



Smart grid projects in Europe: Current status, maturity and future scenarios



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HIGHLIGHTS

- This study is grounded on the smart grid database of the JRC (European Commission).
- The European smart grid projects are analyzed in many respects.
- The Western part is already transitioning to a D&D phase in specific sectors.
- The Eastern part lags behind in terms of smart grid initiatives and investments.
- Short-term future scenarios are created by using time series forecasting models.

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ABSTRACT

The attention on the smart grids and smart grid technologies has grown significantly over the last few years. The analysis made in this study is grounded on the smart grid projects database of the Joint Research Centre (European Commission). The European smart grid projects are analyzed among others in terms of: number, countries, duration and collaboration. Additionally, an analysis is done regarding the annual number of starting and concluded/planned to be concluded projects, the total number of participants per year, the distribution of smart grid applications per stage of development, year and EU country and an overview of the investments in the European smart grid projects is provided. Afterwards a forecast is done regarding the number of projects. As a result of graphical and predictive analyses, many essential inferences are achieved related to the current status and the anticipated short-term trends of smart grid projects.

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Abbreviations: JRC, Joint Research Centre; EC, European Commission; EU, European Union; R&D, Research and Development; D&D, Demonstration and Deployment; AC, alternating current; DER, distributed energy resources; MA, moving average; WMA, weighted moving average; LTR, linear trend regression; ARMA, autoregressive moving average; ARIMA, autoregressive integrated moving average.

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1. Introduction

The existing electric grids were developed based on a large generation-centric approach: a few very high-power AC plants interconnected by transmission systems operating at very high voltages, many substations where the high voltage is stepped down to distribution level and a large number of distribution lines supplying the loads directly or after voltage transformation [1,2]. So, the intelligence is concentrated in central locations and partially in substations, while remote terminals are almost passive [3]. However, a smart power grid is an electricity network that can intelligently integrate the actions of all users (generators, consumers and those that do both) connected to it in order to efficiently deliver sustainable, economic and secure electricity

supplies [4,5]. Various intelligent and automated applications are enabled such as smart metering [6,7], demand side management [8,9], smart distribution management [10,11], smart energy storage [12,13], advanced electricity marketing [14], emission trading [15] and integration of electric vehicles [16,17].

In Europe, the JRC of the European Commission monitored the smart grid projects invested in the European countries, proposed guidelines for the cost-benefit analysis of smart grid projects and smart metering deployment, investigated the complexity features of smart energy grids, and evaluated the social dimension of smart grid projects [18–22].

The data of the smart grid projects catalogue of the JRC is gathered via extensive rolling reviews, started in 2011 and ongoing today, carried out in close cooperation with the European Commission Directorate-General for Energy. The 2014 version of the database includes more than 450 European smart grid projects collected by means of an online questionnaire and a through extensive search of project information on-line and through participation in conferences and workshops. The data collected have been checked for consistency and included in the JRC smart grid project database, which functions as the single repository of European smart grid projects. The catalogue may be incomplete for the recent years since some projects are promoted later in their lifetime and insufficient or no information was available for them. No projects were included where significant information gaps did not allow a consistent project assessment.

The entire number of smart grid projects in the JRC database is divided mainly between the European Union member states with some minor participation from other non-EU countries. The average number of projects per European Union country is around 40, with large disparities comparing the countries. In most countries there is a balanced ratio between the participation in the R&D and Demo & Deployment projects with the notable exception of Denmark where the number of R&D projects is almost three times larger than the number of Demo & Deployment projects. A marginally higher number of Demo & Deployment projects than R&D projects can be found in United Kingdom and Italy, connected to their large smart-metering projects, some of them part of a wider smart grid project. As of 2014, the largest average budgets per project can be found in the two countries which also have the largest budgets: France and United Kingdom, with nearly €5 million per project.

In our previous work [23,24], there was a focus on the critical issues – technologies currently and shortly available that are essential for the security of smart grids – in smart grid technologies. The challenges emerging in information and communication technologies, sensing, measurement, control and automation technologies and power electronics and energy storage technologies have been uncovered for the purpose of enabling the deployment of smarter power grids. With the aim of completing a significant deficiency in the field of smart grids as in our previous study, this work: first analyses and evaluates in a comprehensive way the current status of smart grid projects in Europe; afterwards anticipates short-term scenarios related to the number of smart grid projects by employing different time series forecasting models. As one of the crucial outcomes, this paper provides insights about the current status and short-term scenarios of smart grid projects for relevant stakeholders including manufacturers, contractors, operators, utilities, universities, and research centers.

2. Current status of smart grid projects in Europe

Smart grid projects are categorized into R&D and D&D sub-groups according to their stage in the innovation chain [25]. The R&D projects make a creative work in a systematic way in

order to increase the stock of knowledge and to devise new applications by using this stock of knowledge [26] while the D&D projects aim to employ a technology in realistic user environments in order to analyze its convenience and to implement the technology as a default solution within the geographical boundaries of the project [27,28]. According to the JRC's smart grid database [29], 459 smart grid projects are available with a total investment budget of 3.15 billion. The number of R&D and D&D projects and the number of national and multinational projects are shown in Table 1. The number of national and multinational projects in R&D and D&D projects is also depicted in Table 1.

The number of national projects belonging to each country is given in Fig. 1. Denmark has the largest percentage of national projects, followed by United Kingdom, Austria and France. There are nine countries with no national projects, most of them from East Europe.

Germany has the biggest number of multinational projects (105), followed by Spain, Italy and France with 97, 89 and 76 multinational projects, respectively. It is worth mentioning that all the EU countries are involved in at least 1 multinational partnership.

The annual numbers of starting projects and concluded/planned to be concluded projects are illustrated in Fig. 2. In 2012 a maximum was reached with 101 starting projects. However, the number of starting projects decreased in 2013 and 2014. The main cause for this decrease can be the unreported projects or the projects that are promoted later in their lifetime that were not registered in the JRC's database. On the other hand, the greatest number of concluded projects was accomplished in 2014 with 89. The average number of concluded projects between 2005 and 2014 is ca. 32.

The number of R&D and D&D projects per year is illustrated in Fig. 3. The maximum number of running R&D projects was 42 in 2012 while the maximum number of running D&D projects was 60 in 2011. An increase in the number of D&D projects with respect to the decrease in the number of R&D projects after 2010 is observed.

The number of R&D and D&D projects per EU country is shown in Fig. 4. The number of R&D projects is higher than the number of D&D projects in Denmark, Austria and Belgium. Particularly, Denmark is a leader in research and innovation in the field of smart grids. For Denmark the number of R&D projects is almost three times larger than the number of Demo & Deployment projects whereas the budget is 30% larger. Also, one of the most active organisations in R&D comes from Denmark with participation in 45 projects. On the other side, the number of D&D projects is larger than the number of R&D projects in Germany, United Kingdom, France, Italy, Spain and Netherlands. In the rest of the countries, there are small differences between the number of R&D and D&D projects. It can be concluded from Fig. 4 that a large number of smart grid projects are situated in the western and southern part of the continent.

The 459 smart grid projects from the JRC's database have a total number of ca. 2900 participants and an average of around 6 participants per project. There are ca.1350 participants in R&D projects and ca.1550 participants in D&D projects. More than half of the budget is managed by universities and distribution system operators. The smart grid projects are implemented in more than 550

Table 1
European national and multinational smart grid projects by stage of development.

	National	Multinational	Total
R&D	87	124	211
D&D	85	163	248
Total	172	287	459

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