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L'Abbate Angelo, *Migliavacca Gianluigi, Fulli Gianluca, Gibescu Madeleine and Ciupuliga A*

TRANSMISSION PLANNING IN EURO[PE] FROM CURRENT METHODOLOGIES TO A NEW SYSTEMIC APPRO[ACH]

L'Abbate Angelo, ERSE (former CESI RICERCA), +39 02 3992 5802, angelo.labbate@erse-
Migliavacca Gianluigi, ERSE (former CESI RICERCA), +39 02 3992 5489, gianluigi.migliavacca@erse-
Fulli Gianluca, JRC – European Commission, +31 224 56 52 66, gianluca.fulli@ec.euro
Gibescu Madeleine, Technische Universiteit Delft, +31 15 27 85792, m.gibescu@tud
Ciupuliga Ana R., Technische Universiteit Delft, +31 15 27 84051, a.r.ciupuliga@tud

Overview

In Europe, as well as in other continents/countries, electricity industry in the latest years has been changing from a regulated structure dominated by vertically integrated utilities to a deregulated one organised in competitive markets. The liberalisation process in Europe, with the formation of regional electricity markets, has led to the facilitation of cross-border power trade; consequently, inter-area power exchanges in electricity networks have significantly increased and further growth can be foreseen. This generally results in more recurrent, and more frequently changing, congestion events on transmission networks. Moreover, the penetration of Renewable Energy Sources for Electricity (RES-E), in particular onshore wind power plants, connected to the European grids, has been impressive in recent years; further grid connection of large-scale onshore and offshore wind power plants is expected, in order to meet Europe's environmental and energy policy targets for 2020 and beyond. Then, the large amount of variable RES-E connected to the grids will have to be reliably integrated into the European power system. Additional factors regarding the security of electricity supply and environmental constraints may also impact on the development of the European power system [1]. These issues characterised by increasing uncertainties, mostly related to market decisions and growing variable RES-E deployment, pose new challenges on the European TSOs (Transmission System Operators), whose role has become more complex. In fact, in the past, before the electricity market liberalisation, in a centrally managed power system, the system operator generally controlled the generating units, the transmission and distribution networks and the demand. The goal of the planners was then to expand the transmission network in such a manner that both generation and transmission costs were minimised subject to meeting technical constraints to ensure a secure and economically efficient operation. Nowadays, in a competitive European system, the TSO, in charge of the only transmission system after the utilities' unbundling, plans in general the expansion of its network minimising transmission costs and pursuing maximum social welfare, while meeting technical constraints to ensure a secure and economically efficient operation. In this frame, transmission expansion planning criteria crucially need to be revised and expanded in order to design flexible, coordinated and secure transmission networks based on modern architectural schemes and including innovative technological solutions. More robust methodologies for transmission planning must be pursued to address the above challenges faced by TSOs. The present work, carried out in the frame of REALISEGRID project [2], co-funded by the European Commission, aims to provide an updated picture of the current European transmission network planning challenges and practices and to put forward innovative planning methods and tools to monitor and steer the ongoing changes in the European power system. Particular attention is paid to the cost-benefit analysis on new grid investments, a fundamental stage of the planning process, towards a new systemic approach to transmission expansion planning.

Methods

The transmission planning process is firstly described. The basic tasks of transmission grid planners can be summarised as in the following: to forecast the power and energy flows on the transmission network, drawing upon a set of scenarios of generation/demand evolution for the targeted period; to check whether acceptable technical limits might be exceeded, in standard conditions as well as in contingency cases; to devise a set of possible strategies/solutions to overcome the criticalities and to select the option(s) having the best cost-benefit performance.

