Greater Mekong Subregion (GMS)

Grid Code Knowledge Product

Lessons Learned from the

Development of the GMS Regional Grid Code

Tailoring the GMS RGC to suit TSO Priorities

RPTCC-27 Remote Presentation

October 15, 2020

ADB Knowledge Products Consultant
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SUMMARY

1. ADB Regional Grid Code Knowledge Product
2. Characteristics of Future GMS Regional Grid
3. Rationale for GMS RGC
4. Interconnection Technologies for GMS
5. RPTCC Acceptance of RGC as a Reference Document
6. Tailoring the RGC to Suit TSO Priorities
7. TOC GCKP; Request for RPTCC Comments / Suggestions on Scope & Content of RGCKP

ADB GMS Regional Grid Code Knowledge Product (GCKP)

"The provision of knowledge products and services is a key part of ADB's development assistance with knowledge solutions as one of the drivers of change in its Strategy 2020".

- Review the background to the development of the Regional Grid Code
- Analyze the Role of the ADB in supporting RPCC plans to achieve Regional Power Trading
- Explain the need for the RGC and its continuous development by the RPTCC to Reflect TSO Priorities
- Identify emerging technologies requiring further consideration in adapting the GMS RGC
- Justify further support by ADB to help RPTCC work Groups become self sustaining
- Summarize the Lessons Learned to Facilitate RGC development in GMS and Other ADB Operational Regions

ADB Knowledge Products Relevant to GMS Power Trading

Report Number	*Title*
SES:REG 2012-18	*Knowledge Products and Services: Building a Stronger Knowledge Institution - Special Evaluation Study Nov 2012*
ADB Publications	*See ADB webpage: https://www.adb.org/publications/corrigenda*
ISBN 978-92-9257-726-1	*Energy Storage in Grids with a High Penetration of Variable Generation Feb 2017, Pramod Jain*
ISBN 978-92-9261-471-3	*Handbook on Battery Energy Storage System- Dec 2018*
ISBN 978-92-9254-986-2	*Knowledge and Power: Lessons from ADB Energy Projects – 2015*
TA 7764-REG	*Ensuring Sustainability of Greater Mekong Subregion Regional Power Development; Part 1: Integrating Strategic Environmental Assessment into Power Planning – 2015.*
ISBN- 978-92-9262-038-7	*Harmonising Power Systems in the Grater Mekong Subregion: Regulatory & Pricing Measures to Facilitate Trade – Feb 2020*

Overview of GMS Power Trade Program with ADB Support

- **Since 2002 Various GMS Generation Resource Planning Studies identify big savings with Regional Power Trading.**
- **In 2012 ADB RETA 6440 Consultants present institutional recommendations to Asian Regulators in Singapore.**
- **In 2013 GMS Ministerial MOU Authorize the Establishment of RPCC within the GMS and requested:**
- **RPTCC to Plan & Implement Open Access Transparent Grid-Grid Power Trading within the GMS.**
- **In 2016 ADB prepared a Road Map and RETA 8330 grant to focus RPTCC Working Groups on development of Regional Grid Code that:**
- **Uses ENTSO-e grid codes as a basis for the Technical and Commercial Conditions of GMS Power Trading.**
- **In 2019 RGC accepted as a Reference Document for Further Development of Power Trading in the GMS.**

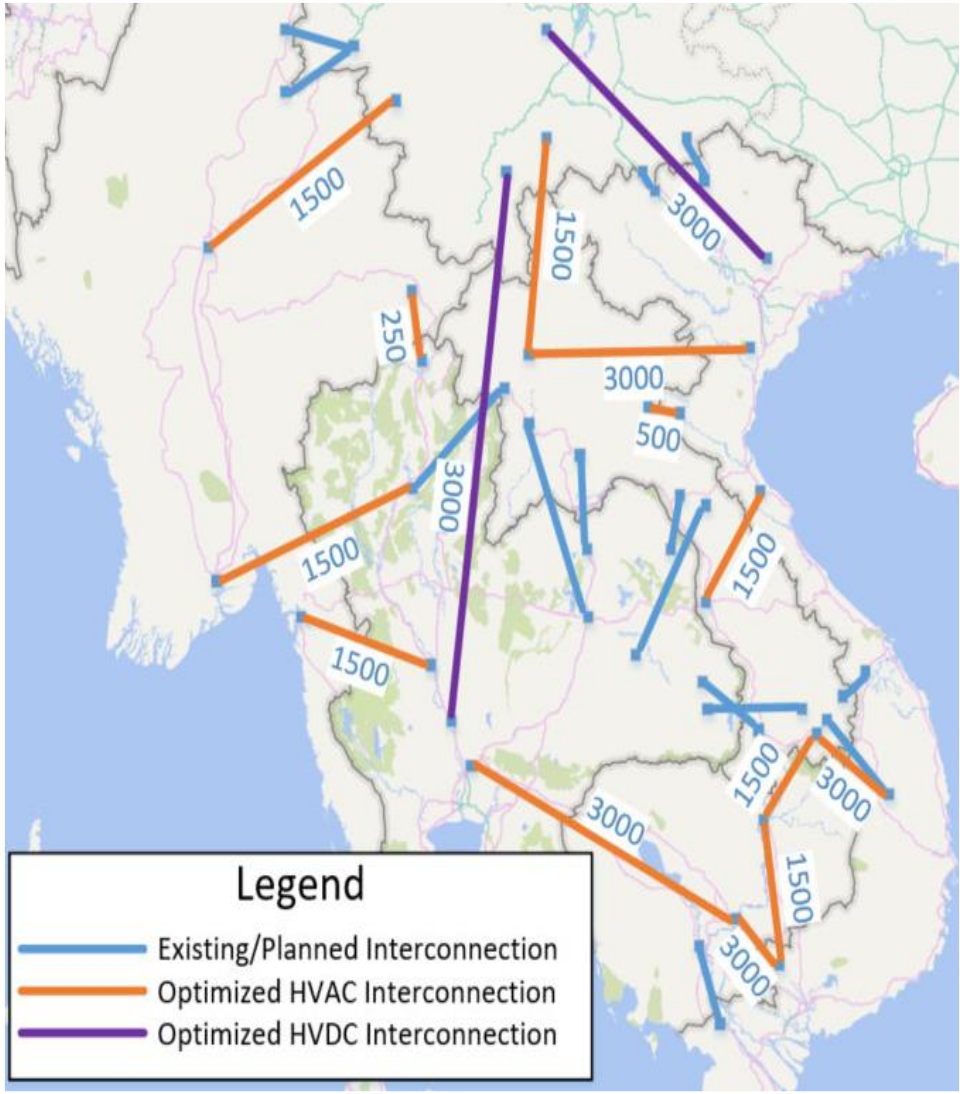
Topography & Conceptual Plans for GMS/ASEAN Regional Transmission Systems

