Uplift Allocation of Voltage and Reliability Constraints

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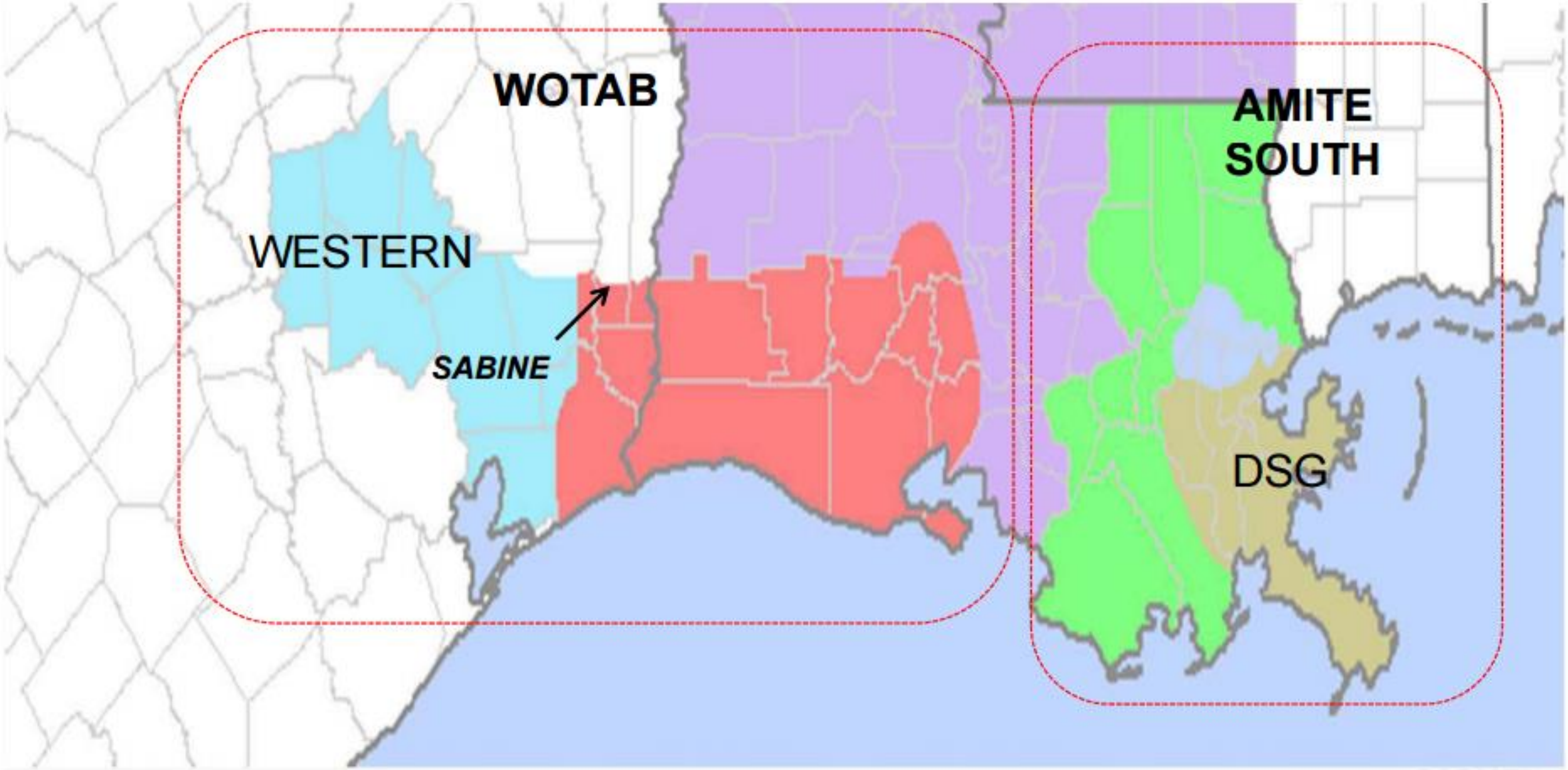
MISO South Load Pockets



Key Takeaways

- Ensure adequate commitment and capacity for voltage and local reliability (VLR) issue.
- Integrate VLR constraints with security constrained unit commitment (SCUC) to lower the operating cost and reduce operators' manual work.
- Identify the commitment reasons for each VLR unit to properly allocate costs.