A review of current transmission planning practices, based on deterministic and probabilistic approaches, as implemented by the TSOs, is then executed in view of the new proposed approach, whose main focus relates to the cost-benefit analysis of the different transmission reinforcement options [3][4]. Towards this scope, it is crucial to quantitatively assess the various benefits provided by transmission expansion: this task, especially in a liberalised power system, generally represents a rather complicate stage as the evaluation strongly depends on the viewpoint taken for each considered benefit. The proposed methodology, instead, while considering the standpoints of the different players - TSOs, producers, customers - evaluates then the transmission expansion benefits from the society's perspective: this is a systemic approach. The benefits provided by transmission expansion can be grouped as: system reliability improvement; quality and security increase; system losses reduction; market benefits; avoidance/postponement of investments; more efficient reserve management and frequency regulation; environmental sustainability benefits; improved coordination of transmission and distribution grids. Concerning the reliability increase evaluation, it is important to note that, in addition to the traditionally used reliability indices (criteria-based approach), like EENS (Expected Energy Not Supplied), LOLP (Loss Of Load Probability), LOLE (Loss Of Load Expectation), new reliability indices, like VOLL (Value Of Lost Load), IEAR (Interruption Energy Assessment Rate) and WTP (Willingness To Pay), are utilised in order to more consistently assess the economic impact of system reliability (value-based approach). These indices can be calculated by a power system simulation tool making use of probabilistic analyses. Regarding the assessment of market benefits provided by a transmission expansion, the increased market competitiveness with a consequent reduction of market power of dominant players, where present, may lead to a market price reduction ('strategic effect'); also, network congestions may be reduced allowing the unlock of more efficient power generation, both within one market and on a multi-national basis ('substitution effect'). Both the strategic and the substitution effects can be measured by the Social Welfare (SW). When planning the utilisation of fast power flow controllers such as FACTS (Flexible Alternating Current Transmission System) and HVDC (High Voltage Direct Current), an additional benefit is the power flows controllability increase granted by these technologies. The environmental sustainability benefits by transmission expansion, evaluated within the analysis, include: a better exploitation of a diversified generation mix, also including variable RES-E (e.g. wind); CO_2, NO_x, SO_2 emissions savings, in presence of more efficient generation, including also RES-E; the reduction of conventional generation external costs (externalities); the decrease of internal (fossil fuel) costs. Transmission upgrades may also bring some additional environmental benefits in terms of land use reduction, visual impact abatement and electromagnetic fields (EMF) level decrease. Other benefits which in the future may gain higher consideration relate to the improved interaction of transmission and distribution grids, within systems either experiencing high shares of distributed generation resources or even evolving towards so-called SmartGrids schemes by a considerable distributed generation deployment. A transmission reinforcement may indeed bring about a more effective exploitation of distributed generation resources, while also better coordinating them when installed in different distribution networks, multiplying then the trading opportunities.

Results

By reviewing the transmission planning practices carried out by the TSOs, the need of evaluating more combinations of load, (renewable) generation and international exchange by applying probabilistic approaches emerges with the goal of a more robust planning under a variety of possible scenarios. Major result of the present work is the development of a systemic approach to transmission planning process with its crucial cost-benefit analysis, quantitatively evaluating the several benefits provided by transmission expansion in a liberalised environment. The application of this methodology requires the utilisation of a simulation tool able to carry out detailed power system studies. In particular, the tool has to: be suitable for power system (optimisation) and market studies, especially for large size systems; carry out reliability studies (probabilistic criteria); address the quantification of transmission expansion benefits in a computationally efficient way; incorporate emission amount and cost calculations; be flexible, expandable and possibly linkable to other existing tools. By the developed tool, it is then possible to calculate and evaluate the economic benefits resulting from a transmission system enhancement for the different players and for the society as a whole. The general methodology emerging from this work will be applied to an important case, namely the group of transmission projects belonging to the Trans-European Network priority axis "EL.2. Borders of Italy with France, Austria, Slovenia and Switzerland".

Conclusions

This work focuses on transmission planning, which will have to change and adapt to new situations and uncertainties mostly represented by market opening from one side and renewable integration on the other side.

