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SESSION 2-III

Special Session: Susplan&Realisegrid

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A TECHNOLOGY RANKING METHODOLOGY FOR THE COST-BENE ANALYSIS OF TRANSMISSION INVESTMENTS IN EURO

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Overview

According to the IEA World Energy Outlook 2008 [1], the world primary energy use will rise by 45% and the electricity share should increase accordingly, if no new government policies and measures are taken by 2030. In the European Union (EU), constant pressures on security of supply, sustainability and competitiveness have brought the EU Member States to lay down a first set of ambitious targets to be reached by 2020: 20% greenhouse gases emissions reduction (compared to 1990 level); 20% overall energy demand covered by renewables (it was 8.5% in 2005); 20% savings in energy consumption (compared to 2020 projections).

Within this background, the European electricity grids – currently consisting of some 230,000 km High Voltage lines and 1,500,000 km Medium/Low Voltage lines - are on the critical path to meet the EU's climate change and energy policy objectives [2]. In fact, the challenge for the EU electricity networks will be the integration of very large amounts of variable renewable energy sources into the European power system, while keeping its security and reliability within an electricity market context. Also, active demand is foreseen to play an increasing role, for instance via Demand Response programs at peak conditions. Overall, times when generation was considered as fully predictable and consumption fully stochastic are changing to ones in which part of generation becomes stochastic and some of the consumption becomes controllable. The need for evolution in the design and operation of transmission and distribution networks emerges in Europe. This requires a technical and market re-engineering process, which will last tens of years and will have to be supported by different measures. Among them, a crucial role will be played by the utilisation of innovative network technologies to be integrated into the existing power system. Concerning transmission, several technology options are currently available and have to be validated for transmission planning purposes: the goal is to detect the most promising solutions for the re-engineering of the pan-European transmission network. The present work, carried out within the FP7 REALISEGRID project [3], focuses on a methodology developed to appraise the barriers or catalysts that could respectively slow down or accelerate the adoption of such innovative technologies by European TSOs. This appraisal will contribute to identifying those transmission technologies with the highest potential in terms of technical system integration and performance, as seen from the electric system perspective. The proposed methodology, validated by different European TSOs, will serve as a basis for an integrated cost-benefit analysis of grid expansion options, which represents a crucial stage of the transmission planning process.

This methodology has been applied to appraise the following advanced transmission technology families scanned within the REALISEGRID project:

- Superconducting cables;
- High Temperature conductors;
- Gas Insulated Lines (GIL) ;
- Phase Shifting Transformers (PST);
- Real Time Thermal Rating (RTTR)-based lines/cables;
- Wide Area Monitoring Systems (WAMS)/Phasor Measurement Units (PMU);
- Flexible Alternating Current Transmission System (FACTS): SVC (Static VAR Compensator); STATCOM (Static Compensator); TCSC (Thyristor Controlled Series Capacitor); SSSC (Static Synchronous Series Compensator); UPFC (Unified Power Flow Controller); DFC (Dynamic Flow Controller); TCPST (Thyristor Controlled Phase Shifting Transformer);
- High Voltage Direct Current (HVDC): Voltage Source Converter (VSC)-based HVDC (VSC-HVDC); Current Source Converter (CSC)-based HVDC (CSC-HVDC);
- Power Storage (possibly operated by TSOs): Flywheel; Supercapacitor; and Superconducting Magnetic Energy Storage (SMES).

In particular, this work pays attention to High Voltage Direct Current (HVDC). This technology exhibits characteristics that have already made it widely attractive over High Voltage Alternating Current (HVAC) transmission for specific applications, such as long distance power transmission, long submarine cable links and interconnection of asynchronous systems. Currently, recent advances in power electronics, coupled with traditional features of HVDC, should help further deploying this technology with the aim of improving operation and supporting the development of onshore and, possibly, offshore European transmission grids. This is the case of the promising Voltage Source Converter (VSC)-based HVDC [4], whose application may provide the European power system with generally enhanced system security and controllability. The latter properties are especially important in a deregulated environment, where VSC-HVDC can be an attractive option to efficiently and timely relieve network constraints, thus reducing the need for building new HVAC lines. In addition, VSC-HVDC gives the possibility to feed reactive power into a network node and provide voltage support. Moreover, VSC-HVDC may offer a lower environmental impact and a smaller territorial footprint respect to HVAC (and also to HVDC lines due to a more compact station design). Also, both HVDC and VSC-HVDC offer undergrounding possibilities by using cables as a transmission medium.

Methods

The proposed methodology, aiming at assessing power transmission technologies, requires addressing two dimensions: the barriers to system integration and the potential performances, once integrated.

The barriers to system integration for a given technology combine two factors:

The maturity of the technology, which measures the vision of system operators about the state of development of the studied technology

The accessibility of the technology, which measures the capacity of system operators to integrate the technology within their own operations.

The potential performance of an innovative technology is defined by two factors:

Security improvement

Stability improvement.

The improvement is defined by means of a comparison between the transmission system having the scanned technology implemented and the current system without the integration of the studied technology. The ranking of a combined use of several technologies is, therefore, excluded from the present approach.

This methodology has been applied to all the above mentioned scanned technologies; the present work focuses on the assessment results related to the emerging VSC-HVDC technology.

