PNNL-SA-118391

DOE/OE Transmission Reliability Program

FIDVR Load Modeling Tool

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Project Objectives

- Utilities have occasionally observed delayed voltage recovery following fault events in regions where a significant portion of the summer peak load is associated with residential air-conditioning.
- This phenomenon, called fault-induced delayed voltage recovery (FIDVR), is associated with motors that are prone to stalling.
- There is a concern that as greater a fraction of on-peak load is associated with motors prone to stalling the FIDVR phenomenon could have more significant detrimental impacts and possibly cause generation tripping or even a blackout.
- The purpose of this project is to generalize the load model development for WECC to address the FIDVR phenomenon in planning studies.

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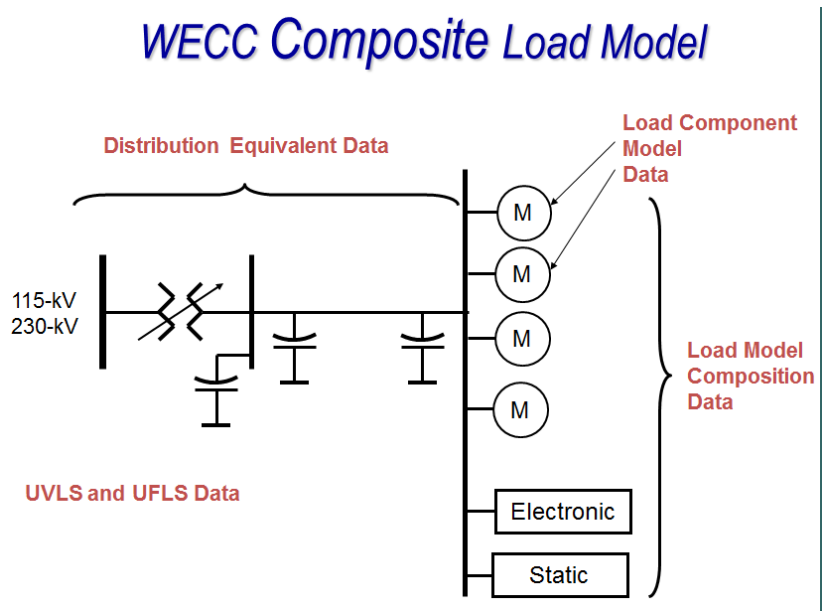
Composite Load Model

- In 2000-2001, WECC used an interim load model
- In 2005, WECC developed an explicit load model
- In 2007, PSLF has the first version of the composite load model



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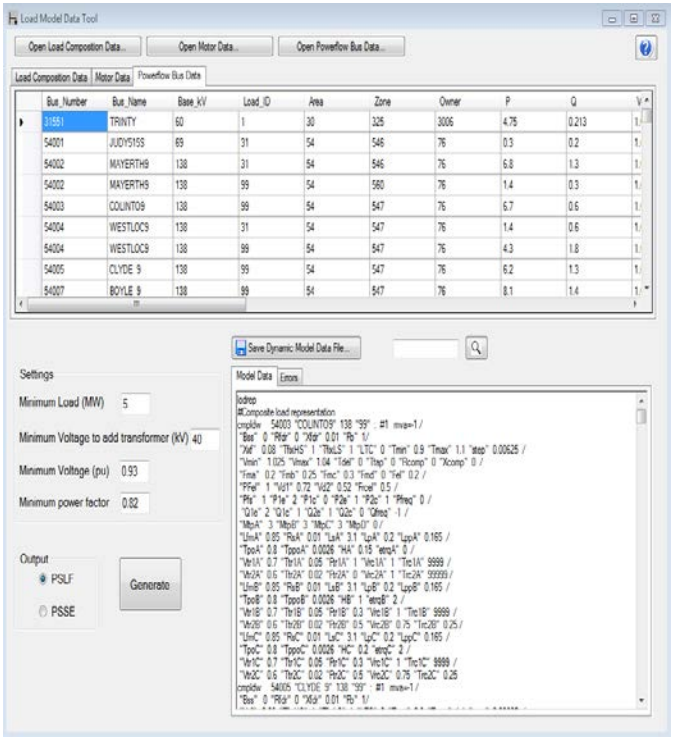
Past major accomplishments

- In 2010, PNNL started the work on load composition model
- Development was funded by DOE through ARRA program
- An Excel tool to create composite load model was developed in 2012.
- Load Model Data Tool (LMDT 1.0) to generate composite load model data records was released under an open source license in 2013



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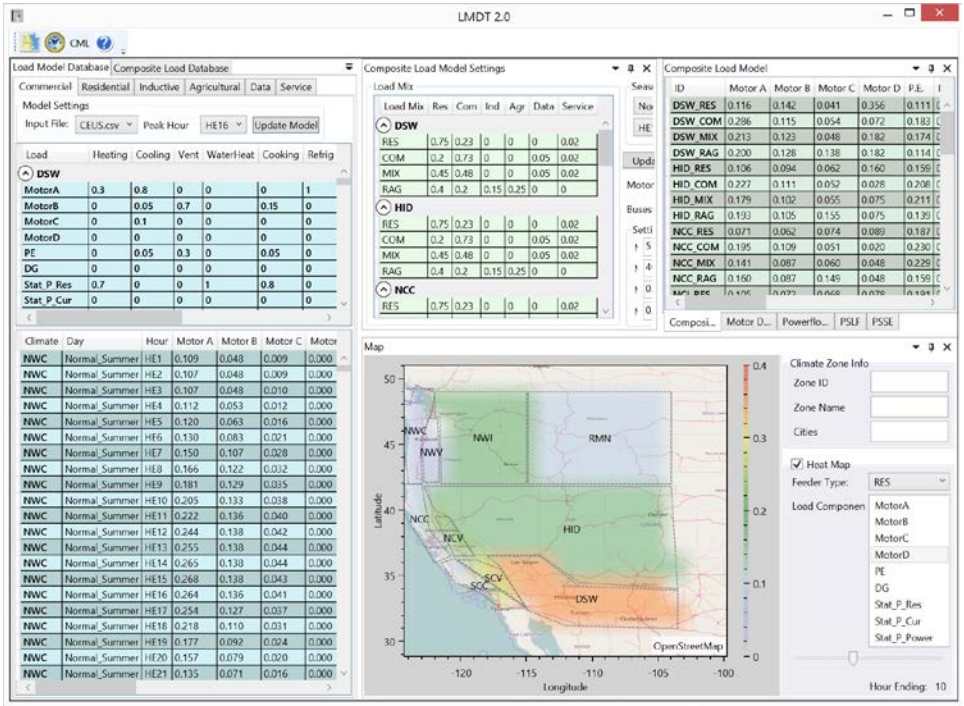
LMDT 2.0

- New version of the LMDT (version 2.0) was released under an open source license in 2015
- LMDT generates the composite load model data records
- LMDT supports GE PSLF and Siemens PSSE formats
- LMDT is a stand-alone MS Windows application
- LMDT was developed in collaboration with Bonneville Power Administration (BPA) and WECC Load Modeling Task Force (LMTF)
- LMDT is used by multiple organizations: WECC, ERCOT, BPA, Dominion, SCE, PG&E, MISO, Duke Energy, and many more.



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Technical Accomplishments FY16

- Fully redesigned GUI
- Advanced functionality
- New visualization capabilities
- Database of load models for different climate zones
- Generating .dyd and .dyr dynamic model records