After a review of transmission planning practices carried out by the TSOs, transmission planning criteria should be expanded to consider probabilistic approaches in order to deal with above uncertainties. Moreover, a crucial stage of the transmission planning process, the cost-benefit analysis, needs to systematically and quantitatively assess the several advantages provided by transmission expansion in a liberalised context. In this view, the present work develops and describes a new systemic approach to transmission planning, aiming to evaluate the different benefits not only from a single perspective but from the society point of view. For the application of this analysis a suitable power system tool has been then developed and tested.

References

[1] European Commission, COM(2008)782, Green Paper "Towards a secure, sustainable and competitive European energy network", Nov. 2008

[2] FP7 REALISEGRID Project http://realisegrid.cesiricerca.it

[3] UCTE Transmission Development Plan 2008

[4] NORDEL Nordic Grid Master Plan 2008

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TRANSMISSION PLANNING IN EUROPE: FROM CURRENT METHODOLOGIES TO A NEW SYSTEMIC APPROACH

Angelo L'Abbate, Gianluigi Migliavacca, ERSE (former CESI RICERCA)
Gianluca Fulli, JRC - European Commission
Madeleine Gibescu, Ana R. Ciupuliga, TU Delft

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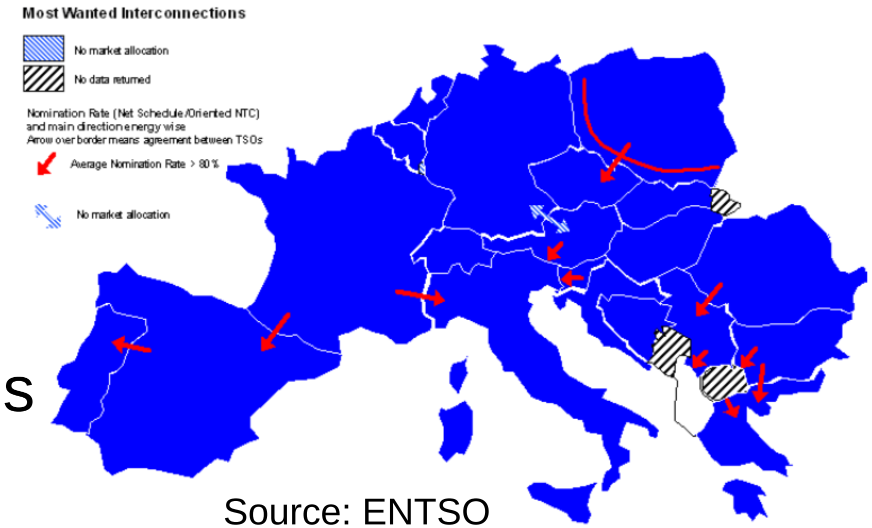
Outline

- CHALLENGES FOR GRID PLANNING
- PLANNING PRACTICES AND NEEDS
- PLANNING METHODS: THEORY
- FOCUS ON COST-BENEFIT ANALYSES
- NEW METHODOLOGY AND TOOL
- CONCLUSIONS

Recent trends on power grids

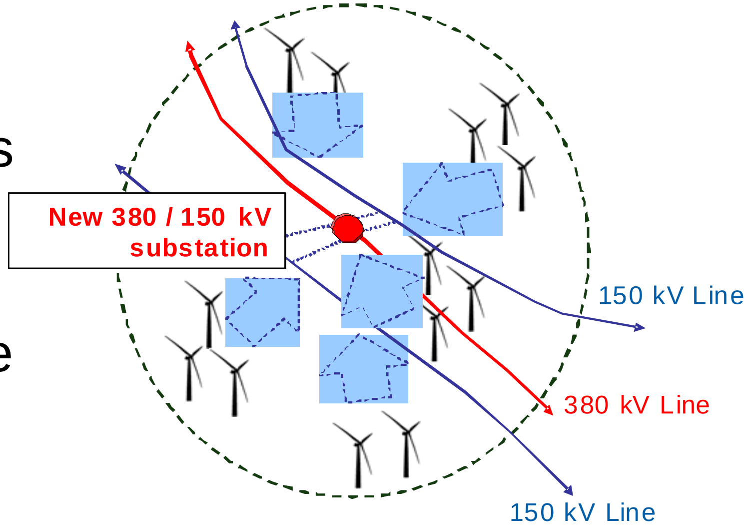
- Vertically integrated utilities replaced by unbundled companies competing in power markets
- Liberalisation process leading to increasing & shifting inter-area exchanges and congestion
- Escalating onshore (and offshore) wind deployment
- Security of supply and environmental concerns



