SOO Green HVDC Link:
Obtaining and Demonstrating Capacity Obligations

PJM HVDC Senior Taskforce Meeting #3

September 15, 2020

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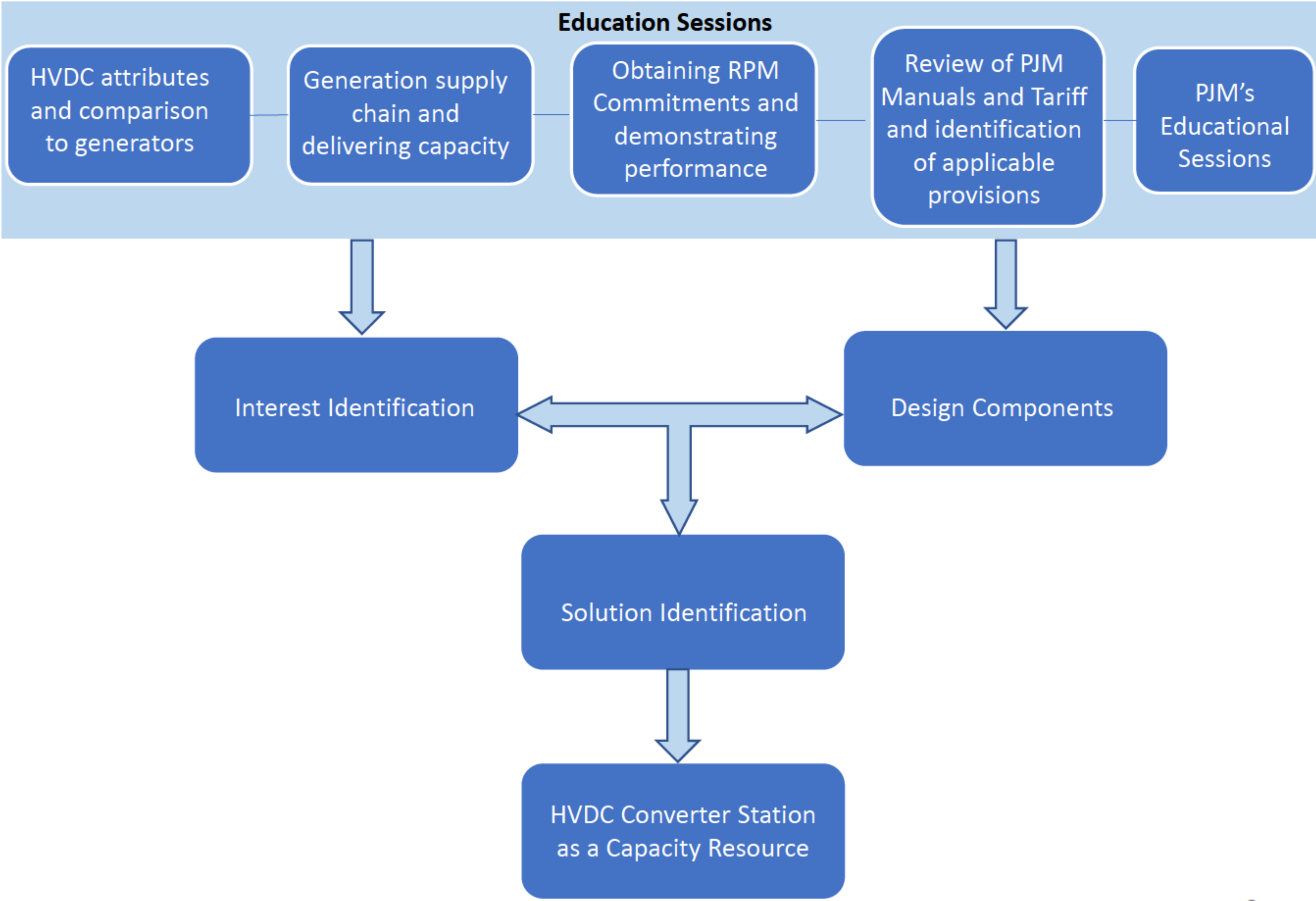
Introduction