VLR Constraints

- Minimum commitment constraints
- Minimum capacity constraints
- Complex binary constraints

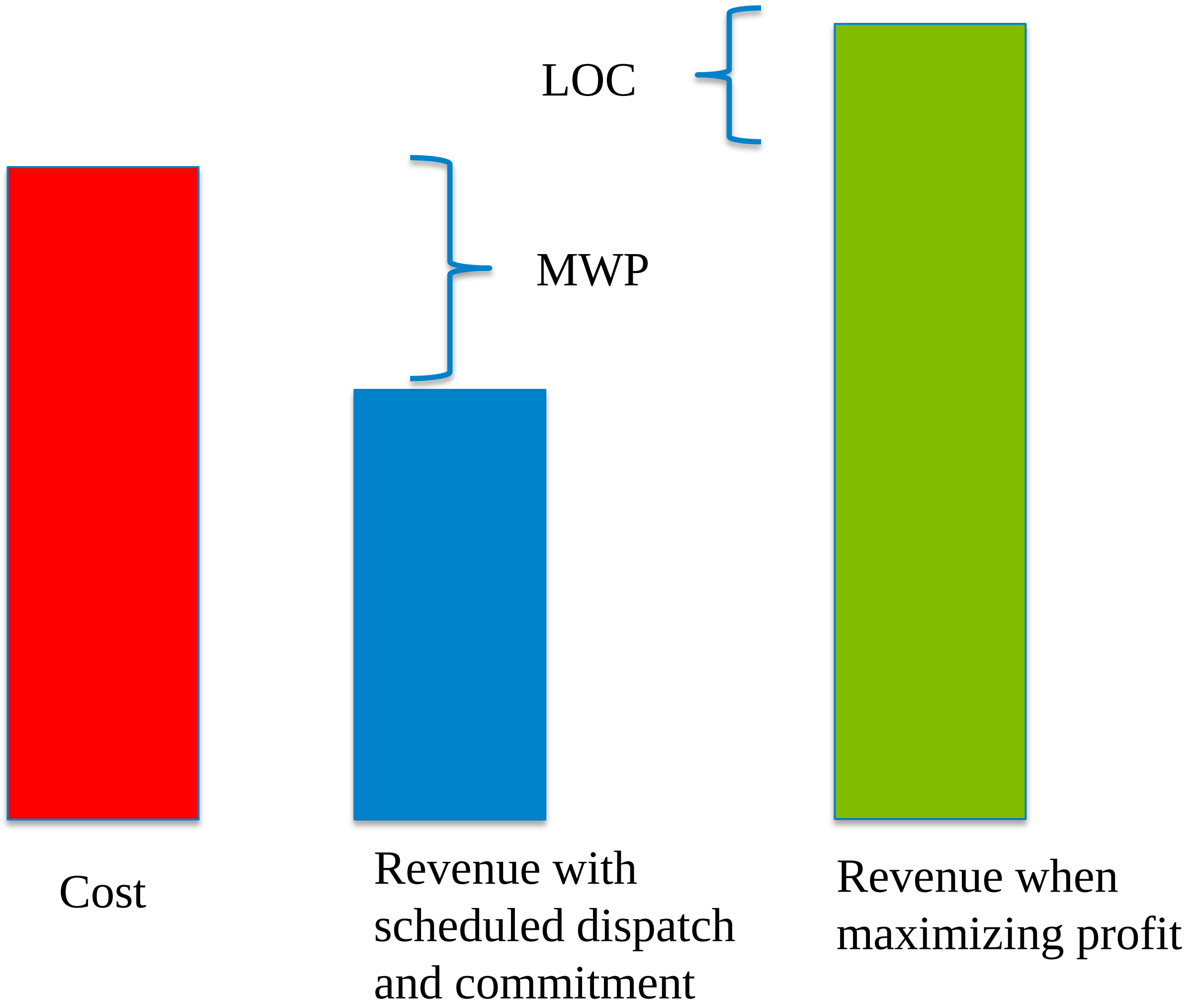
Integer Constraints

Adding VLR constraints in the SCUC can ensure voltage and local reliability. Integer constraints cannot be priced.