Results

Despite all the above described advantages provided by the utilisation of VSC-HVDC, features such as converter losses and technology costs may still make VSC-HVDC less competitive than classic HVDC. Then, more accurate cost-benefit analyses can help to better understand the impact that VSC-HVDC technologies will have on the power system. All these elements are also taken into account while applying the above described approach of assessing the barriers and the potential performance towards system integration of VSC-HVDC. The results, validated by some European TSOs, even with some differences (also due to the different network configurations the involved TSOs have to deal with), show that a more widespread application of the VSC-HVDC technology, for which there is presently an increasing interest also in conjunction with some multi-national pilot projects, may be possible in the mid-term, when the present barriers could be overcome by the technological advance.

Conclusions

The present work introduces a methodology used as a basis for the techno-economic assessment of transmission technologies, validated by some European TSOs. This will allow :

- developing a 2020 and 2030 roadmap for the integration of innovative transmission technologies
- filtering out the set of key technologies that will have to be further analysed
- performing a cost-benefit analysis, key stage of the transmission planning process, which takes also account of the candidate technologies.

References

[1] International Energy Agency (IEA), World Energy Outlook 2008.

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

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

[4] J. Arrillaga, Y.H. Liu, N.R. Watson, "Flexible Power Transmission. The HVDC Options", J. Wiley & Sons Ltd, 2007.

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REALISE GRID

A Technology Ranking Methodology for the Cost-Benefit Analysis of Transmission Investments in Europe

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SPECIAL SESSION: SUSPLAN & REALISEGRID
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SEVENTH FRAMEWORK PROGRAMME

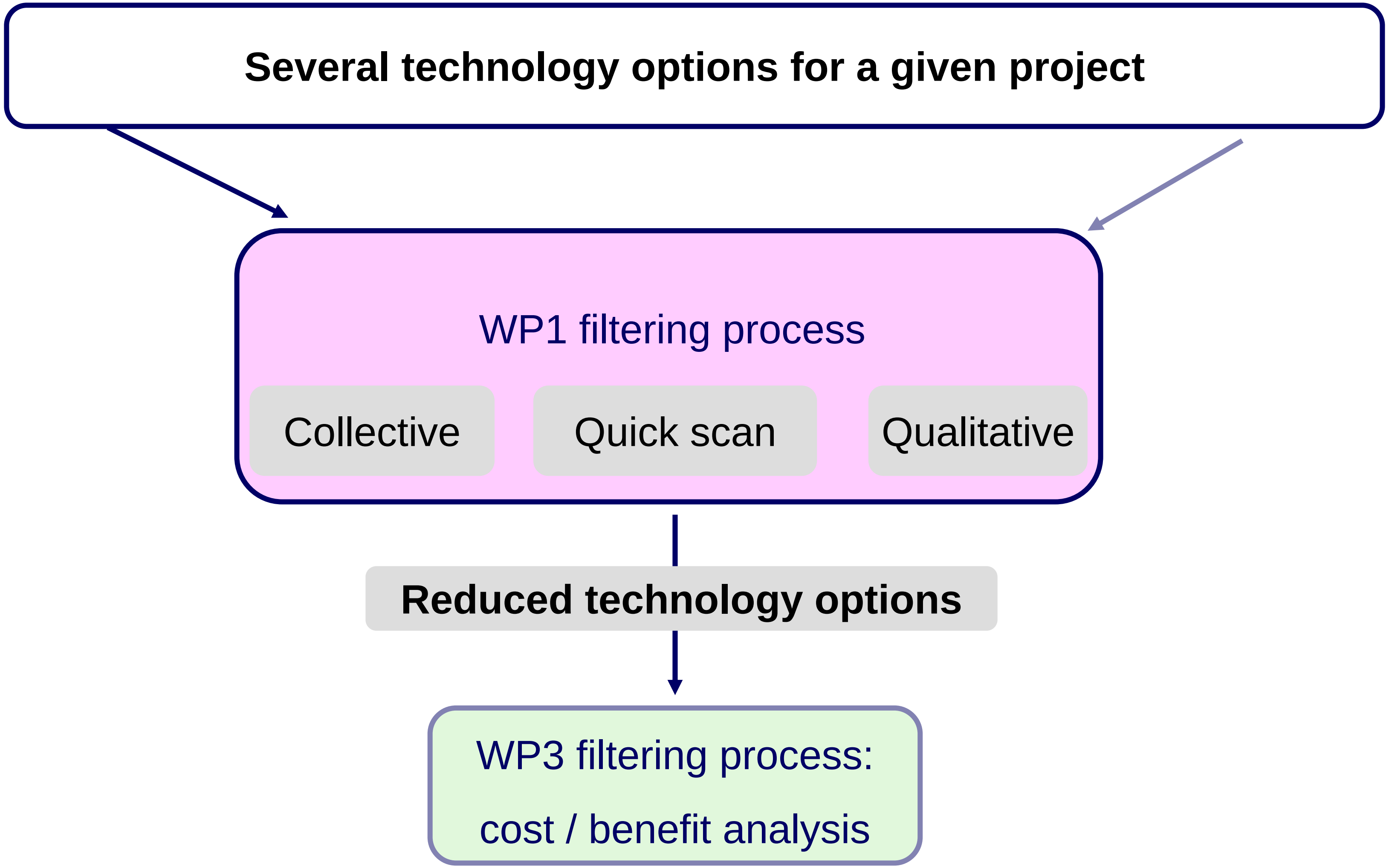
Outline

- Challenges related to the transmission grid expansion in Europe
- A collective quick scan tool to select candidate technologies
- The results of the quick scan tool obtained for two specific technologies
  - Superconducting cables
  - VSC-HVDC: Voltage Source Converter-High Voltage Direct Current
- Conclusions