Source: ENTSO

Wind connection and grid planning

- Network **planning** and generation **connection** are two separate yet **intrinsically interlinked** processes
  - Power production (rather than demand) tends to exert the greatest influence in terms of new transmission requirements
  - Wind electricity has not simply to be connected to the closest busbar of the grid but has to be effectively integrated into the system through targeted network development and optimization actions



Source: TERNA

REALISE GRID

Network planning objectives & tasks

- Network planning before/after liberalisation:
  - Before: the integrated utilities minimised generation and transmission costs, subject to technical constraints
  - After: Transmission System Operators (TSOs) minimise transmission costs and pursue maximum social welfare, while meeting technical constraints
- Basic tasks of TSO planners (iterative process):
  - forecast power and energy flows on the network
  - check the system compliance against a set of criteria
  - devise a set of solutions to overcome the criticalities
  - select the solutions with better cost/benefit performances

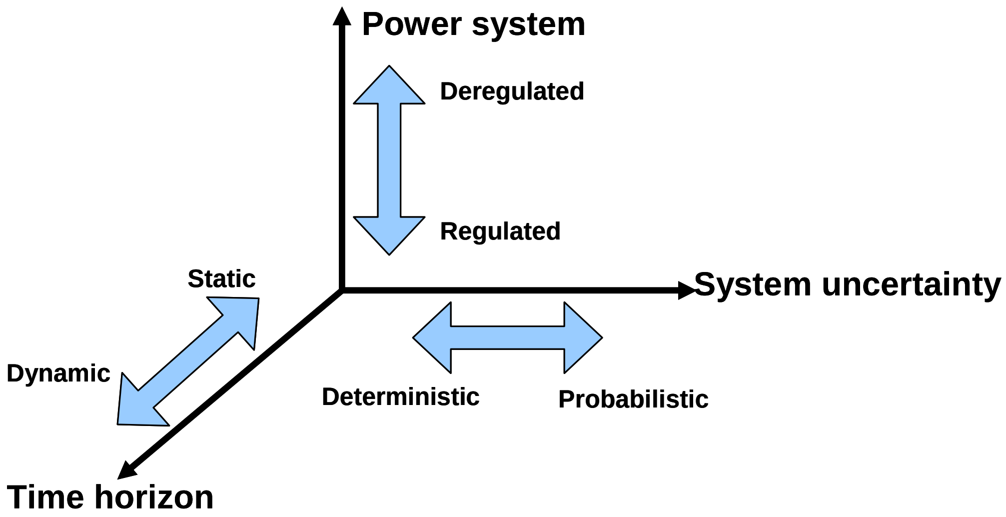
Existing planning practices

- Existing planning methods commonly make use of **worst-case scenario(s)** approach
  - power flow analysis is performed for a small number of cases selected by experienced network planners
- Despite **stochastic** elements are pervading the power systems, probabilistic approaches are not yet fully employed
  - in some cases, they mainly aim to complement **deterministic** analyses, upon which the planning decisions are primarily made

Emerging needs for grid planning

- With the increased uncertainty and the many assumptions necessary for the analysis, more combinations of load, (renewable) generation and international exchange shall be captured for a robust planning under a variety of scenarios
  - **probabilistic** analyses should be further developed
- Transmission planning shall change and be even more focused on
  - better **coordination** between national TSOs (promising initiatives are being set up)
  - **revised** and expanded planning **criteria and tools** to design flexible, coordinated and secure transmission networks including innovative technologies

