



CIGRE US National Committee

Cleveland, OHIO
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2017 Grid of the Future
Symposium

ROLE FOR ADJUSTABLE SPEED PUMPED STORAGE IN THE GRID OF THE FUTURE

Peter Donalek

PRESENTATION

- Adjustable speed pumped storage History
- Types of advanced pumped storage
- Changing Grid System Inertia
- AS PSH Storage Technology
- AS PSH Control Options
- AS PSH in the Grid Of The Future

AS PSH HISTORY

1990'S Japan, TEPCO and Kansai Electric companies were required to reduce imported oil consumption

- Frequency regulation in pump mode
- Yagisawa and Ohkawachi pumped storage plants have Adjustable Speed units.
- Other system benefits

US INTEREST

- EPRI 1995 Report: “Application of Adjustable Speed Machines in Conventional and Pumped Storage Hydro Projects”
- Argonne National Lab 2014 DOE study/report: “Modeling and Analysis of Value of Hydropower in the United States”

USDOE 6 Vol. Report Published 2014

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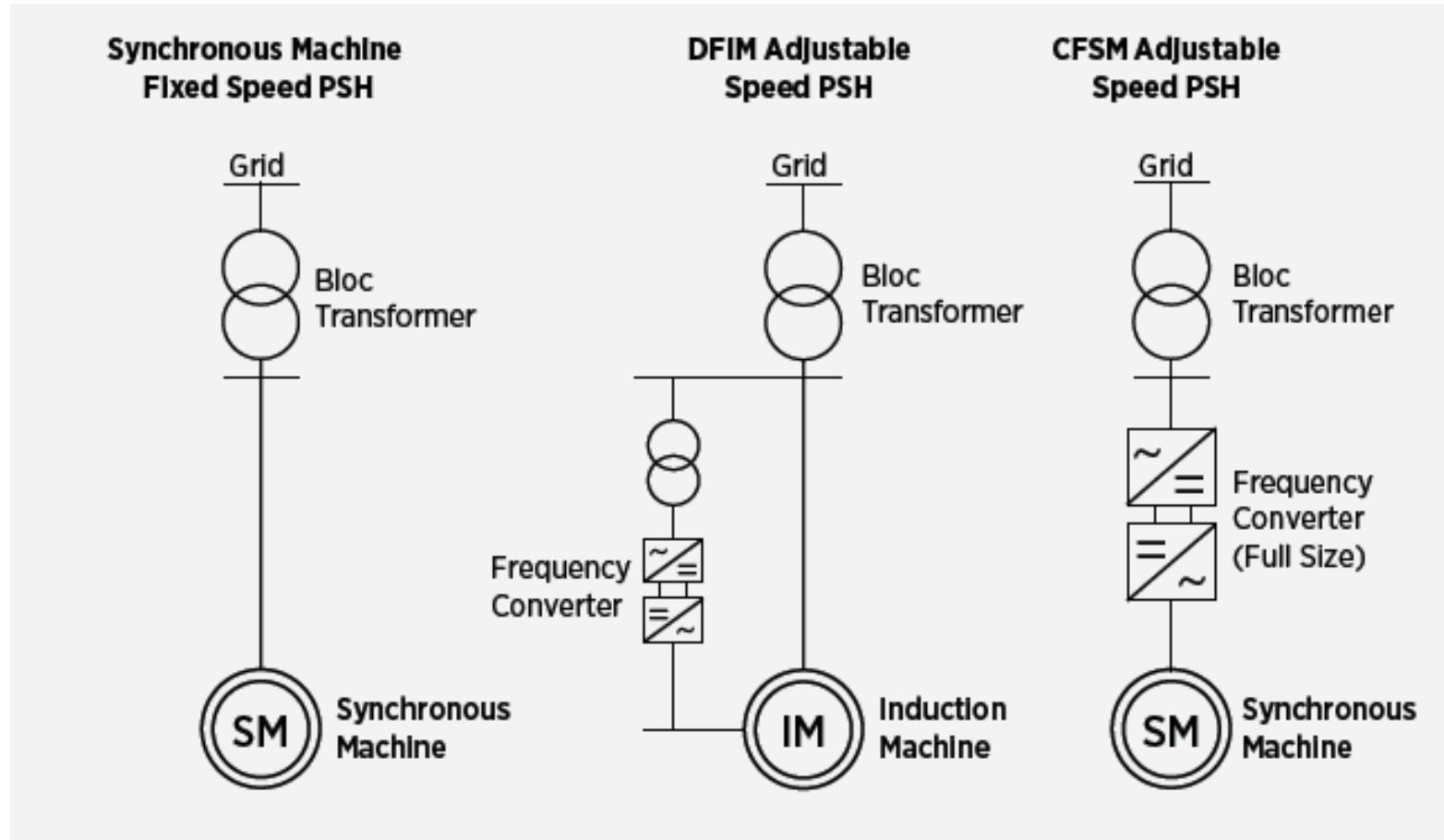
DFIM model,
Ternary Model,
Turbine-Governor
Economic Value,
WECC Model,
Frequency,
Control in Single
Control Area