Challenges

- Future critical investments for interconnected transmission systems involve several TSOs with cross border issues
- For given project, many technological options are available due to the many possible promising transmission system technologies
- There is a need for a preselection of options based on techno-economic criteria
- It is then critical to filter out unrealistic technology options before any cost benefit analysis is processed
- This work deals with the development and use of such a **collective quick scan tool:** It is a building block of the roadmap construction process for new transmission technologies in the electricity grids

A collective quick scan tool



Several technology options for a given project

WP1 filtering process

Collective

Quick scan

Qualitative

Reduced technology options

WP3 filtering process:

cost / benefit analysis

The collective technology quick scan tool: key features

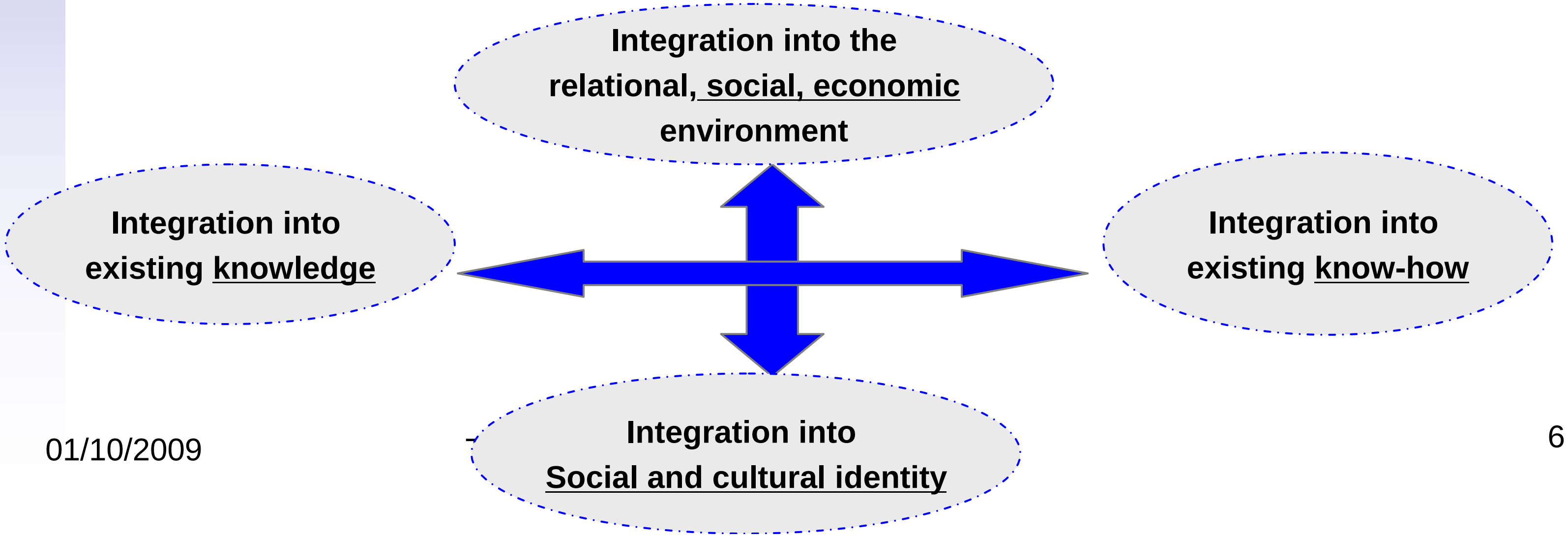
- It is a decision model based on the assessment of:
  i- the **technical performance potential** for the system

  ii- the **technical barriers** impeding their use in the transmission system
- Time horizon is taken into account to support the building of a roadmap (2020 and 2030)
- TSOs are asked to assess a given promising technology on an individual basis (4 marks per technology per TSO for each time horizon)
- Once marks are collected, a collective workshop involving all TSOs allows an analysis of consensus / dissent areas for each studied technology

Why the rating can differ from a TSO to another?

- Each selected innovative power technology has to be integrated into the specific environment of a Transmission System Operator (TSO)
- This integration process has several interrelated components to be taken into account:
  - *the socio-economic integration*
  - *the socio-cultural identity of the company*
  - *the existing knowledge within the company*
  - *the know-how of its experts*

