

Observations on past 3 years Michigan Load & Operation of Ludington Pumped Storage Power Plant



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Presentation to Michigan Public Service Commission
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Background

- Planning Studies at system peak do not capture impact of Ludington Pumped Storage Operation on the system at lower load levels
- Planning Studies consistent with real time system operations need to ensure reliable operation of the Bulk Electric System over a broad spectrum of conditions
 - Identify critical system conditions for NERC compliance at lower load levels in planning studies and model various Ludington dispatch conditions to be tested under wide range of probable contingencies
 - Expected generation and pumping use estimated based on historical operation needs to be correlated with forecasted loads
 - Develop planning cases with forecasted loads representing May month loads to plan for outages

NERC planning events P0-P7 (Draft)

Planning Events						
Category	Initial System Condition	Event ³	BES Elements out of Service ^{2,3}		Interruption of Firm Transmission Service Allowed	Non-Consequential Load Loss Allowed
			(A) > 300 KV	(B) <= 300 KV		
P0 Normal System conditions	Normal System	None	X	X	No	No
P1 Single Contingency	Normal System	Loss of one of the following: 1. Generator 2. Transmission circuit 3. Transformer 4. Shunt device 5. Single pole of a DC line	X	X	No Yes, if transfer is dependent on the outaged DC line.	No

NERC planning events P0-P7 (draft)

Planning Events						
Category	Initial System Condition	Event ³	BES Elements out of Service ^{2,3}		Interruption of Firm Transmission Service Allowed	Non-Consequential Load Loss Allowed
			(A) > 300 KV	(B) <= 300 KV		
P2 Single Contingency	Normal System	Loss of one of the following: 1. Breaker(s) opening without a Fault resulting in a single ended line	X	X	No	No
		2. Bus section	X		No	No
				X	Yes	Yes
		3. Internal Breaker Fault (non-bus-tie)	X		No	No
				X	Yes	Yes
4. Internal Breaker Fault (bus tie)	X	X	Yes	Yes		
P3 Multiple Contingency (Generator + 1)	Loss of a generator followed by System adjustments	Loss of one of the following: 1. Generator 2. Transmission circuit 3. Transformer 4. Shunt device 5. Single pole of a DC line	X	X	No Yes, if transfer is dependent on the outaged DC line.	No

NERC planning events P0-P7 (draft)

