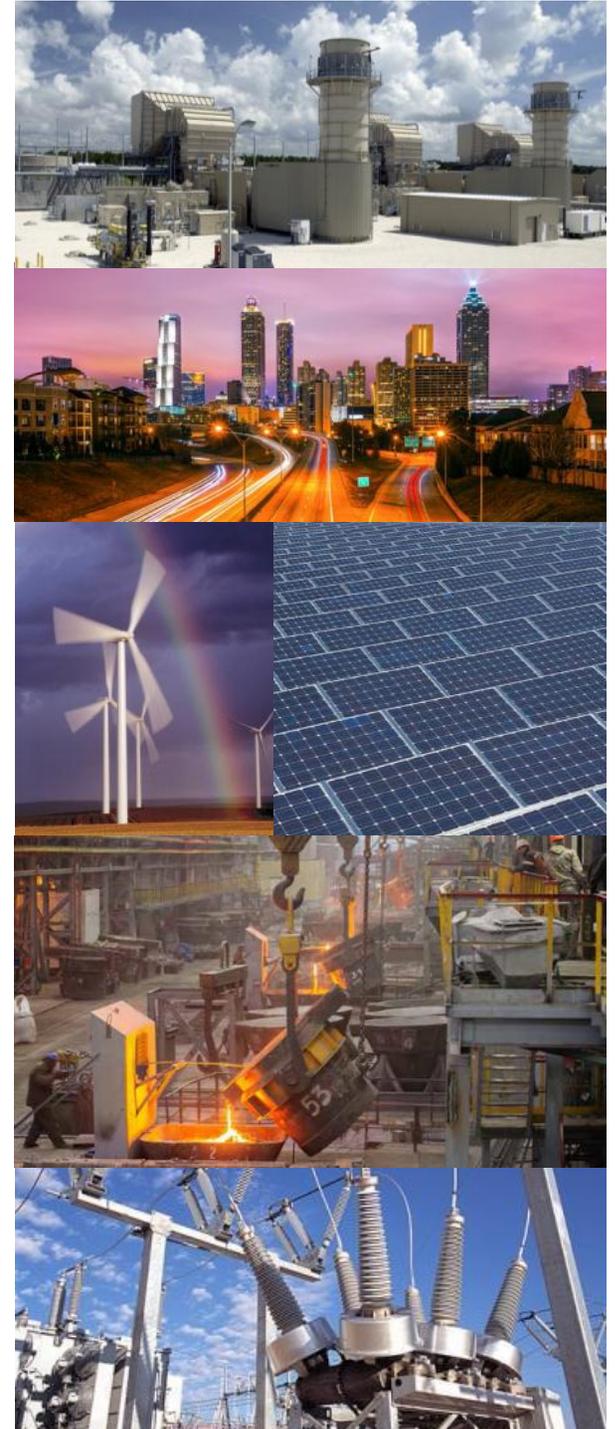# MARS
Multi-Area Reliability Simulation

EOP – On Demand Feature

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GE
**Energy Consulting**

Implementation of an On-Demand Feature for the EOP
Introduction :

- To provide a new feature allowing users to specify a certain EOP margin state as an on-demand EOP
- This feature will allow any EOP MW benefits, if specified, to be used as non-firm emergency assistance only for the area itself and the areas within the same pool, but not to the outside pools.
- This feature will be demonstrated using a 5-area sample system.
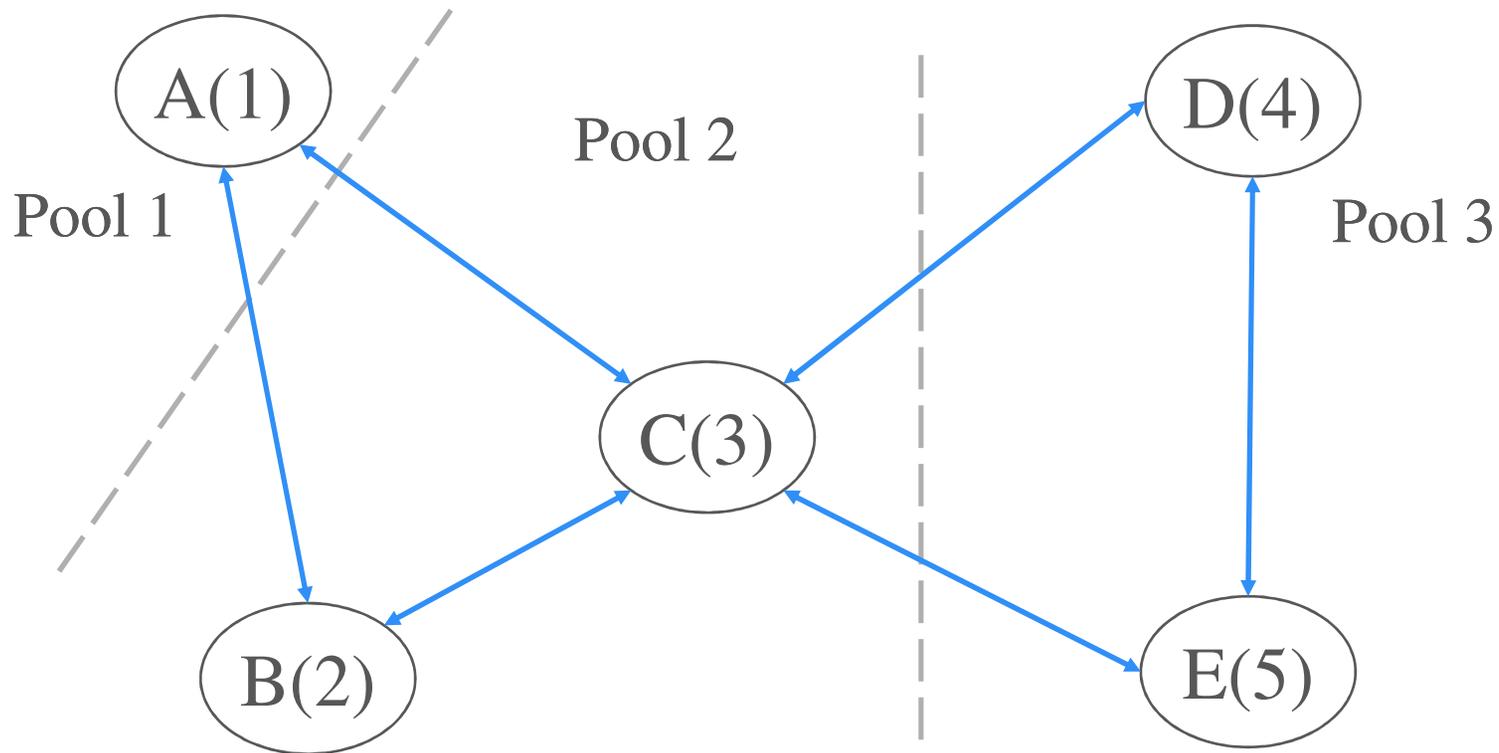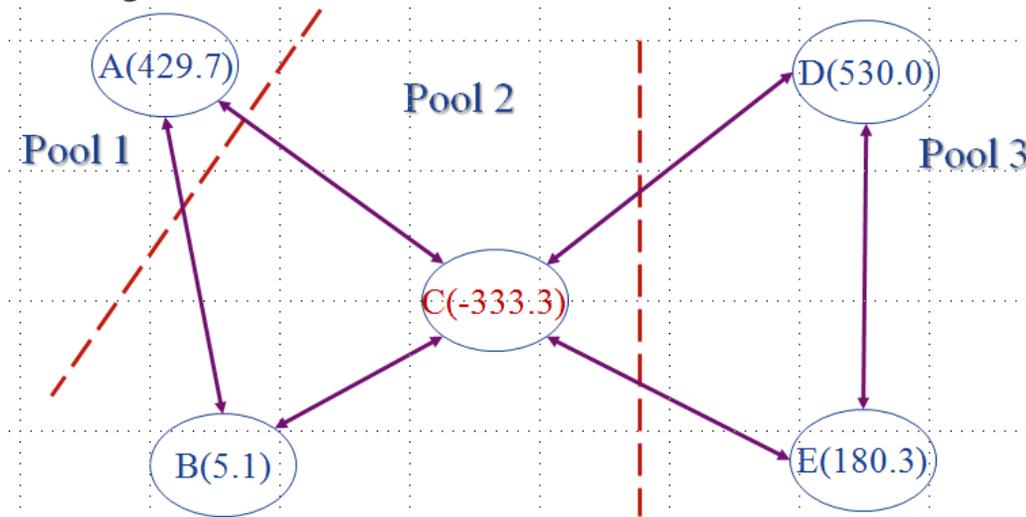
Current EOP Operation

Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

1. Calculate area capacity margins after taking into account all the available thermal capacities
   - EOPs for each area (6 Margin States):

MS	EOP Action	A	B	C	D	E
1	Oper. Resrves	-300	-100	-200	-200	-100
2	Emrg Ratings	100	100	100	50	50
3	Intrpt Lds	75	75	50	50	25
4	Voltage Red.	50	50	50	100	25
5	Cust. Appeal	50	50	50	100	25
6	Reduce O.R.	50	50	50	100	25

   - Area Margin after Margin State #1

Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

2. Apply EOP MW benefits to the isolated system (Margin State #1 – usually negative – Oper. Res.)

A
(-300)
(429.7/129.7)

Pool 2

D
(-200)
(530.0/330.0)

Pool 1

Pool 3

C
(-200)
(-333/-533.3)

B
(-100)
(5.1/-94.9)

E
(-100)
(180.3/80.3)
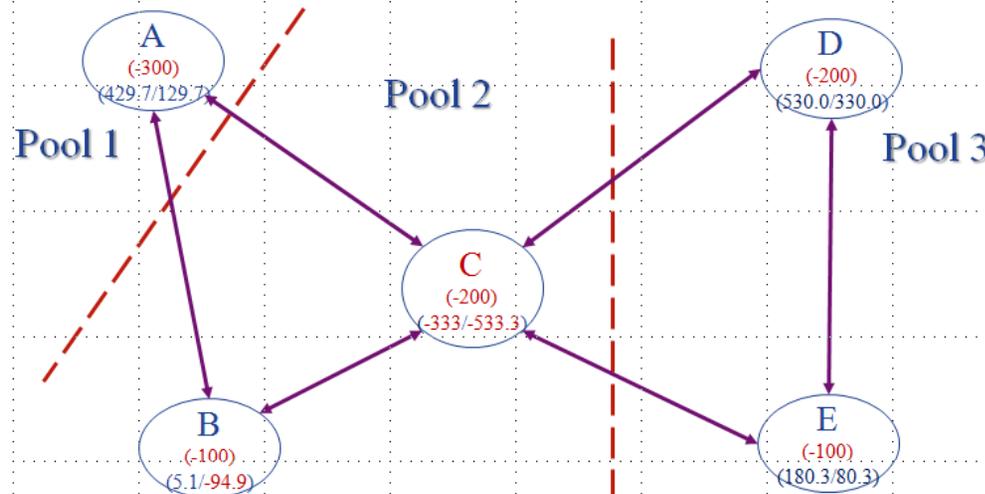
3. Initiate peak shaving by EL2 units

A
(0)
(129.7/129.7)

Pool 2

D
(0)
(330.0/330.0)

Pool 1

Pool 3

C
(50)
(-533.3/-483.3)

B
(0)
(-94.9/-94.9)

E
(0)
(80.3/80.3)
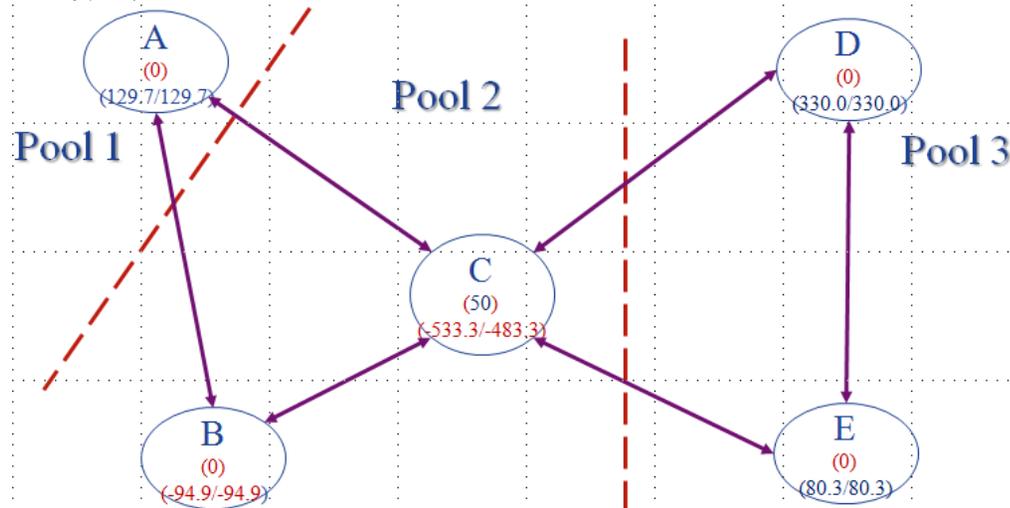
Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

- EOPs for each negative area, B & C:

MS	EOP Action	B Before	EOP	Peak Shave	B After	C Before	EOP	Peak Shave	C After
1	Oper. Resrves	5.1	-100	0	-94.9	-333.3	-200	50	-483.3
2	Emrg Ratings	-94.9	100	0	5.1	-483.3	100	0	-383.3
3	Intrpt Lds					-383.3	50	0	-333.3
4	Voltage Red.					-333.3	50	0	-283.3
5	Cust. Appeal					-283.3	50	0	-233.3
6	Reduce O.R.					-233.3	50	0	-183.3

- It is obvious that Area EOPs for C is insufficient to eliminate its own negative margins. Assistance from other areas or pools are required.

Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

4. Apply Interconnected Peak Shaving and Cutailable Contracts and Reoptimized. (Margin State #1)
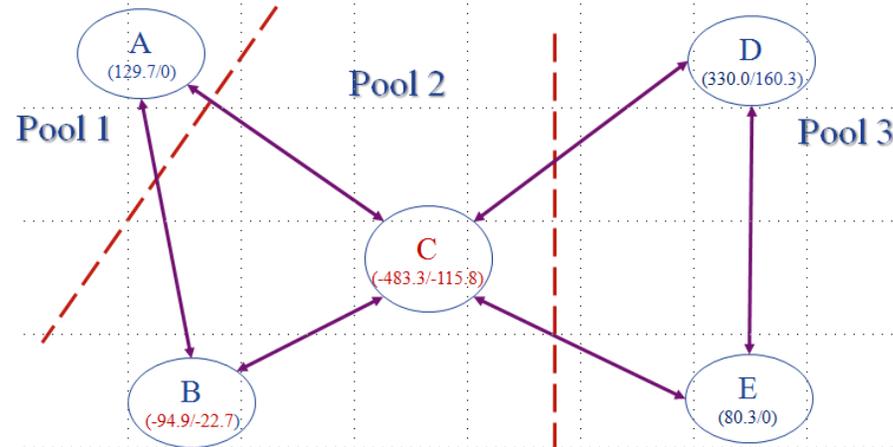
- Both Areas B & C negative margins are reduced, but are still negative. Further EOP actions are required.

5. Apply next Margin State EOPs to negative areas (Margin State #2)

- When an area has 0 margin, its surplus has all been used for itself or for assistance, so EOPs will be deployed for further system assistance.
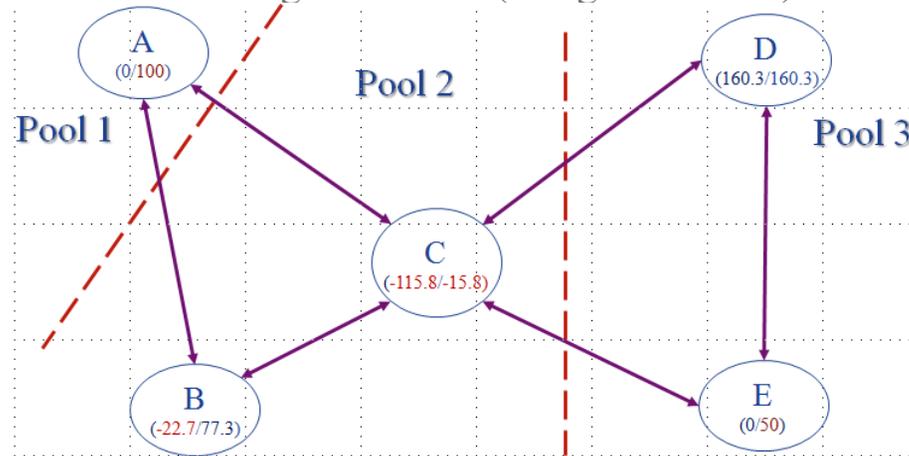
- When an area has positive margin, it implies transfer constraint, so no further EOPs will be deployed in that area.

Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

6. Apply interconnection non-firm assistance to negative areas (Margin State #2)

- Three types of interconnection assistance are performed in the EOP actions:

    1. Pool Priority assistance – assisting only areas within its own pool

    2. Pool Reserve Sharing assistance – assisting areas in outside pools within its designated sharing groups

    3. System-wide assistance – assisting areas to any negative area in the system

- These three actions will be performed in the order given above.

Implementation of an On-Demand Feature for the EOP
Current EOP Operations:

6a. Apply Pool Priority interconnection non-firm assistance to negative areas (Margin State #2)
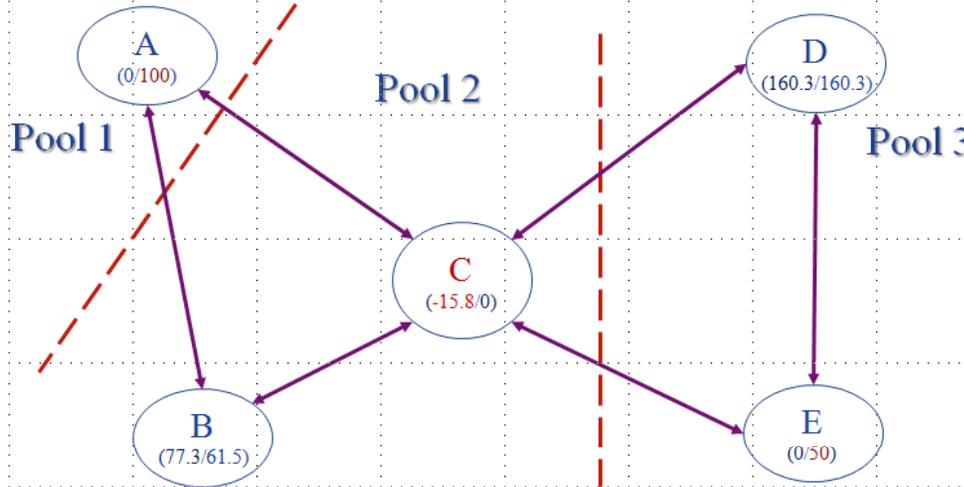
- Area C received 15.8MW assistance from its own pool member B and brought its margin to zero. Both areas already applied their EOP margin state #2.
- No EOP was added to Area D as it is a positive area which implies transmission constraint.
- Areas A and E received EOPs, but nothing was scheduled to assist others.

6b. Apply Pool Reserve Sharing non-firm assistance to negative areas (Margin State #2)
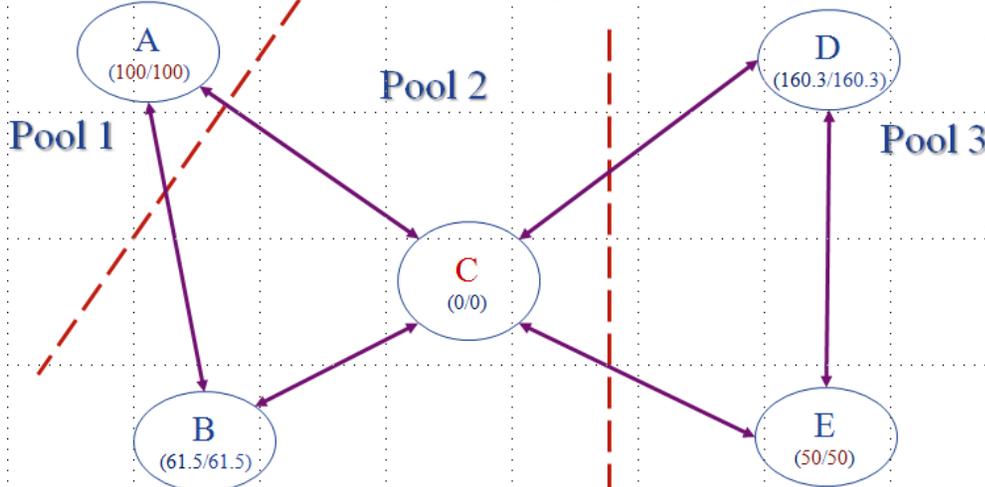
- All areas have either zero or positive margin before this step, there is no more negative margin existing in the system. No Pool Reserve Sharing is therefore needed.
- If negative margin areas still exist, both pool reserve sharing and system-wide sharing will be performed until either all areas have zero or positive margin, or all EOP steps have been applied.

