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Composite Load Model Evaluation

N. Lu
A. Qiao

September 2007

Prepared for the Bonneville Power Administration
Under contract, 00162-00033
With the U.S. Department of Energy
Under DE-AC05-76RL01830

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Richland, Washington 99352

SUMMARY

This final report is prepared for Bonneville Power Administration to document the methodology and procedure used to evaluate the new composite load model, CMPLDW, which is developed by GE Energy. The composite load model structure is provided by the WECC load modeling task force. It is to be used to represent behaviors of different end-user components. GE Energy has implemented this composite load model with a new function CMPLDW in its power system simulation software package, Positive Sequence Load Flow (PSLF). Pacific Northwest National Laboratory (PNNL) and BPA joined forces and conducted the evaluation of the CMPLDW and tested its parameter settings. The PNNL testing results are documented in this report.

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1. INTRODUCITON

The WECC load modeling task force has dedicated its effort in the past few years to developing a composite load model that can represent behaviors of different end-user components. The modeling structure of the composite load model recommended by the WECC load modeling task force has been illustrated in Figure 1. GE Energy has implemented this composite load model with a new function CMPLDW in its power system simulation software package, Positive Sequence Load Flow (PSLF).

For the last several years, Bonneville Power Administration (BPA) has taken the lead and collaborated with GE Energy to develop the new composite load model. Pacific Northwest National Laboratory (PNNL) and BPA joined forces and conducted the evaluation of the CMPLDW and tested its parameter settings to make sure that:

- the model initialized properly
- all the parameter settings were functioning
- the simulation results were as expected.

The PNNL effort focused on testing the CMPLDW in a four-bus system, as shown in Figure 2. Exhaustive testing on each parameter setting has been performed to guarantee each setting works. This report is a summary of the PNNL testing results and conclusions.