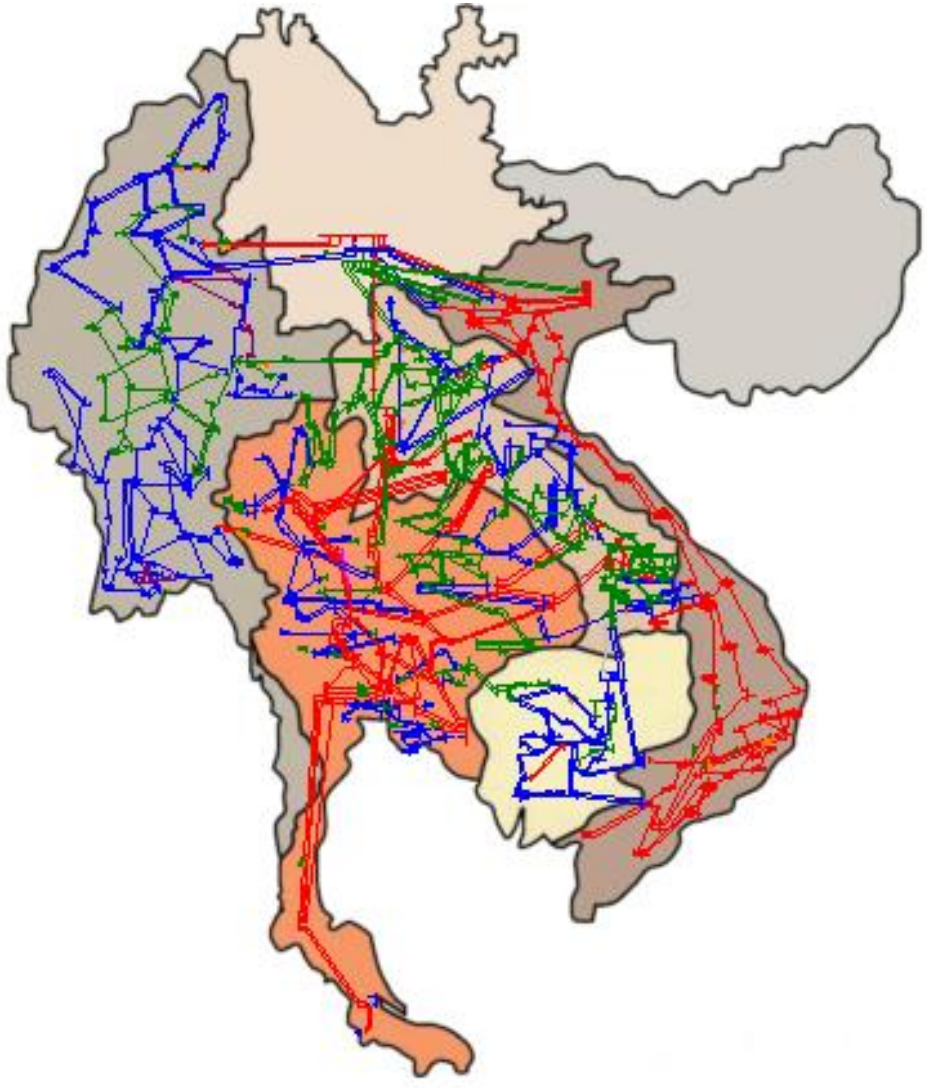
Summary of Existing GMS Grid Transmission Facilities

GMS 2020	Southern China	Thailand	Vietnam	Laos PDR	Myanmar	Cambodia
Peak Dmd (GW)	160	35	40	2	5	2
Exist Gen (GW)	323	50	50	4	6	3
Hydro Plan (GW)		0	13	8	25	4
VRE (GW)	30	9	10		4	1
Area (k km^2)	236+394	513	331	236	656	181
Transmission						
500kV	46000	6600	8000		110	
220kV	80000	15000	17000	850		1000
HVDC	7200	23				
Substations						
500kV	125	31	53	16	2	2
220kV	976	109	8	35	71	28
X Border Exports	4	1	1	14	2	
Planned X border	3			14		1

Sources:
ASEAN data: MHI Draft masterplan Report 2019 & ADBKP 2020: GMS Regulatory & Pricing Issues.
China data: World Bank. 2019. GMS Power Market Development All business cases including the integrated GMS RPTCC Country Reports 2019

Current Proposals for Transmission Interconnections & MHI Study for 2035





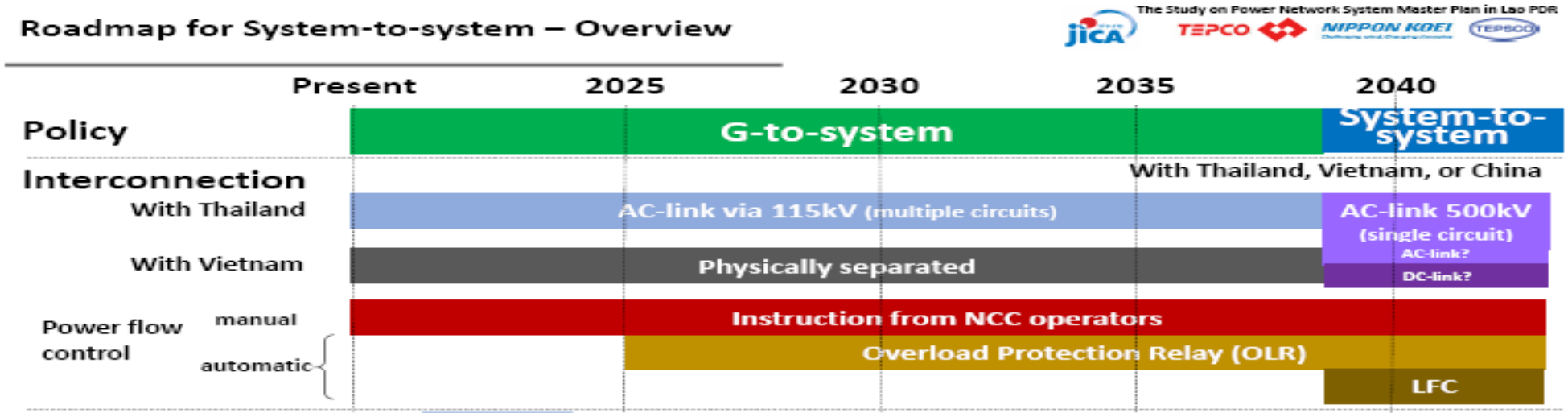
Two Proposed 500kV Grid Synchronization Plans