- HVDCSTF Meeting #1 and Meeting #2 provided PJM and stakeholders with an overview of the similarities in technical attributes as well as the supply-chain and capacity delivery structures between HVDC Converter Station resources and PJM Capacity Resources.
- These meetings also covered attributes critical for a PJM Capacity Resource based on a review of PJM Manuals.
- The discussion during Meeting #2 highlighted the need to address the following capacity obligations and capacity performance:
    - How do PJM Capacity Resources obtain capacity obligations (Reliability Pricing Model/RPM Resource Commitments) and demonstrate performance to meet these capacity obligations?
    - Similarly, how can HVDC Converter Station resources obtain capacity obligations and demonstrate performance to meet these capacity obligations?
- Roadmap:
    - This discussion can inform future HVDCSTF discussions on Design Components, Options and Solution Packages by identifying relevant applicable manual and tariff provisions that may need to be addressed to enable HVDC converter stations as capacity resources.

Road Map



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Generation Resources:

RPM Resource Commitments

How Generation Resources Acquire RPM Resource Commitments

Capacity Interconnection Rights

Capacity Interconnection Rights (CIRs) are granted to each generation resource as a function of the execution of an Interconnection Service Agreement (ISA) or Wholesale Market Participant Agreement (WMPA) at the conclusion of the interconnection process.

Installed Capacity (ICAP)

ICAP is the value of a generation resource based on the summer net capability (dependable rating) of this resource as determined in accordance with PJM's Manual-21. This value is within the capacity interconnection right limits of the generation resource.

Equivalent Demand Forced Outage Rate (EFORd)

EFORd is a measure of the probability that a generation resource is not available due to forced outages or forced deratings when there is demand on this generation resource to operate (Manual-18).

Unforced Capacity (UCAP)

UCAP is the value of a generation resource that is equal to the installed capacity rated at summer conditions that is not, on average, experiencing a forced outage or forced derating:

$$UCAP = ICAP * (1\text{-}EFORd)$$

How Generation Resources Acquire RPM Resource Commitments

Consider a combined cycle generator with the following specifications:

- Capacity Interconnection Right (CIR) = 100 MW
- ICAP = 90 MW (due to 10% ambient temperature reduction)

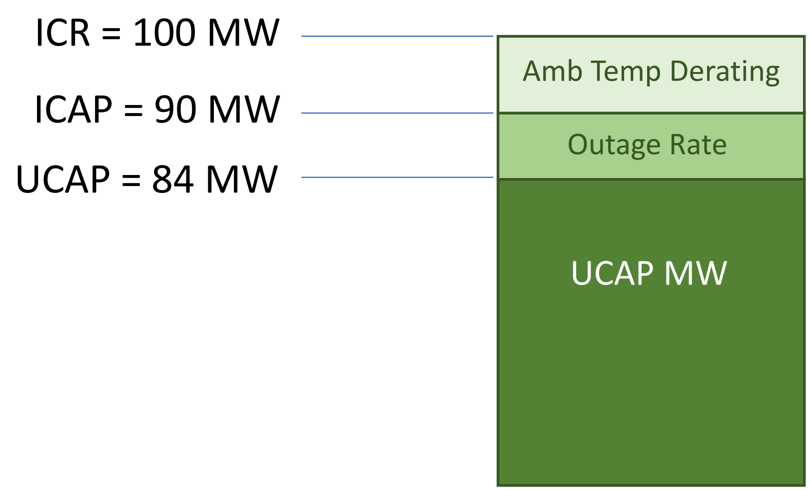
EFORd Calculation:

f_f: full outage factor
f_p: partial outage factor
FOH: full forced outage hours
EFDH: equivalent forced derated hours
SH: service hours (time the unit is electrically connected to the system)