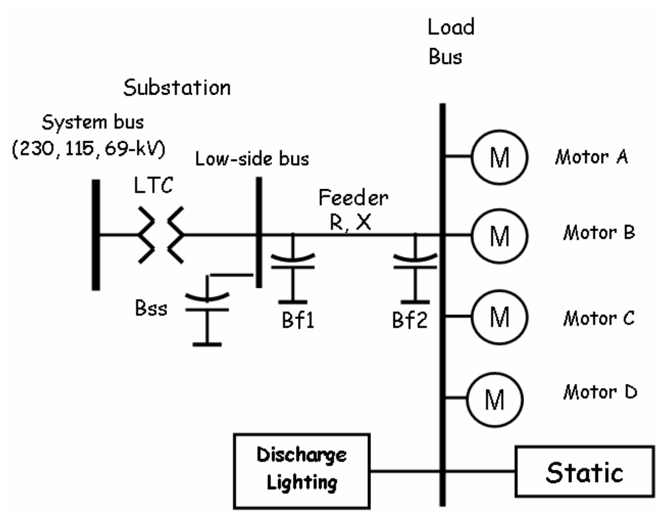


Figure 1: The Composite Load Model Structure

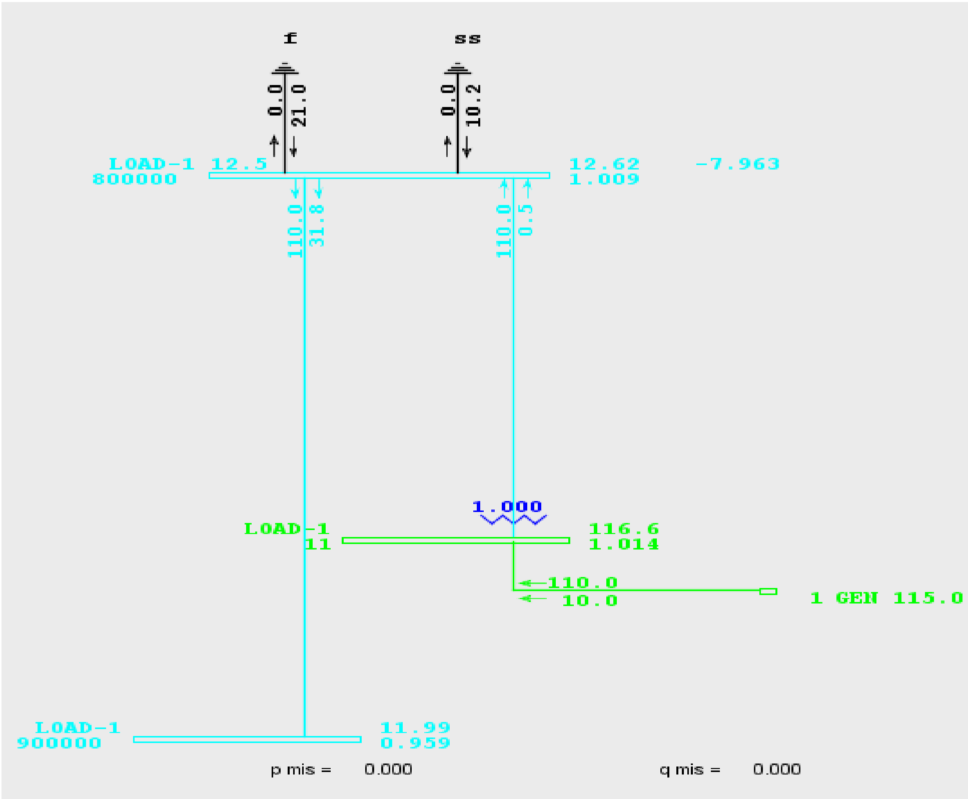


Figure 2: Four-bus load model

2. MODEL EVALUATION METHODOLOGY

The most rigorous way to build confidence in models is to compare model simulation results with field measurements. However, because the CMPLDW model is built upon several known load models, PNNL's evaluation is, therefore, conducted by comparing the simulation results obtained by the validated model and the CMPLDW model.

1. Motor load modeling: Set the static load to zero and operate only one motor load. For example, Motor A is running and Motor B, C, and D are offline. Then, compare the simulation results obtained by CMPLDW with the results by Motor W.
2. Static load modeling: compare with the direct calculations.
3. Test each parameter setting: Exhaustive tests are run, in which only one parameter is changed at a time to observe the results.

Please refer to Appendix V of the GE Energy: WECC Composite Load Model (CMPLDW) Specifications for the parameter settings.

CSV files are used to create the testing signals. PSLF playback function is used to inject different testing signals as shown in Figure 3, which include:

- Voltage sags
- Voltage ramp
- Voltage oscillation
- Voltage hump
- Frequency sag
- Frequency oscillation
- Frequency ramp

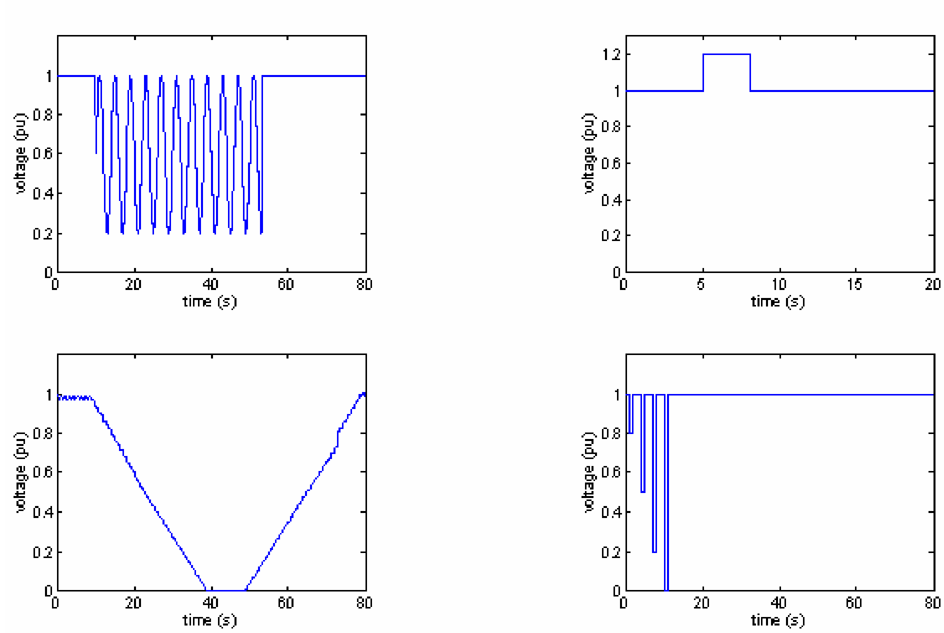


Figure 3: Sample testing signals (oscillation, voltage hump, voltage rampup and rampdown, and voltage sags)