World Bank. 2019. IES/Nordpool Selected Business cases for Power Trade

	2022-24	2025-27	2028-30	2031+
HIGH PRIORITY	Laos (S) ⇔ Vietnam (C) Laos (N) ⇔ Myanmar (N)	Laos (N) ⇔ Vietnam (N) Myanmar ⇔ PRC Myanmar ⇔ Thailand Laos (S) ⇔ Vietnam (S)	Expansions: Myanmar ⇔ Thailand (N) Laos (N) ⇔ Vietnam (N)	Expansions: Laos (S) ⇔ Vietnam (C) Myanmar ⇔ Thailand (N) Laos (N) ⇔ Myanmar (N) Myanmar ⇔ PRC
LOWER PRIORITY	Cambodia ⇔ Vietnam (S) Expansion	Cambodia ⇔ Vietnam (C) Thailand (C) ⇔ Cambodia Expansion	Expansions: Laos (S) ⇔ Vietnam (C) Laos (S) ⇔ Vietnam (S)	Thailand (C) ⇔ Cambodia Cambodia ⇔ Vietnam (S)
GMS INTEGRATION	Stage 1: Enclaves synchronised to neighbouring grids	Stage 2: Four synchronous regions within the GMS	Stage 3: Two synchronous regions within the GMS	Stage 4: Fully integrated GMS
TECHNICAL WORKS	Technical studies to support 3 interconnections	Have in place the Regional Grid Code to govern GMS power system operations and to guide technical studies for cross-border projects Continue to build on experience from progressive interconnection Over this period, the benefits of an integrated GMS are realised		

JICA Study

JICA. 2020. Study of Power Network System master Plan in Lao PDR



Grid Code Applications for Regional Power Trading

- **Regional Power Trade Grid Codes in advanced stage of development in: EU, USA, China, GCCIA, SAARC, Southern Africa, GMS.**
- **Each Region has different issues in terms of history, technology, regulation, geography & resources.**
- **Most Grid Codes for 50Hz operations based on 2016 EU ENTSO-e rules**

- **ENTSO-e Code of Families:**

CONNECTION CODES	• Generator Connection Code • Demand Connection Code • HVDC Connection Code
OPERATING CODES	• Operational Security Code • Operational Planning and Scheduling Code • Load Frequency Control and Reserve Code • Emergency Procedure Code
PLANNING CODES	• Generator Planning Code • Network Planning Code
MARKET CODES	• Market Rules Code • Network Capacity Allocation and Congestion Management Code • HVDC Connection Code

GMS Modes of Cross Border Power Trading

- Existing GMS Bilateral Synchronous Power Trading: IPP to Grid and Grid to Border Towns
- TSO/DSO Grid-Grid Balancing/Ancillary Services
- IPP Wheeling though TSO to Industrial Customers
- Grid-Grid Reserve Sharing via HVAC or HVDC
- Grid-Grid Load Shifting/ Ancillary Services
- Grid-Grid VRE Mitigation and/or Energy Storage
- Grid-Grid-Grid Power Wheeling

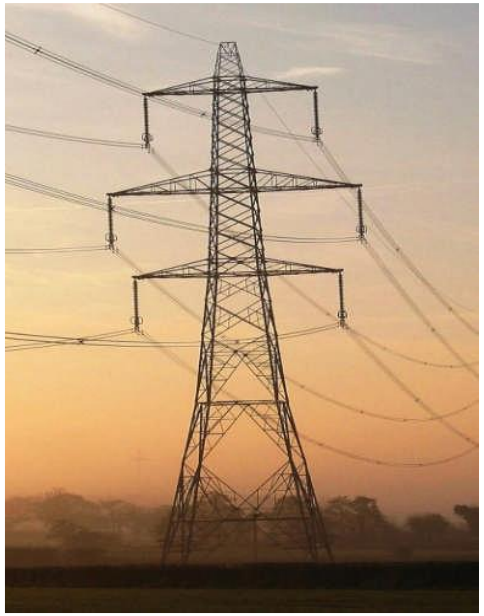
Technical & Market Issues Addressed by GMS RGC

- **General Technical Considerations –** RGC overarches National Grid Codes that can be more stringent to suit local regulatory requirements.
- **Harmonization of National Grid Codes –** compatibility of differences among measurements, methods, procedures, schedules, specifications, or systems.
- **Frequency Regulation –** Primary, Secondary & Tertiary Reserves for containment of frequency fluctuations to maintain synchronous power balancing.
- **Reliability Standards –** Planning Codes to ensure problem in one region not being transferred through interconnections to another.
- **Variable Renewable Energy –** Mitigate impacts of VRE intermittency, enable load shifting and optimize use of GMS hydro storage capability.
- **System Flexibility –** Ability to modify regional transmission and distribution grid codes to enable new distributed technologies to compete in power market.
- **TSO Operations –** coordination between independent national TSO/DSOs for load balancing and during emergencies.
- **Communications, Control & Data Management–** SCADA for load dispatch and Emergency operations, cybersecurity & confidentiality of data.
- **Regulation & Pricing –** Barriers, Open Access, Wheeling Charges, Short Term Trading Rules, Balancing Mechanism – covered under ADBKP Feb 2020

Characteristics of GMS Transmission Networks

- Unlike the 36 contiguous EU countries where ENTSO-e is enshrined into EU law, the 6 GMS countries are independent & operate asynchronously: https://www.entsoe.eu/data/map/
- ENTSO-e planning to move from mostly synchronous HVAC grids to an integrated hybrid AC/DC system.
- Status of HVAC power system development varies significantly between Southern China, Vietnam and Thailand versus Laos, Cambodia and Myanmar.
- With no RGCC Grid-Grid Power Trade requires national regulatory approval of RGC.
- Long distances through mountainous rainforests from main generation to load centers justify HVDC interconnections for initial trade in reserve sharing.
- Long term PPAs with IPPs will need to be renegotiated to join GMS regional market.
- Opportunities to optimize regional hydro storage to increase uptake of Variable Renewable Energy (VRE)
- China a world leader in HVDC, Wind and Solar technologies