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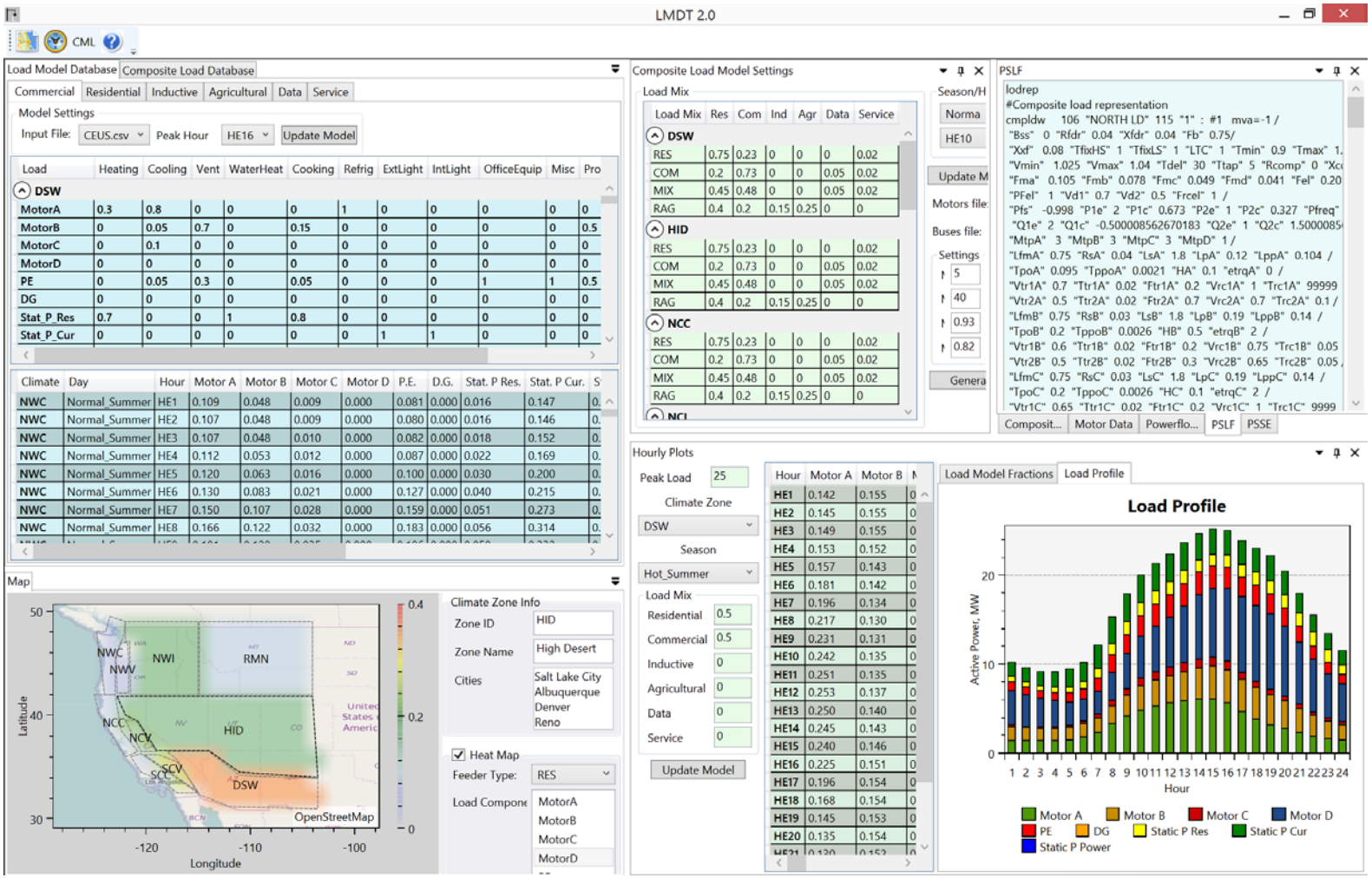
LMDT 2.0 Redesigned GUI



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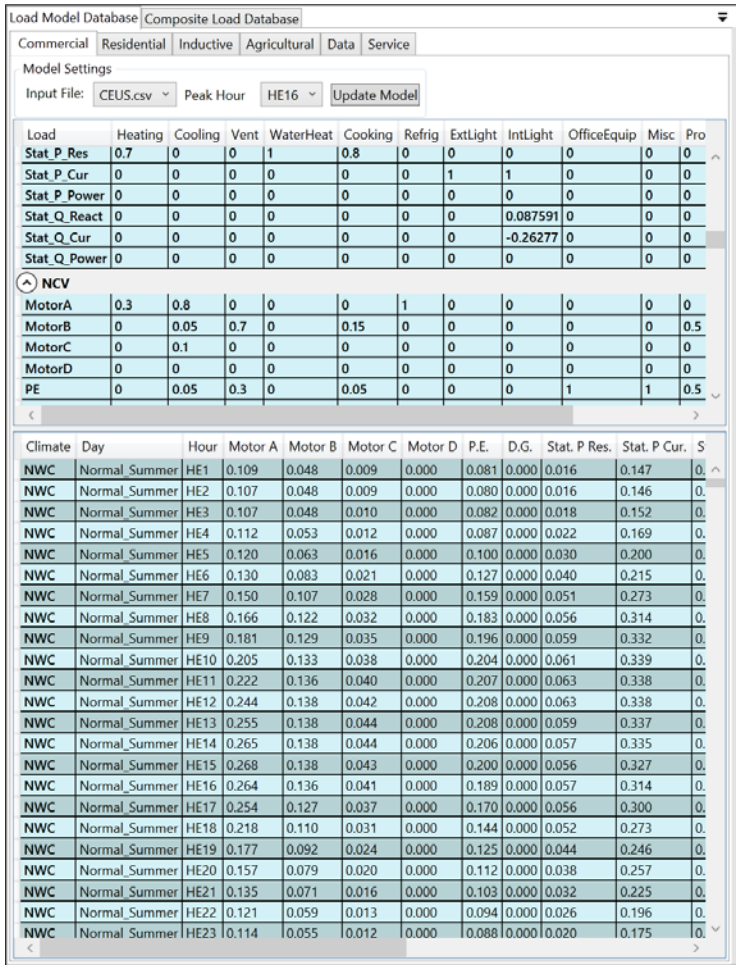
LMDT 2.0 Database

- Different load types:
  - Commercial
  - Residential
  - Industrial
  - Agricultural
  - Data
  - Service
- Climate zones
- Operating hours
- Seasons



Load Model Database | Composite Load Database

Commercial | Residential | Inductive | Agricultural | Data | Service

Model Settings

Input File: CEUS.csv Peak Hour: HE16 Update Model

Load	Heating	Cooling	Vent	WaterHeat	Cooking	Refrig	ExtLight	IntLight	OfficeEquip	Misc	Pro
Stat_P_Res	0.7	0	0	1	0.8	0	0	0	0	0	0
Stat_P_Cur	0	0	0	0	0	0	1	1	0	0	0
Stat_P_Power	0	0	0	0	0	0	0	0	0	0	0
Stat_Q_React	0	0	0	0	0	0	0	0.087591	0	0	0
Stat_Q_Cur	0	0	0	0	0	0	0	-0.26277	0	0	0
Stat_Q_Power	0	0	0	0	0	0	0	0	0	0	0
NCV											
MotorA	0.3	0.8	0	0	0	1	0	0	0	0	0
MotorB	0	0.05	0.7	0	0.15	0	0	0	0	0	0.5
MotorC	0	0.1	0	0	0	0	0	0	0	0	0
MotorD	0	0	0	0	0	0	0	0	0	0	0
PE	0	0.05	0.3	0	0.05	0	0	0	1	1	0.5

Climate	Day	Hour	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	Stat. P Res.	Stat. P Cur.	S
NWC	Normal_Summer	HE1	0.109	0.048	0.009	0.000	0.081	0.000	0.016	0.147	0.
NWC	Normal_Summer	HE2	0.107	0.048	0.009	0.000	0.080	0.000	0.016	0.146	0.
NWC	Normal_Summer	HE3	0.107	0.048	0.010	0.000	0.082	0.000	0.018	0.152	0.
NWC	Normal_Summer	HE4	0.112	0.053	0.012	0.000	0.087	0.000	0.022	0.169	0.
NWC	Normal_Summer	HE5	0.120	0.063	0.016	0.000	0.100	0.000	0.030	0.200	0.
NWC	Normal_Summer	HE6	0.130	0.083	0.021	0.000	0.127	0.000	0.040	0.215	0.
NWC	Normal_Summer	HE7	0.150	0.107	0.028	0.000	0.159	0.000	0.051	0.273	0.
NWC	Normal_Summer	HE8	0.166	0.122	0.032	0.000	0.183	0.000	0.056	0.314	0.
NWC	Normal_Summer	HE9	0.181	0.129	0.035	0.000	0.196	0.000	0.059	0.332	0.
NWC	Normal_Summer	HE10	0.205	0.133	0.038	0.000	0.204	0.000	0.061	0.339	0.
NWC	Normal_Summer	HE11	0.222	0.136	0.040	0.000	0.207	0.000	0.063	0.338	0.
NWC	Normal_Summer	HE12	0.244	0.138	0.042	0.000	0.208	0.000	0.063	0.338	0.
NWC	Normal_Summer	HE13	0.255	0.138	0.044	0.000	0.208	0.000	0.059	0.337	0.
NWC	Normal_Summer	HE14	0.265	0.138	0.044	0.000	0.206	0.000	0.057	0.335	0.
NWC	Normal_Summer	HE15	0.268	0.138	0.043	0.000	0.200	0.000	0.056	0.327	0.
NWC	Normal_Summer	HE16	0.264	0.136	0.041	0.000	0.189	0.000	0.057	0.314	0.
NWC	Normal_Summer	HE17	0.254	0.127	0.037	0.000	0.170	0.000	0.056	0.300	0.
NWC	Normal_Summer	HE18	0.218	0.110	0.031	0.000	0.144	0.000	0.052	0.273	0.
NWC	Normal_Summer	HE19	0.177	0.092	0.024	0.000	0.125	0.000	0.044	0.246	0.
NWC	Normal_Summer	HE20	0.157	0.079	0.020	0.000	0.112	0.000	0.038	0.257	0.
NWC	Normal_Summer	HE21	0.135	0.071	0.016	0.000	0.103	0.000	0.032	0.225	0.
NWC	Normal_Summer	HE22	0.121	0.059	0.013	0.000	0.094	0.000	0.026	0.196	0.
NWC	Normal_Summer	HE23	0.114	0.055	0.012	0.000	0.088	0.000	0.020	0.175	0.