Dimensions influencing the TSO's environment



Integration into the relational, social, economic environment

Integration into existing knowledge

Integration into existing know-how

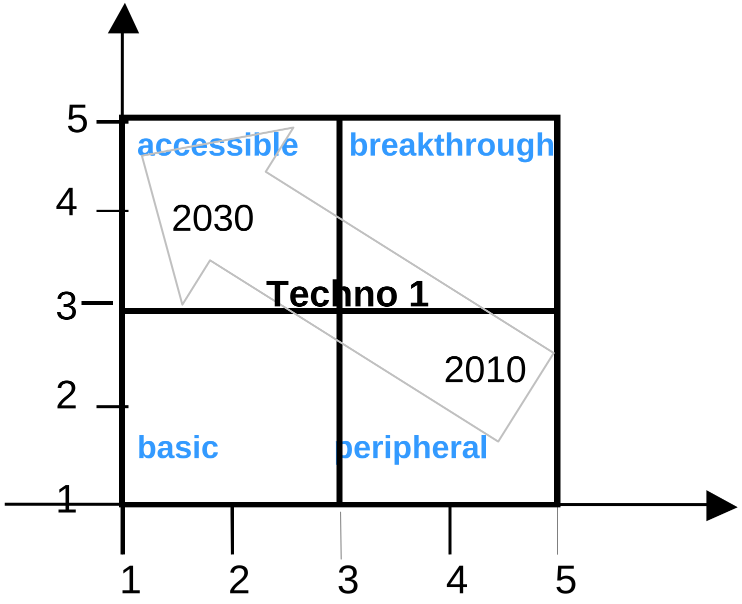
Integration into Social and cultural identity

The technology ranking methodology: Description

Summary of Ranking for Techno 1

Technical Performance potential for the system

1: Limited improvement brought by the technology in terms of security and stability
2: Low improvement
3: Average improvement
4: Significant improvement
5: Major improvement



Technical barriers towards System integration

1:Limited level of barriers in term of technology maturity and accessibility
2: Low level of barriers
3: Average level of barriers
4: Significant level of barriers
5: Major level of barriers

Application in REALISEGRID

- The REALISEGRID **ranking** of **innovative power technologies** by TSOs gives a first short list of promising technologies prior to an in-depth evaluation of the costs & benefits of their real-life implementation

- This first circle of the 4 REALISEGRID TSOs **will be enlarged** to additional ones in a Stakeholder board to be held on Sept 29th 2009 in Paris

- The **preliminary outputs** will be used during 2nd year of REALISEGRID to answer the following questions:
  - *Which technologies show the highest potential in terms of technical system integration and performance to be considered in CBA studies?*
  - *What is the ideal development roadmap spanning the period 2010-2030, which will guide investments to support the grid integration of such technologies?*

Selected promising technologies

- **Superconducting cables**
- **High Temperature conductors**
- **Gas Insulated Lines (GIL)**
- **XLPE underground cables**
- **Phase Shifting Transformers (PST)**
- **Real Time Thermal Rating (RTTR)-based lines/cables**
- **Wide Area Monitoring Systems (WAMS)/ Phasor Measurement Units (PMU)**
- **Flexible Alternating Current Transmission System (FACTS):**

SVC (Static VAR Compensator); STATCOM (Static Compensator); TCSC (Thyristor Controlled Series Capacitor);

SSSC (Static Synchronous Series Compensator); UPFC (Unified Power Flow Controller); DFC (Dynamic Flow Controller);

TCPST (Thyristor Controlled Phase Shifting Transformer)

- **High Voltage Direct Current (HVDC):**

Voltage Source Converter (VSC)-based HVDC (VSC-HVDC)

Current Source Converter (CSC)-based HVDC (CSC-HVDC)

- **Power Storage (possibly operated by TSOs)**:

Flywheel; Supercapacitor; and Superconducting Magnetic Energy Storage (SMES)

Selected promising technology families

Real-Time monitoring equipments (RT)

RT1) Real Time Thermal Rating (RTTR)

RT2) Wide Area Monitoring Systems (WAMS) / Phasor Measurement Units (PMU)

Passive equipments (P)

- P1) XLPE underground cables
- P2) Gas Insulated Lines (GIL)
- P3) High Temperature Conductors
- P4) Superconducting cables

Active equipments (A)

A1) **Phase Shifting Transformers (PST)**

A2-3) **High Voltage Direct Current (HVDC)**

Voltage Source Converters (HVDC-VSC)
Current Source Converters (HVDC-CSC)

