Methodology to Shift Resources from and to Zones A, C, D, J and K

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Example: If 1000MW wind capacity (@90% EFORd) is added to a zone, the maximum amount of perfect generation that can be removed would be increased only by ≈ 100MW (10% of 1000MW)

It is not possible to remove large amount of capacity from a zone that has a very high average EFOR (such as in the case of wind), because there will be insufficient effective excess to be removed from the zone before it becomes resource deficit

The removal should therefore be based on the "Perfect" capacity excess instead of the "Real" capacity excess.

Purpose of This Discussion:

Given the amount of "Real" capacity to be removed from or added to zones A, C & D, e.g. X(MW), how do we compute the MOD-MWMD entries for zones A, C & D using the "Perfect" capacity excess instead of the "Real" capacity excess?

Methodology to Shift Resources from and to Zones A, C, D, J and K

Summary of Equations: (Derivation and Numerical Examples Starting Next Page)

Given: X(MW) real capacity is to be removed from zones A, C & D
Calculate the MOD-MDMW table entries for zones A, C, & D using the "Perfect" (UCAP) capacity excess instead of the "Real" (ICAP) capacity excess?

$$X_{Ap} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_A$$

$$X_{Cp} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_C$$

$$X_{Dp} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_D$$

These are the amount of "Perfect" capacity to be inputted to the MOD-MDMW table
The first term (left-hand term in red) is the same for all three and can be calculated just once

where,

X_{ip} = Perfect capacity to be removed from or added to zone i (MOD-MDMW table entry for zone i)

X = Real capacity to be removed from or added to A, C & D

$EFOR_i$ = Weighted EFOR for Zone i

$$EFOR_i = \frac{\sum_{j=1}^{n} G_{ji} \cdot EFORd_{ji}}{\sum_{j=1}^{n} G_{ji}}$$

R_i = "Perfect" capacity excess ratios for zone i

$$\Delta GL_i = Gi \cdot (1 - EFOR_i) - Load_i \text{ ; i = A, C or D}$$

$$R_i = \frac{\Delta GL_i}{\Delta GL_A + \Delta GL_C + \Delta GL_D} \text{ ; i = A, C or D}$$

Derivation of Equations and Numerical Examples

Step 1: Calculate the Weighted Equivalent Forced Outage Rate (EFOR) for Each Zone

Case 1: External Contracts modeled as external contracts

$$EFOR = \left(\frac{G_1 \cdot EFORd_1 + G_2 \cdot EFORd_2 + \ldots + G_n \cdot EFORd_n + SCRs \cdot EFORd_{SCRs} + ExternalContracts \cdot EFORd_{contracts}}{G_1 + G_2 + \ldots + G_n + SCRs + ExternalContracts} \right)$$

G_i = Total Resources in Zone i = $Generation_i$ + $SCRs_i$ + External $Contracts_i$

or

Case 2: External Contracts modeled by derating the ties

$$EFOR = \left(\frac{G_1 \cdot EFORd_1 + G_2 \cdot EFORd_2 + \ldots + G_n \cdot EFORd_n + SCRs \cdot EFORd_{SCRs} + ExternalContracts \cdot EFORd_{contracts}}{G_1 + G_2 + \ldots + G_n + SCRs + ExternalContracts} \right)$$

G_i = Total Resources in Zone i = $Generation_i$ + $SCRs_i$

SCRs and external contracts are also included since they are part of the mix of resources that count towards the IRM calculation

$EFOR_i$ = Weighted Average Equivalent Forced Outage Rate for Zone i

EFOR is used to represent the weighted value in order to be distinguishable from the original EFORd

$$EFOR_D = \frac{\sum_{i=1}^{n} G_{iD} \cdot EFORd_{iD}}{\sum_{i=1}^{n} G_{iD}}$$

Step 1: (continued) Calculate the Weighted Equivalent Forced Outage Rates for Each Zone

Numerical Examples:

Example 1:

Zone D Generation

- **1,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
Load	Load	Load	Gen	Gen	Gen
2701	3114	754	5014	6707	2271

A	C	D
EFORd	EFORd	EFORd
0.0593	0.0290	0.4253

$$EFOR_D = \frac{\sum_{i=1}^{n} G_{iD} \cdot EFORd_{iD}}{\sum_{i=1}^{n} G_{iD}}$$

$$= \frac{(1271)\cdot(0.0520) + (1000)\cdot(0.9000)}{(1271)+(1000)}$$

$$= 0.4253$$

Example 2:

Zone D Generation

- **10,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
Load	Load	Load	Gen	Gen	Gen
2701	3114	754	5014	6707	11271

A	C	D
EFORd	EFORd	EFORd
0.0593	0.0290	0.8043

$$EFOR_D = \frac{\sum_{i=1}^{n} G_{iD} EFORd_{iD}}{\sum_{i=1}^{n} G_{iD}}$$

$$= \frac{(1271)\cdot(0.0520) + (10000)\cdot(0.9000)}{(1271)+(10000)}$$

$$= 0.8043$$

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Step 2: Calculate the Zonal Perfect (UCAP) Excess Capacities

$$\Delta GL_i = G_i \cdot (1 - EFOR_i) - Load_i$$

Example 1:

Zone D Generation

- **1,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
Load	Load	Load	Gen	Gen	Gen
2701	3114	754	5014	6707	2271

A	C	D
EFORd	EFORd	EFORd
0.0593	0.0290	0.4253

A	C	D
ΔGL	ΔGL	ΔGL
2015	3399	551

$$\Delta GL_D = G_D \cdot (1 - EFOR_D) - Load_D$$
$$= (1271 + 1000) \cdot (1 - 0.4253) - 754 = 551$$

Example 2:

Zone D Generation

- **10,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
Load	Load	Load	Gen	Gen	Gen
2701	3114	754	5014	6707	11271

A	C	D
EFORd	EFORd	EFORd
0.0593	0.0290	0.8043

A	C	D
ΔGL	ΔGL	ΔGL
2015	3399	1451

$$\Delta GL_D = G_D \cdot (1 - EFOR_D) - Load_D$$
$$= (1271 + 10000) \cdot (1 - 0.8043) - 754 = 1451$$

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Step 3: Calculate the Zonal Excess Capacity Ratios

$$R_i = \frac{\Delta GL_i}{\Delta GL_A + \Delta GL_C + \Delta GL_D}$$

Key Change: Ratios are calculated based on the "Perfect" capacities (UCAP) rather than the "Real" (ICAP) capacities

Example 1:

Zone D Generation

- **1,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D
ΔGL	ΔGL	ΔGL
2015	3399	551

A	C	D
R_A	R_C	R_D
33.78%	56.98%	9.24%

$$R_D = \frac{\Delta GL_D}{\Delta GL_A + \Delta GL_C + \Delta GL_D} = \frac{551}{2015 + 3399 + 551} = \frac{551}{5965} = 9.24\%$$

Example 2:

Zone D Generation

- **10,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D
ΔGL	ΔGL	ΔGL
2015	3399	1451

A	C	D
R_A	R_C	R_D
29.35%	49.51%	21.14%

$$R_D = \frac{\Delta GL_D}{\Delta GL_A + \Delta GL_C + \Delta GL_D} = \frac{1451}{2015 + 3399 + 1451} = \frac{1451}{6865} = 21.14\%$$

Step 4: Calculate the "Perfect" Capacity to be Added or Removed for Each Zone (Values to be Inputted to the MOD-MDMW Table)

Let X(MW) be the real generation added to or removed from Zones A, C and D:

$$X = X_A + X_C + X_D$$

where,

X_i = the amount of "Real" generation that needs to be added to or removed from Zone i

Let X_p = the total amount of "Perfect" generation (UCAP) that needs to be added to or removed from zones A, C and D, hence,

$$X_p = X_{Ap} + X_{Cp} + X_{Dp} \quad = X_p R_A + X_p R_C + X_p R_D$$

Zone split according to Ratios of Perfect Excess Capacities

where,

X_{ip} = the amount of "Perfect" generation that needs to be added to or removed from Zone i

$$X = X_A + X_C + X_D$$

On the ICAP side, this must also hold

$$X = \frac{X_{Ap}}{1-EFOR_A} + \frac{X_{Cp}}{1-EFOR_C} + \frac{X_{Dp}}{1-EFOR_D}$$

Using relationship between ICAP & UCAP

$$X = \frac{X_p R_A}{1-EFOR_A} + \frac{X_p R_C}{1-EFOR_C} + \frac{X_p R_D}{1-EFOR_D} \quad = X_p\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)$$

Zonal split ratios

or,

$$X_p = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)}$$

This equation provides a conversion between the ICAP amount and the equivalent UCAP amount of capacity to be added or removed from zones A, C and D.