ADVANCED PUMPED STORAGE TECHNOLOGIES



THREE TYPES OF HYDRO STORAGE



Note: DFIM=Doubly-Fed Induction Machine, CFM= Converter-Fed Synchronous Machine.

Source: Koritarov et al. 2015

FOCUS IS ON DFIM ADJUSTABLE SPEED PSH

- **World wide, Adjustable Speed Pumped Storage with Doubly Fed Induction motor/generators is the dominant Grid Scale storage technology in commercial operation**
- **Therefore this presentation is focused on DFIM AS Pumped Storage hydro.**

PUMPED STORAGE IN US

40 GRID SCALE SINGLE SPEED PUMPED STORAGE UNITS, 22 GW

Large: Six Unit, Bath County: 3,003 MW

Small: Two Unit, Lake Hodges: 40 MW

To date: there are no adjustable speed pumped storage units in the US

ADVANCED PUMP STORAGE IN US

- Several states are recognizing the need for grid scale storage.
- California, Virginia, New York and other states are encouraging storage as part of the capacity mix.

NEW PUMPED STORAGE IN US

- **As of Aug 2017 - 19 PSH project sites with FERC preliminary permits**
- **Largest is 811 MW and smallest is 554 MW**
- **Expect several will get permits and be constructed**
- **Likely that some will include units with advanced technology**

CHANGING GRID SYSTEM INERTIA



CHANGING GRID SYSTEM INERTIA

- Increased non-dispatchable wind & solar
- Retirement of large base-load turbine – generators
- Impact on system operation: frequency regulation, ramping, response to system events

EFFECTS OF CHANGE

- UK: New class of frequency regulation called “Enhanced Frequency Response”
- South Australia: September 2016 blackout linked to periods with low inertia due to increased amount of renewables
- Japan: AS PSH, “flywheel effect” role in major system events; ex. earthquakes