To summarize, the CLM settings tested are:

- Compared with Motor W
- Static load only
- Four motor loads
  - Partial tripping settings: Vtr1, Ftr1, Vtr2, Ftr2
  - Load torque settings: etrq
  - H settings
  - Different motor parameters: big industrial load, small industrial load, compressor loads
- Static load plus one motor load

As a result of the overwhelming figures created from the test data, only a selected few are presented in Appendices I through IV. If the results are as expected, the test was considered "passed".

3. EVALUATION TEST PROCEDURES AND RESULTS

3.1 Test 1: Compare Motor W with CMPLDW

In this test, all the motor parameters were set equal. The fraction of the motor load fraction to be "Fma" 1.0 "Fmb" 0.0 "Fmc" 0.0 "Fmd" 0.0 "Fdl" 0.0 /, or "Fma" 0.0 "Fmb" 1.0 "Fmc" 0.0 "Fmd" 0.0 "Fdl" 0.0 /, or "Fma" 0.0 "Fmb" 0.0 "Fmc" 1.0 "Fmd" 0.0 "Fdl" 0.0 /, or "Fma" 0.0 "Fmb" 0.0 "Fmc" 0.0 "Fmd" 1.0 "Fdl" 0.0 /. An example of the *.dyd files is shown in Figure 4.

```
lodrep

cmpldw      11  "LOAD-1  "  115.00 "A "  : #3  mva=100.410004  "Bss"   0.3057 "Rfdr"
0.03465 "Xfdr" 0.04331 "Fb" 0.00/

 "Xxf" 0.08 "TfixHS" 1 "TfixLS" 1 "LTC" 1  "Tmin"   1 "Tmax" 1 "step" 0.00625 /

 "Vmin"   1.025 "Vmax" 1.04 "Tdel" 30  "Ttap"   5 "Rcomp" 0 "Xcomp" 0 /

 "Fma"   1.0 "Fmb" 0.0 "Fmc" 0.0 "Fmd"   0.0 "Fdl" 0.0 /

 "Pfs"   0.99806 "P1e" 2 "P1c" 0 "P2e" 1 "P2c"   0 "Pfreq" 1 /

        "Q1e" 2 "Q1c" 0 "Q2e" 1 "Q2c"   0 "Qfreq" -1 /

 "MtpA"   3 "LfmA" 0.85 "RsA" 0.02 "LsA" 3.58 "LpA" 0.177 "LppA"   0.177 "TpoA" 0.56
"TppoA" 0.02 /

 "HA"   0.3 "atrqA" 0 "btrqA" 0 "dtrqA" 1 "etrqA"   2 /

 "Vtr1A" 0 "Ttr1A" 99999  "Ftr1A" 0 "Vrc1A" 0.8 "Trc1A" 0.5 /

 "Vtr2A" 0.4 "Ttr2A" 0.02  "Ftr2A" 0 "Vrc2A" 999 "Trc2A" 999
```

Figure 4: An example *.dyd file

The following scenarios were tested and results are included in Appendix I and also summarized in Table 1.

Table 1: Compare with Motor W

Scenarios	Pass	Not pass
Voltage Sags	✓	
Voltage Ramp	✓	
Voltage Oscillation	✓	
Voltage Hump	✓	
Frequency Sag	✓	
Frequency Oscillation	✓	
Frequency Ramp	✓	

3.2 Test 2: Static Load Only Simulations

P and Q of the static load model can be described in the following equations:

$$P = P_0(P1c(\frac{V}{V_0})^{P1e} + P_{2C}(\frac{V}{V_0})^{P2e} + P3)(1 + pf * \Delta f)$$

$$Q = Q_0(Q1c(\frac{V}{V_0})^{Q1e} + Q_{2C}(\frac{V}{V_0})^{Q2e} + Q3)(1 + pf * \Delta f)$$

In the static load simulation, the motor fraction was set to zero,

"Fma" 0 "Fmb" 0 "Fmc" 0 "Fmd" 0 "Fdl" 1 / "Pfs" 0.96187

and three cases were analyzed. The simulation parameters and results are included in Appendix II and also summarized in Table 2.