Testing the New EOP Feature

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- A new category for the EOP type: "D" – on-demand EOP – this EOP will only be available for its own area, and areas within its own pool. It is not available for areas outside its own pool where there are any designated sharing group or not.
- Disabling EOP from assisting outside pools does not necessarily affect the final LOLE outcomes
    - eventually deficient areas would acquire sufficient assistance from other places or from the remaining EOP margin states to meet its deficiency.
    - If a system has sufficient reserves, or if there are sufficient EOP states where areas can receive assistance, the pool may not experience any more loss of load than if the on-demand is not enabled.
    - This is particularly true for large system with many interconnections.
- This feature, however, will affect the number of EOP used and distribution of EOP assistance for each area, particularly for the area at which this is enabled and its nearby areas.
- The effect may not be very noticeable if the EOP amount is relatively small.
- To demonstrate the effect of a large EOP implemented at a certain state, several adjustments were made to hopefully amplify the impacts:
    - EOP of area B at margin state #2 was changed from 100MW to 300MW.
    - The loads of the areas have been adjusted to increase the amount of loss of load so as to amplify the impacts.
    - The LOLE is calculated at margin state #4 instead of at the end of the maximum margin state to show impacts after this feature without the influence from higher margin states.
    - Some interface limits are relaxed so that the benefit will not be bottled due to the interface limits. However, it is not necessary effective for large system where there are many interconnections.

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

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- Disabling EOP from assisting outside pools does not necessarily affect the final LOLE outcomes
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    - If a system has sufficient reserves, or if there are sufficient EOP states where areas can receive assistance, the pool may not experience any more loss of load than if the on-demand is not enabled.
    - This is particularly true for large system with many interconnections.
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    - Some interface limits are relaxed so that the benefit will not be bottled due to the interface limits. However, it is not necessary effective for large system where there are many interconnections.

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- In the beginning after EOP margin state #1 (operating reserve, negative), both cases should be the same.

	Case #	After MS #	Ater PkShave
Area A	1	1	-218.0
Area B	1	1	0.0
Area C	1	1	-173.2
Area D	1	1	0.0
Area E	1	1	0.0
Area A	2	1	-218.0
Area B	2	1	0.0
Area C	2	1	-173.2
Area D	2	1	0.0
Area E	2	1	0.0

- In this case, all area margins are either zero or negative, so all areas will receive EOP in #2 margin state.

	Case #	After MS #	Ater PkShave	EOP	After EOP
Area A	1	1	-218.0	100.0	-118.0
Area B	1	1	0.0	300.0	300.0
Area C	1	1	-173.2	100.0	-73.2
Area D	1	1	0.0	50.0	50.0
Area E	1	1	0.0	50.0	50.0
Area A	2	1	-218.0	100.0	-118.0
Area B	2	1	0.0	300.0	300.0
Area C	2	1	-173.2	100.0	-73.2
Area D	2	1	0.0	50.0	50.0
Area E	2	1	0.0	50.0	50.0

- After EOP addition, areas A and C are still negative. The system would enter the Pool-Priority assistance stage.

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- Pool Priority Assistance for areas in the same pool. Area B margin was reduced to 226.8MW.
- At this time, surplus will only be available to areas of the same pool. Area A therefore is not assisted.

	Case #	MS #	After PkShave	EOP	After EOP	After PP
Area A	1	1	-218.0	100.0	-118.0	-118.0
Area B	1	1	0.0	300.0	300.0	226.8
Area C	1	1	-173.2	100.0	-73.2	0.0
Area D	1	1	0.0	50.0	50.0	50.0
Area E	1	1	0.0	50.0	50.0	50.0
Area A	2	1	-218.0	100.0	-118.0	-118.0
Area B	2	1	0.0	300.0	300.0	226.8
Area C	2	1	-173.2	100.0	-73.2	0.0
Area D	2	1	0.0	50.0	50.0	50.0
Area E	2	1	0.0	50.0	50.0	50.0

- Surplus in area B in case 1 is available for Pool Reserve Sharing, but not in case 2 because of the on-demand setting. Case 2 area B flag is set and margin set to zero so that no EOP surplus from this margin state will be available for Pool Reserve Sharing.

	Case #	MS #	After PkShave	EOP	After EOP	After PP	OD Flag	Adj. Before PS
Area A	1	1	-218.0	100.0	-118.0	-118.0	0	-118.0
Area B	1	1	0.0	300.0	300.0	226.8	0	226.8
Area C	1	1	-173.2	100.0	-73.2	0.0	0	0.0
Area D	1	1	0.0	50.0	50.0	50.0	0	50.0
Area E	1	1	0.0	50.0	50.0	50.0	0	50.0
Area A	2	1	-218.0	100.0	-118.0	-118.0	0	-118.0
Area B	2	1	0.0	300.0	300.0	226.8	1	0.0
Area C	2	1	-173.2	100.0	-73.2	0.0	0	0.0
Area D	2	1	0.0	50.0	50.0	50.0	0	50.0
Area E	2	1	0.0	50.0	50.0	50.0	0	50.0

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- Area A in case 1 was eliminated with the assistance from Area B. But in case 2, area A remains negative as there was no possible assistance from other areas which it connects to (Areas B and C)

	Case #	MS #	After PkShave	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS
Area A	1	1	-218.0	100.0	-118.0	-118.0	0	-118.0	0.0
Area B	1	1	0.0	300.0	300.0	226.8	0	226.8	108.8
Area C	1	1	-173.2	100.0	-73.2	0.0	0	0.0	0.0
Area D	1	1	0.0	50.0	50.0	50.0	0	50.0	50.0
Area E	1	1	0.0	50.0	50.0	50.0	0	50.0	50.0
Area A	2	1	-218.0	100.0	-118.0	-118.0	0	-118.0	-118.0
Area B	2	1	0.0	300.0	300.0	226.8	1	0.0	0.0
Area C	2	1	-173.2	100.0	-73.2	0.0	0	0.0	0.0
Area D	2	1	0.0	50.0	50.0	50.0	0	50.0	50.0
Area E	2	1	0.0	50.0	50.0	50.0	0	50.0	50.0

- After the Pool Reserve Sharing calculation, area margin of Area B was reset back to its previous value of 226.8, as they would be once again available for local area and pool support .

