Final Report Summary - E-HIGHWAY2050 (Modular Development Plan of the Pan-European Transmission System 2050)

Executive Summary:
The e-Highway2050 project is a collaborative research and demonstration project supported by the EU Seventh Framework Programme (Grant Agreement N° 308908) and aimed at:
- developing a methodology to support the planning of the Pan-European Transmission Network, capable of meeting European needs between 2020 and 2050 and in line with the European energy policy pillars, as well as
- illustrating it through the delivery of a Modular Development Plan of the pan-European transmission system at the 2050 time horizon and supporting the planning of a pan-European "Electricity Highway System".

The 40-month research and development e-Highway2050 was launched in September 2012 and has been performed by a consortium of 28 partners including Transmission System Operators (TSO).
been performed by a consortium of 28 partners including Transmission System Operators (TSO), Research and Development performers, energy agencies, associations and other professionals, under the technical management and coordination of RTE (the French TSO).

The project workflow was developed around five extreme but realistic scenarios at long term horizon. The pan-European power system is represented by a consistent set of zones, while system simulations are performed in order to highlight weak points of the transmission grid. This led to identify few grid architectures per scenario, corresponding to technological choices reflecting each a different degree of public acceptance of the deployment of new overhead lines. A Cost-Benefit Analysis was then performed in order to score the architectures and assess the most efficient one, constituting the basis for analysing optimal implementation routes from now up to 2050.

The e-Highway2050 project reached successfully its complementary overarching goals, namely the modular plan at 2050 for the pan-European System and the development of novel planning methodologies.

The final results of the research project have been displayed in various forms including the final international conference, presentations to events and workshops, public deliverables, short advertising movie, synthetic booklet of results, articles in various conferences. Results of research have also been presented in international conferences and are available through the project website http://www.e-highway2050.eu/e-highway2050/ or through the European Electricity Grid Initiative (EEGI) knowledge Sharing Platform http://www.gridinnovation-on-line.eu/.

The project has also been labelized Core project by the EEGI in December 2013.

After the project completion, the main results of the e-Highway2050 project are expected to be further developed, used and disseminated. More specifically, the top-down planning methodology organized in modular blocks, the modular plan of pan-European grid architectures at 2050 (including data), and the database of cost and performances of power system technologies are expected to be further used by ENTSOE for the preparation of future TYNDP exercises.

Project Context and Objectives:

The Energy Union policy has fixed ambitious goals for 2020 and 2030, for the climate protection, where the interconnected European electricity grid with more cross-border interconnections, storage facilities, and smart grids to manage demand should ensure a secure energy supply in a system with higher shares of variable renewable energy. In this respect the gradual construction of the pan-European electricity highways should play a key role.

However, the related high investment costs of such infrastructures relating the big consumption centres to the often decentralized location of Renewable Energy Sources generation imply a new methodology of analysis oriented to the very long time horizon and considering the spatial complexity of the European continent with regard to the transmission system.

In that context the e-Highway2050 project was launched with two complementary overarching goals:
- the identification of the European grid architectures that could be necessary at that time horizon under five contrasted low-carbon energy scenarios and the related expansion plan for the pan-European electricity transmission network from 2030 to 2050, as well as
electricity transmission network from 2030 to 2050, as well as
the development of novel planning methodologies of the pan-European electricity transmission network, able to address very long-term horizons allowing further implementation of such innovative top-down methodologies in a rigorous and transparent way.

Project Results:
Four main achievements have been reached by the e-Highway2050 project (ended in December 2015):
- Top-down planning methodology organized in modular blocks
- The modular plan of pan-European grid architectures at 2050 (including data)
- A database of cost and performances of power system technologies
- A toolbox for carrying out advanced benefit cost analyses
- Enhanced transmission expansion planning based on optimisation methods.

A detailed exploitation plan (deliverable D9.3.2) has analytically detailed each piece of foreground produced by the project and available for exploitation (30 identified elements), each of these 30 elements being either a methodology, an application of methodology or recommendations for a given class of stakeholder.

The identified foreground was then analyzed with regard to its potential of exploitation according to one of the five identified forms of exploitation, namely:
- A future TYNDP exercise by ENTSO-E;
- New RD&D and services based upon project findings (two-sided, typically bilateral contracts between one TSO and a non-TSO)
- New RD&D and services based upon project findings (multilateral, at the pan-European scale)
- Data sets / data bases created by the project that have a long-term (2050), pan-European dimension (maintenance and exploitation of these databases)
- Data sets / data bases that have a long-term (2050), with a pan-European dimension (use by associations, NGOs, institutions in their missions).