Uplift Allocation

- The goal of uplift is to achieve market equilibrium so resources will not have incentive to deviate from their scheduled dispatch and commitment.
- Make-whole payment (MWP) recover their offer costs and make them whole.
- Resources may have lost opportunity cost (LOC) so resources may have incentive to deviate from scheduled dispatch and commitment. Current MISO settlement scheme does not pay LOC in day-ahead market.
- Cost allocation should maintain efficiency and equity on a cost causation basis.

MWP and LOC


LOC
MWP
Cost
Revenue with scheduled dispatch and commitment
Revenue when maximizing profit

Lost Opportunity Cost and Make Whole Payment with Different Reasons

- Make whole payment is payment to recover unit offer when the unit has a negative profit.
- Lost opportunity cost is the opportunity cost to continue providing the scheduled service instead of deviating from scheduled service.
- Further decompose make whole payment and lost opportunity cost into VLR and non-VLR reason.
  - MWP_j^V: VLR make whole payment
  - MWP_j^{NV} : Non-VLR make whole payment
  - LOC_j^V: VLR lost opportunity cost
  - LOC_j^{NV}:Non-VLR lost opportunity cost

Fengyu Wang, Yonghong Chen, "Uplift allocation of Voltage and Local Reliability Constraints", IEEE Transactions on Power Systems, Early access, Feb. 2018.

Commitment Reasons of VLR Units

In-The-Money (Positive profit) → Economically Committed

Out-Of-Money (Negative profit)
- VLR Constraints → Cost allocated to load pockets those are benefited
- Other Constraints → Cost allocated system-wide

If a unit is committed with negative profit and this unit relieves a VLR constraint of a load pocket, the associated uplift cost should be allocated to the corresponding load pockets

MISO

Profit Maximization

Profit= **Revenue** **–** **Cost**

Max [LMP*UnitMW–(StartupCost +NoloadCost + FuelCost*UnitMW)]

Subject to:

Resource Level Constraints

VLR Constraints

Price from SCUC with fixed binaries

VLR Constraints may enforce some units on.