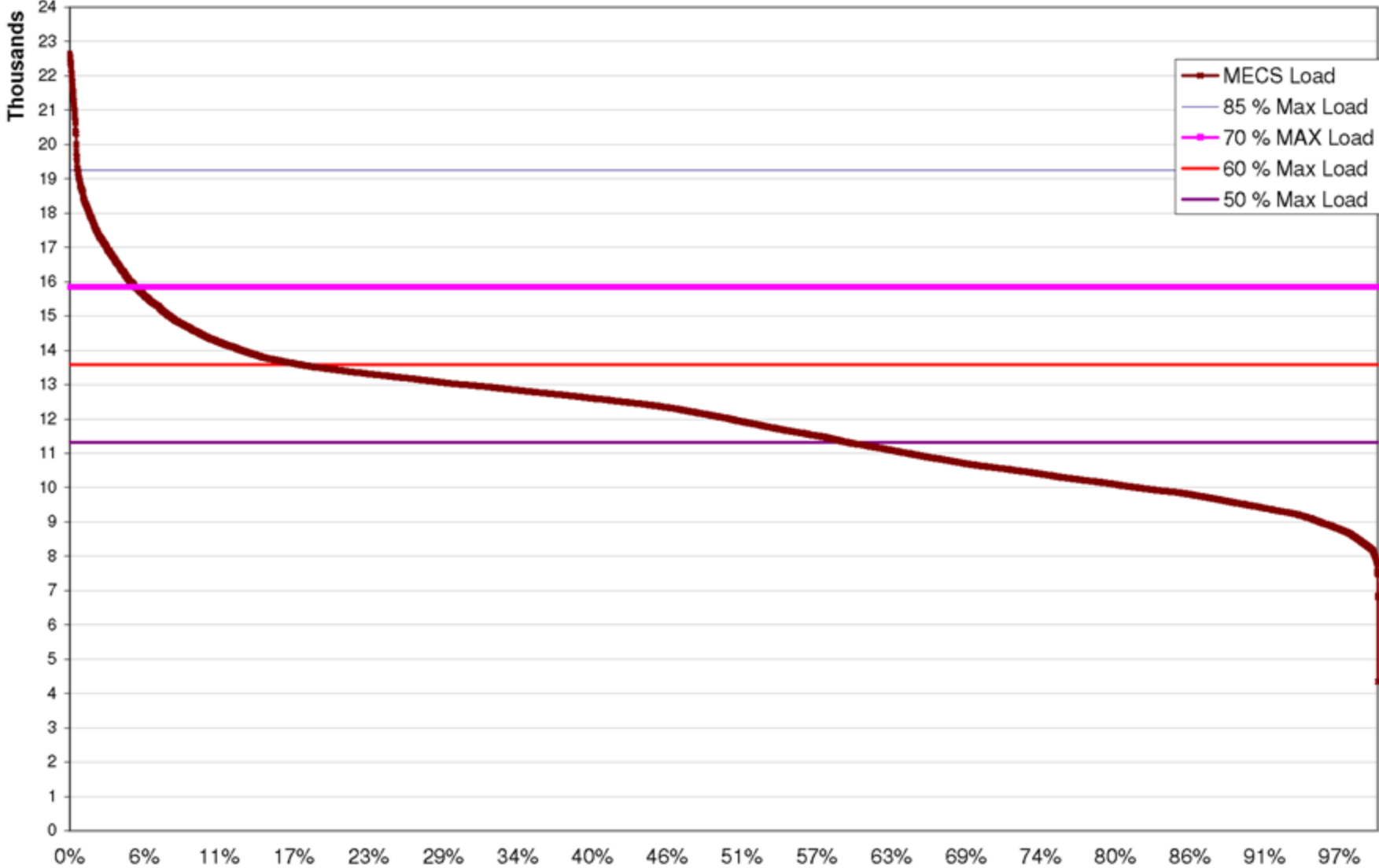
Planning Events						
Category	Initial System Condition	Event ²	BES Elements out of Service ^{1,3}		Interruption of Firm Transmission Service Allowed	Non-Consequential Load Loss Allowed
			(A) > 300 KV	(B) <= 300 KV		
P4 Multiple Contingency (Fault plus stuck breaker) ¹	Normal System	Stuck breaker (non-bus-tie) attempting to clear a Fault on one of the following:	X		No	No
		1. Generator 2. Transmission circuit 3. Transformer 4. Shunt device 5. Bus section				
		6. Stuck breaker (bus tie) attempting to clear a Fault on the associated bus	X	X	Yes	Yes
P5 Multiple Contingency (Fault plus Protection System failure)	Normal System	Loss of multiple elements due to a single component failure within a Protection System associated with clearing a Fault on one of the following:	X		No	No
		1. Generator 2. Transmission circuit 3. Transformer 4. Shunt device 5. Bus section				

NERC planning events P0-P7 (draft)

Planning Events						
Category	Initial System Condition	Event ³	BES Elements out of Service ^{1,3}		Interruption of Firm Transmission Service Allowed	Non-Consequential Load Loss Allowed
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P6 Multiple Contingency (Two overlapping single Contingencies)	Loss of one of the following, followed by System adjustments: 1. Transmission circuit 2. Transformer 3. Single pole of a DC line 4. Shunt device	Loss of one of the following: 1. Transmission circuit 2. Transformer 3. Single pole of a DC line 4. Shunt device	X	X	Yes	Yes
P7 Multiple Contingency (Common Structure)	Normal System	1. Loss of any two Transmission circuits on a common structure. (Excludes circuits that share a common structure for 1 mile or less.) 2. Loss of a bipolar DC line	X	X	Yes	Yes