NERC & SYNCHRONOUS INERTIAL RESPONSE

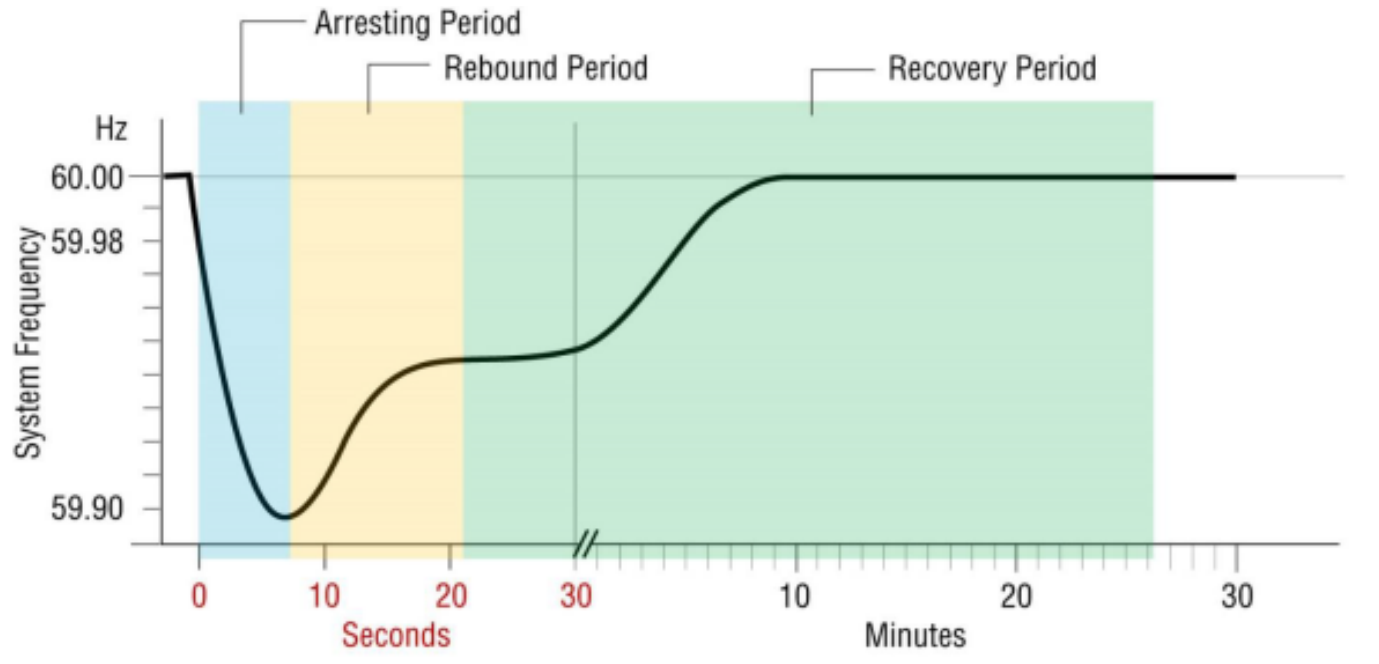
2014: NERC Established an Essential Reliability Services Task Force

2015: Report & RTO/ISO question “Is System Inertia Trending Down?”