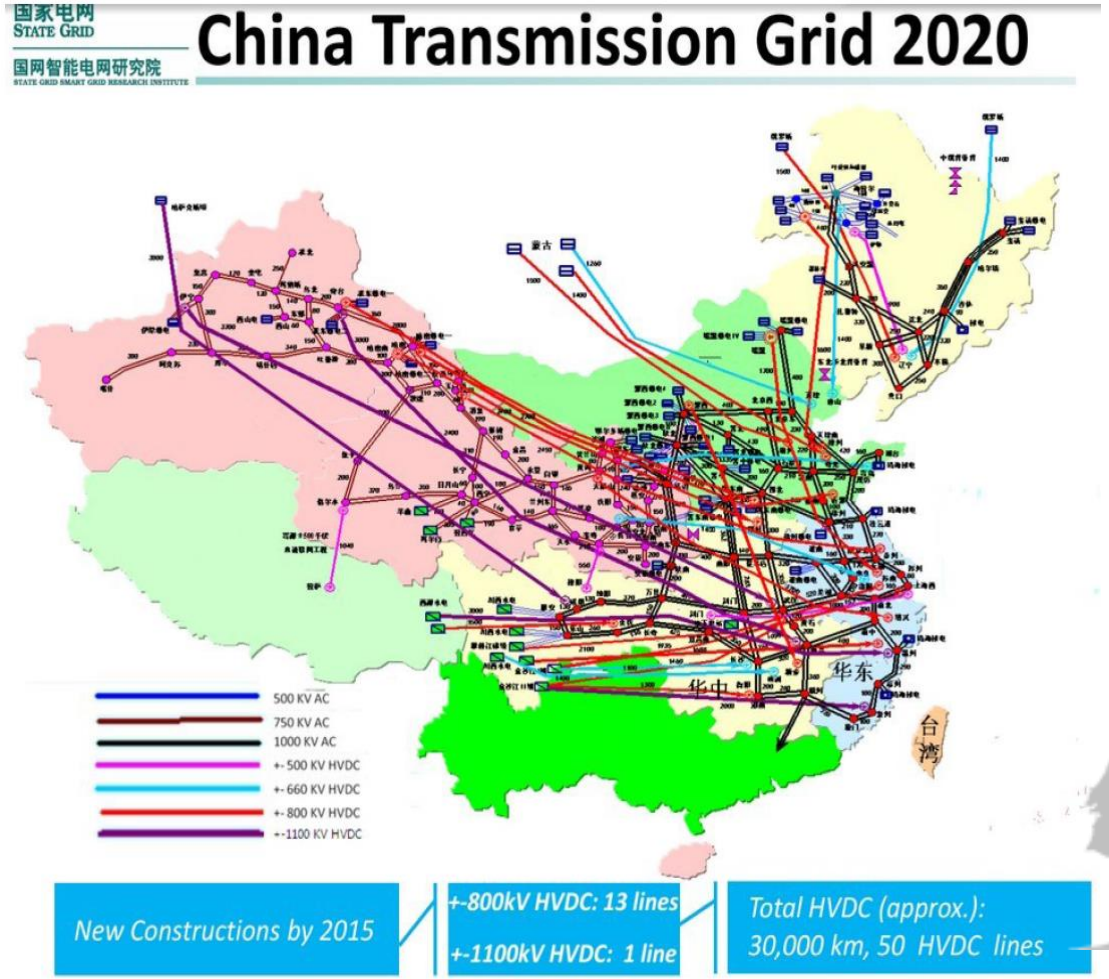
HVAC versus HVDC or VFT Interconnections

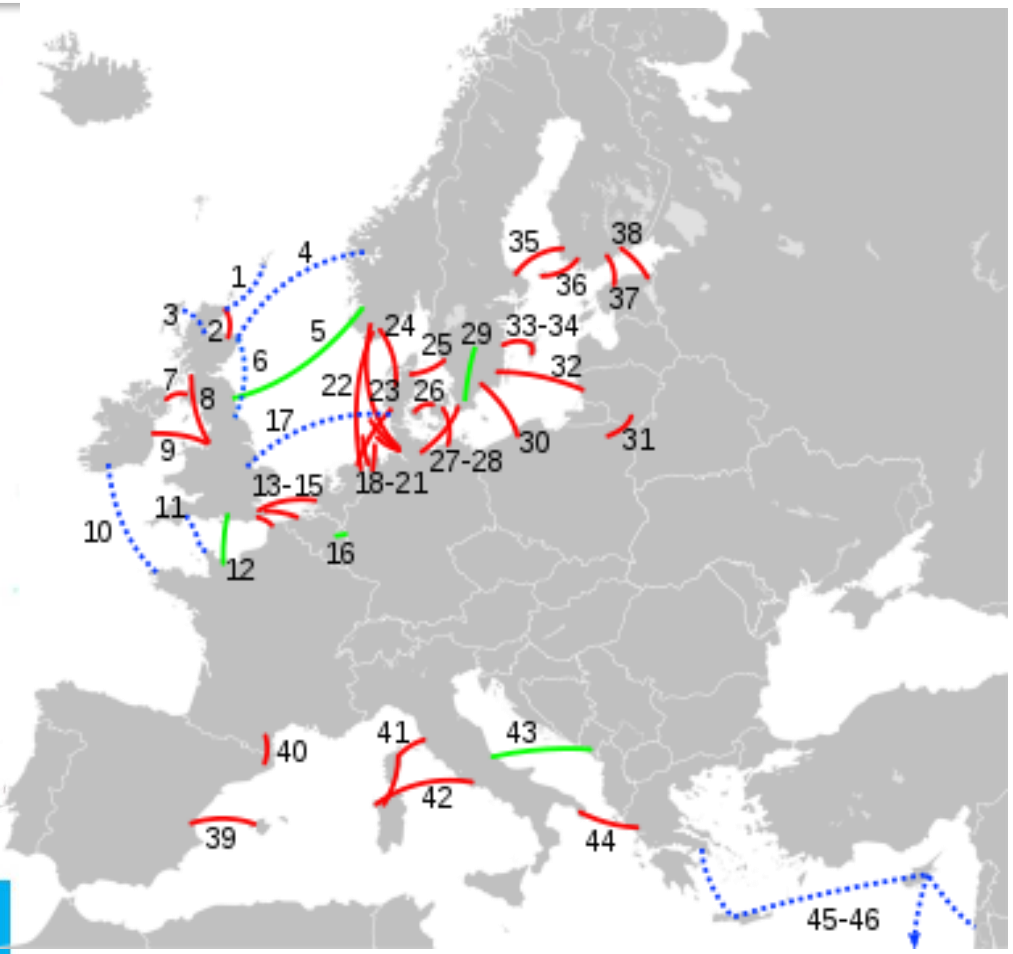


- 500kV HVAC at $400/km lowest cost for under 400km connections.
- Many grid-grid connections required to maintain synchronism with potential circulating currents.
- FACTS required for Voltage Stability
- Asynchronous HVAC with Variable Frequency Transformers at $30/kVA.