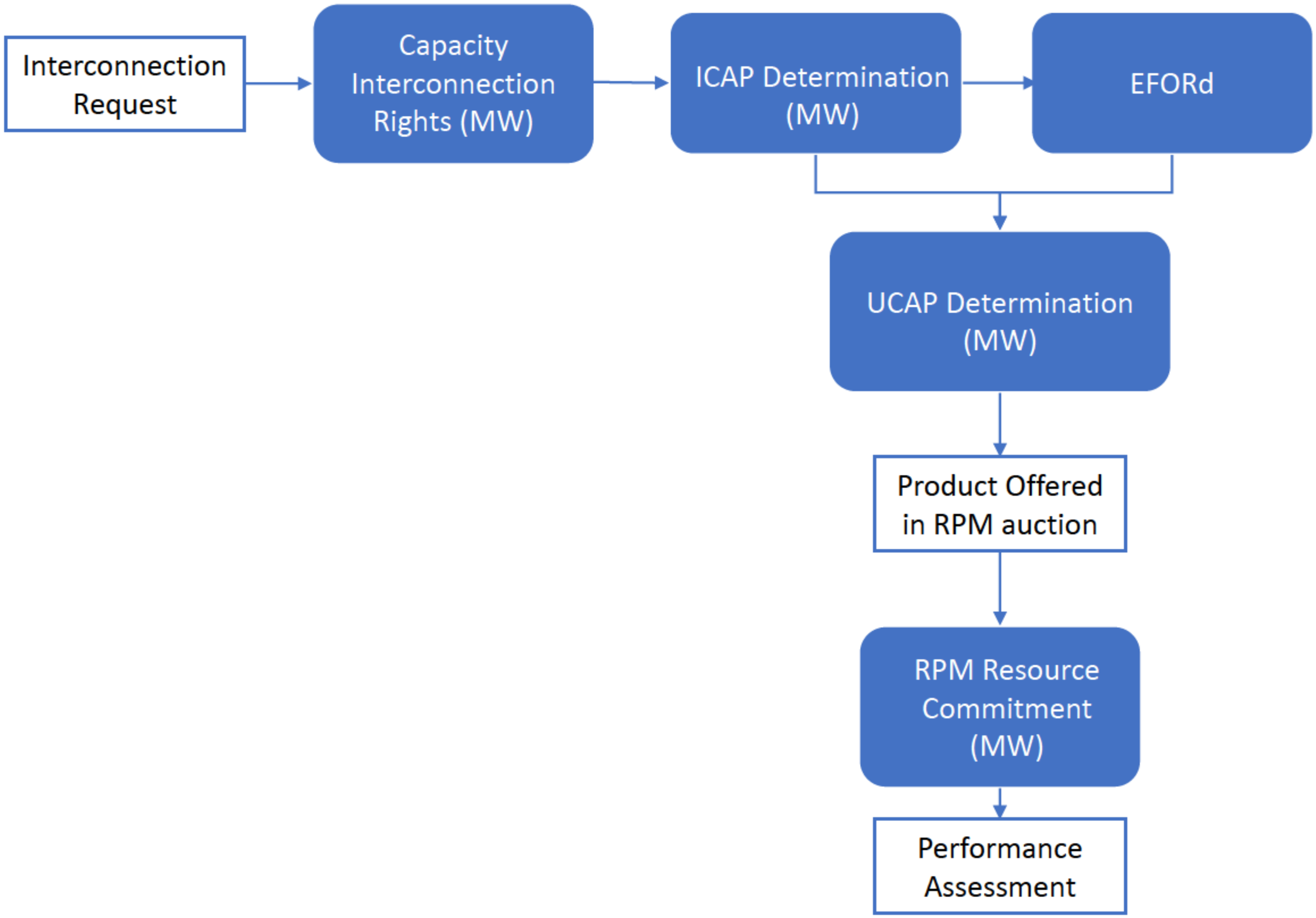
$$EFOR_d\ (\%) = \{(f_f * FOH + f_p * EFDH)/(SH + f_f * FOH)\} * 100$$