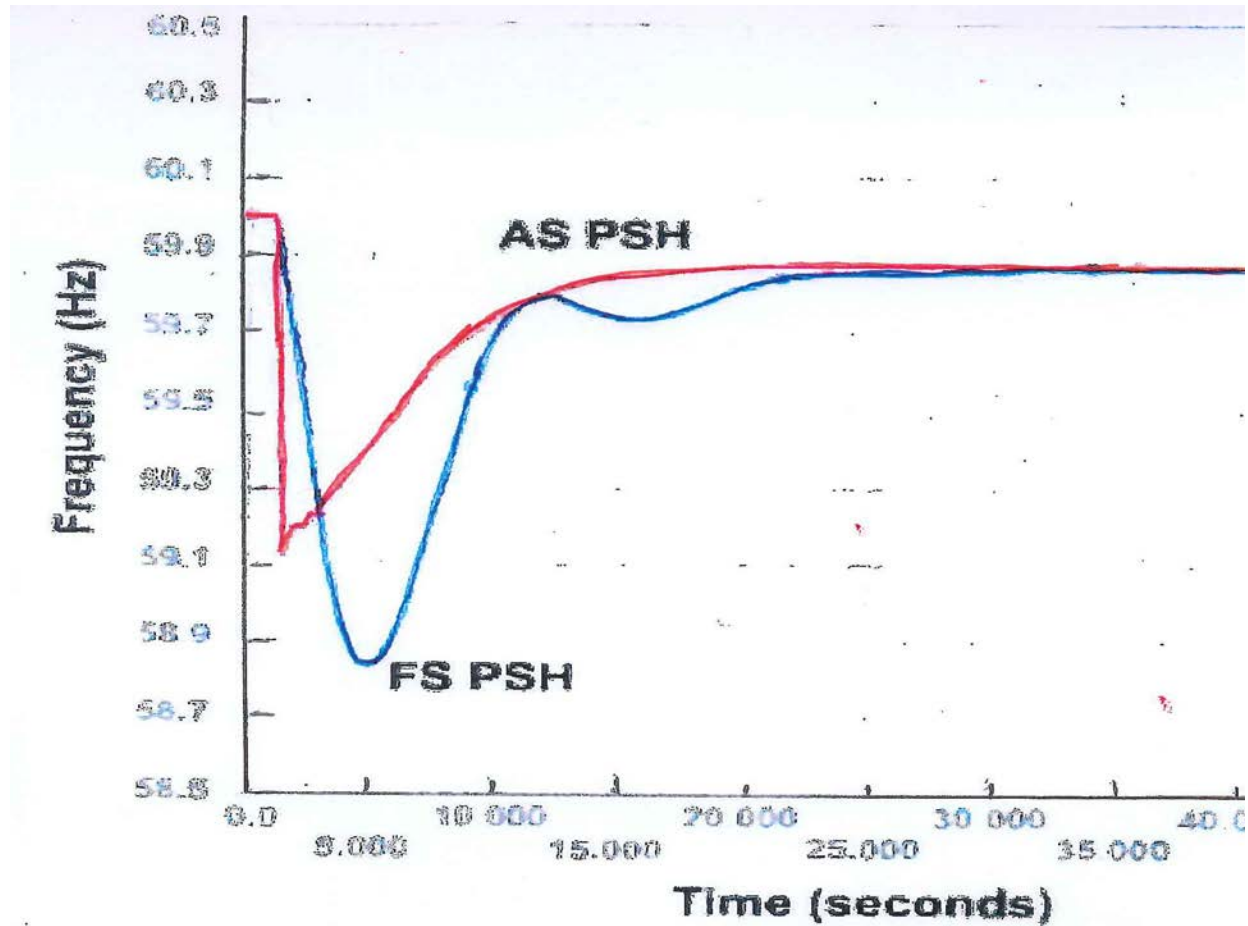
2 yes, 2 some what, 4 no to little, and 1 no