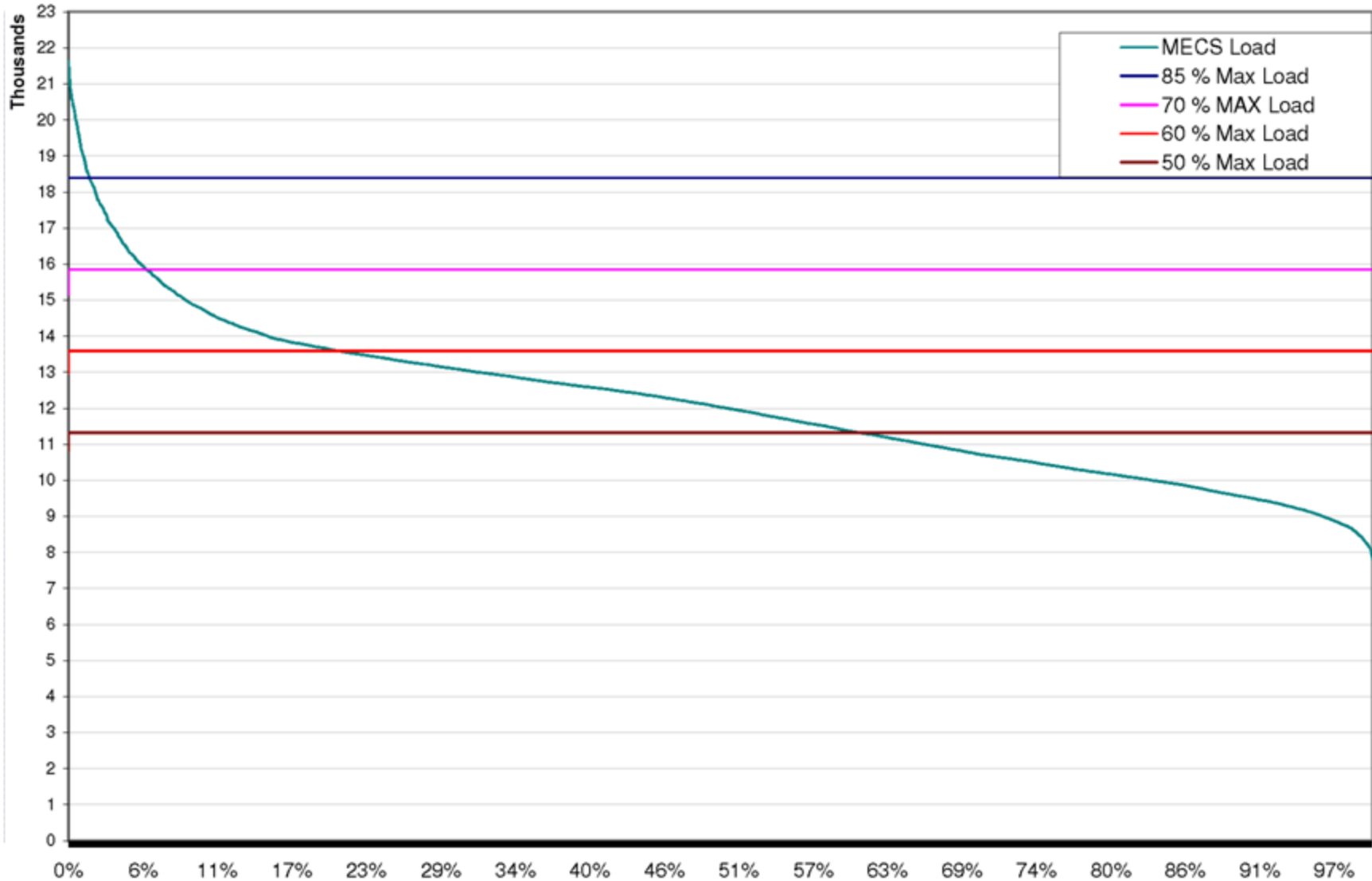
Load Duration Curve – Michigan Load Full Year 2006