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Commercial Load Database

- Based on California Commercial End-Use Survey (CEUS) dataset

Load Categories

- Heating
- Cooling
- Vent
- Water Heat
- Cooking
- Refrig
- ExtLight
- IntLight
- OfficeEquip
- Misc
- Process
- Motors
- AirComp

Climate	Day	Hour	Index	Heating	Cooling	Vent	WaterHea	Cooking	Refrig	ExtLight	IntLight	OfficeEqui	Misc	Process	Motors	AirComp
NWC	1	1	NWC_1_1	18013.4	45501.09	98512.63	6018.348	11751.97	150090.7	86210.11	176526.2	76903.18	35097.9	581.9765	24750.01	3149.639
NWC	1	2	NWC_1_2	19787.99	41137.65	98622.19	5982.864	10857.57	149790.4	84762.44	175458.6	76987.2	34059.48	581.9765	24797.91	3229.504
NWC	1	3	NWC_1_3	19777.67	38672.65	96780.72	6312.676	14534.83	149996.1	84163.46	187183.4	78383.16	35705.51	582.5969	26744.72	3716.611
NWC	1	4	NWC_1_4	21114.27	46195.18	103406.7	7285.416	21632.26	151107.3	83279.66	217878.9	81414.23	40172.07	762.4479	32009.76	5135.343
NWC	1	5	NWC_1_5	22733.72	53116.31	114906.4	8780.183	35997.77	157854.5	83184.13	273621.8	90566.8	48744.34	1695.633	45220.92	7800.704
NWC	1	6	NWC_1_6	29482.36	66811.13	152257.7	11018.55	49192.82	159868.9	11284.81	372232.1	112372.8	62926.99	2183.107	60773.96	10970.94
NWC	1	7	NWC_1_7	39941.22	99316.23	194145.8	13066.53	61541.72	162309.3	5283.075	483525.3	137058.3	78515.25	2863.85	78658.49	14858.17
NWC	1	8	NWC_1_8	40866.27	129141.5	220766.4	14767.83	71350.68	164423.6	2546.161	558655.2	158152.6	90720.38	3731.361	88740.07	17124.39
NWC	1	9	NWC_1_9	36943.23	153521	231604.6	15476.71	79745.22	171273.2	1791.388	591533.8	170530.2	97075.85	4628.85	92663.41	18003.85
NWC	1	10	NWC_1_1	33315.8	205326.6	236423.3	15746.55	86591.45	173067.6	1791.388	603636.5	176411.1	99966.3	4886.361	94040.59	18332.38
NWC	1	11	NWC_1_1	30565.4	243187.5	238799	16132.63	92894.75	174921.4	1791.388	602202.6	177840.7	100991.9	4907.59	94411	18369.95
NWC	1	12	NWC_1_1	27760.82	286609.6	240551.1	16123.61	97281.84	180990.7	1791.388	602173.1	177662.3	101137.2	4894.697	94069.55	18346.82
NWC	1	13	NWC_1_1	24530.41	310285.6	241365.2	15771.1	91132.02	181649.7	1791.388	601142.4	175795.3	100906.3	4875.804	93480.09	18291.19
NWC	1	14	NWC_1_1	23894.75	327380.1	243455.5	15618.31	86298.97	186764.5	1932.318	596163.9	172080.5	99779.69	4858.325	90342.84	17494.91
NWC	1	15	NWC_1_1	23625.49	337493.6	243662.8	15263.67	86370.6	186354.8	2911.397	581113.5	164063.7	96988.41	4820.937	86086.87	16107.08
NWC	1	16	NWC_1_1	22786.78	337806.3	243979.8	14238.56	88736.89	180166.3	4908.253	555435.9	149731.6	91738.61	4738.683	79036.17	13955.92
NWC	1	17	NWC_1_1	22778.05	321480.7	230640.2	12924.83	88399.52	178643.5	24034.88	511697.9	129301.2	82873.38	4395.098	67870.19	10808.65
NWC	1	18	NWC_1_1	19878.93	255060.8	200390.1	11418.96	83426.24	171820	43349.93	443960.5	105570	73409.08	3955.05	58709.8	7913.631
NWC	1	19	NWC_1_1	14115.62	171744.5	166953.6	10226.23	73964.2	169432.4	47477.3	392400.5	91868.37	66733.58	3636.109	51621.89	6028.194
NWC	1	20	NWC_1_2	14239.5	129937.3	144968.7	9188.862	60175.91	166842.9	114571	344724.7	85312.59	61071.98	2951.982	45303.77	5035.499
NWC	1	21	NWC_1_2	15119.28	89745.39	133698	8076.77	48108.79	159903.2	113213.4	289138.7	81686.74	53527.31	2193.282	40408.83	4399.942
NWC	1	22	NWC_1_2	15097.83	61763.32	113279.9	7195.246	35243.66	158480.8	107419.4	242370.5	79559.33	48108.45	1557.382	35261.26	3959.716
NWC	1	23	NWC_1_2	16593.3	54178.13	108503.5	6588.746	21314.65	151903.7	105978.2	206606.1	77981.02	43119.63	1176.947	31376.21	3569.224

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Commercial Load Database

Commercial Load Settings

Load Model Database | Composite Load Database

Commercial | Residential | Inductive | Agricultural | Data | Service

Model Settings

Input File: CEUS.csv Peak Hour HE16 Update Model

Load	Heating	Cooling	Vent	WaterHeat	Cooking	Refrig	ExtLight	IntLight	OfficeEquip	Misc	Pro
Stat_Q_Cur	0	0	0	0	0	0	0	-0.26277	0	0	0
Stat_Q_Power	0	0	0	0	0	0	0	0	0	0	0
NWC											
MotorA	0.3	0.8	0	0	0	1	0	0	0	0	0
MotorB	0	0.05	0.7	0	0.15	0	0	0	0	0	0.5
MotorC	0	0.1	0	0	0	0	0	0	0	0	0
MotorD	0	0	0	0	0	0	0	0	0	0	0
PE	0	0.05	0.3	0	0.05	0	0	0	1	1	0.5
DG	0	0	0	0	0	0					
Stat_P_Res	0.7	0	0	1	0.8	0					
Stat_P_Cur	0	0	0	0	0	0					
Stat_P_Power	0	0	0	0	0	0					
Stat_Q_React	0	0	0	0	0	0					
Stat_Q_Cur	0	0	0	0	0	0					
Stat_Q_Power	0	0	0	0	0	0					
NWI											