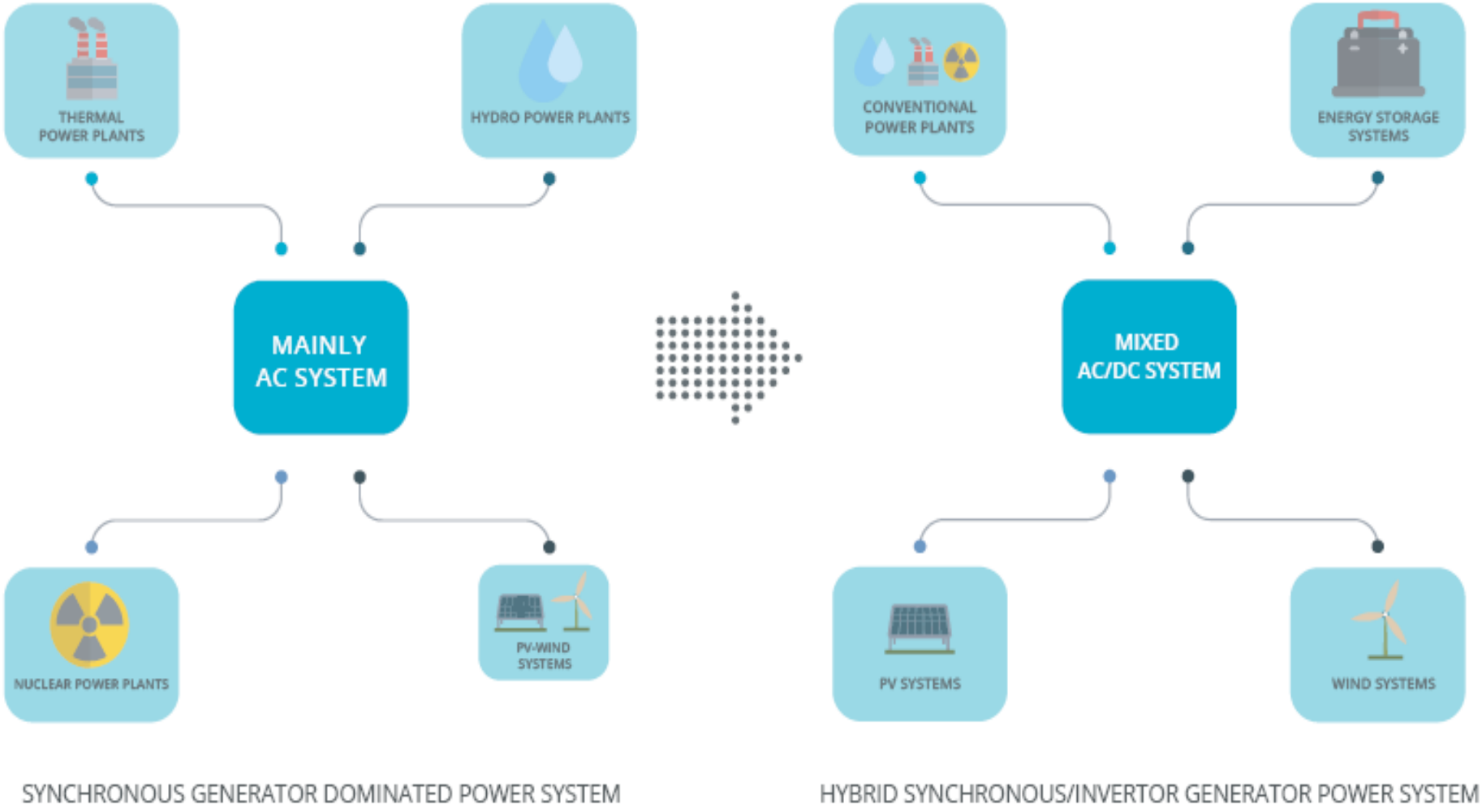
- HVDC lines 60% lower cost but require converters at $100/kVA/converter
- HVDC BtB high cost for limited applications
- HVDC can control power flows and provide Ancillary Services
- HVDC can overlay 500kV and will provide basis for future Supergrid

Development of HVDC in China and in Europe





ENTSO-e Strategy: Hybrid HVAC HVDC Networks



GMS Interconnections with Generators and/or HVDC

Potential for Changes to RGC Grid Connection Codes

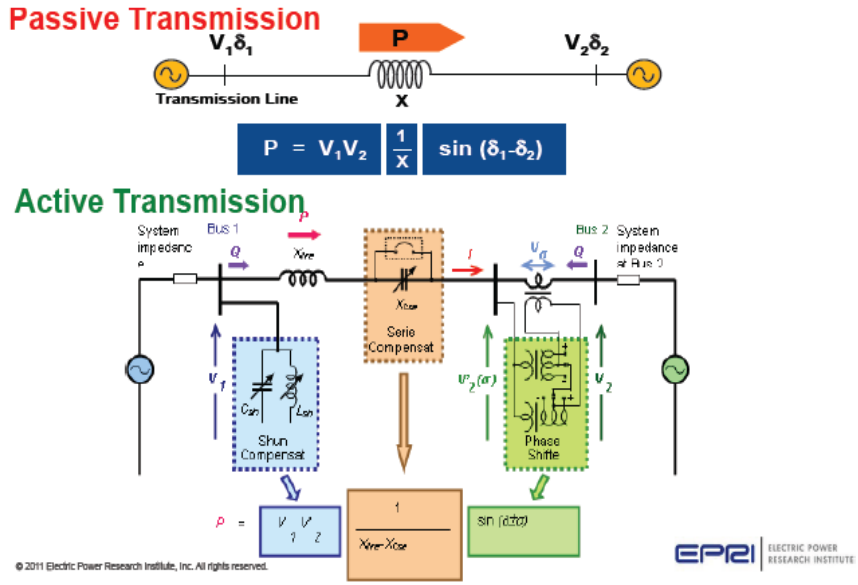
- Current Interconnections with IPPs under National Grid Codes