.

Table 2: Static load simulation

Scenarios	Pass	Not pass
CASE 1: "P1e" 2 "P1c" 0 "P2e" 1 "P2c" 1 "Pfreq" 0 / "Q1e" 2 "Q1c" 0 "Q2e" 1 "Q2c" 1 "Qfreq" 0 /	✓	
CASE2: "P1e" 2 "P1c" 1 "P2e" 1 "P2c" 0 "Pfreq" 0 / "Q1e" 2 "Q1c" 1 "Q2e" 1 "Q2c" 0 "Qfreq" 0	✓	
CASE3 "P1e" 2 "P1c" 0 "P2e" 1 "P2c" 0 "Pfreq" 0 / "Q1e" 2 "Q1c" 0 "Q2e" 1 "Q2c" 0 "Qfreq" 0 /	✓	

3.3 Test 3: Four Motor Loads

In the four motor dynamic simulations, the motor parameters of MA, Mb, MC and MD were varied one at a time, while the rest of the parameters remained the same. The simulation parameters and results are attached in Appendix III and also summarized in Table 3.

Table 3: Four Motor Loads

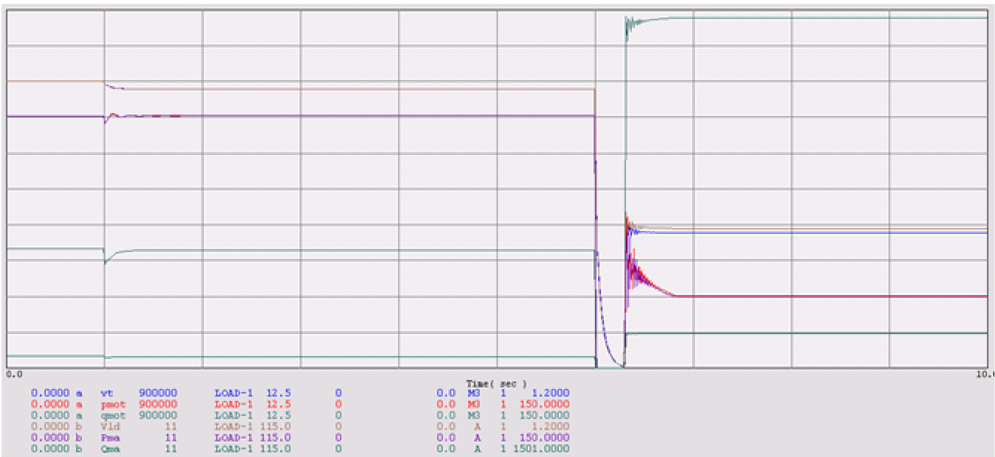
Scenarios	Pass	Not pass
Vary H, set etrq=0	✓	
Vary H, set etrq=2	✓	
Vary etrq	✓	
Vary Rs	✓	
Vary Fm	✓	
Vary Vtr2	✓	
Vary Ftr2	✓	
Vary Vtr1, set Ttr1=2	✓	

4. CONCLUSION

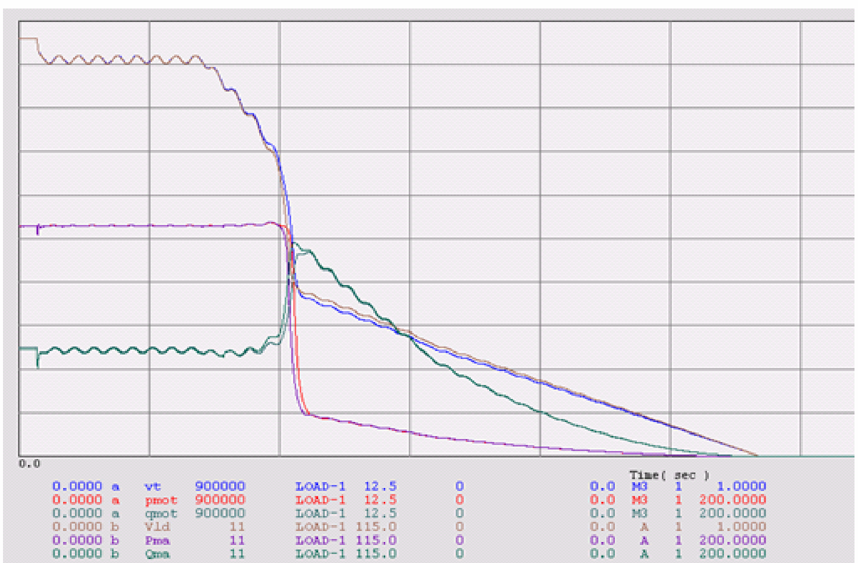
After extensive testing, the authors conclude that the CMPLDW model is correctly implemented and all the parameter settings are functioning properly.