For this example, EFORd = 6.63%

- UCAP = 90 * (1 – 0.0663) = 84 MW



How Generation Resources Acquire RPM Resource Commitments



How Generation Resources Acquire RPM Resource Commitments

Characteristics required to participate in the RPM:

In accordance with Manual-18, generation resources must verify the following characteristics to qualify in the RPM:

- Zone assignment
- LDA assignment
- Generation resource location
- Generation resource type
- Product Type/Capacity Performance assignment (whether the generation resource is able to submit a Capacity Performance offer segments)
- ICAP value converted to UCAP using the EFORd value

Existing generation capacity resources are required to offer into each RPM Auction. Participation is voluntary for planned generation resources. Each generation resource is required to submit offer-bids under Capacity Performance product.

At the conclusion of the Base Residual Auction (BRA), each cleared generation resource is assigned RPM Resource Commitment.

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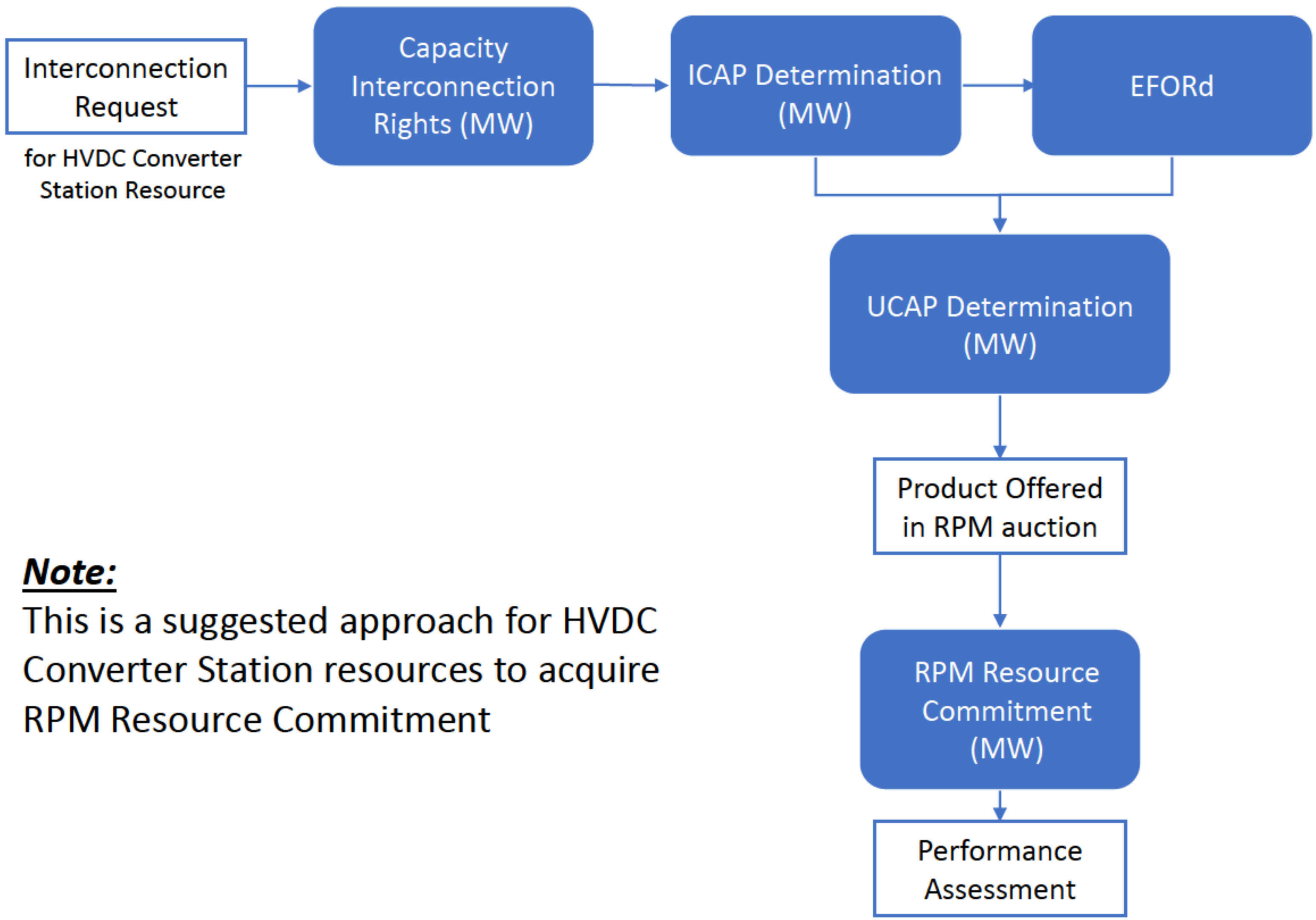
HVDC Converter Stations:

RPM Resource Commitments

How HVDC Converter Station Resources Can Acquire RPM Resource Commitments



Note:

This is a suggested approach for HVDC Converter Station resources to acquire RPM Resource Commitment

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How HVDC Converter Station Resources Can Acquire RPM Resource Commitments

Capacity Interconnection Rights for HVDC Converter Station Resource

CIRs would be granted to an HVDC Converter Station resource as a function of the execution of an Interconnection Service Agreement (ISA) at the conclusion of the interconnection process.

These rights determine the maximum capability of injection from the HVDC Converter Station resource.

Installed Capacity (ICAP) for HVDC Converter Station Resource

ICAP is the value of the HVDC Converter Station resource based on the summer net capability (dependable rating) of this resource similar to the process of determination for generation resource in accordance with PJM's Manual-21.

This value is within the capacity interconnection right limits of the HVDC Converter Station resource.

Unforced Capacity (UCAP)

UCAP is the value of an HVDC Converter Station resource that is equal to the installed capacity rated at summer conditions not, on average, experiencing a forced outage or forced derating:

$$UCAP = ICAP * (1\text{-}EFORd)$$

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How HVDC Converter Station Resources Can Acquire RPM Resource Commitments

Consider an HVDC Converter Station resource with the following specifications:

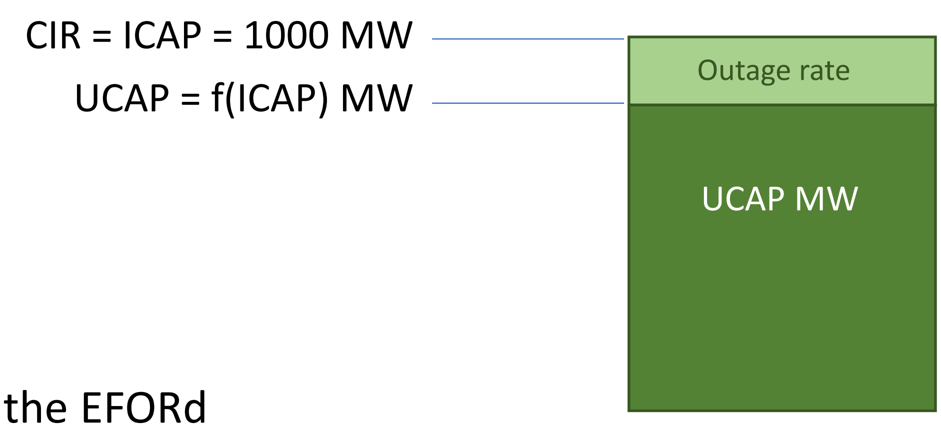
- Capacity Interconnection Right (CIR) = 1000 MW