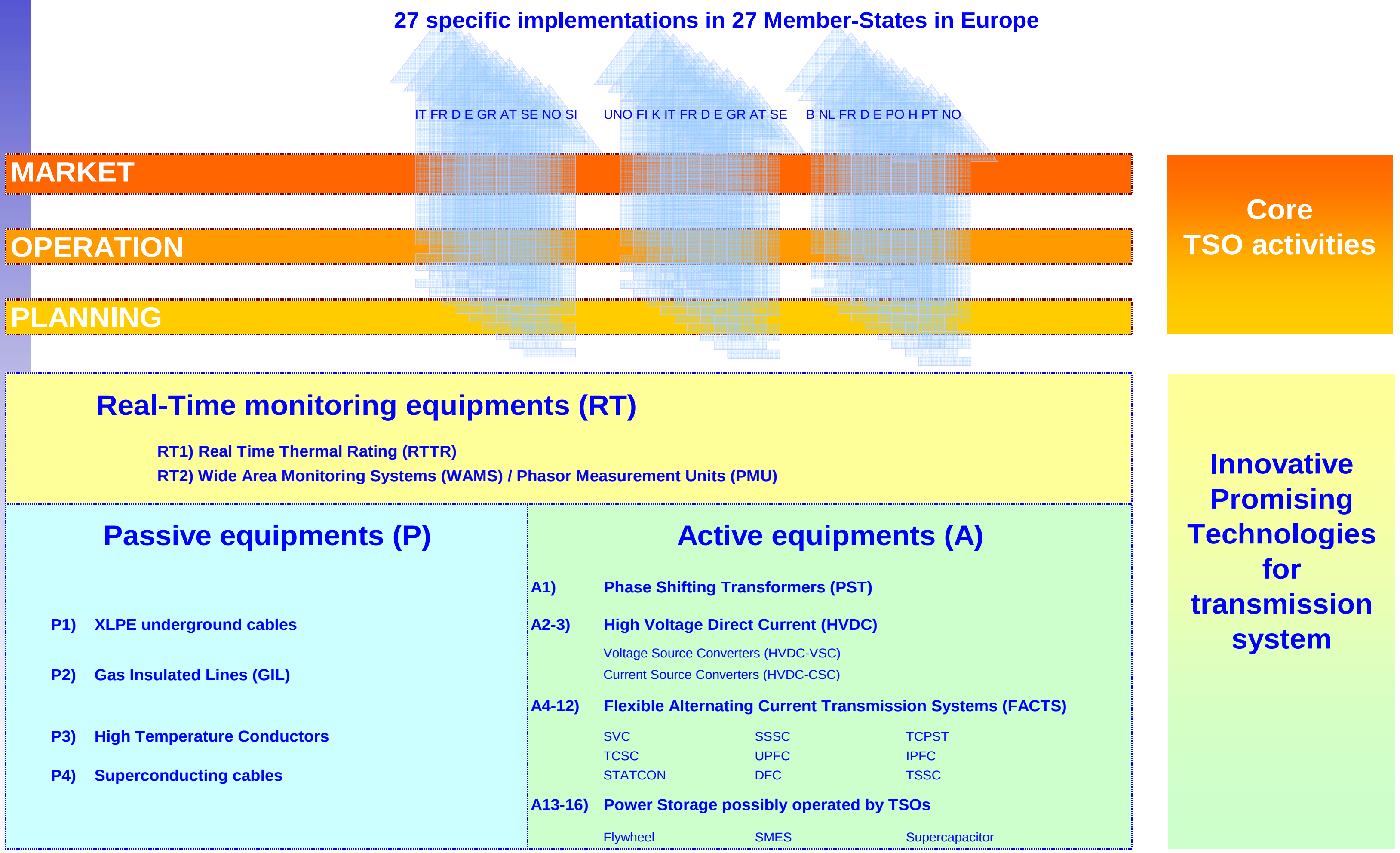
A4-12) **Flexible Alternating Current Transmission Systems (FACTS)**

SVC
TCSC
STATCON
SSSC
UPFC
DFC
TCPST
IPFC
TSSC

A13-16) **Power Storage possibly operated by TSOs**

Flywheel
SMES
Supercapacitor

Selected promising technology families



27 specific implementations in 27 Member-States in Europe

MARKET

OPERATION

PLANNING

Core TSO activities

Real-Time monitoring equipments (RT)

RT1) Real Time Thermal Rating (RTTR)
RT2) Wide Area Monitoring Systems (WAMS) / Phasor Measurement Units (PMU)

Passive equipments (P)

- **P1) XLPE underground cables**
- **P2) Gas Insulated Lines (GIL)**
- **P3) High Temperature Conductors**
- **P4) Superconducting cables**

Active equipments (A)

A1) Phase Shifting Transformers (PST)

A2-3) High Voltage Direct Current (HVDC)

Voltage Source Converters (HVDC-VSC)
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A4-12) Flexible Alternating Current Transmission Systems (FACTS)