Commercial load model

Climate	Day	Hour	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	Stat. P Res.	Stat. P Cur.	Stat. P Power.	Stat. Q React.	Stat. Q Cur.	Stat. Q Power.	Ptotal	Stat P	Stat Q	Stat PF
NWC	Normal_Summer	HE1	0.109	0.048	0.009	0.000	0.081	0.000	0.016	0.147	0.000	0.009	-0.026	0.000	0.410	0.163	-0.017	-0.994
NWC	Normal_Summer	HE2	0.107	0.048	0.009	0.000	0.080	0.000	0.016	0.146	0.000	0.009	-0.026	0.000	0.406	0.162	-0.017	-0.994
NWC	Normal_Summer	HE3	0.107	0.048	0.010	0.000	0.082	0.000	0.018	0.152	0.000	0.009	-0.028	0.000	0.415	0.170	-0.018	-0.994
NWC	Normal_Summer	HE4	0.112	0.053	0.012	0.000	0.087	0.000	0.022	0.169	0.000	0.011	-0.032	0.000	0.454	0.191	-0.021	-0.994
NWC	Normal_Summer	HE5	0.120	0.063	0.016	0.000	0.100	0.000	0.030	0.200	0.000	0.013	-0.040	0.000	0.528	0.230	-0.027	-0.993
NWC	Normal_Summer	HE6	0.130	0.083	0.021	0.000	0.127	0.000	0.040	0.215	0.000	0.018	-0.055	0.000	0.616	0.254	-0.036	-0.990
NWC	Normal_Summer	HE7	0.150	0.107	0.028	0.000	0.159	0.000	0.051	0.273	0.000	0.024	-0.071	0.000	0.767	0.324	-0.047	-0.989
NWC	Normal_Summer	HE8	0.166	0.122	0.032	0.000	0.183	0.000	0.056	0.314	0.000	0.027	-0.082	0.000	0.873	0.370	-0.055	-0.989
NWC	Normal_Summer	HE9	0.181	0.129	0.035	0.000	0.196	0.000	0.059	0.332	0.000	0.029	-0.087	0.000	0.931	0.391	-0.058	-0.989
NWC	Normal_Summer	HE10	0.205	0.133	0.038	0.000	0.204	0.000	0.061	0.339	0.000	0.030	-0.089	0.000	0.979	0.399	-0.059	-0.989
NWC	Normal_Summer	HE11	0.222	0.136	0.040	0.000	0.207	0.000	0.063	0.338	0.000	0.030	-0.089	0.000	1.005	0.401	-0.059	-0.989
NWC	Normal_Summer	HE12	0.244	0.138	0.042	0.000	0.208	0.000	0.063	0.338	0.000	0.030	-0.089	0.000	1.035	0.401	-0.059	-0.989
NWC	Normal_Summer	HE13	0.255	0.138	0.044	0.000	0.208	0.000	0.059	0.337	0.000	0.029	-0.088	0.000	1.041	0.397	-0.059	-0.989
NWC	Normal_Summer	HE14	0.265	0.138	0.044	0.000	0.206	0.000	0.057	0.335	0.000	0.029	-0.088	0.000	1.044	0.391	-0.058	-0.989
NWC	Normal_Summer	HE15	0.268	0.138	0.043	0.000	0.200	0.000	0.056	0.327	0.000	0.028	-0.085	0.000	1.032	0.383	-0.057	-0.989
NWC	Normal_Summer	HE16	0.264	0.136	0.041	0.000	0.189	0.000	0.057	0.314	0.000	0.027	-0.082	0.000	1.000	0.370	-0.054	-0.989
NWC	Normal_Summer	HE17	0.254	0.127	0.037	0.000	0.170	0.000	0.056	0.300	0.000	0.025	-0.075	0.000	0.943	0.355	-0.050	-0.990
NWC	Normal_Summer	HE18	0.218	0.110	0.031	0.000	0.144	0.000	0.052	0.273	0.000	0.022	-0.065	0.000	0.827	0.324	-0.044	-0.991
NWC	Normal_Summer	HE19	0.177	0.092	0.024	0.000	0.125	0.000	0.044	0.246	0.000	0.019	-0.058	0.000	0.708	0.290	-0.038	-0.991
NWC	Normal_Summer	HE20	0.157	0.079	0.020	0.000	0.112	0.000	0.038	0.257	0.000	0.017	-0.051	0.000	0.663	0.295	-0.034	-0.993
NWC	Normal_Summer	HE21	0.135	0.071	0.016	0.000	0.103	0.000	0.032	0.225	0.000	0.014	-0.043	0.000	0.581	0.257	-0.028	-0.994
NWC	Normal_Summer	HE22	0.121	0.059	0.013	0.000	0.094	0.000	0.026	0.196	0.000	0.012	-0.036	0.000	0.509	0.221	-0.024	-0.994
NWC	Normal_Summer	HE23	0.114	0.055	0.012	0.000	0.088	0.000	0.020	0.175	0.000	0.010	-0.030	0.000	0.464	0.195	-0.020	-0.995
NWC	Normal_Summer	HE24	0.108	0.046	0.010	0.000	0.082	0.000	0.016	0.151	0.000	0.009	-0.027	0.000	0.413	0.167	-0.018	-0.994
NWV	Normal_Summer	HE1	0.126	0.057	0.010	0.000	0.101	0.000	0.013	0.160	0.000	0.008	-0.023	0.000	0.466	0.173	-0.015	-0.996
NWV	Normal_Summer	HE2	0.123	0.055	0.009	0.000	0.100	0.000	0.013	0.156	0.000	0.008	-0.023	0.000	0.457	0.169	-0.015	-0.996
NWV	Normal_Summer	HE3	0.122	0.055	0.010	0.000	0.102	0.000	0.014	0.157	0.000	0.008	-0.023	0.000	0.460	0.171	-0.016	-0.996
NWV	Normal_Summer	HE4	0.125	0.059	0.011	0.000	0.108	0.000	0.017	0.166	0.000	0.009	-0.028	0.000	0.487	0.183	-0.018	-0.995
NWV	Normal_Summer	HE5	0.132	0.064	0.013	0.000	0.118	0.000	0.023	0.195	0.000	0.012	-0.036	0.000	0.546	0.218	-0.024	-0.994
NWV	Normal_Summer	HE6	0.142	0.085	0.015	0.000	0.140	0.000	0.031	0.198	0.000	0.017	-0.050	0.000	0.611	0.229	-0.033	-0.989

Residential Load Database

Load Categories

- Heating
- Cooling
- Vent
- WaterHeat
- Cooking
- Refrig
- ExtLight
- IntLight
- Electronics
- Appliances
- Misc
- Vehicle

Load Model Database | Composite Load Database

Commercial | Residential | Inductive | Agricultural | Data | Service

Residential Load Settings

Model Settings

Input File: Residential_Input.csv Peak Hour: HE16 Update Model

Load	Heating	Cooling	Vent	WaterHeat	Cooking	Refrig	ExtLight	IntLight	Electronics	Appliances	Misc	Vehicle
DSW												
MotorA	0	0	0	0	0	0	0	0	0	0	0	0
MotorB	0	0.1	1	0	0.15	0	0	0	0	0	0	0
MotorC	0	0	0	0	0	0	0	0	0	0.3	0.3	0
MotorD	0.3	0.85	0	0	0	1	0	0	0	0	0	0
PE	0	0.05	0	0	0	0	0	0	1	0.2	0.2	1
DG	0	0	0	0	0	0	0	0	0	0	0	0
Stat_P_Res	0.7	0	0	1	0.85	0	1	1	0	0.5	0.5	0
Stat_P_Cur	0	0	0	0	0	0	0	0	0	0	0	0
Stat_P_Power	0	0	0	0	0	0	0	0	0	0	0	0
Stat_Q_React	0	0	0	0	0	0	0	0	0	0	0	0
Stat_Q_Cur	0	0	0	0	0	0	0	0	0	0	0	0
Stat_Q_Power	0	0	0	0	0	0	0	0	0	0	0	0
HID												