2016: Report, synchronous inertial response

INERTIA – BASED CONTROLS

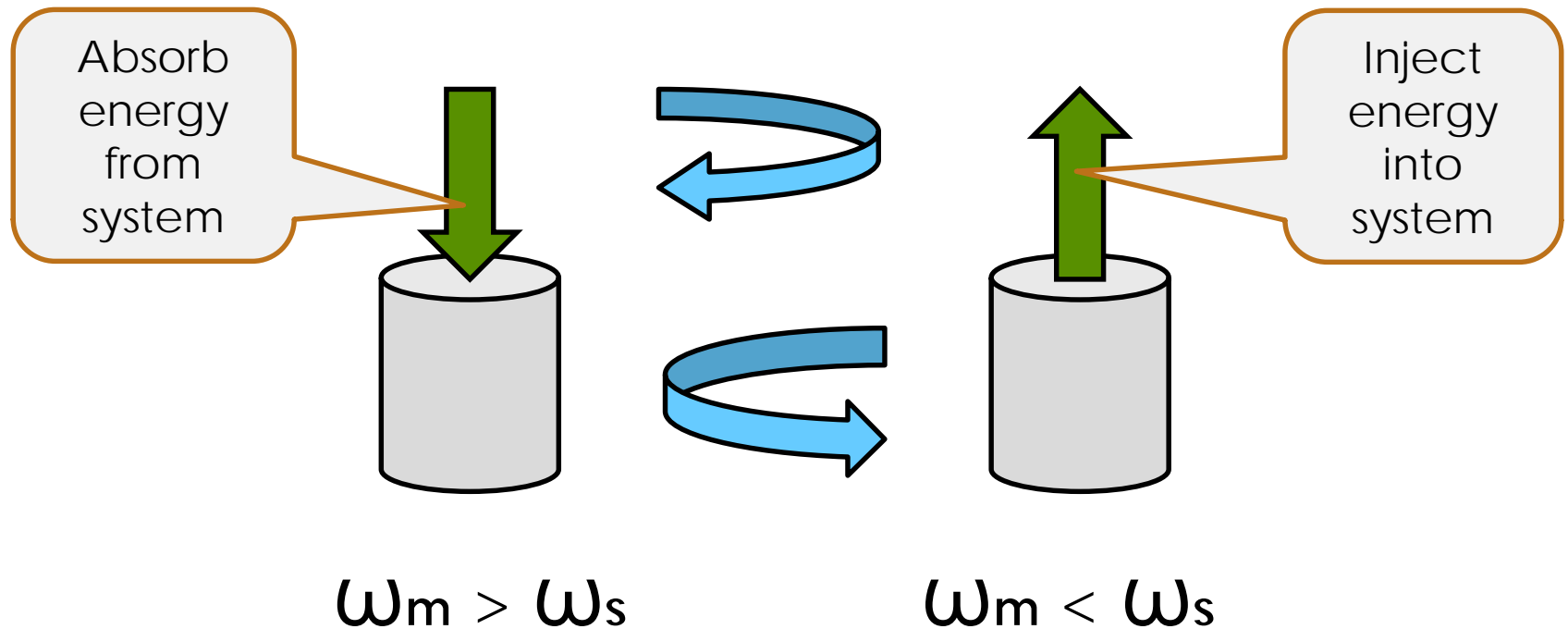


RESPONSE COMPARISON



KINETIC ENERGY & ROTOR INERTIA

Interchange inertial kinetic energy with grid system in both pump and generation modes



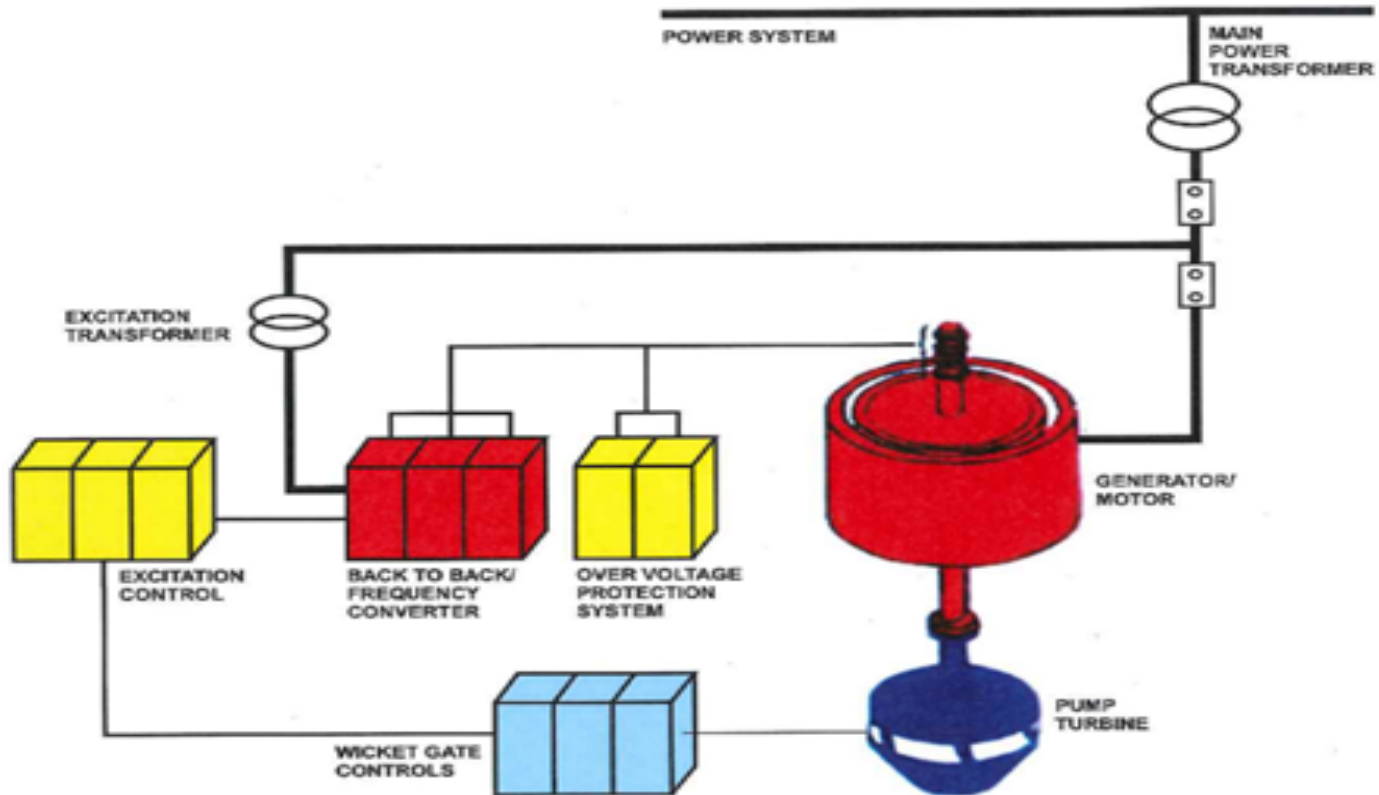
ADJUSTABLE SPEED PUMPED STORAGE TECHNOLOGY