Profit maximization problem without VLR Constraints

Profit maximization problem with VLR Constraints

Difference caused by VLR Constraints

Cost Allocation Metric

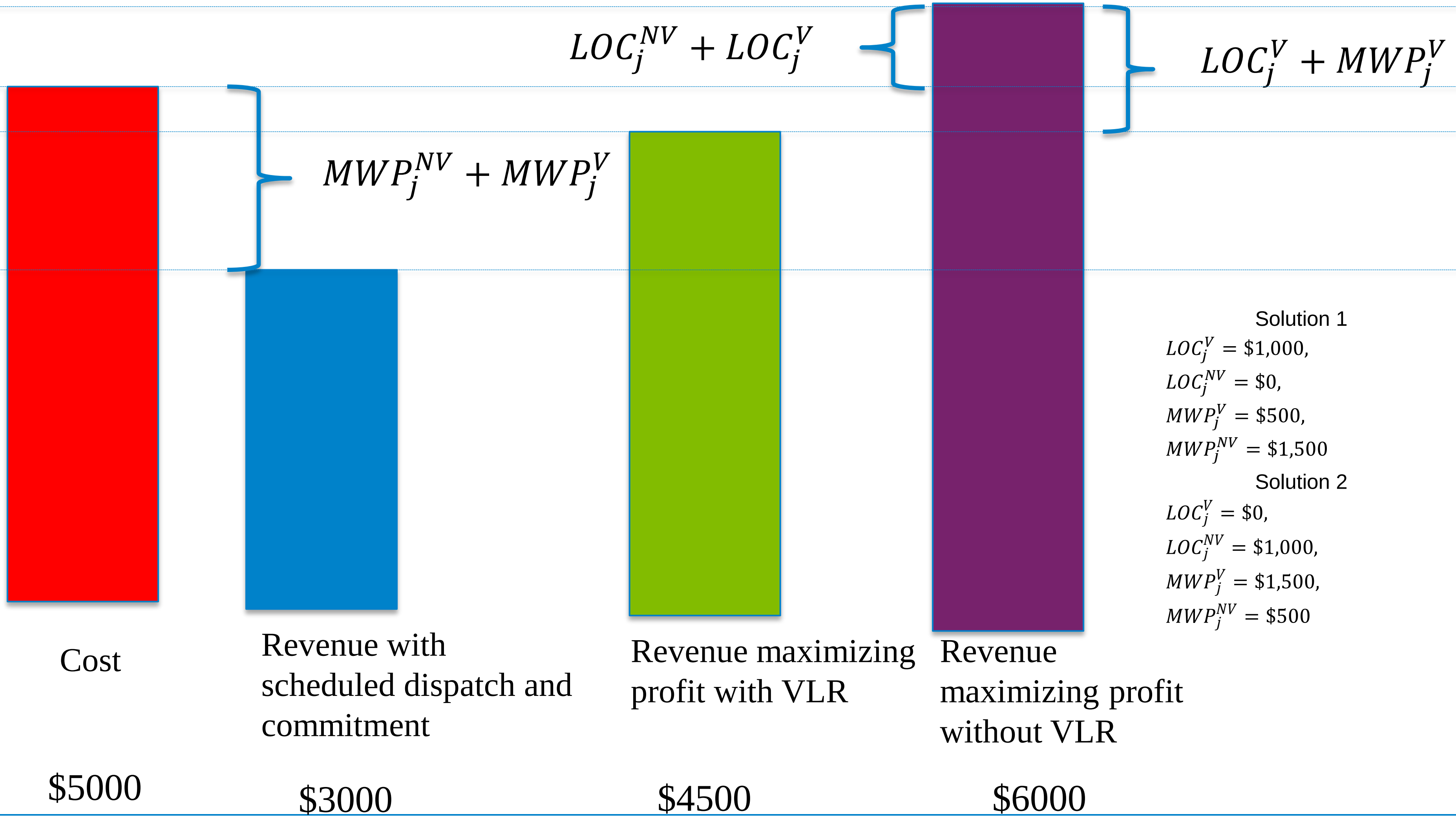
$$Min\ MWP_j^V$$
$$LOC_j^V + MWP_j^V = PT_j^{NV} - PT_j^V$$
$$MWP_j^{NV} + MWP_j^V = \max\{0, -PT_j^{DA}\}$$
$$LOC_j^{NV} + LOC_j^V = \max\{0, PT_j^{NV}\} - \max\{0, PT_j^{DA}\}$$
$$LOC_j^V, LOC_j^{NV}, MWP_j^V, MWP_j^{NV} \geq 0$$

Minimizing VLR make whole payment MWP_j^V can reduce ex-post price changes led by uplift cost because system-wide load has larger denominator than load pocket to digest the make whole payment.

PT_j^{DA}: Profit from day-ahead SCUC
PT_j^{NV}: Profit from profit maximization without VLR constraints
PT_j^V: Profit from profit maximization without VLR constraints

$PT_j^{DA} <= PT_j^{NV} <= PT_j^V$

Example



Solution 1

$LOC_j^{V} = \$1{,}000,$

$LOC_j^{NV} = \$0,$

$MWP_j^{V} = \$500,$

$MWP_j^{NV} = \$1{,}500$

Solution 2

$LOC_j^{V} = \$0,$

$LOC_j^{NV} = \$1{,}000,$

$MWP_j^{V} = \$1{,}500,$

$MWP_j^{NV} = \$500$

Possible Scenarios

	Profit Max NonVLR (PM^{NoVLR})			
Profit Max VLR (PM^{VLR})	Profit	Positive	Zero	Negative
	Positive	$MWP_j^V: 0$ $LOC_j^V: PT_j^{NV} - PT_j^V$	Impossible	Impossible
	Zero	$MWP_j^V: PT_j^{NV} - PT_j^V$ $LOC_j^V: 0$	$MWP_j^V: 0$ $LOC_j^V: 0$	Impossible
	Negative	$MWP_j^V: -PT_j^V$ $LOC_j^V: PT_j^{NV}$	$MWP: -PT_j^V$ $LOC_j^V: 0$	$MWP_j^V: PT_j^{NV} - PT_j^V$ $LOC_j^V: 0$