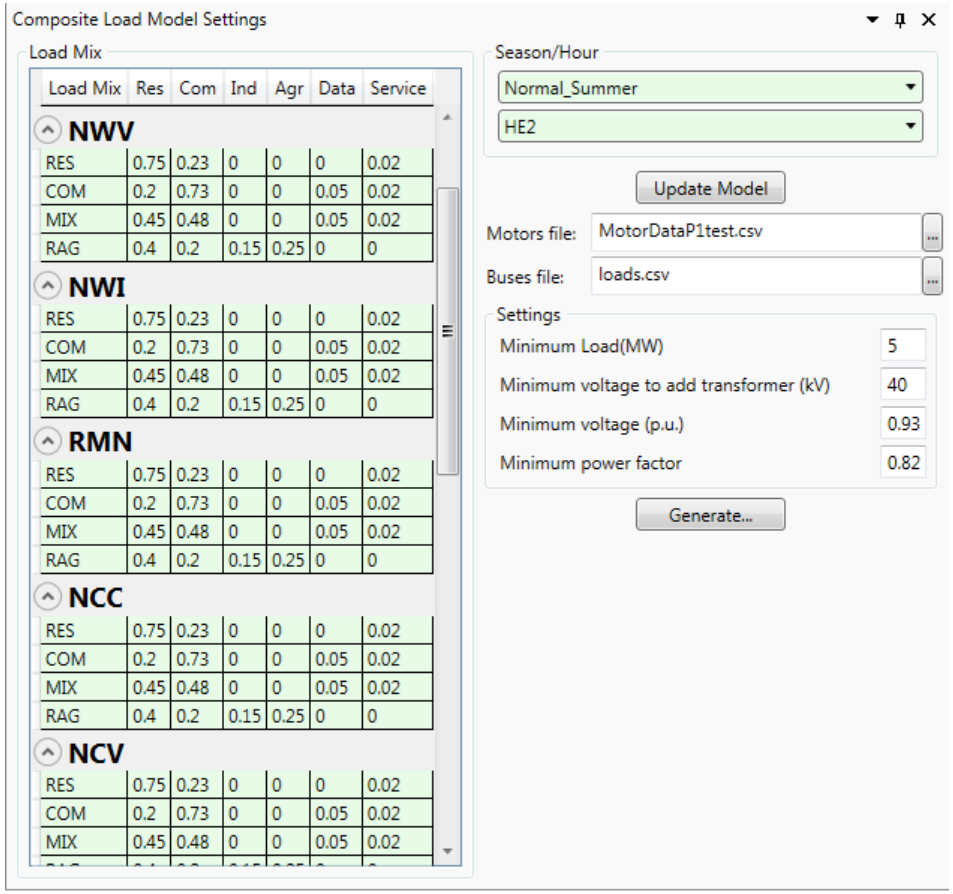
Residential load model

Climate	Day	Hour	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	Stat. P Res.	Stat. P Cur.	Stat. P Power.	Stat. Q React.	Stat. Q Cur.	Stat. Q Power.	Ptotal	Stat P	Stat Q	Stat PF
NWC	Normal_Summer	HE1	0.000	0.023	0.012	0.090	0.053	0.000	0.303	0.000	0.000	0.000	0.000	0.000	0.481	0.303	0.000	0.000
NWC	Normal_Summer	HE2	0.000	0.023	0.005	0.090	0.048	0.000	0.247	0.000	0.000	0.000	0.000	0.000	0.414	0.247	0.000	0.000
NWC	Normal_Summer	HE3	0.000	0.023	0.003	0.090	0.047	0.000	0.219	0.000	0.000	0.000	0.000	0.000	0.383	0.219	0.000	0.000
NWC	Normal_Summer	HE4	0.000	0.023	0.002	0.090	0.047	0.000	0.213	0.000	0.000	0.000	0.000	0.000	0.375	0.213	0.000	0.000
NWC	Normal_Summer	HE5	0.000	0.023	0.003	0.090	0.047	0.000	0.229	0.000	0.000	0.000	0.000	0.000	0.392	0.229	0.000	0.000
NWC	Normal_Summer	HE6	0.000	0.024	0.008	0.090	0.050	0.000	0.309	0.000	0.000	0.000	0.000	0.000	0.481	0.309	0.000	0.000
NWC	Normal_Summer	HE7	0.000	0.025	0.020	0.090	0.059	0.000	0.492	0.000	0.000	0.000	0.000	0.000	0.686	0.492	0.000	0.000
NWC	Normal_Summer	HE8	0.000	0.027	0.036	0.090	0.114	0.000	0.671	0.000	0.000	0.000	0.000	0.000	0.937	0.671	0.000	0.000
NWC	Normal_Summer	HE9	0.000	0.027	0.045	0.090	0.120	0.000	0.694	0.000	0.000	0.000	0.000	0.000	0.977	0.694	0.000	0.000
NWC	Normal_Summer	HE10	0.000	0.027	0.057	0.090	0.128	0.000	0.707	0.000	0.000	0.000	0.000	0.000	1.008	0.707	0.000	0.000
NWC	Normal_Summer	HE11	0.000	0.027	0.063	0.090	0.132	0.000	0.691	0.000	0.000	0.000	0.000	0.000	1.002	0.691	0.000	0.000
NWC	Normal_Summer	HE12	0.000	0.028	0.062	0.090	0.131	0.000	0.645	0.000	0.000	0.000	0.000	0.000	0.956	0.645	0.000	0.000
NWC	Normal_Summer	HE13	0.000	0.032	0.056	0.101	0.128	0.000	0.603	0.000	0.000	0.000	0.000	0.000	0.920	0.603	0.000	0.000
NWC	Normal_Summer	HE14	0.000	0.047	0.052	0.156	0.129	0.000	0.560	0.000	0.000	0.000	0.000	0.000	0.944	0.560	0.000	0.000
NWC	Normal_Summer	HE15	0.000	0.058	0.046	0.195	0.145	0.000	0.519	0.000	0.000	0.000	0.000	0.000	0.963	0.519	0.000	0.000
NWC	Normal_Summer	HE16	0.000	0.068	0.045	0.226	0.146	0.000	0.516	0.000	0.000	0.000	0.000	0.000	1.000	0.516	0.000	0.000
NWC	Normal_Summer	HE17	0.000	0.077	0.046	0.243	0.175	0.000	0.561	0.000	0.000	0.000	0.000	0.000	1.104	0.561	0.000	0.000
NWC	Normal_Summer	HE18	0.000	0.087	0.049	0.251	0.250	0.000	0.672	0.000	0.000	0.000	0.000	0.000	1.309	0.672	0.000	0.000
NWC	Normal_Summer	HE19	0.000	0.085	0.052	0.253	0.269	0.000	0.719	0.000	0.000	0.000	0.000	0.000	1.378	0.719	0.000	0.000
NWC	Normal_Summer	HE20	0.000	0.067	0.054	0.211	0.268	0.000	0.695	0.000	0.000	0.000	0.000	0.000	1.295	0.695	0.000	0.000
NWC	Normal_Summer	HE21	0.000	0.046	0.055	0.151	0.247	0.000	0.705	0.000	0.000	0.000	0.000	0.000	1.204	0.705	0.000	0.000
NWC	Normal_Summer	HE22	0.000	0.026	0.056	0.090	0.217	0.000	0.739	0.000	0.000	0.000	0.000	0.000	1.128	0.739	0.000	0.000
NWC	Normal_Summer	HE23	0.000	0.025	0.046	0.090	0.166	0.000	0.661	0.000	0.000	0.000	0.000	0.000	0.987	0.661	0.000	0.000

CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Composite Load Model Settings

- Load Mix
- Season
- Operating Hour
- Feeder type



Load Mix	Res	Com	Ind	Agr	Data	Service
NWV						
RES	0.75	0.23	0	0	0	0.02
COM	0.2	0.73	0	0	0.05	0.02
MIX	0.45	0.48	0	0	0.05	0.02
RAG	0.4	0.2	0.15	0.25	0	0
NWI						
RES	0.75	0.23	0	0	0	0.02
COM	0.2	0.73	0	0	0.05	0.02
MIX	0.45	0.48	0	0	0.05	0.02
RAG	0.4	0.2	0.15	0.25	0	0
RMN						
RES	0.75	0.23	0	0	0	0.02
COM	0.2	0.73	0	0	0.05	0.02
MIX	0.45	0.48	0	0	0.05	0.02
RAG	0.4	0.2	0.15	0.25	0	0
NCC						
RES	0.75	0.23	0	0	0	0.02
COM	0.2	0.73	0	0	0.05	0.02
MIX	0.45	0.48	0	0	0.05	0.02
RAG	0.4	0.2	0.15	0.25	0	0
NCV						
RES	0.75	0.23	0	0	0	0.02
COM	0.2	0.73	0	0	0.05	0.02
MIX	0.45	0.48	0	0	0.05	0.02

CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Composite Load Model and Dynamic Records

- Input
  - Composite Load Model
  - Motor Data
  - Power Flow Data
- Output
  - .dyd record
  - .dyr record

Composite Load Model

LID	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	Stat. P Res.	Stat. P Cur.	Stat. P Power.	Stat. Q Rea
NWC_RES	0.0581962257299157	0.0671750772341789	0.0234231540620738	0.159337929087532	0.133907234322453	0	0.446033355295082	0.111927024268765	0	-0.5000000.
NWC_COM	0.188073408621696	0.091207630609136	0.0286283562898101	0.0404696028681403	0.24394591755841	0	0.137240117587813	0.270434966464994	0	-0.5000000.
NWC_MIX	0.127238431158409	0.0771340310804133	0.0261756379276999	0.0906390034221776	0.225036099813742	0	0.265920420431232	0.187856376166326	0	-0.5000000.
NWC_RAG	0.106595856030381	0.0755700936445514	0.361470410653437	0.0557236290807248	0.101145331026857	0	0.219715143477197	0.0797795360868523	0	-0.5000000.
NWV_RES	0.0922000840696639	0.0759628312164063	0.0277041661234826	0.1344637386195 3	0.153919741970613	0	0.353169212792718	0.162580225207586	0	-0.5
NWV_COM	0.212546613769651	0.0986831761950485	0.0279315827802641	0.0245634077455132	0.266614307881551	0	0.0837171041239891	0.285943807503983	0	-0.5
NWV_MIX	0.163450498233608	0.0860672703253064	0.0277030738503056	0.0627791211192055	0.258068206843145	0	0.176044997380701	0.22588683224773	0	-0.5
NWV_RAG	0.122556766371452	0.0793810812650852	0.396279030599677	0.0374033140755608	0.105168943166337	0	0.167923062287073	0.0912878022348139	0	-0.5

Powerflow Bus Data

BusNumber	BusName	BasekV	LoadID	Area	Zone	Owner	P	Q	Voltage	LID
106	NORTH LD	115	1	1	1	0	1000	0	1.023064	NWC_MD
202	MIDWAY	115	1	1	1	0	300	150	1.018719	NWV_RA
306	SOUTH LD	115	1	1	1	0	2700	0	1.030094	NWI_COM
102	NORTH G1	18	1	1	1	0	100	50	1	RMN_CO
104	NORTH G2	18	1	1	1	0	100	50	1	NWC_CO
302	SOUTH G1	18	1	1	1	0	100	50	1	NWC_RES
304	SOUTH G2	18	1	1	1	0	100	50	1	NWC_MD

Motor Data

# Type	ID	L.F.	P.F.	Ls	Lps	Lpps	Ra	Tpo	Tppo	H	Etrq	Vtr1	Ttr1	Ftr1	Vrc1
M3	MA	0.75	0.78	1.8	0.12	0.104	0.04	0.095	0.0021	0.1	0	0.7	0.02	0.2	1
M3	MB	0.75	0.78	1.8	0.19	0.14	0.03	0.2	0.0026	0.5	2	0.6	0.02	0.2	0.75
M3	MC	0.75	0.78	1.8	0.19	0.14	0.03	0.2	0.0026	0.1	2	0.65	0.02	0.2	1
M3	IA	0.85	0.89	3.1	0.2	0.165	0.01	0.8	0.0026	0.15	0	0.7	0.05	1	1
M3	IB	0.85	0.89	3.1	0.2	0.165	0.01	0.8	0.0026	1	2	0.7	0.05	0.3	1
M3	IC	0.85	0.89	3.1	0.2	0.165	0.01	0.8	0.0026	0.2	2	0.7	0.05	0.3	1
M3	PA	0.85	0.89	3.1	0.2	0.165	0.01	0.8	0.0026	0.15	0	0.7	0.1	1	1