The five achievements consist in a set of the identified foreground (see id code in the box below)
- Achievement 1 includes the identified foreground: 1.1 2.1 2.3 2.5 3.1 4.1 4.2 4.3 5.1
- Achievement 2 includes the identified foreground: P.1 1.2 2.2 2.4 2.6 2.7 5.2 6.3
- Achievement 3 includes the identified foreground: 3.2
- Achievement 4 includes the identified foreground: 6.1 6.2
- Achievement 5 includes the identified foreground: 8.1 8.2.

Results were regularly presented to the public and to targeted audiences through dedicated workshops and consultations. Policy-makers in governments, regulatory agencies and the electricity industry, which have been included in the research process from the outset by the consortium partners, are expected to use the proposed solutions as the groundwork for the subsequent expansion of the pan-European transmission network.

In parallel the network planning methodology is made available to all ENTSO-E members and beyond in order to serve in future as the basis for further research and innovations in the development of improved planning tools for the network expansion.

In order to allow an easy access to project public deliverables the following table of correspondence links...
In order to allow an easy access to project public deliverables the following table of correspondence links each individual piece of foreground to the type of support and to the physical location where a potential user could access to the created knowledge.

Potential Impact:
After the project completion, the main results of the e-Highway2050 project are expected to be further developed, used and disseminated as described in the e-Highway2050 Final Exploitation Plan (D9.3.2).

More specifically, the top-down planning methodology organized in modular blocks, the modular plan of pan-European grid architectures at 2050 (including data), and the database of cost and performances of power system technologies are expected to be further used by ENTSOE for the preparation of future TYNDP exercises. Practical implementation according to the exploitation plan proposed by the project are currently under validation by the ENTSOE TYNDP teams.

In parallel some partners intend to continue the development of the enhanced transmission expansion planning based on optimization methods.

Period m1-m12
Scientific publications (peer reviewed)

Participation in International Conferences
- Smart Grids Paris, June 2013
- EURELECTRIC Annual Convention & Conference 2013 - Innovative Investments: Re-energising Europe, Bologna, 3-4 June 2013
- Europacable General Assembly, Brussels, 27 June 2013

Participation in public workshops
- EHSP workshop, EC, 9 October 2012, Brussels
- 23rd meeting of the European Electricity Regulatory Forum, Florence Forum, 20 November 2012
- Innogrid2020+, 20-21st February 2013, Brussels

E-Highway2050 communication material
- Project public web site
- Press release
- Brochure; Poster

Period m13-m24
Scientific publications (peer reviewed)
- A cost and performance database of power system technologies in support of the development of the pan-European electricity highways system at the 2050 time horizon, E. Peirano et alia, presented at CIGRE Belgium, Innovation for secure and efficient transmission grid, 12-14 March 2014
A methodology for the development of the Pan-European Electricity Highways System for 2050, T. Anderski, S. Galant, G. Migliavacca, G. Sanchis, presented at Cigre, Paris (France), 24-29 August 2014

Participation in International Conferences
- UPEC 2013, 2-5 Sept 2013, Dublin (Ireland)
- EWEA Offshore 2013, 19-21 November 2013, Frankfurt (Germany)
- Eurelectric DSO Power Distribution conference, 28 November 2013, Brussels (Belgium)
- 4th International ETP Conference “Underground Cables: High performance transmission - underground”, 30-31 January 2014 (Germany)
- Power Tech 2014 “Advanced Technologies in Power Transmission to Improve Infrastructure Management”, 12-13 February 2014, Amsterdam (the Netherlands)
- Cigre Belgium, “Innovation for secure and efficient transmission grids”, 12-14 March 2014 Brussels (Belgium)
- Innogrid2020+, 25-26 March 2014, Brussels
- European Energy Market 2014 (EEM14), 28-30 May 2014 in Krakow (Poland)
- Cigre Biennial Session, Paris, 24-29 August 2014

Participation in public workshops
- See WP7 on the eHighway2050 workshops

e-Highway2050 communication material
- Posters presented at Innogrid2020+
- Poster presented at CIGRE Belgium conference, March 2014
- Poster presented at EWEA Offshore, November 2013 in Frankfurt
- The REVOLVE booklet

Period m25-m40 and scheduled events beyond project end
Scientific publications (peer reviewed)

“The role of spatial correlations in Monte Carlo studies on power system” B. Sequinot, A. Zani, Power...
The role of spatial correlations in Monte Carlo studies on power system. B. Seguinot, A. Zani, Powertech, Eindhoven, Article presented in Powertech conference in Eindhoven, The Netherlands, 29 June - 2 July 2015


Article to the 14th IAEE European Energy Conference —Sustainable Energy Policy and Strategies for Europe, Rome, 28-31 October 2014, LUISS University of Roma


e-Highway2050: Planning the European transmission grid for 2050. Grisey, Nathalie; Sanchis, Gérald; Anderski, Thomas; Migliavacca, Gianluigi; Peirano, Eric; Vafeas, Athanase; Pestana, Rui. Article to be presented in ENERGYCON 2016, Leuven, Belgium. 4-8 April 2016