Literature review of planning methods



- Classified by approach
  - deterministic, non-deterministic
- Classified by timeframe horizon
  - static, dynamic, pseudo-dynamic
- Classified by power system structure
  - regulated systems, restructured systems
- Classified by technique
  - classic optimisation, heuristic, meta-heuristic

Need for improved cost-benefit analyses

- A cost-benefit analysis should take into account the improvements in terms of both reliability and market competitiveness, as well as the interests of consumers and other market players
- Unlike what happened in old vertical integrated markets, grid expansions may be controversial as they can advantage:
  - some stakeholder on others, enhancing or reducing producers' possibility to exercise market power
  - a zone on another (especially for cross-border investments) and provide diversified incentives to new generation

New systemic approach

- A valuable cost-benefit analysis should evaluate the advantages of new investments both system-wide and locally, considering the viewpoint of consumers, producers and TSOs (systemic approach)
- New technologies (WAMS, FACTS, HVDC,…) to better exploit the grid are also assessed
- The **new approach** proposed by REALISEGRID, will consider the different benefits (economic, environmental and SmartGrid,...) and weigh them together by carrying out a **multi-criteria analysis**
  - A scoring number is calculated to rank possible reinforcements and select the most promising ones in the society's perspective

Benefits from transmission expansion

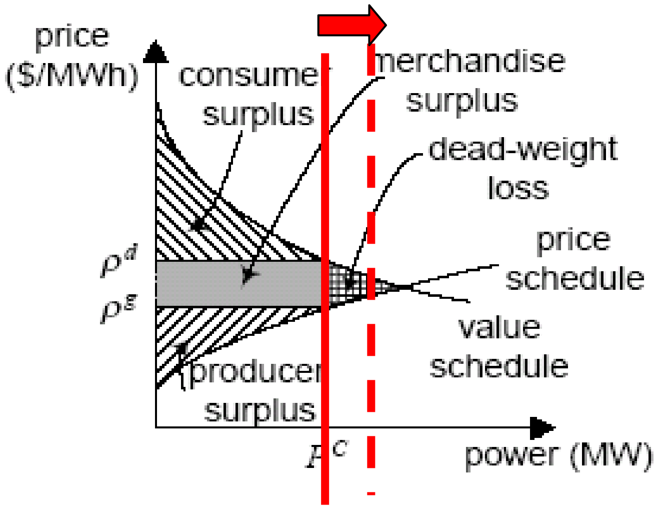
- System reliability, quality and security increase
- System congestions reduction
- Market competitiveness increase
- System losses reduction
- Avoidance/postponement of investments
- More efficient reserve management
- Exploitation of energy mix (also in presence of RES)
- Emission savings (in presence of RES)
- Power flows controllability increase (via FACTS/HVDC)
- External and internal costs reduction (in presence of RES)
- Improved coordination of transmission and distribution grids