PSLF

```
lodrep
#Composite load representation
cmpldw    106 "NORTH LD" 115 "1" : #1   mva=-1 /
 "Bss"  0 "Rfdr" 0.04 "Xfdr" 0.04 "Fb" 0.75/
 "Xxf"  0.08 "TfixHS" 1 "TfixLS" 1 "LTC" 1 "Tmin" 0.9 "Tmax" 1.1 "step" 0.00625 /
 "Vmin"  1.025 "Vmax" 1.04 "Tdel" 30 "Ttap" 5 "Rcomp" 0 "Xcomp" 0 /
 "Fma"  0.127 "Fmb" 0.077 "Fmc" 0.026 "Fmd" 0.091 "Fel" 0.225 /
 "PFel"  1 "Vd1" 0.7 "Vd2" 0.5 "Frcel" 1 /
 "Pfs"  -0.999 "P1e" 2 "P1c" 0.586 "P2e" 1 "P2c" 0.414 "Pfreq" 0 /
  "Q1e"  2 "Q1c" -0.500000002907323 "Q2e" 1 "Q2c" 1.50000002907323 "Qfreq" -1 /
 "MtpA"  3 "MtpB" 3 "MtpC" 3 "MtpD" 1 /
 "LfmA" 0.75 "RsA" 0.04 "LsA" 1.8 "LpA" 0.12 "LppA" 0.104 /
 "TpoA" 0.095 "TppoA" 0.0021 "HA" 0.1 "etrqA" 0 /
 "Vtr1A" 0.7 "Ttr1A" 0.02 "Ftr1A" 0.2 "Vrc1A" 1 "Trc1A" 99999 /
 "Vtr2A" 0.5 "Ttr2A" 0.02 "Ftr2A" 0.7 "Vrc2A" 0.7 "Trc2A" 0.1 /
 "LfmB" 0.75 "RsB" 0.03 "LsB" 1.8 "LpB" 0.19 "LppB" 0.14 /
 "TpoB" 0.2 "TppoB" 0.0026 "HB" 0.5 "etrqB" 2 /
 "Vtr1B" 0.6 "Ttr1B" 0.02 "Ftr1B" 0.2 "Vrc1B" 0.75 "Trc1B" 0.05 /
 "Vtr2B" 0.5 "Ttr2B" 0.02 "Ftr2B" 0.3 "Vrc2B" 0.65 "Trc2B" 0.05 /
 "LfmC" 0.75 "RsC" 0.03 "LsC" 1.8 "LpC" 0.19 "LppC" 0.14 /
```

PSSE

```
 106  'USRLOD'  1  'CMLDBLU1'  12 1 0  132  27  146  48
 -1   0   0.04   0.04   0.75   0
 1   1   1   0.9   1.1
 0.00625   1.025   1.04   30   5
 0   0   0.127   0.077   0.026
 0.091   0.225   1   0.7   0.5
 -0.999   2   0.586   1   0.414   0
 2   -0.500000029073231   1   1.50000002907323   -1
 3   0.75   0.04   1.8   0.12   0.104
 0.095   0.0021   0.1   0   0.7
 0.02   0.2   1   99999   0.5
 0.02   0.7   0.7   0.1
 3   0.75   0.03   1.8   0.19   0.14
 0.2   0.0026   0.5   2   0.6
 0.02   0.2   0.75   0.05   0.5
 0.02   0.3   0.65   0.05
 3   0.75   0.03   1.8   0.19   0.14
 0.2   0.0026   0.1   2   0.65
 0.02   0.2   1   9999   0.5
 0.02   0.3   0.65   0.1
```

CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Hourly Analysis

- Climate Zones
- Seasons
- Load Mix

Hourly Plots

Peak Load 25

Peak Hour

Climate Zone

NWI

Season

Hot_Summer

Load Mix

Residential 0.5

Commercial 0.5

Inductive 0

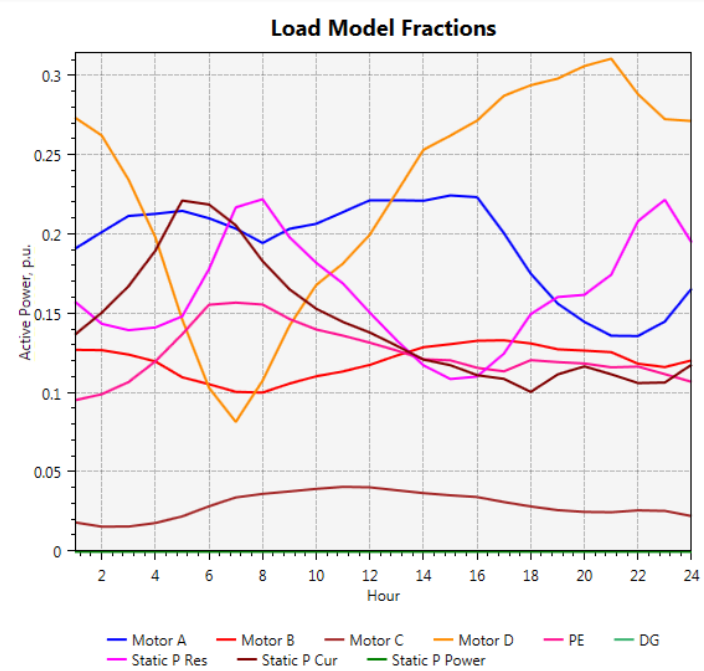
Agricultural 0

Data 0

Service 0

Update Model

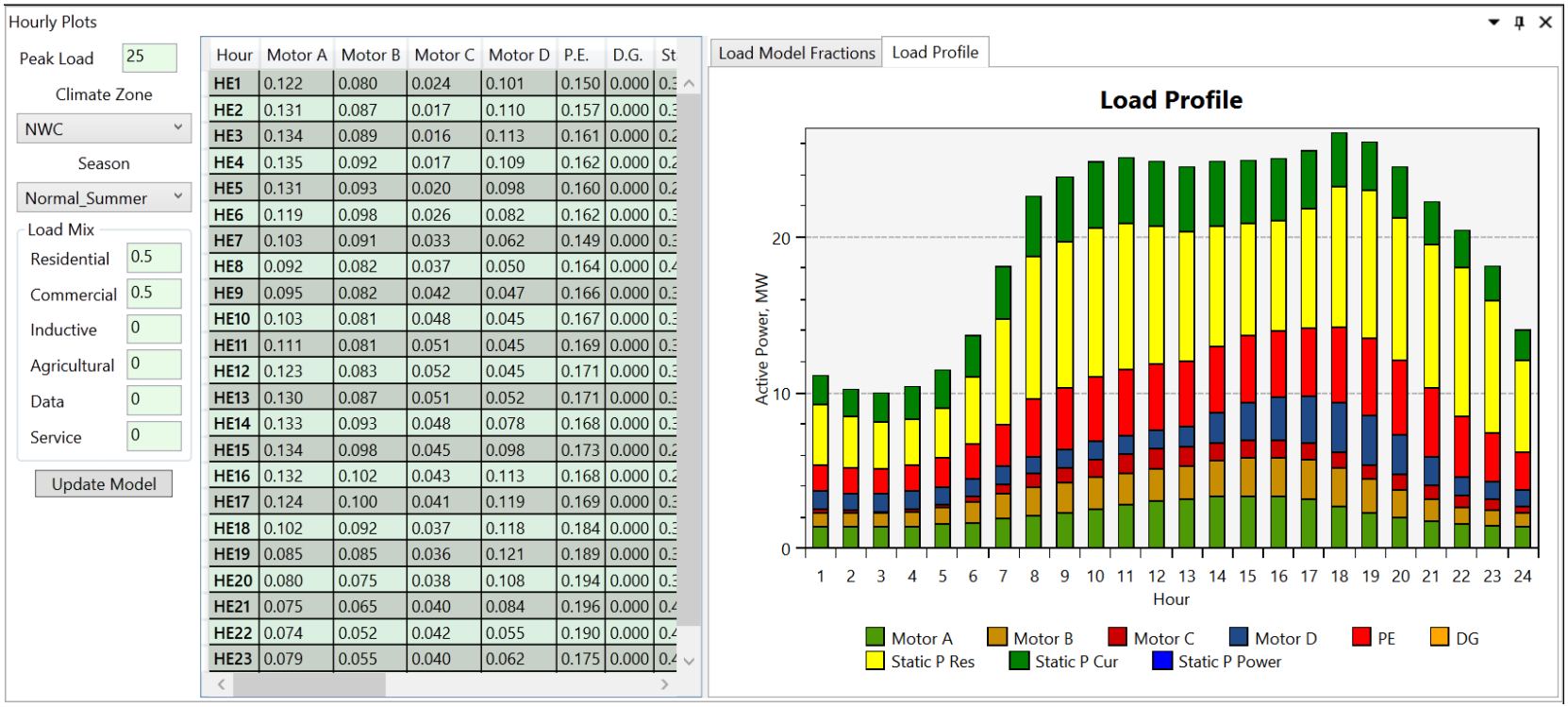
Hour	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	Stat. P Res.	Stat. P Cur.	Stat. P Power.	Stat.
HE1	0.191	0.127	0.018	0.274	0.095	0.000	0.158	0.137	0.000	-0.50
HE2	0.201	0.127	0.016	0.262	0.099	0.000	0.144	0.151	0.000	-0.50
HE3	0.212	0.124	0.016	0.235	0.107	0.000	0.140	0.167	0.000	-0.50
HE4	0.213	0.120	0.018	0.198	0.120	0.000	0.141	0.190	0.000	-0.50
HE5	0.215	0.110	0.022	0.146	0.137	0.000	0.148	0.221	0.000	-0.50
HE6	0.210	0.106	0.028	0.103	0.156	0.000	0.178	0.219	0.000	-0.50
HE7	0.204	0.101	0.034	0.082	0.157	0.000	0.217	0.206	0.000	-0.50
HE8	0.195	0.100	0.036	0.108	0.156	0.000	0.222	0.183	0.000	-0.50
HE9	0.204	0.106	0.038	0.142	0.147	0.000	0.198	0.165	0.000	-0.50
HE10	0.207	0.111	0.039	0.168	0.140	0.000	0.182	0.153	0.000	-0.50
HE11	0.214	0.114	0.041	0.182	0.136	0.000	0.169	0.145	0.000	-0.50
HE12	0.222	0.118	0.040	0.200	0.132	0.000	0.151	0.138	0.000	-0.50
HE13	0.222	0.124	0.039	0.227	0.127	0.000	0.133	0.130	0.000	-0.50
HE14	0.221	0.129	0.037	0.253	0.121	0.000	0.117	0.121	0.000	-0.50
HE15	0.225	0.131	0.035	0.262	0.121	0.000	0.109	0.118	0.000	-0.50
HE16	0.224	0.133	0.034	0.272	0.116	0.000	0.110	0.111	0.000	-0.50
HE17	0.201	0.133	0.031	0.287	0.114	0.000	0.125	0.109	0.000	-0.50
HE18	0.175	0.131	0.028	0.294	0.121	0.000	0.150	0.101	0.000	-0.50
HE19	0.156	0.128	0.026	0.298	0.119	0.000	0.160	0.112	0.000	-0.50
HE20	0.145	0.127	0.025	0.306	0.119	0.000	0.162	0.117	0.000	-0.50
HE21	0.136	0.126	0.025	0.311	0.116	0.000	0.175	0.112	0.000	-0.50
HE22	0.136	0.118	0.026	0.288	0.117	0.000	0.208	0.106	0.000	-0.50
HE23	0.145	0.116	0.026	0.273	0.112	0.000	0.222	0.107	0.000	-0.50
HE24	0.166	0.121	0.022	0.272	0.107	0.000	0.195	0.118	0.000	-0.50



CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Hourly Analysis

- Climate Zones
- Seasons
- Load Mix

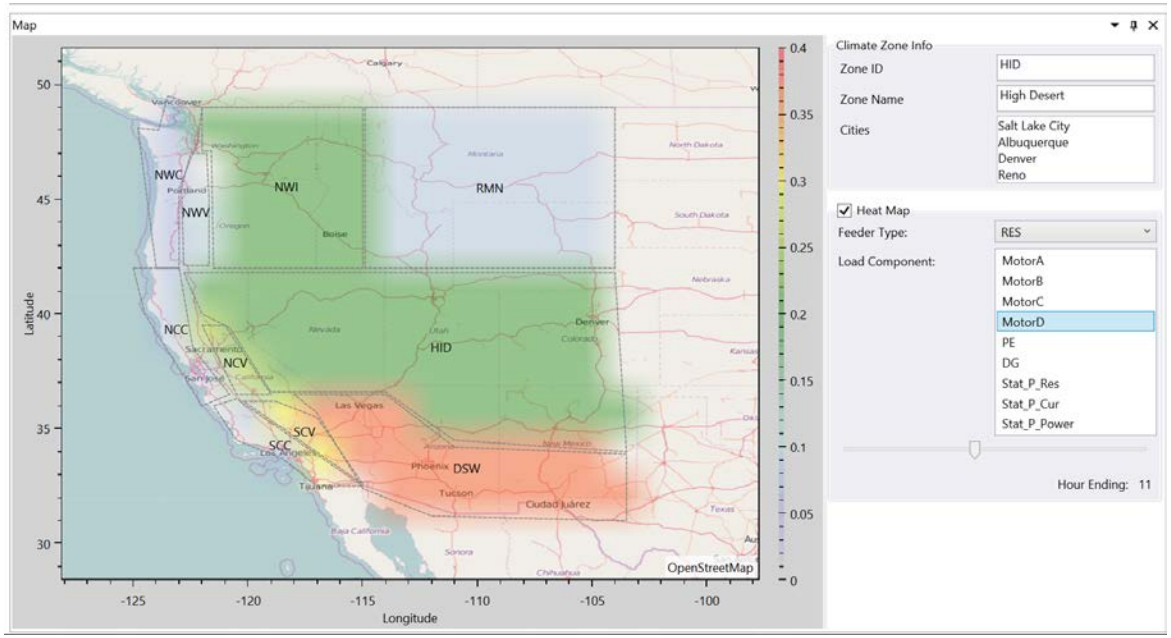


Hour	Motor A	Motor B	Motor C	Motor D	P.E.	D.G.	St
HE1	0.122	0.080	0.024	0.101	0.150	0.000	0.3
HE2	0.131	0.087	0.017	0.110	0.157	0.000	0.3
HE3	0.134	0.089	0.016	0.113	0.161	0.000	0.2
HE4	0.135	0.092	0.017	0.109	0.162	0.000	0.2
HE5	0.131	0.093	0.020	0.098	0.160	0.000	0.2
HE6	0.119	0.098	0.026	0.082	0.162	0.000	0.3
HE7	0.103	0.091	0.033	0.062	0.149	0.000	0.3
HE8	0.092	0.082	0.037	0.050	0.164	0.000	0.4
HE9	0.095	0.082	0.042	0.047	0.166	0.000	0.3
HE10	0.103	0.081	0.048	0.045	0.167	0.000	0.3
HE11	0.111	0.081	0.051	0.045	0.169	0.000	0.3
HE12	0.123	0.083	0.052	0.045	0.171	0.000	0.3
HE13	0.130	0.087	0.051	0.052	0.171	0.000	0.3
HE14	0.133	0.093	0.048	0.078	0.168	0.000	0.3
HE15	0.134	0.098	0.045	0.098	0.173	0.000	0.2
HE16	0.132	0.102	0.043	0.113	0.168	0.000	0.2
HE17	0.124	0.100	0.041	0.119	0.169	0.000	0.3
HE18	0.102	0.092	0.037	0.118	0.184	0.000	0.3
HE19	0.085	0.085	0.036	0.121	0.189	0.000	0.3
HE20	0.080	0.075	0.038	0.108	0.194	0.000	0.3
HE21	0.075	0.065	0.040	0.084	0.196	0.000	0.4
HE22	0.074	0.052	0.042	0.055	0.190	0.000	0.4
HE23	0.079	0.055	0.040	0.062	0.175	0.000	0.4

CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Map

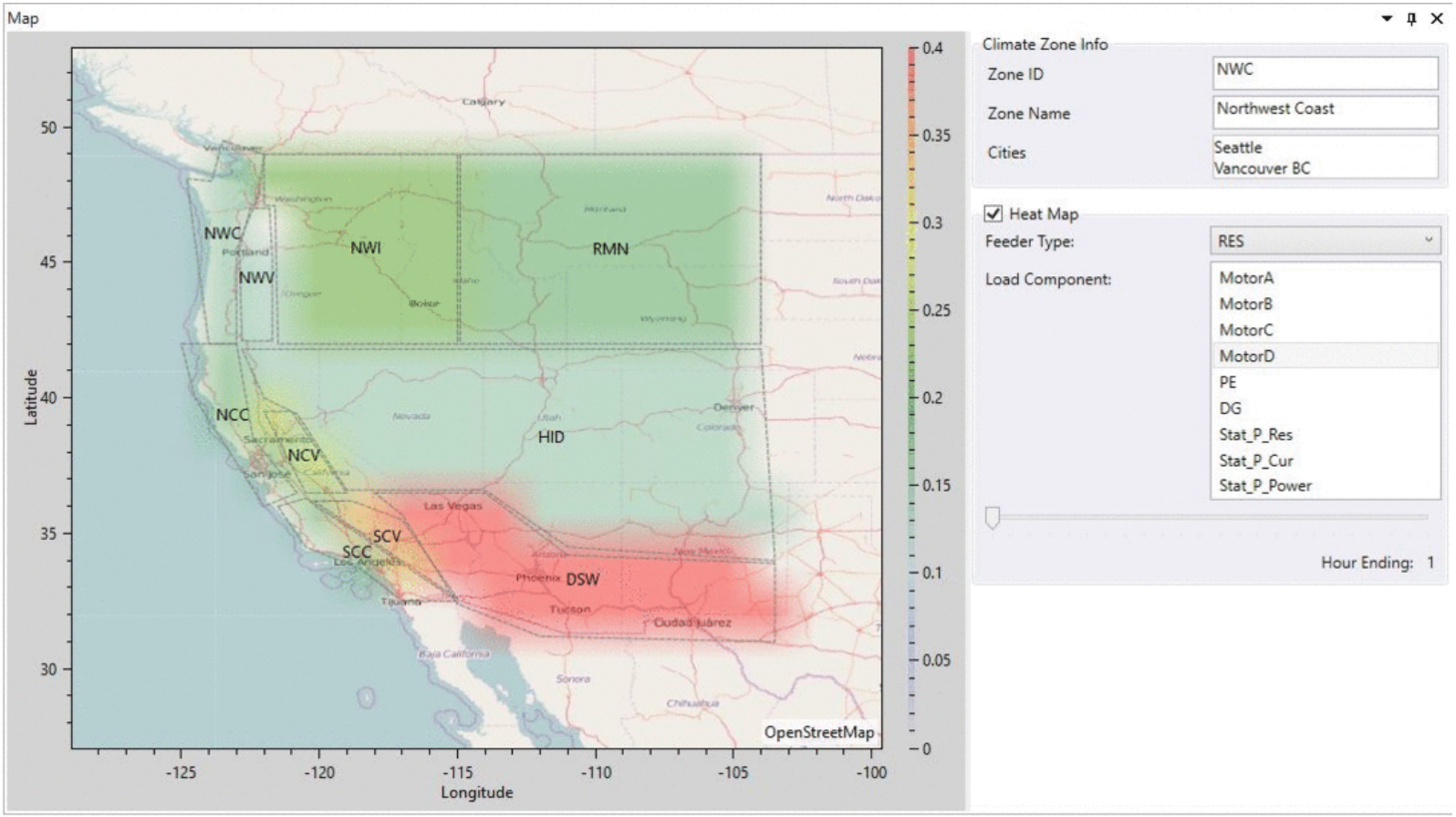
- Visualization of composite load parameters on the map for different:
  - Climate zones
  - Feeder types
  - Seasons
  - Operating hours