Cigre Paris 2016: Article “System Development and Economics : New System Solutions and Planning Techniques for Flexible and Robust System Plan” (article under preparation under the coordination of T. Anderski at the project end)

Participation in International Conferences

UPEC (Universities’ Power Engineering Conference) 2 -5 September 2014, Romania Communication “Impacts of ICT on the pan-European Power Systems up to the 2050 Time Horizon” submitted by Brunel on February 21st

Communication to ENTSOE. Communication to System Operation Committee dated 17th September 2014. Communication to Staff meeting dated 7 July 2014


Utility Week 2014, 4-6 November 2014, Amsterdam, the Netherlands. The grid & Renewables integration. e-Highway2050 project. Presentation by Gérald Sanchis, project coordinator

OVANET Workshop “HVDC Grids for Infrastructure Integration and International Connection”, November 19, 2014, Berlin “HVDC Grids for infrastructures integration and international connection e-Highway2050 project”. Presentation by Gérald Sanchis, project coordinator


- Performance data base for transmission technologies at the 2050 time horizon. Presentation by Eric Peirano, Technofi
- Kabeldag 2014, Congress Center Elektrum, hosted by DNV GL, 27 Nov 2014, Arnhem (NL) International development in cable technology. Presentation for DNV GL Kabeldag 2014 by Dr. Volker Wendt, Europacable
- IIR Konferenz Erdkabel, Vienna, Austria, 3 Dec 2014. Communication of Dr. Volker Wendt, Europacable
- 5th International ETP Conference: Underground cables in High-Capacity Transmission, 29-30 January 2015, Berlin, Germany. Communication by Europacable on WP3 findings HVAC and HVDC Cable technologies for the Pan-European Transmission System 2050 "Underground Cables in High-Capacity Transmission" Dr. Volker Wendt, Director Public Affairs, Europacable
- Ewea Offshore 2015, 10 - 12 March 2015, Copenhagen, Denmark. Poster presented by EWEA
- Power Transmission Tech 2015, 25-26 March 2015, Vienna, Austria. G. Migliavacca chairman of the event presented the project available results
- Innogrid2020+, 31 March, 1st April 2015. Participation to the poster session and communication by the coordinator on the project available results
- PowerTech, Eindhoven, The Netherlands, 29 June - 2 July. Four papers (RTE): The importance of spatial correlations in Monte Carlo adequacy simulations; Network partition based on critical branches for large-scale transmission expansion planning; Snapshot selection based on statistical clustering for transmission expansion planning; A fundamental study on the impact of HVDC lines on transient stabil-ity of power system
- Workshop of presentation of draft results to ENTSOE: ENTSO-E Board and e-Highway2050 Workshop on Results of Electricity Highways, 7 July 2015, Brussels
- IEEE PES GM, Denver, July 26 – July 30, 2015 General paper on WP8 results
- EWEA annual conference 2015 17 November 2015, Paris. Participation to a panel session
- COP21/CMP21 EU side events; 30 Nov-11 December 2015. Presentation of the results of the eHighway2050 project
Transmission grid for 2050: N. Grisey, G. Sanchis; T. Anderski, G. Migliavacca, E. Perano, A. Vafeas; T. Pestana
- Cigre Paris 2016: Article to be presented (Study Committee SC1): “e-Highway2050: a research project analysing very long term investment needs for the pan-European transmission system”. T. Anderski, F. Careri, N. Grisey, G. Migliavacca D. Orlic, G. Sanchis

Participation in public workshops
- See D7.3 on the eHighway2050 workshops: WP8 workshop in Madrid 28th–29th May 2015

E-Highway2050 communication material
- Poster on draft results presented at Innogrid2020+
- Short video on project results presented at the final conference
- Booklet on project results (50 pages length) presented at the final conference

Other
- Twitter account: @e_Highway2050
- Project website: http://www.e-highway2050.eu/e-highway2050/

Regarding the exploitation of results the complete analysis is made in D9.3.2. This document details the cross-analysis of the 30 pieces of foreground for each of the five identified form of exploitation. The 30 pieces of foreground include:
- 18 e-Highway2050 “methodology” results,
- 9 e-Highway2050 “application of the methodology” results and the
- 3 e-Highway2050 “set of recommendations” results.

List of Websites:
The public website of the e-Highway2050 project is located at http://www.e-highway2050.eu/e-highway2050/

Other related information platform:
• the EEGI knowledge sharing platform developed by Grid+ project: http://www.gridinnovation-on-line.eu

Social medias have also been used by the project:
- The project website (news) http://www.e-highway2050.eu/news/
- Social media: Twitter account twitter.com/e_Highway2050
- YouTube channel https://www.youtube.com/user/eHighway2050/videos

Related documents
final1-160329-e-highway2050-summary.pdf