Load Duration Curve - 2006



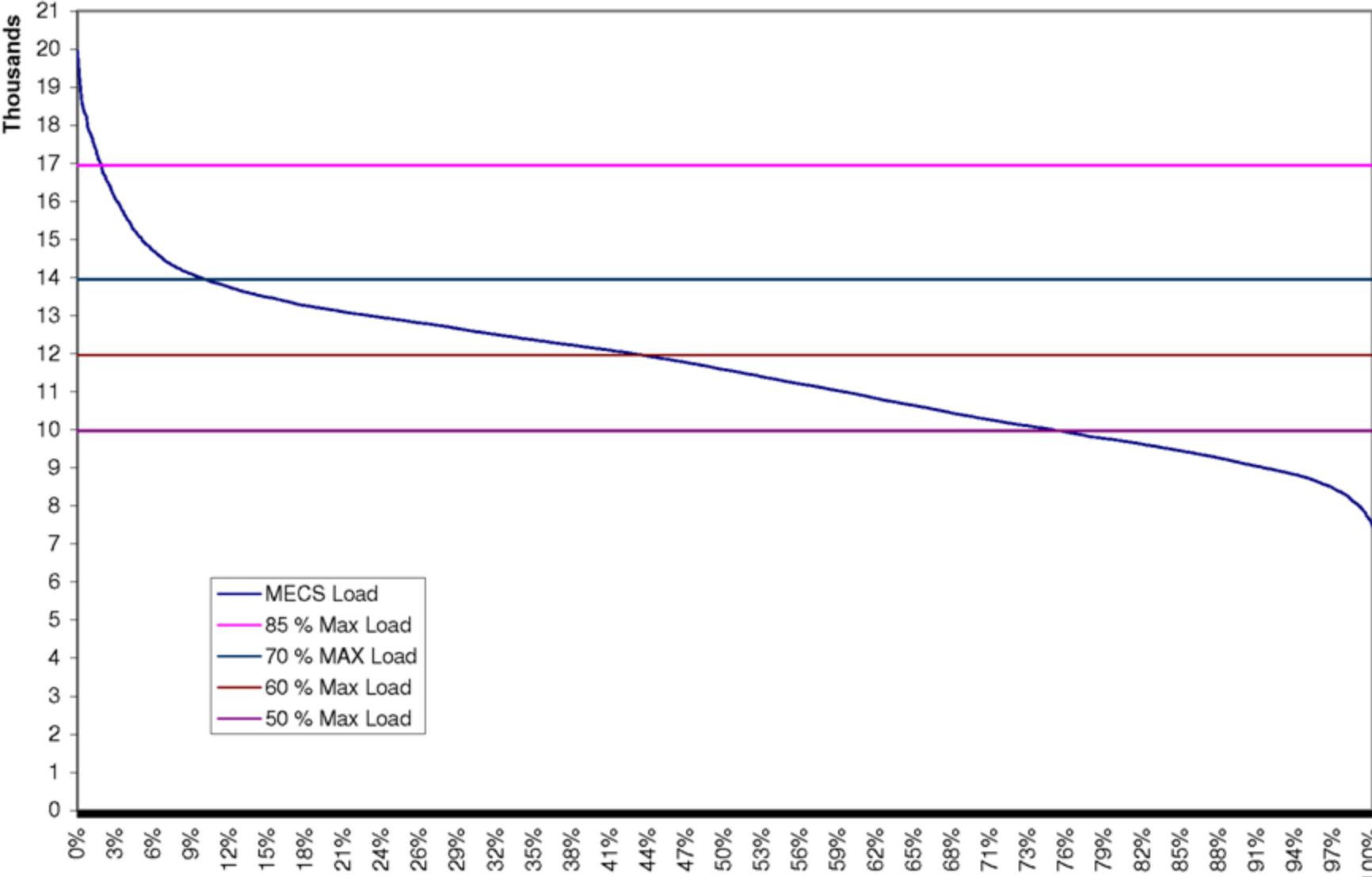
Load Duration Curve – Michigan Load Full Year 2007