	Case #	MS #	After PkShave	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS	Reset Margin
Area A	1	1	-218.0	100.0	-118.0	-118.0	0	-118.0	0.0	0.0
Area B	1	1	0.0	300.0	300.0	226.8	0	226.8	108.8	108.8
Area C	1	1	-173.2	100.0	-73.2	0.0	0	0.0	0.0	0.0
Area D	1	1	0.0	50.0	50.0	50.0	0	50.0	50.0	50.0
Area E	1	1	0.0	50.0	50.0	50.0	0	50.0	50.0	50.0
Area A	2	1	-218.0	100.0	-118.0	-118.0	0	-118.0	-118.0	-118.0
Area B	2	1	0.0	300.0	300.0	226.8	1	0.0	0.0	226.8
Area C	2	1	-173.2	100.0	-73.2	0.0	0	0.0	0.0	0.0
Area D	2	1	0.0	50.0	50.0	50.0	0	50.0	50.0	50.0
Area E	2	1	0.0	50.0	50.0	50.0	0	50.0	50.0	50.0

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- Implement EOP margin state #3

	Case #	After MS #	Margin	EOP	After EOP
Area A	2	2	-118.0	75.0	-43.0
Area B	2	2	226.8	75.0	226.8
Area C	2	2	0.0	50.0	50.0
Area D	2	2	50.0	50.0	50.0
Area E	2	2	50.0	25.0	50.0

- Area B has positive margin, no new EOP is added, but the amount is added to the total unused EOP. After Pool Priority assistance, nothing changes as only area A is negative and there is no other positive area in the pool.

	Case #	After MS #	Margin	EOP	After EOP	After PP
Area A	2	2	-118.0	75.0	-43.0	-43.0
Area B	2	2	226.8	75.0	226.8	276.8
Area C	2	2	0.0	50.0	50.0	50.0
Area D	2	2	50.0	50.0	50.0	50.0
Area E	2	2	50.0	25.0	50.0	50.0

- Before Pool Reserve Sharing, margin of Area B was reset back to 0.0 as it was from a on-demand EOP.

	Case #	After MS #	Margin	EOP	After EOP	After PP	OD Flag	Adj. Before PS
Area A	2	2	-118.0	75.0	-43.0	-43.0	0	-43.0
Area B	2	2	226.8	75.0	226.8	276.8	1	0.0
Area C	2	2	0.0	50.0	50.0	50.0	0	50.0
Area D	2	2	50.0	50.0	50.0	50.0	0	50.0
Area E	2	2	50.0	25.0	50.0	50.0	0	50.0

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- Area A received assistance from Area C during the Pool Reserve Sharing allocation. All areas are now positive.

	Case #	MS #	Margin	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS
Area A	2	2	-118.0	75.0	-43.0	-43.0	0	-43.0	0.0
Area B	2	2	226.8	75.0	226.8	276.8	1	0.0	0.0
Area C	2	2	0.0	50.0	50.0	50.0	0	50.0	7.0
Area D	2	2	50.0	50.0	50.0	50.0	0	50.0	50.0
Area E	2	2	50.0	25.0	50.0	50.0	0	50.0	50.0

- Margin for Area B was reset back to previous value of 276.8. Since there are no more negative margin, calculation is complete.

	Case #	MS #	Margin	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS	Reset Margin
Area A	2	2	-118.0	75.0	-43.0	-43.0	0	-43.0	0.0	0.0
Area B	2	2	226.8	75.0	226.8	276.8	1	0.0	0.0	226.8
Area C	2	2	0.0	50.0	50.0	50.0	0	50.0	7.0	7.0
Area D	2	2	50.0	50.0	50.0	50.0	0	50.0	50.0	50.0
Area E	2	2	50.0	25.0	50.0	50.0	0	50.0	50.0	50.0

- In both cases, negative margins were all eliminated, so no loss of load will be recorded. However, the resulting usage of EOP will be different.
- The system would go through the same process for all hours as the area margin conditions for each hour can be different.
- If negative margin areas still exists, the remaining on-demand EOP will be recorded and used only in Pool Priority allocation, but EOPS that are not designated as on-demand will be available to assist other areas outside the pool.

Implementation of an On-Demand Feature for the EOP
Testing the New EOP Feature by Tracing the Operations:

- Area A received assistance from Area C during the Pool Reserve Sharing allocation. All areas are now positive.

	Case #	After MS #	Margin	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS
Area A	2	2	-118.0	75.0	-43.0	-43.0	0	-43.0	0.0
Area B	2	2	226.8	75.0	226.8	276.8	1	0.0	0.0
Area C	2	2	0.0	50.0	50.0	50.0	0	50.0	7.0
Area D	2	2	50.0	50.0	50.0	50.0	0	50.0	50.0
Area E	2	2	50.0	25.0	50.0	50.0	0	50.0	50.0

- Margin for Area B was reset back to previous value of 276.8. Since there are no more negative margin, calculation is complete.

	Case #	After MS #	Margin	EOP	After EOP	After PP	OD Flag	Adj. Before PS	After PS	Reset Margin
Area A	2	2	-118.0	75.0	-43.0	-43.0	0	-43.0	0.0	0.0
Area B	2	2	226.8	75.0	226.8	276.8	1	0.0	0.0	226.8
Area C	2	2	0.0	50.0	50.0	50.0	0	50.0	7.0	7.0
Area D	2	2	50.0	50.0	50.0	50.0	0	50.0	50.0	50.0
Area E	2	2	50.0	25.0	50.0	50.0	0	50.0	50.0	50.0

- In both cases, negative margins were all eliminated, so no loss of load will be recorded. However, the resulting usage of EOP will be different.
- The system would go through the same process for all hours as the area margin conditions for each hour can be different.
- If negative margin areas still exists, the remaining on-demand EOP will be recorded and used only in Pool Priority allocation, but EOPs that are not designated as on-demand will be available to assist other areas outside the pool.