Type	MW	Voltage	Functionality
A	<1	LV/MV	Basic capability to withstand widescale critical events Limited automated response and control
B	1-40	<110kV	Automated dynamic response and resilience System Operator control
C	40-75	<110kV	Stable and controllable dynamic response Covering all operational network states
D	>75	>110kV	Widescale network operation and stability Balancing services

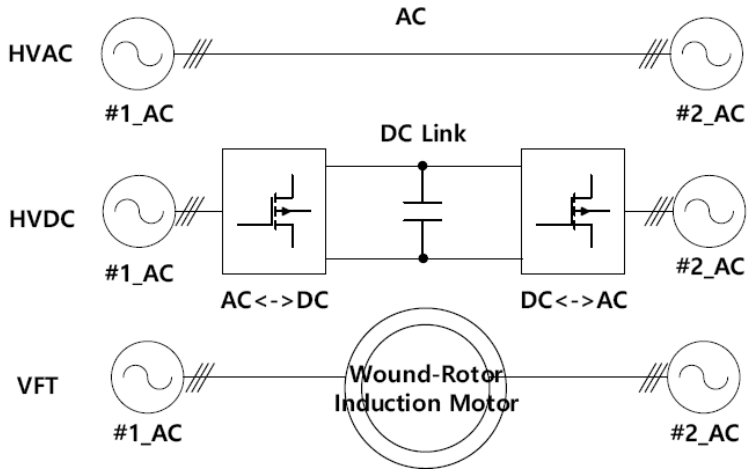
- Wind Farms connection codes in development in USA, EU & China.
- GMS Floating Solar PV Farms – HVDC/HVAC Hybrid operation in conjunction with existing Hydro.
- Inertia market needed to compensate for increased PV/Wind participation.
- Grid Battery applications to optimize storage, load shifting & to provide competition in ancillary services.

HVAC FACTS Dynamic Line Ratings & Interconnection Modes

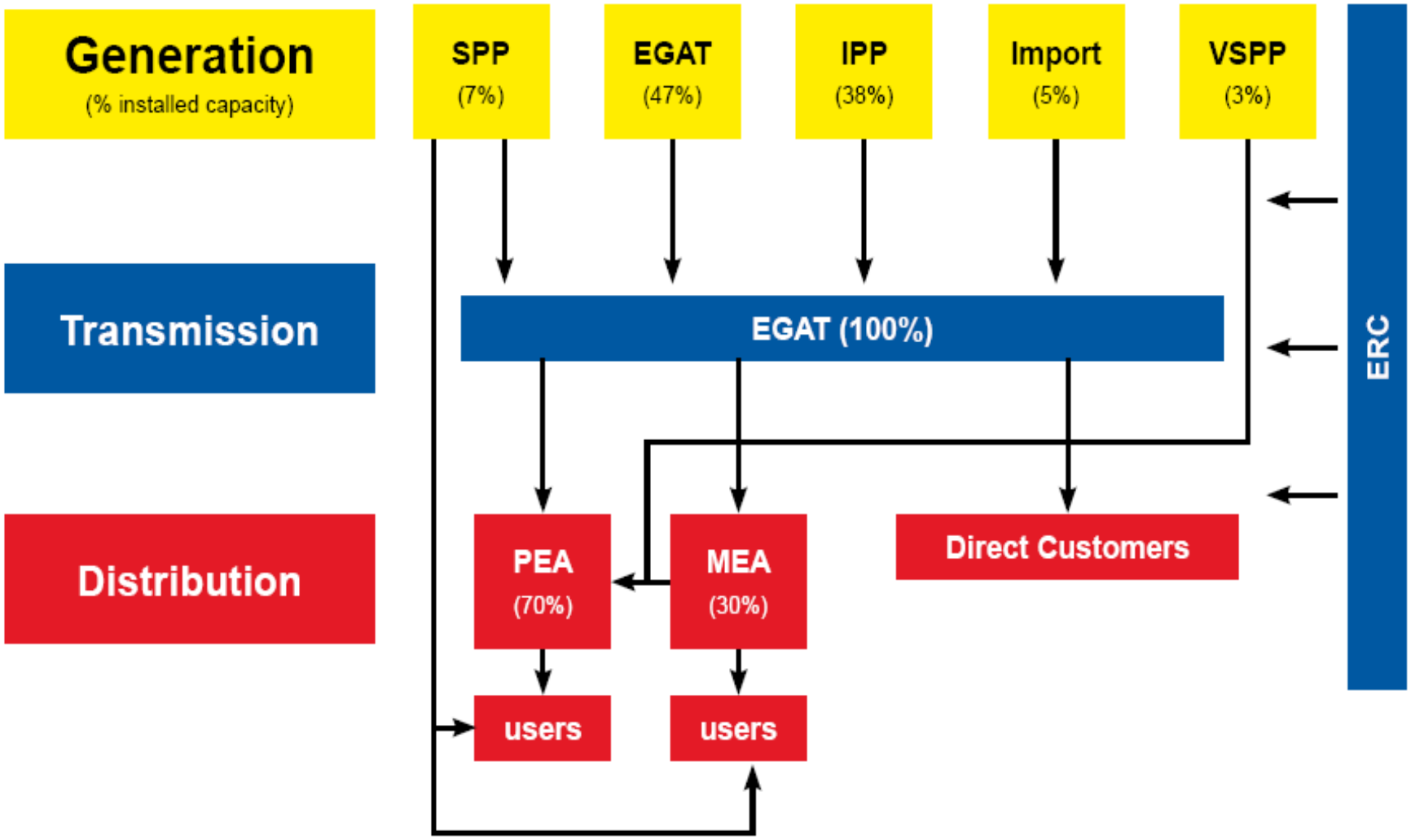
- Series Compensation
- Static VAR Compensation
- STATCOM
- SCV Frequency Stabilizer
- Synchronous Condensers
- Mechanically Switched Capacitors



- HVAC Synchronous
- HVDC Asynchronous
- Variable Frequency Transformers (VFT)