Load Duration Curve - 2007



Load Duration Curve – Michigan Load Full Year 2008

Load Duration Curve - 2008



Historical Ludington Pumping Use

Year	Michigan Load (Range +/- 3%)	Average Number of Pumps	Maximum Number of Pumps	90% of Maximum Number of Pumps	Hours of Ludington operation above 90% of Maximum Number of Pumps
2006	85%	1.2	3.0	2.7	1
	70%	2.2	4.9	4.4	12
	60%	1.1	4.9	4.4	14
	50%	2.4	4.9	4.5	207
2007	85%	0.0	0.1	0.1	1
	70%	1.5	4.7	4.2	2
	60%	1.9	4.9	4.4	376
	50%	3.2	5.0	4.5	319
2008	85%	0.0	0.0	0.0	1
	70%	1.3	4.6	4.1	2
	60%	1.9	4.9	4.4	386
	50%	3.1	4.9	4.4	173

Historical Ludington Generating Use

Year	Michigan Load (Range +/- 3%)	Average Number of Generators	Maximum Number of Generators	90% of Maximum Number of Generators	Hours of Ludington operation above 90% of Maximum Number of Generators
2006	85%	3.8	5.2	4.7	9
	70%	2.7	5.4	4.9	11
	60%	2.1	5.6	5.0	8
	50%	1.2	4.7	4.3	9
2007	85%	3.4	5.7	5.1	13
	70%	2.8	5.6	5.1	5
	60%	2.0	5.6	5.0	12
	50%	1.5	4.9	4.4	11
2008	85%	2.7	5.9	5.3	2
	70%	2.5	5.5	4.9	19
	60%	1.7	5.5	5.0	5
	50%	1.2	4.2	3.8	5

Develop Critical System Conditions to study NERC planning events P0-P7 (**revised draft std.'s**)