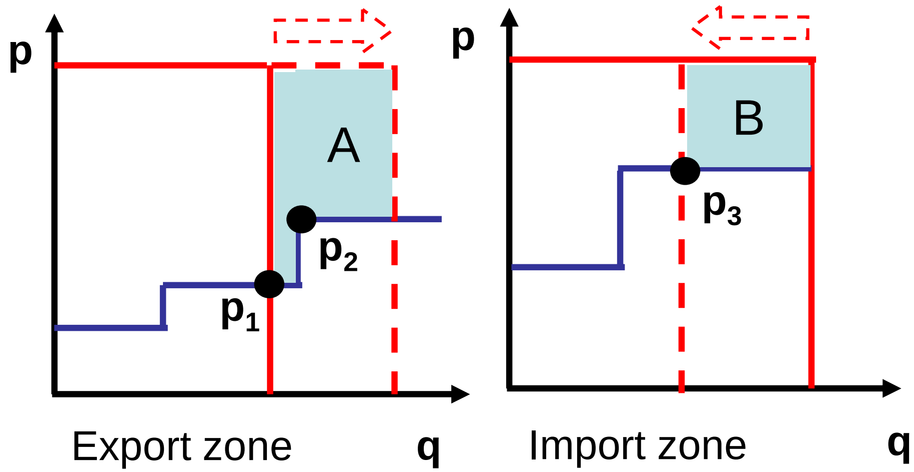
How to gauge the reliability benefits

1. Criteria-based approach:
   - EENS (Expected Energy Not Supplied)
   - LOLP (Loss Of Load Probability)
   - LOLE (Loss Of Load Expectation)
   - SAIDI (System Average Interruption Duration Index)
   - CAIDI (Customer Average Interruption Duration Index)
   - SAIFI (System Average Interruption Frequency Index)
2. Value-based approach:
   - VOLL (Value Of Lost Load)
   - IEAR (Interruption Energy Assessment Rate)
   - WTP (Willingness To Pay)
   - ECOST (Expected Customer Outage CoST)

Market related benefits

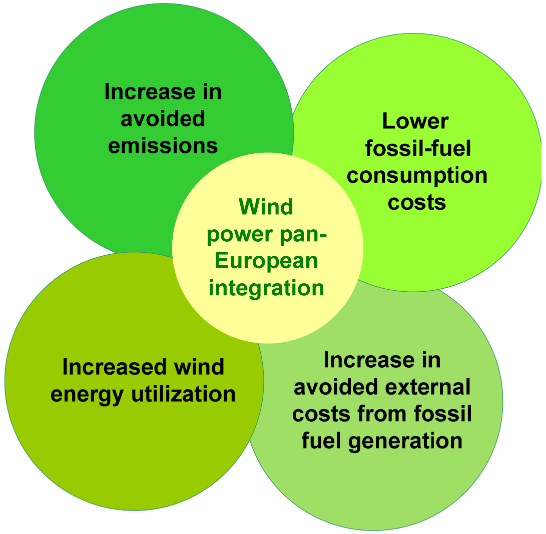
- Increased market competitiveness leading to market price reduction (‘**strategic effect**’) and network congestions reduction allowing the unlock of more efficient power generation (‘**substitution effect**’) can be measured by the Social Welfare (SW)





Other benefits

- Sustainability benefits (in presence of variable RES)
  - Better exploitation of RES (wind) in the generation mix
  - Emissions savings (CO_2, NO_x, SO_2)
  - Reduction of conventional generation external costs
  - Internal (fossil-fuel) costs reduction



- SmartGrids development benefits
  - Improved interaction of transmission and distribution grids

New methodology and tool

- REALISEGRID is developing a systemic approach to transmission planning, to quantify the benefits of grid expansion in a liberalised environment
- REALISEGRID is developing a new tool able to calculate the economic benefits resulting from a transmission system enhancement for the different players and for the society as a whole
- The new simulation tool, among others, has to:
  - be suitable for power system and market studies
  - carry out reliability studies (probabilistic criteria)
  - incorporate emission amount and cost calculations

Conclusions

- Transmission planning will have to adapt to new situations and uncertainties (mostly represented by market opening and renewable integration)
  - Transmission planning criteria should be expanded to **consider probabilistic** approaches
  - **Improved cost-benefit** analyses need to systematically and quantitatively assess grid expansion advantages
- REALISEGRID is developing a **new systemic approach** and tool for transmission planning, to better evaluate the benefits of grid expansion
  - This will be tested on the projects belonging to the Trans-European Network priority axis "EL.2. Borders of Italy with France, Austria, Slovenia and Switzerland"

Thanks for your attention

Gianluca Fulli

EC - Joint Research Centre - Institute for Energy

gianluca.fulli@ec.europa.eu