Results

Unit Profit for VLR and Non-VLR Profit Maximization Problems

Units	Profit with VLR (PT_j^V)	Profit without VLR (PT_j^{NV})	Difference ($PT_j^{NV} - PT_j^V$)	Make whole Payment (MWP_j^V)	Lost opportunity Cost (LOC_j^V)
Unit 1	-$20,619	$0	$20,619	$20,619	$0
Unit 2	-$14,507	$0	$14,507	$14,507	$0
Unit 3	$30,795	$30,795	$0	$0	$0
Unit 4	-$11,206	$0	$11,206	$11,206	$0
Unit 5	$847,840	$847,840	$0	$0	$0
Unit 6	-$2,482	$613	$3,095	$2,482	$613
Unit 7	-$6,988	-$6,988	$0	$0	$0
Unit 8	$3,436	$4,388	$952	$0	$952

Commit Reason Table by Load Pocket

	Load pockets				
Units	LP 1	LP 2	LP 3	LP 4	LP5
Unit 1	0	1	0	0	0
Unit 2	0	1	0	0	0
Unit 4	0	0	0	0	1
Unit 6	0	0	1	0	1

Conclusion

- VLR constraints are binary constraints, which cannot be priced.
- Proposed uplift allocation method can efficiently allocate uplift cost and reduce the price distortion.
- Proposed method does not impact the current day-ahead market clearing engine

Thank you!

Appendix

Cost Allocation Metric (Cont'd)

- $PT_j^{NV} < 0$. There is no positive component for uplift, and thus $LOC_j^{NV} + LOC_j^{V} = 0$
- $PT_j^{NV} = PT_j^{DA} > 0$. The commitment and dispatch schedule is efficient with the market clearing prices, so $\mathrm{LOC_j^{NV}} + \mathrm{LOC_j^{V}} = 0$.
- $PT_j^{NV} > 0 > PT_j^{DA}$. The total uplift $MWP_j^{NV} + MWP_j^{V} + LOC_j^{NV} + LOC_j^{V}$ is $PT_j^{NV} - PT_j^{DA}$ and total make whole payment $MWP_j^{NV} + MWP_j^{V}$ is $-PT_j^{DA}$. Therefore, $LOC_j^{NV} + LOC_j^{V} = PT_j^{NV}$.
- $PT_j^{NV} > PT_j^{DA} > 0$. The total uplift $MWP_j^{NV} + MWP_j^{V} + LOC_j^{NV} + LOC_j^{V}$ is $PT_j^{NV} - PT_j^{DA}$. Since $PT_j^{DA} > 0$, $MWP_j^{NV} + MWP_j^{V} = 0$. Therefore, $LOC_j^{NV} + LOC_j^{V} = PT_j^{NV} - PT_j^{DA}$.

		Profit from RSC		
Profit Max Non-VLR	Profit	Positive	Zero	Negative
	Positive	MWP_j^V:0 MWP_j^{NV}:0 $LOC_j^V: PT_j^{NV} - PT_j^V$ $LOC_j^{NV}: PT_j^V - PT_j^{DA}$	MWP_j^V:0 MWP_j^{NV}:0 $LOC_j^V: PT_j^{NV} - PT_j^V$ $LOC_j^{NV}: PT_j^V$	$MWP_j^V: -PT_j^V + max\{0, PT_j^V\}$ $MWP_j^{NV}: PT_j^V - PT_j^{DA} - max\{0, PT_j^V\}$ $LOC_j^V: PT_j^{NV} - max\{0, PT_j^V\}$ $LOC_j^{NV}: max\{0, PT_j^V\}$
	Zero	Impossible	MWP_j^V:0 MWP_j^{NV}:0 LOC_j^V: 0 LOC_j^{NV}: 0	$MWP_j^V: -PT_j^V$ $MWP_j^{NV}: PT_j^V - PT_j^{DA}$ LOC_j^V: 0 LOC_j^{NV}: 0
	Negative	Impossible	Impossible	$MWP_j^V: PT_j^{NV} - PT_j^V$ $MWP_j^{NV}: PT_j^V - PT_j^{NV} - PT_j^{DA}$ LOC_j^V: 0 LOC_j^{NV}: 0