SVC	SSSC	TCPST
TCSC	UPFC	IPFC
STATCON	DFC	TSSC

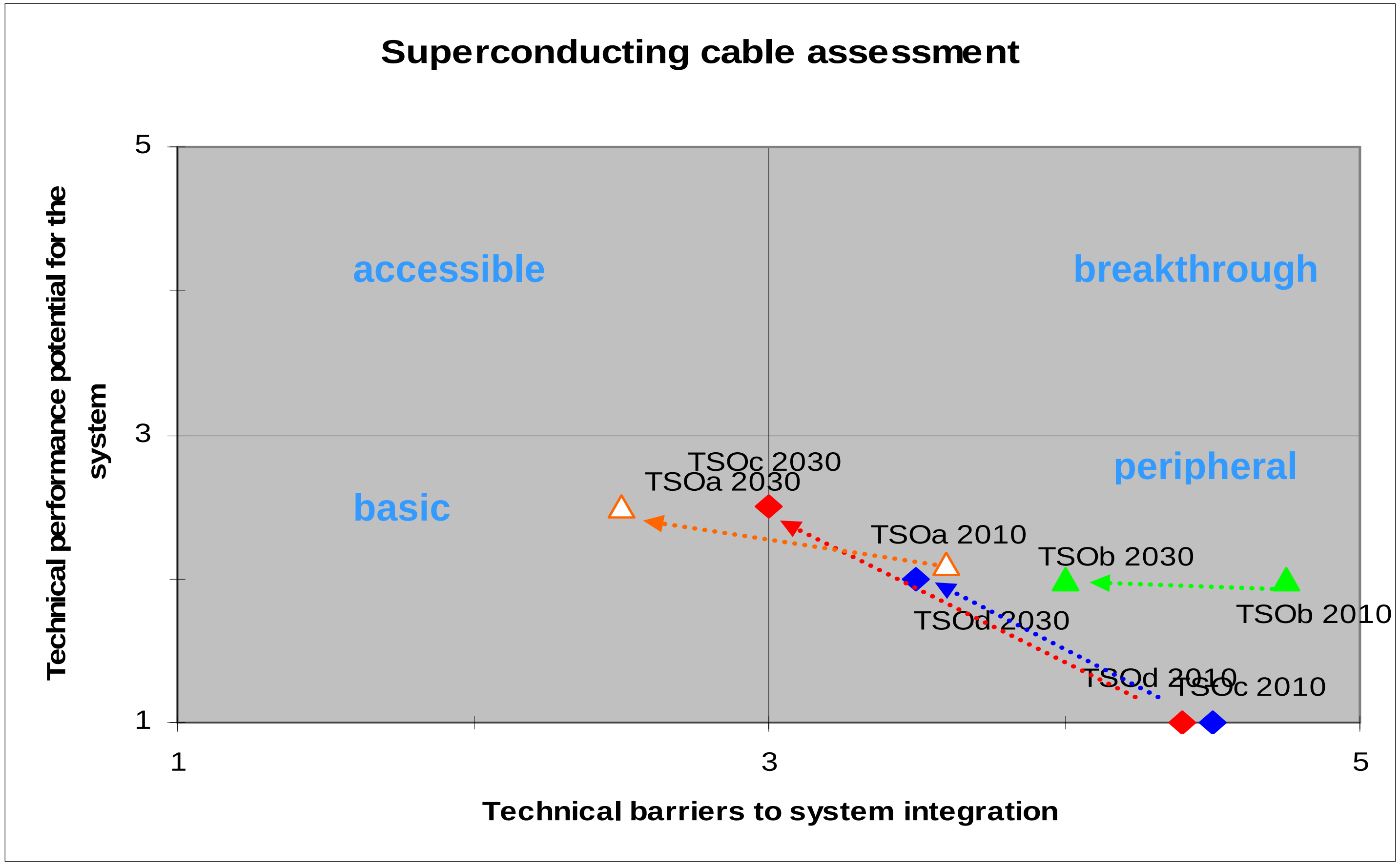
A13-16) Power Storage possibly operated by TSOs

Flywheel	SMES	Supercapacitor

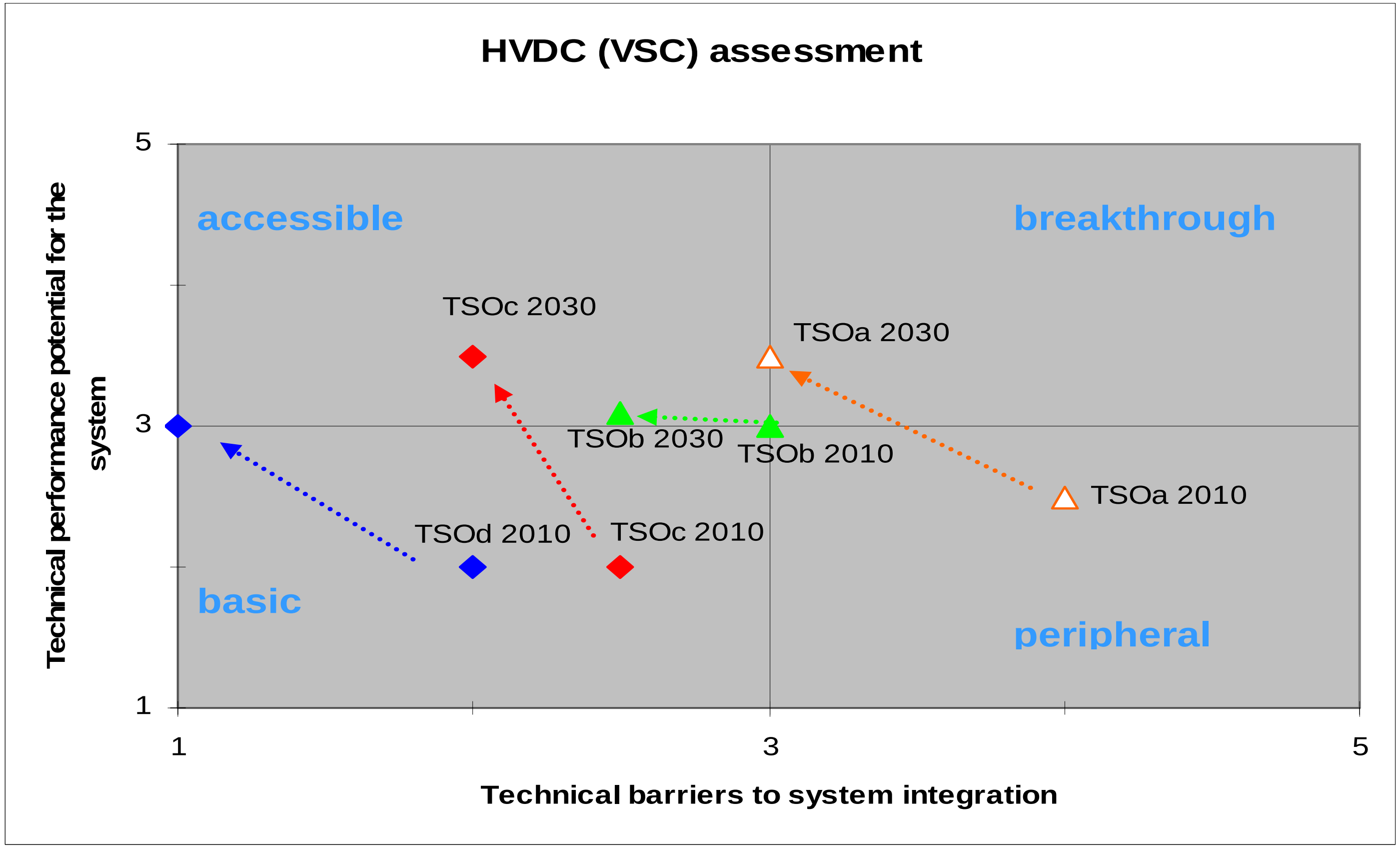
Innovative Promising Technologies for transmission system

