles standalone in the network or even in the form of microgrids, local energy networks, etc. [3]. ***This transition does, however, need to be supported by a comprehensive framework for coordinating actions across various levels to help address the challenges arising***. In a European context, the Energy Roadmap for 2050 lays down ambitious plans for the decarbonisation of Europe [4]. By 2050, 80-95% cutting of greenhouse gas emissions below 1990 levels[1] is envisioned. Greece has a long way to go before being able to realise the targets set by the EU and efforts around a successful digitalisation of energy systems can allow high levels of success at relatively lower costs. The subsections below highlight key areas of transformation needed for the Greek energy transition to succeed.

Energy system transformation

A complete transformation of how energy systems are planned and operated is very much necessary. This accounts for the ways noted below in a holistic manner, and innovation shall be focusing on such activities:

- Smart, advanced information and communication technologies (ICT) are an increasingly important feature supporting smart operation of energy, transport and urban applications [5]. Digitalisation and smart control of today's energy systems across all levels are a key theme of the energy transition, as they are believed to be an enabler for the shift to a decentralised and bottom-up approach for system operation. Essentially, ICT can support the communication, information exchange, etc. between the resources of the system regardless of the latter 1) being installed in

[1] In 2009, electricity and heat production accounted for 36.5% of total CO2 emissions in the European Union (EU).

low, medium or high voltage networks and 2) being standalone or in the form of local energy networks, microgrids, aggregators, etc.

- Penetration of renewable energy sources (RES) needs to expand to levels beyond the ones suggested a decade ago. Coordinated efforts from product development to mass production and deployment, integration of various technologies and financial incentives enhance shares of RES.
- Smart network technologies and approaches, including smart meters and demand response, are recognised as a key enabler for today's energy transition in a cost-effective manner.
- Storage spanning across static storage [6] and in other forms, such as electric vehicles (EVs) [7], is expected to be able to multiply the benefits of supporting the system operation, better exploiting RES and extending to electro-mobility for decarbonisation of transport and development of renewable energy within the latter sector.
- Energy efficiency following a bottom-up consideration, translating into energy-efficiency measures from consumers (houses, buildings, etc.) [8] to large-scale power systems [9]. This will indicate the significance of local energy systems (e.g. islands), which are expected to play a pivotal role in the discussed transformation. In fact, these small-scale consumers can reduce their consumption through insulating materials, but can also produce more energy than they consume, and therefore access to capital and innovative business models would be critical to allow installation of the necessary generating units.

Network operators in Greece, including HEDNO, have been in the forefront of this transformation with key strategic projects being implemented that will allow digitalisation of the energy system; key projects include i) upgrade of control centres and automation systems, ii) IT applications supporting network development and operation, iii) customer service applications, iv) infrastructure for non-interconnected islands, v) telemetry/smart meter roll-out and vi) supply chain reorganisation.

Restructuring the energy market

The targets mentioned above also impose challenges to energy markets in the transition to a low-carbon system providing a high level of energy security and affordable electricity supplies, as below:

- New ways of managing electricity markets from a local to a national and international level. Firstly, there is an increased need for effectively-managed flexible resources (e.g. storage, demand side management, etc.), particularly as RES penetration increases [10]. These resources need to participate strongly in the energy markets creating investable business models. Secondly, the characteristics of RES as well as various flexible resources should be appropriately captured in the energy prices to avoid very low (wholesale) prices that would reduce the revenues for all generators, including those needed to ensure sufficient capacity to meet demand when intermittency of natural resources is high [11, 12]. This will, in turn, create conditions for increased security of supply and a healthy investment environment that would allow investors to recover costs. As explained, access to markets needs to be ensured for all types of generating sources providing various types of system support services, which of course need to be suitably rewarded. Note that relevant innovation projects across the EU propose an enhanced market design with a novel framework of energy services to effectively deliver and reward the right flavour of flexibility, at the right time and at the right place [13].
- Integrating local energy resources with large-scale transmission and distribution systems is also considered to be a key factor towards massively decarbonised operation and better utilisation of the technologies mentioned above ([14]), particularly in the presence of so-called resilience scenarios. Provided that local energy systems are an energy market participant, an integrated view of the various systems top to bottom is expected to offer profound benefits to all stakeholders, including reduced losses and energy prices, less reliance on fossil-fuelled generation and reduced capital-intensive reinforcements [15].

- Analysis performed by various organisations, including the European Technology Platform for Smart Grids, indicates that to realise the decarbonisation targets mentioned focus shall be given on analysing electricity systems as an integrated system, enhanced with other energy carriers such as heat and mobility demand, thus enabling a whole energy system view [16]. The requirement to integrate all these energy vectors while utilising low carbon technologies will necessitate the development of more active networks and provision of network access without resorting to extensive investments [17].

Engaging with the public

Aside from the technical aspects underpinning successful implementation of the system described previously, focus shall also be given on the critical aspect of social engagement [18]. Lack of awareness from the public side regarding the use of energy and the various aspects relating to energy system operation is a rather important factor that can impede the successful implementation of smart approaches, such as demand response techniques, that can benefit both the system and the end users in multiple ways, and eventually help energy systems smoothly transition towards the smart grid era. It is believed that active customers will quickly and drastically change from today's passive and inelastic consumers to much more active and conscious actors (also known as prosumers) with the capability to indirectly determine how the grid is operated in our days [19].

Key areas of innovation activities suggested for Greece up to 2030

1. *(Imminent need)* Policy and legislation upgrades to ensure the creation of a framework for introduction of new types of energy services to be traded in the markets; this would allow 1) a healthy investment environment allowing high return-on-investment for investors and 2) the means to ensuring resilience and security of supply even under high-RES scenarios. Note that the framework shall account for ancillary services, including flexibility sharing, system restart and synthetic inertia.
2. *(Imminent need)* Establishment of innovation framework for allowing introduction of novel technologies at network level with creation of state-of-the-art testing and validation centres for speeding up prototyping processes. Key actors to participate are network operators (HEDNO, IPTO), energy suppliers/retailers, the Regulatory Authority of Energy and involved Ministries.
3. *(Ongoing activity with further efforts recommended up to 2025)* Digitalisation expansion supported by relevant metering, sensing and ICT applications to allow real-time monitoring, optimisation and control operation strategies would also be critical. Note that such efforts shall be conducted in a coordinated manner ensuring a whole energy system (coupling electricity, gas and transport sectors).
4. *(Post 2025)* Innovation activities shall also focus on enhanced data insight capabilities to usher in the smart grid era and allow for better forecasts, changing operational techniques and planning capabilities.

Further analysis and more detailed explanations can be provided on the above recommendations, as necessary.

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