  EFORd for an HVDC Converter Station can be based on:

  Full outage hours (FOH)
  Derated outage hours (DOH)
  Service hours (SH)

  $EFOR_d$ (%) = ƒ(FOH, DOH, SH)

- UCAP = ICAP * (1 – EFORd)



Note:

These are suggested factors that affect the EFORd calculation for an HVDC Converter Station

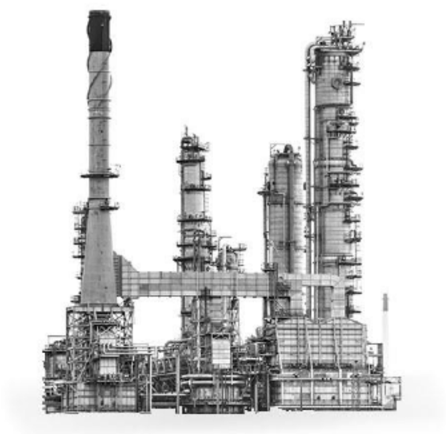
Generator and HVDC Converter Stations:

RPM Resource Performance Measurement

How Generation Resources Meet RPM Resource Commitment through Performance

Requirements & Performance Measures	Description
Energy Market Must-Offer	All generation resources that have an RPM Resource Commitment must offer into PJM's Day Ahead Energy Market
RPM Commitment Compliance	Each generation capacity resource has to demonstrate sufficient unforced capacity during Delivery Year to meet its RPM commitments
Non-Performance Assessment	PJM will evaluate the performance of each committed capacity resources during emergency conditions
Summer/Winter Capability Testing	PJM will determine if generation capacity resource can demonstrate its ICAP commitment amount through summer and winter testing

How Generation Resources Meet RPM Resource Commitment through Performance



Example of a combined cycle generation resource:

- RPM Resource Commitment = 84 MW for Delivery Year
- ICAP = 90 MW (Summer and Winter)

Energy Market Must-Offer:
Resource submits offer-bids into Day-Ahead market for 90 MW

RPM Commitment Compliance:
PJM measures resource performance daily through the Delivery Year for 84 MW

Non-Performance Assessment:
PJM will compare resource expected performance to actual performance during emergency conditions

Summer/Winter Capability Testing:
Resource will demonstrate that it can achieve 90 MW in summer and winter periods

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How HVDC Converter Station Can Meet RPM Resource Commitment through Performance

Example of an HVDC Converter Station resource:

- RPM Resource Commitment = 900 MW for Delivery Year
- ICAP = 1,000 MW (Summer and Winter)

Energy Market Must-Offer:
This resource submits offer-bids into day-ahead market for 1,000 MW

RPM Commitment Compliance:
PJM measures this resource's performance daily through the Delivery Year for 900 MW

Non-Performance Assessment:
PJM will compare this resource's expected performance to actual performance during emergency conditions

Summer/Winter Capability Testing:
Resource will demonstrate that it can achieve 1,000 MW in summer and winter periods

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Integration of HVDC Converter as a New Type of Capacity Resource

Problem / Opportunity Statement

PJM's existing Tariff (Reliability Assurance Agreement/RAA and OATT) and manuals allow dispatchable generation resources, intermittent resources and energy storage resources to participate in PJM's Reliability Pricing Model (RPM) capacity market. High Voltage Direct Current (HVDC) transmission lines that have a converter station directly connected to the PJM system, that can follow PJM dispatch instructions and that are backed by a portfolio of firm generation supply are similarly situated to these other capacity resources and can provide reliability benefits to PJM. However, current PJM Tariffs do not allow such HVDC converters to participate in the RPM market—presenting a market barrier to merchant resources seeking to sell bundled energy and capacity in the PJM market.