Verifying the New EOP Feature

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts of the On-Demand EOP:

- Three systems were created for comparison:
    1. Sample Modified System Base Case with EOP of 100MW at margin state #2 of Area B.
    2. Sample Modified System Base Case with EOP of 300MW at margin state #2 of Area B.
    3. Sample Modified System Base Case with EOP of 750MW at margin state #2 of Area B.
- For each area, the first line in the table represent EOP for itself; second line, between areas of the same pool; and third line, outside pools

AREA	System 1 - EOP Margin States					AREA	System 1 - EOP Margin States				
	2	3	4	5	6		2	3	4	5	6
AREA-A	87.80	41.40	20.20	10.60	4.00	AREA-A	87.80	45.60	23.40	12.40	4.20
	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60		22.20	10.00	5.00	1.60	0.60
AREA-B	120.20	39.00	15.20	6.00	2.00	AREA-B	120.20	39.00	15.20	6.00	2.00
	3.80	11.00	6.60	2.40	0.40		3.20	11.00	6.60	2.40	0.40
	10.60	7.40	4.60	2.80	0.60		0.00	3.80	4.40	2.80	0.60
AREA-C	114.20	42.40	18.20	6.60	2.00	AREA-C	114.20	42.40	18.20	6.60	2.00
	4.00	3.20	1.40	0.40	0.60		4.00	3.20	1.40	0.40	0.60
	10.60	8.20	6.80	4.00	1.00		11.80	12.80	10.20	5.60	1.40
AREA-D	34.00	19.00	12.20	3.00	0.80	AREA-D	34.00	19.00	12.20	3.00	0.80
	5.60	1.60	1.40	0.80	0.20		5.60	2.00	1.40	0.80	0.20
	25.00	13.40	4.80	1.40	0.40		26.40	14.20	4.80	1.40	0.40
AREA-E	27.80	9.80	5.60	2.40	1.00	AREA-E	27.80	9.80	5.60	2.40	1.00
	9.00	5.00	1.00	0.20	0.00		9.00	5.00	1.00	0.20	0.00
	41.40	17.40	9.40	1.40	0.20		44.40	18.20	9.40	1.40	0.20

- For system #1, second table (right) shows that it did not provide any assistance to the outside pools (third line) at margin state #2 (see red line box), as this EOP was designated as for itself and pool members only.

- Consequently, Area A, which generally receives assistance from B and C, will now have to supply its own EOP more times than before (see blue line box).

- Area C also contributes more to the assistance of outside pools than when B was available (see brown line box).

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts of the On-Demand EOP:

- Three systems were created for comparison:
  1. Sample Modified System Base Case with EOP of 100MW at margin state #2 of Area B.
  2. Sample Modified System Base Case with EOP of 300MW at margin state #2 of Area B.
  3. Sample Modified System Base Case with EOP of 750MW at margin state #2 of Area B.
- For each area, the first line in the table represent EOP for itself; second line, between areas of the same pool; and third line, outside pools

AREA	System 1 - EOP Margin States					AREA	System 1 - EOP Margin States				
	2	3	4	5	6		2	3	4	5	6
AREA-A	87.80	41.40	20.20	10.60	4.00	AREA-A	87.80	45.60	23.40	12.40	4.20
	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60		22.20	10.00	5.00	1.60	0.60
AREA-B	120.20	39.00	15.20	6.00	2.00	AREA-B	120.20	39.00	15.20	6.00	2.00
	3.80	11.00	6.60	2.40	0.40		3.20	11.00	6.60	2.40	0.40
	10.60	7.40	4.60	2.80	0.60		0.00	3.80	4.40	2.80	0.60
AREA-C	114.20	42.40	18.20	6.60	2.00	AREA-C	114.20	42.40	18.20	6.60	2.00
	4.00	3.20	1.40	0.40	0.60		4.00	3.20	1.40	0.40	0.60
	10.60	8.20	6.80	4.00	1.00		11.80	12.80	10.20	5.60	1.40
AREA-D	34.00	19.00	12.20	3.00	0.80	AREA-D	34.00	19.00	12.20	3.00	0.80
	5.60	1.60	1.40	0.80	0.20		5.60	2.00	1.40	0.80	0.20
	25.00	13.40	4.80	1.40	0.40		26.40	14.20	4.80	1.40	0.40
AREA-E	27.80	9.80	5.60	2.40	1.00	AREA-E	27.80	9.80	5.60	2.40	1.00
	9.00	5.00	1.00	0.20	0.00		9.00	5.00	1.00	0.20	0.00
	41.40	17.40	9.40	1.40	0.20		44.40	18.20	9.40	1.40	0.20

- For system #1, second table (right) shows that it did not provide any assistance to the outside pools (third line) at margin state #2 (see red line box), as this EOP was designated as for itself and pool members only.
- Consequently, Area A, which generally receives assistance from B and C, will now have to supply its own EOP more times than before (see blue line box).
- Area C also contributes more to the assistance of outside pools than when B was available (see brown line box).

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts of the On-Demand EOP:

- Larger on-demand EOPs at B helps only Areas B and C. The number of EOP usage for local pool assistance for both Areas B and C drops to zero after the implementation of 750MW on-demand EOP at B.

AREA	System 1 - EOP Margin States					System 3 - EOP 300D Margin States					System 3 - EOP 750D Margin States				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
AREA-A	87.80	45.60	23.40	12.40	4.20	87.80	42.60	19.60	8.40	2.80	86.00	43.25	20.25	8.25	1.75
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60	8.00	3.80	1.20	0.60	0.20	4.00	1.50	0.50	0.25	0.00
AREA-B	120.20	39.00	15.20	6.00	2.00	120.20	6.80	1.40	0.40	0.00	119.50	0.00	0.00	0.00	0.00
	3.20	11.00	6.60	2.40	0.40	3.20	10.80	3.60	0.80	0.20	3.75	0.00	0.00	0.00	0.00
	0.00	3.80	4.40	2.80	0.60	0.00	2.20	2.40	1.00	1.00	0.00	0.25	0.00	0.00	0.00
AREA-C	114.20	42.40	18.20	6.60	2.00	114.20	18.80	6.00	1.20	0.20	114.25	4.25	1.25	0.25	0.25
	4.00	3.20	1.40	0.40	0.60	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.80	12.80	10.20	5.60	1.40	13.20	20.80	12.80	4.40	1.40	14.00	27.25	15.50	4.50	1.00
AREA-D	34.00	19.00	12.20	3.00	0.80	34.00	18.80	11.60	3.00	0.80	32.75	16.75	10.00	2.50	0.75
	5.60	2.00	1.40	0.80	0.20	5.00	1.80	1.40	0.40	0.20	4.75	2.00	1.50	0.50	0.00
	26.40	14.20	4.80	1.40	0.40	19.20	9.40	2.40	0.40	0.20	16.50	8.25	2.00	0.50	0.25
AREA-E	27.80	9.80	5.60	2.40	1.00	27.80	9.80	5.20	2.20	1.00	28.00	10.25	5.50	2.50	0.75
	9.00	5.00	1.00	0.20	0.00	9.00	4.60	1.00	0.20	0.00	8.75	3.75	0.50	0.00	0.00
	44.40	18.20	9.40	1.40	0.20	33.40	12.00	5.00	0.40	0.20	29.25	10.75	4.50	0.50	0.25

- EOP usage in margin #3 for Area B drops from 39.00 to 6.80 for 300MW EOP and to 0.00 for 700MW EOP
- Number of EOP used in margin #3 for Area C drops from 42.40 to 18.80 for 300MW EOP and to 4.25 for 700MW because of larger assistance from B; other areas were not affected much as B cannot assist areas outside the pool.
- As the on-demand EOPs increases in magnitude, the same phenomenon can still be observed. The large surplus in B assists also C, therefore it requires less number of EOP assistance for itself. C therefore is also more available to provide assistance to Area A.
- All three tables show an absence of EOP assistance to the outside pools at margin state #2 for area B as expected.
- System with small on-demand EOP will be required to go through many more stages of EOPs to eliminate its negative margins, whereas larger amount of EOP obviously will eliminate larger amount of deficiency earlier less EOP steps will be required compared to that of a smaller EOP system.