Technology ranking of a Superconducting cable

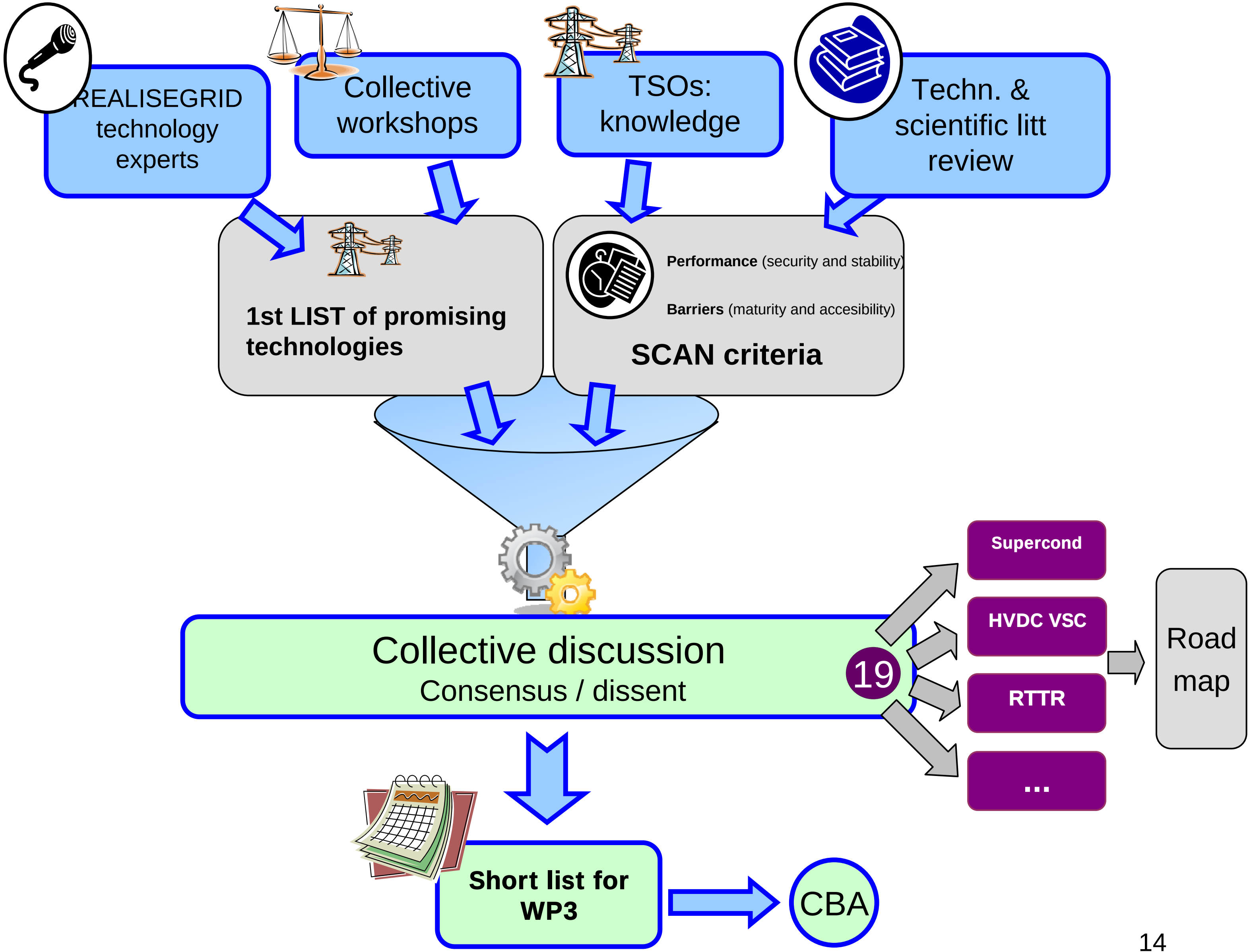
- This exercise involves the experience of European TSOs involved in REALISEGRID



Technology ranking of a VSC-HVDC



Conclusions: the quick scan tool in REALISEGRID



REALISEGRID technology experts

Collective workshops

TSOs: knowledge

Techn. & scientific litt review

1st LIST of promising technologies

Performance (security and stability)

Barriers (maturity and accesibility)

SCAN criteria

Collective discussion
Consensus / dissent

19

Supercond

HVDC VSC

RTTR

...