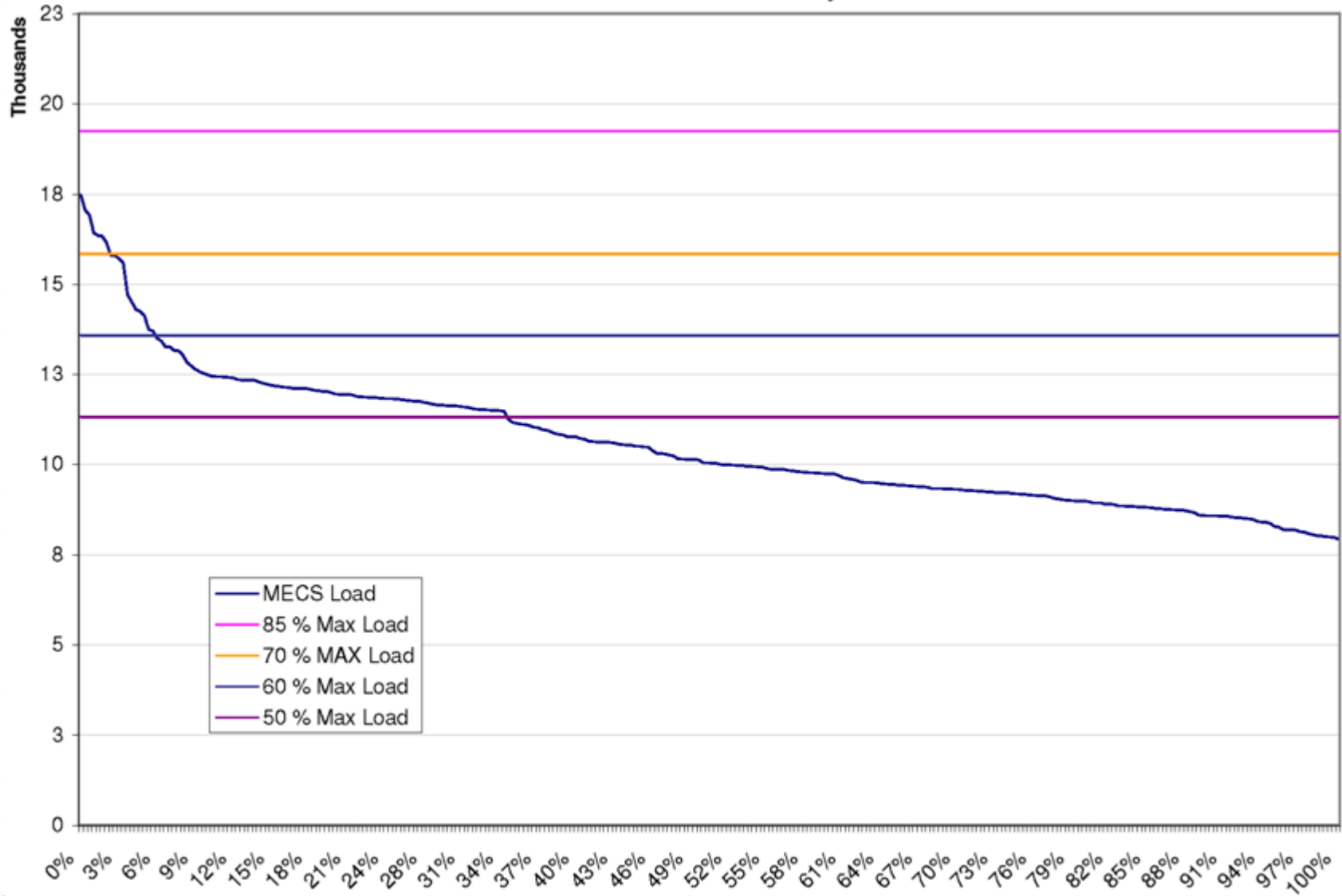
- Develop additional planning models (other than peak load) to study the above scenarios:
 - Michigan Load at 85% with 1 Ludington Pump fully dispatched (340 MW of pumping load)
 - Michigan Load at 85% with 5 Ludington generating units fully dispatched (1560 MW of pumping load)
 - Michigan Load at 70% with 4 Ludington Pumps fully dispatched (1360 MW of pumping load)
- To ensure that planning studies are consistent with operational use of Ludington pumps
 - If more than 1 pump operates at load levels at or greater than 85% of the projected peak load of corresponding year, and transmission constraints are seen on the Bulk Electric System due to firm transactions, pumps in excess of 1 unit may be curtailed as necessary to relieve transmission constraint.
 - If more than 4 pumps operate at load levels at or greater than 70% of the projected peak load of corresponding year, and transmission constraints are seen on the Bulk Electric System due to firm transactions, pumps in excess of 4 units may be curtailed as necessary to relieve transmission constraint.
 - Planning assumptions be re-visited on an annual basis to be in synch with changing trends of Ludington Pumped Storage operation

NERC planning event P6 (draft)

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P6 Multiple Contingency (Two overlapping single Contingencies)	Loss of one of the following, followed by System adjustments: 1. Transmission circuit 2. Transformer 3. Single pole of a DC line 4. Shunt device	Loss of one of the following: 1. Transmission circuit 2. Transformer 3. Single pole of a DC line 4. Shunt device	X	X	Yes	Yes