CERTS CONSORTIUM *for* ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

Heat Map

- Motor D, Residential Feeder, Summer season



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Deliverables FY15

- LMDT 2.0 and tool documentation available at: https://svn.pnl.gov/LoadTool
- Chassin D., Zhang Y., Etingov P., et al. "Load Composition Modeling and Tools", Pacific Northwest National Laboratory, Richland, WA, July 2015.
- James D., Kueck J. "Commercial Building Motor Protection Response Report", Pacific Northwest National Laboratory, Richland, WA, July 2015.

#	Milestone/Deliverable	Target Date
1	*Tool Requirements*	May 2015 (completed)
2	*Tool specification*	September 2015 (completed)
3	*Tool prototype*	December 2015 (completed)
4	*Final tool release*	September 2016 (completed)

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Industry Outreach

The LMDT application has been presented at different industrial events including:

- WECC Modeling and Validation Work Group (MVWG)
- WECC Load Modeling Task Force (LMTF)
- NERC Load Modeling Task Force (LMTF)
- North American Transmission Forum (NATF) Dynamic Load Modeling Working Group
- Webinars for western and eastern interconnection utilities.

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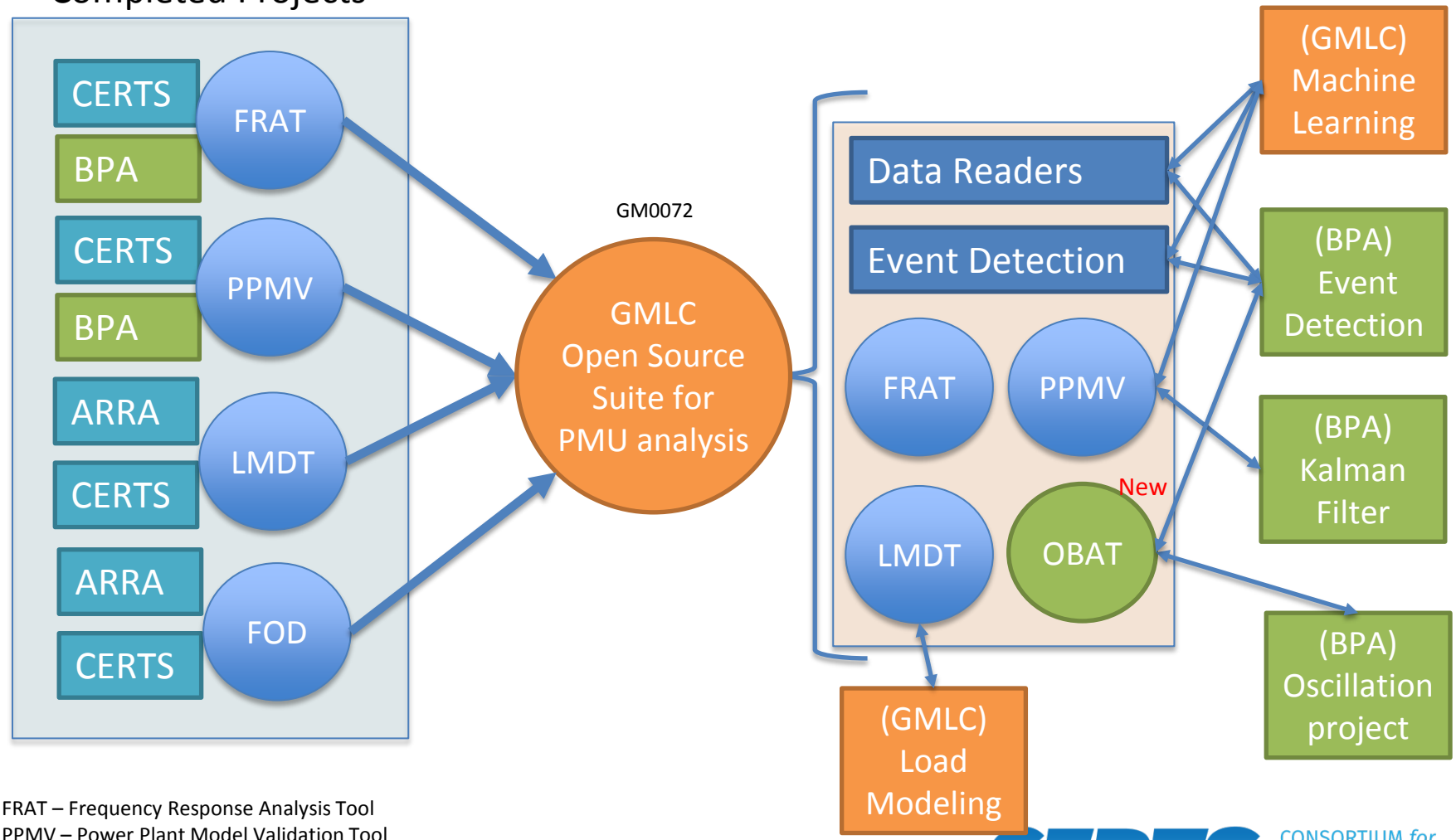
Risk factors

- Risk factors are low.
- Feedback and guidance from industrial users are very important for the success of the project.

Future plans

Completed Projects



FRAT – Frequency Response Analysis Tool
PPMV – Power Plant Model Validation Tool
LMDT – Load Modeling Data Tool
FOD – Forced Oscillation Detection
OBAT – Oscillation Baselining and Analysis Tool

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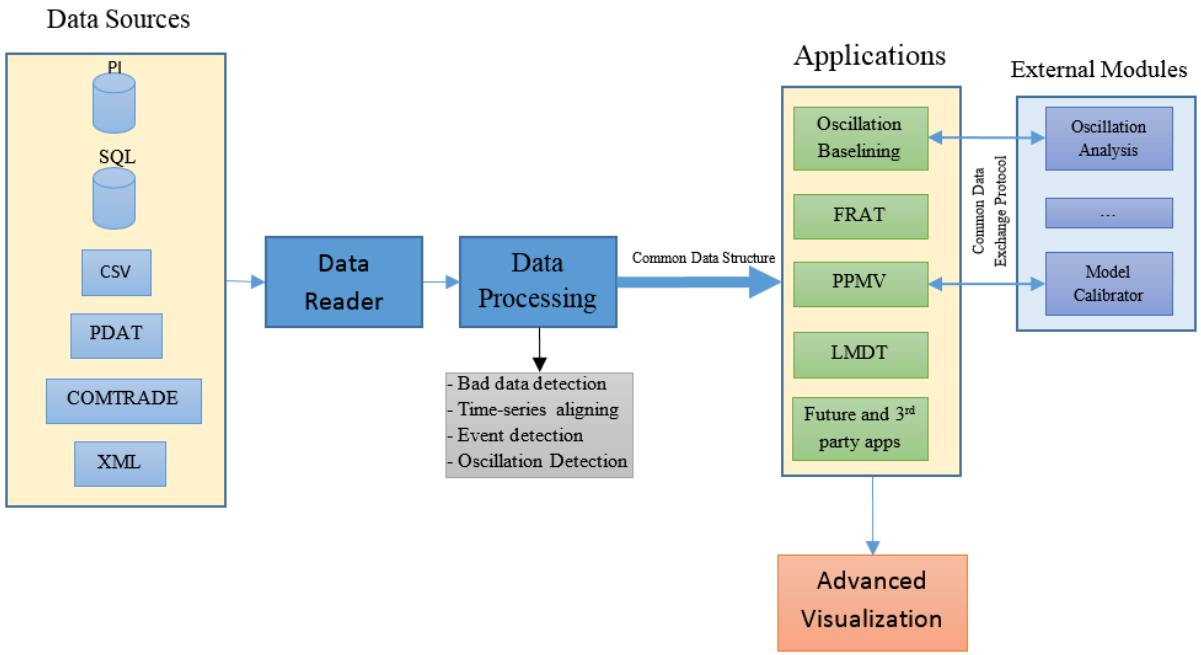
Open Platform for Engineering Applications

- Based on Open Source Components
  - Extended WPF Toolkit™
  - OxyPlot
  - Math.NET
- Create building blocks and solutions for future and 3rd party applications
- Common data structure and data exchange protocols
- Support external modules/solvers
  - Oscillation Analysis
  - Model Calibration



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