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts of the On-Demand EOP:

AREA	System 1 - EOP Margin States					System 2 - EOP 300 Margin States					System 2 - EOP 750 Margin States				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
AREA-A	87.80	41.40	20.20	10.60	4.00	87.80	26.60	12.40	4.60	2.40	87.80	15.40	6.60	3.00	1.60
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60	8.00	3.60	1.20	0.60	0.20	4.00	1.00	0.40	0.20	0.00
AREA-B	120.20	39.00	15.20	6.00	2.00	120.20	6.80	1.40	0.40	0.00	120.20	0.00	0.00	0.00	0.00
	3.80	11.00	6.60	2.40	0.40	3.80	10.80	3.60	0.80	0.20	3.80	0.00	0.00	0.00	0.00
	10.60	7.40	4.60	2.80	0.60	10.60	7.00	2.40	1.00	1.00	10.60	0.60	0.00	0.00	0.00
AREA-C	114.20	42.40	18.20	6.60	2.00	114.20	18.80	6.00	1.20	0.20	114.20	3.80	1.00	0.20	0.20
	4.00	3.20	1.40	0.40	0.60	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.60	8.20	6.80	4.00	1.00	11.60	8.60	5.00	1.40	0.80	12.00	5.00	2.40	0.60	0.00
AREA-D	34.00	19.00	12.20	3.00	0.80	34.00	18.60	11.40	3.00	0.80	34.00	18.40	11.20	3.00	0.80
	5.60	1.60	1.40	0.80	0.20	4.40	1.20	1.40	0.40	0.20	3.40	0.80	1.00	0.40	0.00
	25.00	13.40	4.80	1.40	0.40	13.40	6.80	1.60	0.40	0.20	6.20	2.60	0.60	0.20	0.00
AREA-E	27.80	9.80	5.60	2.40	1.00	27.80	9.60	4.80	2.20	1.00	27.80	9.00	4.40	2.20	1.00
	9.00	5.00	1.00	0.20	0.00	9.00	4.20	1.00	0.20	0.00	9.00	3.80	0.60	0.00	0.00
	41.40	17.40	9.40	1.40	0.20	20.00	8.60	2.40	0.20	0.20	7.80	4.00	0.60	0.20	0.00

AREA	System 1 - EOP Margin States					System 3 - EOP 300D Margin States					System 3 - EOP 750D Margin States				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
AREA-A	87.80	45.60	23.40	12.40	4.20	87.80	42.60	19.60	8.40	2.80	86.00	43.25	20.25	8.25	1.75
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60	8.00	3.80	1.20	0.60	0.20	4.00	1.50	0.50	0.25	0.00
AREA-B	120.20	39.00	15.20	6.00	2.00	120.20	6.80	1.40	0.40	0.00	119.50	0.00	0.00	0.00	0.00
	3.20	11.00	6.60	2.40	0.40	3.20	10.80	3.60	0.80	0.20	3.75	0.00	0.00	0.00	0.00
	0.00	3.80	4.40	2.80	0.60	0.00	2.20	2.40	1.00	1.00	0.00	0.25	0.00	0.00	0.00
AREA-C	114.20	42.40	18.20	6.60	2.00	114.20	18.80	6.00	1.20	0.20	114.25	4.25	1.25	0.25	0.25
	4.00	3.20	1.40	0.40	0.60	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.80	12.80	10.20	5.60	1.40	13.20	20.80	12.80	4.40	1.40	14.00	27.25	15.50	4.50	1.00
AREA-D	34.00	19.00	12.20	3.00	0.80	34.00	18.80	11.60	3.00	0.80	32.75	16.75	10.00	2.50	0.75
	5.60	2.00	1.40	0.80	0.20	5.00	1.80	1.40	0.40	0.20	4.75	2.00	1.50	0.50	0.00
	26.40	14.20	4.80	1.40	0.40	19.20	9.40	2.40	0.40	0.20	16.50	8.25	2.00	0.50	0.25
AREA-E	27.80	9.80	5.60	2.40	1.00	27.80	9.80	5.20	2.20	1.00	28.00	10.25	5.50	2.50	0.75
	9.00	5.00	1.00	0.20	0.00	9.00	4.60	1.00	0.20	0.00	8.75	3.75	0.50	0.00	0.00
	44.40	18.20	9.40	1.40	0.20	33.40	12.00	5.00	0.40	0.20	29.25	10.75	4.50	0.50	0.25

- It was shown previously that the unavailability of the state #2 EOP from Area B forces Area A to deploy its own EOP many more times than when it is available. For a 750 on-demand EOP at B, EOP deployment in state 3 almost doubled and about 3 times in states 4 and 5 and about the same in state 6.
- the number of EOP assist from Area C to external pools increases many folds when EOP in Area B is on-demand.
- System EOP usages show quite a different behavior with on-demand EOPs. The larger the on-demand EOPs, the more changes to the distribution of the EOP usages at different margin states for each area, particularly those areas that are very close to the area where the on-demand EOP is implemented.

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts of the On-Demand EOP:

AREA	System 1 - EOP Margin States					System 2 - EOP 300 Margin States					System 2 - EOP 750 Margin States				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
AREA-A	87.80	41.40	20.20	10.60	4.00	87.80	26.60	12.40	4.60	2.40	87.80	15.40	6.60	3.00	1.60
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60	8.00	3.60	1.20	0.60	0.20	4.00	1.00	0.40	0.20	0.00
AREA-B	120.20	39.00	15.20	6.00	2.00	120.20	6.80	1.40	0.40	0.00	120.20	0.00	0.00	0.00	0.00
	3.80	11.00	6.60	2.40	0.40	3.80	10.80	3.60	0.80	0.20	3.80	0.00	0.00	0.00	0.00
	10.60	7.40	4.60	2.80	0.60	10.60	7.00	2.40	1.00	1.00	10.60	0.60	0.00	0.00	0.00
AREA-C	114.20	42.40	18.20	6.60	2.00	114.20	18.80	6.00	1.20	0.20	114.20	3.80	1.00	0.20	0.20
	4.00	3.20	1.40	0.40	0.60	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10.60	8.20	6.80	4.00	1.00	11.60	8.60	5.00	1.40	0.80	12.00	5.00	2.40	0.60	0.00
AREA-D	34.00	19.00	12.20	3.00	0.80	34.00	18.60	11.40	3.00	0.80	34.00	18.40	11.20	3.00	0.80
	5.60	1.60	1.40	0.80	0.20	4.40	1.20	1.40	0.40	0.20	3.40	0.80	1.00	0.40	0.00
	25.00	13.40	4.80	1.40	0.40	13.40	6.80	1.60	0.40	0.20	6.20	2.60	0.60	0.20	0.00
AREA-E	27.80	9.80	5.60	2.40	1.00	27.80	9.60	4.80	2.20	1.00	27.80	9.00	4.40	2.20	1.00
	9.00	5.00	1.00	0.20	0.00	9.00	4.20	1.00	0.20	0.00	9.00	3.80	0.60	0.00	0.00
	41.40	17.40	9.40	1.40	0.20	20.00	8.60	2.40	0.20	0.20	7.80	4.00	0.60	0.20	0.00