Grid-Grid Interconnections TSOs/ DSOs & Direct Consumers



TSO/DSO Digitalization & Advanced Asset Management

- Complexity of Transmission System Operations will Increase with reversed flow from DSOs
- Interoperability needs to be ensured between IT systems such as Load Dispatch, SCADA, Outage Management and T&D Applications
- Application of new IT platforms – Increased Cybersecurity
- Verification of Dynamic generation models
- Blockchains to enables Peer-to-Peer Wheeling through TSO
- More Sensors at Primary Equipment
- Risk Based Asset Management

Interconnections with Large Industries & ESS

Large Industry TSO/DSO Power Market Services

- Voltage stabilization and flicker
- Harmonic distortions
- Power factor improvements
- Unbalanced loads
- DSM response capability

Energy Storage Systems (ESS)

- Grid Batteries behave like a hybrid generator/ DSM facilities - providing reserve capability versus GTs
- PV/HVDC Inverter characteristics with Ancillary Service capability.
- Require greater TSO/DSO cooperation as DG and Virtual Power Plant (V2G) aggregation grows.
- Grid Codes for ESS under development in US and ENTSOe

ADB Road Map

Table 16: Road Map for Implementing the GMS Cross-Border Trade to Achieve Stage 2

Milestone	Activities	Schedule
Study to identify the regulatory barriers to the development of power trade and implementation of Stage 2	Complete the study to identify the regulatory barriers to develop power trade and consider for adoption the measures and institutional arrangements to address regulatory barriers	2016
Study on a GMS Grid Code (operational procedures, performance standards, technical requirements, and regional planning)	Complete the study on a GMS grid code and consider for adoption the findings of the study, which include: (i) GMS performance standards (ii) Coordination procedures between system operators to schedule and control across border flows, management of deviations (iii) Metering and communications (iv) Process and analytical framework for coordinated regional planning (v) Sharing of power reserves and supporting during emergencies	2017
Study on Stage 2 Transmission Regulations to allow third-party access in interconnections, with priority to contracts/PPAs, including Stage 2 power trade rules, and a Dispute Resolution Mechanism	Complete the study on Stage 2 transmission regulations and consider for adoption the findings of the study, which include: (i) Development of payment agreements/tariffs for third-party use, to compensate countries that host flows linked to third parties' trading (ii) Power trade rules for short-term cross-border trading (iii) Power trade rules for settlement of deviations to scheduled power trade in grid-to-grid interconnections	Mid-2019
Final review of Stage 2 readiness	Complete necessary legal, regulatory, and operation procedures to launch Stage 2	September 2019
Launch of Stage 2	Grid-to-grid power trading between any pair of GMS countries using transmission facilities of a third regional country	January 2020

GMS = Greater Mekong Subregion, PPA = power purchase agreement; TPA = third-party access.
Source: ADB compilation.

Significant Events

- 10 ADB TA projects since 2004
- RETA 6440
- MOU
- RETA 8330
- RPTCC: WGPG & WGRI
- ADB GC Consultants
- GMS RGC Reference Document
- ADB KP for Wheeling
- ADB KP for RGC
- Gaps Assessment
- WG Plans for Stage II of ADB Road Map
- Scope of next RETA

ADB RETA Working Group Activities & Outcomes

RETA 6440: Recommendations to Asian Regulators in Singapore 21 Oct 2012:

"Facilitation of Development of the Regional Power Trade (RPT)," and "Capacity Development for Environmental Impact Assessment of Power Projects."

After RETA 8330 Closed: 7 RPTCC Meetings (2017-2019)

ADB	Publication of Road Map (Annex B)
RPTCC-22	Presentation of Transmission Policies, Plan for WGPG plan meetings for August, October for review at RPTC#23 in December
RPTCC-23	Transmission Policies (1.2,3, 4), LFC Control & Reserves, Metering Arrangements, GMS grid V1.0; Work Program for Implementation
WGPG#12	
WGPG#13	Presentation of GC v1.1, Connection Code, Operation Codes, Gap Assessment od PS compliance
RPTCC-24	GMS GC v2.0, Program for GMS GC
WGPG#14	Progress Report Connection/Operation Codes/PS compliance
WGPG#15	Grid Code V.3.0, Codes for Connections, Operations, Market, Metering, Training
RPTCC-25	GMS GC v4 (complete)
WGPG#16	Compliance Assessment for Implementation
RPTCC-25	1 Establish Road Map for Implementation of GMS GC
	2 Establish LFC organization for GMS synchronous zones
	3 Establish technical specifications for Electronic Highway
	4 Establishment of GMS metering Organization & Architecture
RPTCC-26	Review of progress

RETA 6440: Presentation to Regional Regulators in 2012

RETA 6440 / GMS – Regional Power Trading and Environmentally Sustainable Development

ADB

Part 2 – Presentation of ADB/GMS TA No 6440 - REG

A- Objectives of RETA No 6440:

- PLANNING the Development of Resources for the National Power Systems as part of the Development of Resources for the Regional Electric Power System;
- Proposing of the Setting up LEGAL FRAMEWORKS, RULES, PROTOCOLS and REGIONAL MECHANISMS & BODIES responsible for the Reliable, Secure and Cost-effective Operation of the Regional Interconnected Network and the Introduction of a Regional Electricity Power Market;
- Proposing Implementing MECHANISMS and STRUCTURE for the Development and the Operation of Regional Electric Power Projects;
- Ensuring that Investments and Infrastructure Development toward the RPT are ENVIRONMENTALLY and SOCIALLY SUSTAINABLE, and that Environmental and Social Aspects are considered at an earlier stage in the Planning Process;
- Proposing the Various Steps necessary to SET UP a REGIONAL ORGANIZATION that will be Responsible for the Implementation of these Actions, and for the Operation of the Regional Interconnected Power System.