Road map

Short list for WP3

CBA

Conclusions

- A methodology, validated by four TSOs, has been developed to be used for an early techno-economic assessment of innovative transmission technologies

- This methodology will allow:
  - filtering-out the set of key technologies that have to be further scrutinized
  - developing a 2020 and 2030 roadmap for the integration of innovative transmission technologies
  - performing a cost-benefit analysis, a key stage of the transmission planning process, which takes account of the candidate technologies.

ADDITIONAL presentation on the two main dimensions of the quick scan tool

Technical performance
technical barriers
(only if needed for questions)

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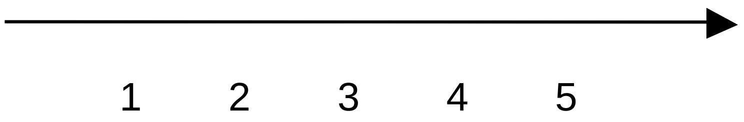
The technology ranking methodology: Description



1 2 3 4 5

Technical barriers towards System integration

- **Technical Barriers towards system integration** combine two factors :
  - **Maturity :** it measures TSOs’ vision about the state of development of the studied technology
  - **Accessibility to the technology** : it measures TSOs’ capacity to integrate the technology within their own operations

The technology ranking methodology: Description

- A linear combination of the two dimensions, ‘technology maturity” and “accessibility of technology”, gives a picture of the barriers to system integration

Accessibility to the technology

1: New daily process implementation requiring redesign of part of the system

2: Important impact on daily process implementation

3: Average impact on the daily process implementation

4 Limited impact on the daily process implementation

5: No impact on the daily process implementation

Technology maturity

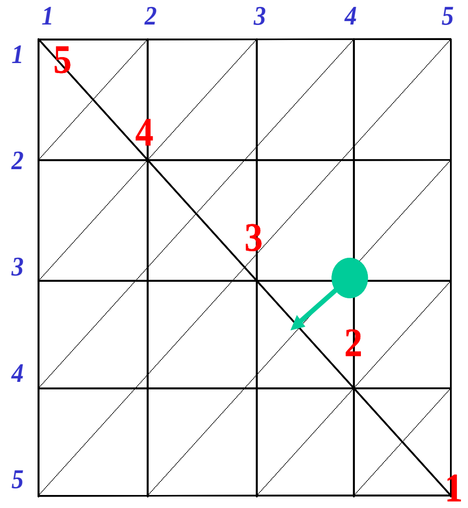
1: just at the idea stage.

2 first on going technology developments

3: validated prototypes exist

4: already applied in a few systems

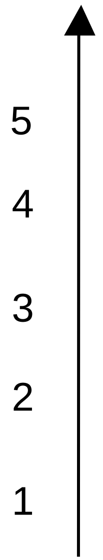
5: standard technology applied at a large scale



Barrier to system integration =2,5

The technology ranking methodology: Description

Technical Performance potential for the system



- **Technical Performance Potential** depends on:
  - Security improvement
  - Stability improvement
- These two factors contribute to the **reliability of the system** when integrated in the long-run
- **Assumptions**
  - The improvement is defined with respect to the same transmission system without the integration of the studied technology
  - The technologies are assessed when implemented as a **stand-alone solution**
  - This is a **limitation** of the present work: e.g., the maximization of transmission capacity to face wind issues in some areas of Europe requires the joint use of RTTR, PST and WAMS

The technology ranking methodology: Description

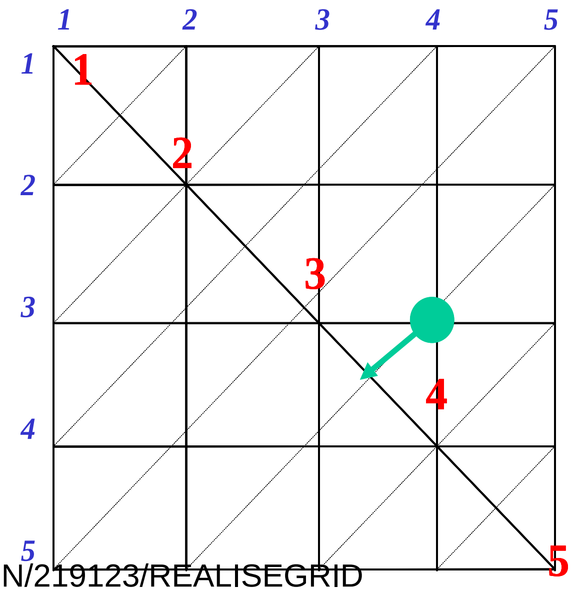
- A linear combination of the two dimensions, ‘security improvement” and “stability improvement”, gives a picture of the barriers to system integration

Security improvement

1: Limited improvement of the security
2: Low improvement of the security
3: Average improvement of the security
4 : Significant improvement of the security
5: Major improvement of the security

Stability improvement

1: Limited improvement of stability
2: Low improvement of stability
3: Average improvement of stability
4 : Significant improvement of stability
5: Major improvement of stability



PP =3,5