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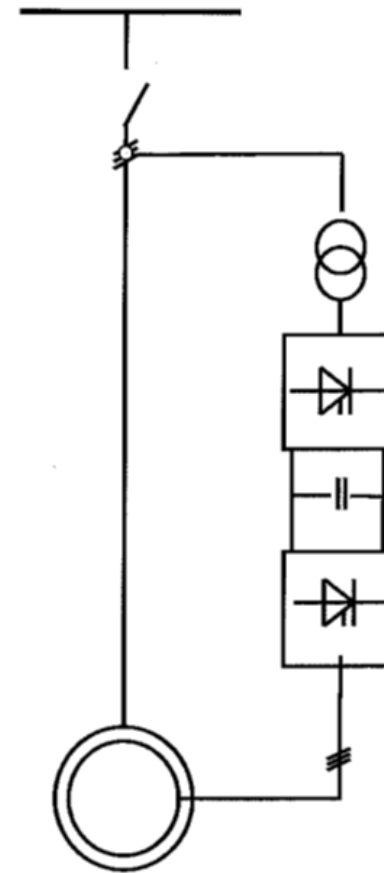
www.alamy.com - ESKONE

DFIM TECHNOLOGY



DFIM ADJUSTABLE SPEED – ROTOR EXCITATION

- Preferred configuration uses a voltage source frequency converter.
- Converter provides sinusoidal current to create a three-phase magnetic field on the rotor.
- Frequency converter MVA capacity rating is roughly proportional to slip speed range.



CONTROL OPTIONS

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CONTROL OPTIONS

Three control approaches are possible with DFIM AS PSH units:

1. Fast Power Control: Most Prevalent
2. Fast Speed Control: Not often used
3. Fast speed (Slip frequency) control with governor free operation

PLANT DESIGN AND TRANSMISSION INTERCONNECTION

- Establish unit equipment ratings and develop plant single line diagram.
- Evaluate and select control option
- Identify preferred point of interconnection with host system
- Start LGIA interconnection process