An HVDC converter station connected to PJM would be capable of performing like any other generating resource on the PJM system. It could contract for firm "fuel" (generation) supply, enabling it to be fully dispatchable with high availability. In fact, HVDC converter stations utilizing modern Voltage Source Conversion (VSC) technology have a demonstrated ability to respond to dispatch instructions quickly. Such stations can provide substantial amounts of reactive power at the point of interconnection, independent of the amount of real power requested. If connected to the PJM grid, such a station could enhance PJM grid stability by mimicking rotating inertia and could provide voltage and frequency support. An HVDC converter could undergo the interconnection process in accordance with PJM Manual 14 like any other generator. Furthermore, the ability to respond to dispatch signals from the PJM system operator would allow an HVDC converter to operate with the same or better responsiveness as other PJM dispatchable generating resources. Finally, in the same way that generating resources can contract for firm fuel supply, shippers on an HVDC facility could secure firm generation supply.

Any other similarly interconnected resource in PJM with the technical capabilities and firm fuel contracts analogous to the technical capabilities and firm supply described above would be eligible to participate in the RPM. However, PJM's existing Tariff (Reliability Assurance Agreement/RAA and OATT) and manuals preclude RPM participation to existing or new generating resources, intermittent resources, and energy storage resources. Given the essential similarities described above, an HVDC converter station located in PJM, delivering generation from another RTO, with the necessary interconnection and shipper arrangements, should be eligible to provide capacity through the RPM.

We would like to work with PJM and its stakeholders to develop a mechanism that would allow HVDC converter stations configured as described above to participate directly in the PJM capacity market. By providing for the integration of merchant inter-RTO HVDC connections into the capacity market, PJM and its customers would benefit from increased competition, greater geographic and technological generation diversity, and the additional instantaneous control offered by dispatchable HVDC facilities.

Direct Connect Development Company

Contacts

Trey Ward, CEO
Direct Connect Development Company
(404) 783-7757
tward@directconnect-dc.com

Joseph DeVito, President
Direct Connect Development Company
(512) 608-8448
jdevito@directconnect-dc.com

Steve Frenkel, Vice President
Direct Connect Development Company
(312) 590-8888
sfrenkel@directconnect-dc.com

Ruta Skucas, Partner
PierceAtwood
(202) 530-6428
rskucas@pierceatwood.com

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Appendix

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EFORd Calculation Overview

EFORd Calculation – Class Average

EFORd is calculated as follows:

$$EFOR_d\ (\%) = \{(f_f{*}FOH + f_p{*}\ EFDH)/(SH + f_f{*}FOH)\}{*}100$$

Where:

f_f: full outage factor

f_p: partial outage factor

FOH: full forced outage hours

EFDH: equivalent forced derated hours

SH: service hours (time the units is electrically connected to the system)

Equivalent derated or full outage hours are calculated as follows:

$$E = \sum_i \left(\frac{D * T}{C}\right)_i$$

Where:

Di: capacity deration for event i, MW

Ti: time accumulated during event i, hours

Ci: unit monthly net dependable capacity at the time of this event, MW

Di=Ci for full outage

EFORd Calculation Example

Consider a combined cycle generator with the following specifications:

- Capacity Interconnection Right (CIR) = 100 MW
- ICAP = 90 MW (due to 10% ambient temperature reduction)
- Service Hours – SH = 6460
- Reserve Shutdown Hours – RSH = 516
- Available Hours – AH = 6976
- Actual Starts = 17
- Attempted start = 18

EFDH = 131.03, FOH = 340, FO events = 14

r (Avg forced outage duration)= FOH/FO events = 340/14,

T(Avg reserve shutdown) = RSH/# attempted starts =516/18,

D(Avg demand time)=SH/# of actual starts= 6460/17

f = $(\frac{1}{r}+\frac{1}{T})/(\frac{1}{r}+\frac{1}{T}+\frac{1}{D})$= 0.9666, fp = SH/AH = 0.0926

EFORd = 6.63%