AREA	System 1 - EOP Margin States					System 3 - EOP 300D Margin States					System 3 - EOP 750D Margin States				
	2	3	4	5	6	2	3	4	5	6	2	3	4	5	6
AREA-A	87.80	45.60	23.40	12.40	4.20	87.80	42.60	19.60	8.40	2.80	86.00	43.25	20.25	8.25	1.75
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	22.20	10.00	5.00	1.60	0.60	8.00	3.80	1.20	0.60	0.20	4.00	1.50	0.50	0.25	0.00
AREA-B	120.20	39.00	15.20	6.00	2.00	120.20	6.80	1.40	0.40	0.00	119.50	0.00	0.00	0.00	0.00
	3.20	11.00	6.60	2.40	0.40	3.20	10.80	3.60	0.80	0.20	3.75	0.00	0.00	0.00	0.00
	0.00	3.80	4.40	2.80	0.60	0.00	2.20	2.40	1.00	1.00	0.00	0.25	0.00	0.00	0.00
AREA-C	114.20	42.40	18.20	6.60	2.00	114.20	18.80	6.00	1.20	0.20	114.25	4.25	1.25	0.25	0.25
	4.00	3.20	1.40	0.40	0.60	1.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.80	12.80	10.20	5.60	1.40	13.20	20.80	12.80	4.40	1.40	14.00	27.25	15.50	4.50	1.00
AREA-D	34.00	19.00	12.20	3.00	0.80	34.00	18.80	11.60	3.00	0.80	32.75	16.75	10.00	2.50	0.75
	5.60	2.00	1.40	0.80	0.20	5.00	1.80	1.40	0.40	0.20	4.75	2.00	1.50	0.50	0.00
	26.40	14.20	4.80	1.40	0.40	19.20	9.40	2.40	0.40	0.20	16.50	8.25	2.00	0.50	0.25
AREA-E	27.80	9.80	5.60	2.40	1.00	27.80	9.80	5.20	2.20	1.00	28.00	10.25	5.50	2.50	0.75
	9.00	5.00	1.00	0.20	0.00	9.00	4.60	1.00	0.20	0.00	8.75	3.75	0.50	0.00	0.00
	44.40	18.20	9.40	1.40	0.20	33.40	12.00	5.00	0.40	0.20	29.25	10.75	4.50	0.50	0.25

- It was shown previously that the unavailability of the state #2 EOP from Area B forces Area A to deploy its own EOP many more times than when it is available. For a 750 on-demand EOP at B, EOP deployment in state 3 almost doubled and about 3 times in states 4 and 5 and about the same in state 6.
- the number of EOP assist from Area C to external pools increases many folds when EOP in Area B is on-demand.
- System EOP usages show quite a different behavior with on-demand EOPs. The larger the on-demand EOPs, the more changes to the distribution of the EOP usages at different margin states for each area, particularly those areas that are very close to the area where the on-demand EOP is implemented.

Implementation of an On-Demand Feature for the EOP
Verifying the New EOP Feature Based on the Impacts on the Area LOLEs:

- On-demand EOP may change the distribution of the EOP usage significantly, but may not affect the final area LOLEs.
- The deficient situation in Areas A and C were eliminated after the third EOP state whether there is on-demand EOP or not.
- The LOLE is not depending on how the negative margins are eliminated, but on the final outcome out of the EOP actions.
- The on-demand feature does not necessarily affect the LoL counts unless the system including EOPs would not have enough to eliminate all the negative margins anyway.

EOP	AREA	100MW Interconn LOLE	300MW Interconn LOLE	750MW Interconn LOLE
No	AREA-A	10.60	4.60	3.00
On	AREA-B	6.00	0.40	0.00
Demand	AREA-C	6.60	1.20	0.20
	AREA-D	3.00	3.00	3.00
	AREA-E	2.40	2.20	2.20
On	AREA-A	12.40	8.40	8.25
Demand	AREA-B	6.00	0.40	0.00
at State 2	AREA-C	6.60	1.20	0.25
Ara B	AREA-D	3.00	3.00	2.50
	AREA-E	2.40	2.20	2.50

- LOLEs were calculated at margin state #4 instead of at the end of the EOP states before other EOP actions were carried out.
- As larger EOPs are available, it is expected that the LOLE of all areas will decrease because of mutual assistance. In the case of on-demand EOPs, other areas (e.g. A) cannot be benefitted from this large assistance and LOLEs are higher.
- The reduction in LOLEs become less and less as larger and larger EOP is introduced in Area B. This is because eventually all negative margins will be resolved in earlier states of EOP as the magnitude of the EOP increases. By the time state margin #4 is implemented, this is where the LOLE indices calculated, the LOLEs will no longer change significantly.
- It is expected that Area B's LOLE will drop quickly to zero as larger and larger EOP is introduced. Area C will see the same effect whether the EOP is on-demand or not, as Area C can receive EOP assistance from B in both cases.

Implementation of an On-Demand Feature for the EOP
Conclusions:

- This feature was implemented to avoid certain area inadvertently providing too much assistance to its external pools and therefore will significantly affect the reliability of those pools.

- The test cases demonstrated that this would not necessarily be the case, as EOP assistance is governed by many factors. This is particularly true for larger power systems.

- It, however, provides a safeguard to have the ability to limit the impact of a large EOP on external pools.

- The feature was tested using a sample system with different levels of on-demand EOPs. The intermediate results of each area in each hour were monitored and verified that the implementation was carried out correctly.

- There are usually very few outage situations that will cause MARS to enter the EOP subroutines as most of the time there will be sufficient capacities available.
  - When it does, many of the situations would already be resolved using the peak shaving, and curtailable contracts.
  - For a few cases when EOP action is needed, most of the times, the EOPs would be sufficient to eliminate the area deficit.
  - Only under very few situations when outside EOPs are really needed to provide assistance to eliminate the deficit, this is where a large EOP may cause some difference to the results.
  - Even under this situation, provided that there is no transfer constraints, assistance from different areas would be redistributed to assist negative areas. Unless the total surplus in the system itself cannot eliminate the total deficit or there is transfer constraint somewhere, the area loss of load may not be affected significantly even if large on-demand EOP exists.

- In most of the cases, whether the large EOP is on-demand or not, the large surplus would most likely be bottled due to limited interface transfer capabilities between pools and would not be available to the members of other pools.