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Step 4: Calculate the "Perfect" Capacity to be Added or Removed for Each Zone (Values to be Inputted to the MOD-MDMW Table)

$$X_p = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)}$$

These are the amount of "Perfect" capacities to be inputted to the MOD-MDMW table.
The first term (left-hand term in red) is equal to X_p and can be calculated just once.

$$X_{Ap} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_A$$

$$X_{Cp} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_C$$

$$X_{Dp} = \frac{X}{\left(\frac{R_A}{1-EFOR_A} + \frac{R_C}{1-EFOR_C} + \frac{R_D}{1-EFOR_D}\right)} R_D$$

Example 1:

Zone D Generation

- **1,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
EFORd	EFORd	EFORd	R_A	R_C	R_D
0.0593	0.0290	0.4253	33.78%	56.98%	9.24%

MDMW Entries		
A	C	D
X_{Ap}	X_{Cp}	X_{Dp}
-305.27	-514.87	-83.47

$$X_{Ap} = \frac{1000}{\left(\frac{0.3378}{(1-0.0593)} + \frac{0.5698}{(1-0.0290)} + \frac{0.0924}{(1-0.4253)}\right)}(0.3378)$$

$$= 305.27$$

Example 2:

Zone D Generation

- **10,000MW wind generation (EFORd = 0.9)**
- **1,271MW regular generation (EFORd = 0.052)**

A	C	D	A	C	D
EFORd	EFORd	EFORd	R_A	R_C	R_D
0.0593	0.0290	0.8043	29.35%	49.51%	21.14%

MDMW Entries		
A	C	D
X_{Ap}	X_{Cp}	X_{Dp}
-154.32	-260.27	-111.11

$$X_{Ap} = \frac{1000}{\left(\frac{0.2935}{(1-0.0593)} + \frac{0.4951}{(1-0.0290)} + \frac{0.2114}{(1-0.4253)}\right)}(0.2935)$$

$$= 154.32$$

Check:

Example 1:

Zone D Generation

- 1,000MW wind generation (EFORd = 0.9)
- 1,271MW regular generation (EFORd = 0.052)

MDMW Entries			ICAP Amount		
A	C	D	A	C	D
X_{Ap}	X_{Cp}	X_{Dp}	X_A	X_C	X_D
-305.27	-514.87	-83.47	324.51	530.24	145.25

$$X_A = \frac{X_{Ap}}{(1 - EFOR_A)} = \frac{305.27}{(1 - 0.0593)} = 324.51$$

$$\text{Total UCAP Removed} = 305.27 + 514.87 + 83.47 = 903.6\text{MW}$$

$$\text{Total ICAP Removed} = 324.51 + 530.24 + 145.25 = 1000\text{MW}$$

Example 2:

Zone D Generation

- 10,000MW wind generation (EFORd = 0.9)
- 1,271MW regular generation (EFORd = 0.052)

MDMW Entries			ICAP Amount		
A	C	D	A	C	D
X_{Ap}	X_{Cp}	X_{Dp}	X_A	X_C	X_D
-154.32	-260.27	-111.11	164.04	268.05	567.91

$$X_A = \frac{X_{Ap}}{(1 - EFOR_A)} = \frac{154.32}{(1 - 0.0593)} = 164.04$$

$$\text{Total UCAP Removed} = 154.32 + 260.27 + 111.11 = 525.7\text{MW}$$

$$\text{Total ICAP Removed} = 164.04 + 268.05 + 567.91 = 1000\text{MW}$$

The total UCAP removed in Example 1 is less than that in Example 2 because the Weighted EFOR for Example 2 is much higher due to the large amount of wind generation (EFOR = 0.9)

- Zone D EFOR increases from 0.4253 (for 1000MW of wind generation) to 0.8043 (for 10000MW of wind generation)

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Procedure to Shift X(MW) of Real (ICAP) Generation from Zone J to Zones A, C, and D Using the MOD-MDMW Table in MARS:

1. **Subtract X.(1-FOR_J) to the MOD-MDMW table for zone J**

2. **Calculate the UCAP split for zones A, C and D using the method described previously for the amount of ICAP removed from zone J, these amount should be positive (adding generation)**

3. **Add these amounts (positive) to the amounts for A, C, and D in the MOD-MDMW table. Generally, the numbers for A, C and D before addition should be negative, as generation has been removed from each zone to adjust the total State generation to the IRM level.**