5th Capacity Building Programme for Officers of Electricity Regulatory Commissions 17 / 99

ADB GMS GCKP: RPTCC Acceptance of GMS RGC

Summary Table of GMS Regional Grid Code

Vol	Code Title	**Summary of Code Particulars** (Draft in WORD format – Revisions Mode)
1	Preamble V0.4 Dec 2018	Context and Objectives of Regional Grid Code. Detailed summaries of each of the following sections:
2	Governance V0.4 Dec 2018	Provisions necessary for the overall administration and review of the various aspects of the Regional Grid Code
3	Connection V0.4 Dec 2018	Connection conditions for power-generator facilities, HVDC systems including DC connected power modules and Demand facilities
4	Operational Security V 0.2 Dec 2018	Principles for Transmission Systems applicable to all TSOs, DSOs and Significant Grid Users in Normal and Alert System State.
5	Operational Planning & Scheduling V0.2 Dec 2018	Requirements for ensuring coherent and coordinated operational planning processes of the Synchronous Areas
6	Load Frequency Control & Reserves V0.1 Dec 2018	Minimal requirements and principles for load-frequency control and reserves
7	Emergency & Restoration V0.2 Dec 2019	Operational Security requirements and principles applicable for Emergency State, Blackout State and Restoration
8	Market V.02 Dec 2018	Capacity Allocation and Congestion Management, Forward Capacity Allocation, and Electricity Balancing
9	Metering V0.2 Dec 2018	Minimum technical, design and operational criteria to be complied with for the metering of each point of interchange of energy between Control Areas
10	Operational Training V0.2 Sept 2018	Framework for operational training for dispatchers to operate the power system in a safe and reliable manner under all conditions and at all times
11	GLOSSARY OF TERMS	List of terms, acronyms and units commonly used in the GMS Transmission Regulations – Policy 1 to 4, and the GMS Grid Code.

Review of WGPO Comments & Consultants Response

Comments by RPTCC members (attached to WORD version Draft RGC dated Dec 2018)

RGC Section	Pages	Month /Year	Original/ Review	RPC	THAI	VIET	CAM	MYN	Laos	Remarks (none signed as accepted)
1 Preamble	11	12/18	GC/MC	1		5			3	Minor observations
2 Governance	23	4/18	GC/MC	1	2	2			1	Text changes made
3 Connections	94	6/18	GC/JH/MC	10	7	25				Several disagreements
4 Operational Security	49	8/18	MC/MC	10	3	6				Some modifications
5 LFC & Reserves	64	4/18	MC/MC							No comments
6 Emergency & Restoration	42	8/18	MC/MC	5	1					Some resolution required
7 Market Code	20	4/18	GC/JH/MC		4					Minor modifications
8 Metering	13	8/18	MC/MC	1	1	1				RPTCC#24 Comments
9 Operational Training	12	9/18	GC/JH/MC	3						Minor additions
10 Glossary	48									No comments

Original/Reviewer initials: GC = Graeme Chown, MC= Michel Caubet, CN=Clair Newton, JH= Jonathon Hedgecock

WGRI Work Plans and Indicative GMS Priorities

- **Institutional Issues:** Establishment of RPCC to resolve Perquisites for Institutional Legal, Regulatory Functions, Technical Standards, Contract Obligations.
- **Pilot Wheeling Project:** Implement GMS-ASEAN Pilot Laos-Thailand-Malaysia-Singapore project to test GCKP tariff proposals
- **Pilot HVDC Reserve Sharing Project:** Interconnect Vietnam and Thailand with intermediate terminal in Laos
- **Private Sector Stakeholders:** Negotiation Strategy to integrate IPPs into Regional Power Market
- **Expand Ancillary Services Market:** to enable ESS and Aggregated V2G Virtual Power Plants
- **Create Electricity Storage Market:** to increase uptake of Floating PV and Wind

WGPO Work Plans and Indicative GMS Priorities

- **Publicize RGC on RPTCC website:** Review comments and signoff. Form RGC review committee to consider amendments.
- **SCADA and Communications & Metering project:** Prepare designs for integrating RGCC with existing TSO SCADA centers
- **Cybersecurity and Confidentiality of Data Bases** for use by TSOs and other approved parties.
- **Strategic Planning of Interconnections:** Review MHI proposals and identify those that can be integrated in future HVDC/HVAC hybrid grid
- **Development of Synchronization Strategy:** Review WB, JICA, China and MHI proposals. Potential for backbone 500kV grid
- **Build HVDC links between main Grids** for reserve sharing prior to synchronous power trading.

Review - Tailoring the GMS RGC to suit TSO Priorities

Executive Summary

1-CHARACTERICS OF GMS TRANSMISSION NETWORKS

2-GRID CODE APPLICATIONS

3-TECHNICAL ASPECTS OF INTERCONNECTIONS

4-BUILDING A CONCESSUS

5-SCOPE OF THE GMS RGC

6-IMPLEMENTATION OF THE GMS RGC

7-LESSONS LEARNED FROM THE GMS EXPERIENCE

Draft TOC Regional Grid Code Knowledge Product (GCKP)

Suggested Questions for Discussions at RPTCC Meeting

Question	Clarification
Does RGC Reflect GMS TSO Concerns	While changes have been made to the ENTSO-e rules to reflect the concerns of GMS TSOs, how do the working groups see the RGC being adapted further to consider the geography, the stage of development of the GMS transmission systems, the role of IPPs, the technological advances in HVDC and VRE development.
Involvement of GMS Ministries	Although the Ministerial MOU is specific in charging the RPTCC with the responsibility to establish an RPCC, this has not been possible. What other requirements should be addressed in a second Ministerial MOU?
Establishment of the RPCC Function.	Could the RPCC be established in in one or two temporary quarters as suggested by RETA 6440 consultants using cloud technology to share and store data between TSOs
Involvement of GMS Regulators/Private Sector IPP	Should the RPTCC update the regional regulators and IPPs with the plans for Stage II. Should this include a review of IPP contracts to determine how their interest might be affected in a open access power trading regime.
Resources for GMS Working Groups	Could the Working Groups have come to a consensus without the ADB consultants. How will WGPO & WGRI plan convene future meetings without the ADB having to assume a coordinating role? What resources do the WGs require to be able to work from their TSO offices until a RGCC is established?
Earliest Date for Grid-Grid Power Trading	What would be a credible grid-grid target date that could build on from a pilot trading project between Laos and Singapore, a reserve sharing project between Thailand and Vietnam, a bulk power trade project from China to Thailand or Vietnam 500kV networks.
Objectives and Design of next ADB RETA	What sort of experts would the WGRI and WGPO to have to assist them to make progress? Should the experts be from other Regions with characteristics similar to GMS where a RGC is being developed (e.g. GCCIA).
Advice to other ADB Regional Authorities	What are the lesson learned from this project that other ADB regional agencies should do to work cooperatively to a common goal!

THANK YOU IN ADVANCE FOR YOUR COMMENTS & SUGGESTIONS

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