AS PSH AND THE GRID OF THE FUTURE

U.S. pumped hydroelectric storage capacity, 2011

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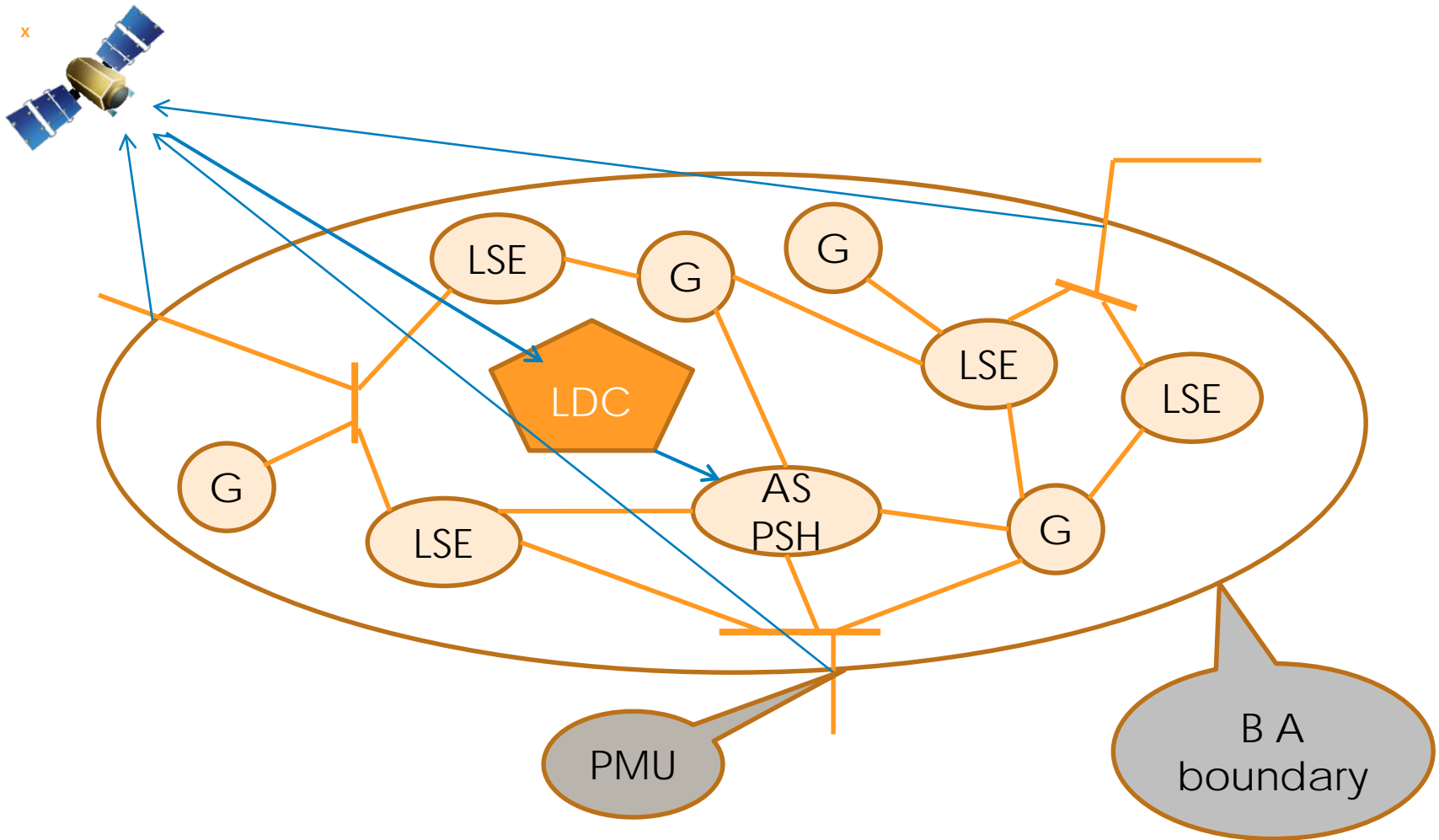


ADJUSTABLE SPEED PSH & BALANCING AUTHORITY

CIGRE Technical Brochure 316

- Defense Plan Against Extreme Contingencies
- Overview of Existing Defense Plans
- Propose response-based Wide-Area stability and voltage Control System (WACS) for the Western North American interconnected power grid

ADJUSTABLE SPEED AS PART OF WACS BALANCING AUTHORITY



CONCLUSIONS

- Confirm performance of control option with System Impact Studies
- Can System Impact Studies be made with Laplace based models or will EMTP studies be required?
- Need generic models, with data, for planning and design studies

FINAL QUESTION

**Will Grid Scale Adjustable
Speed Pumped Storage be
part of the future US Grid ?**

***Niels Bohr, The famous
Danish physicist has the
answer***



**“Prediction is very difficult,
especially if it’s about the
future”**

QUESTIONS

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THANK YOU
FOR YOUR
ATTENTION