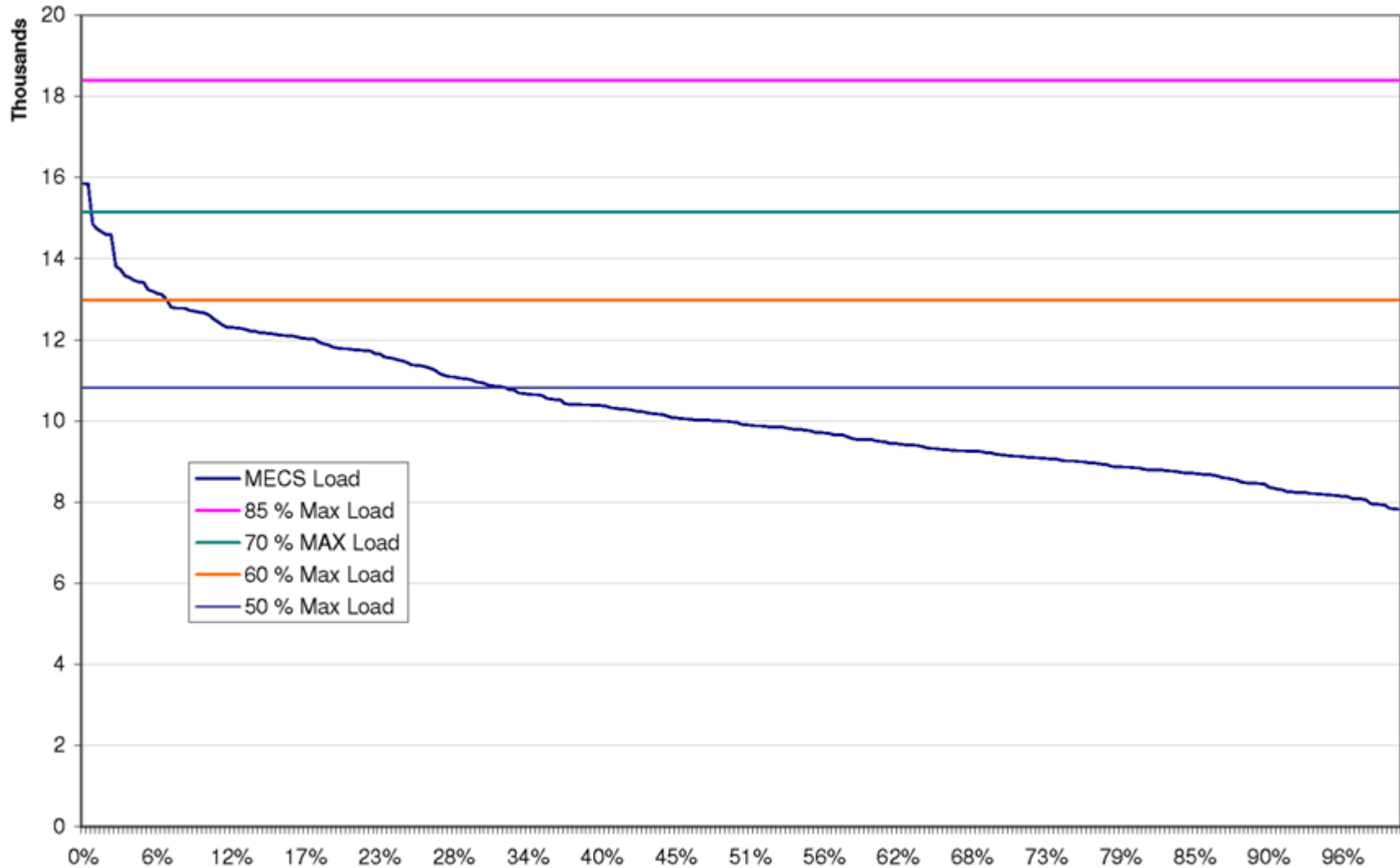
2006 May Night time Load Duration Curve

Load Duration Curve - May 06

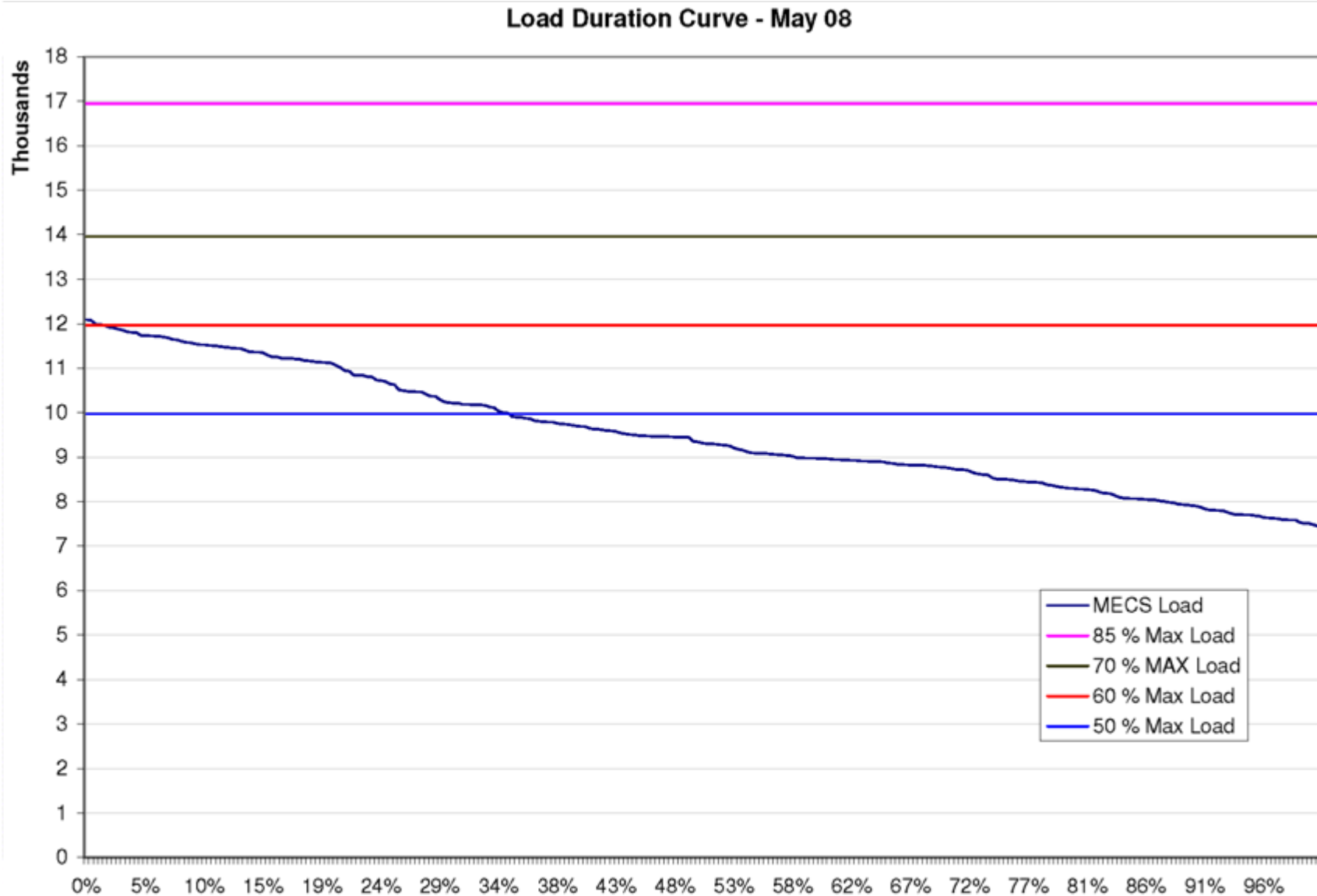


2007 May Night time Load Duration Curve

Load Duration Curve - May 07



2008 May Night time Load Duration Curve



Develop Critical System Conditions to study NERC planning event P6 as n-1-1 (**revised draft std.'s**)

- P6 at lower load modeling in planning studies is to enable planning for outages.
 - It has been Midwest ISO's planning practice to plan the system so as to be able to take planned outages up to May month.
 - May peak loads shown to be near 85% of corresponding year peak load
 - May month night time (excluding weeknights) loads shown to exceed 70% of corresponding year peak load

Develop Critical System Conditions to study NERC planning event P6 as n-1-1

- To model Ludington units in pumping mode to study this outage
 - Since planning model with 70% load level will be created to study other planning events, to limit scope of work, the same 70% load model with 4 Ludington units fully pumping could be used for studying n-1-1 planned + forced outage events.
- To model Ludington units in generating mode to study this outage
 - Develop planning model with 85% load level and model 5 Ludington units fully generating
- To ensure that planning studies are consistent with operational use of Ludington pumps
 - If planned outages cannot be taken in May due to Ludington operation (generating or pumping), any pumping in excess of 4 units and generation in excess of 5 units be available for curtailment to accommodate planned outages
 - Planning assumptions be re-visited on an annual basis to be in synch with changing trends of Ludington Pumped Storage operation