Appendix I - Comparison with MOTOR W

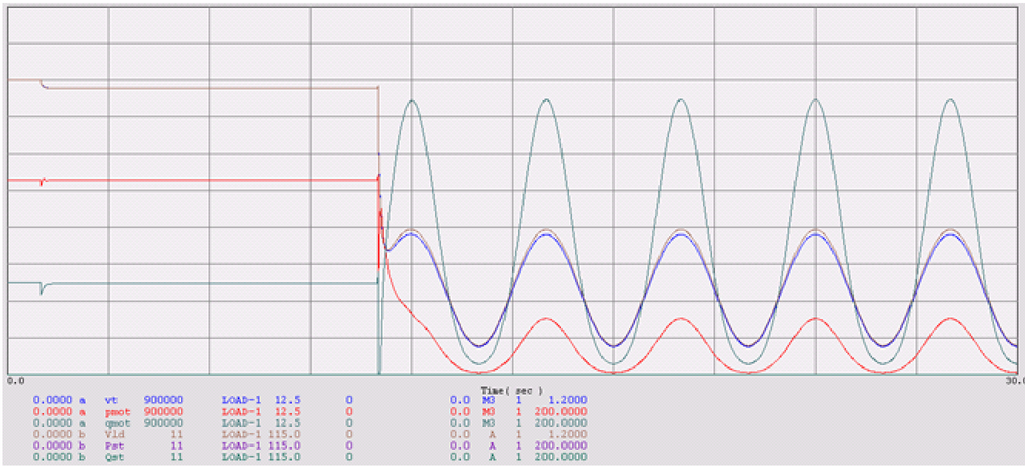
1 motor: Voltage Sags



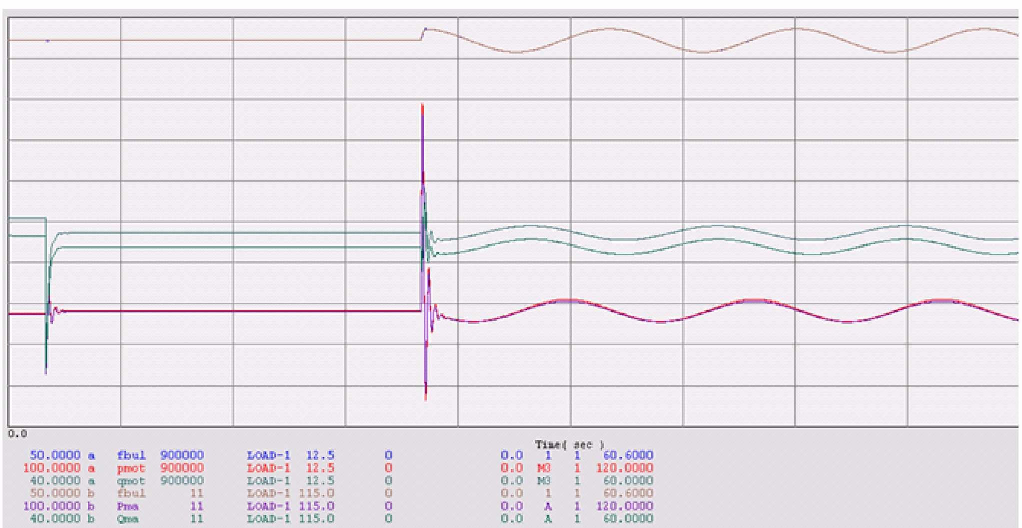
1 motor: Voltage Ramp



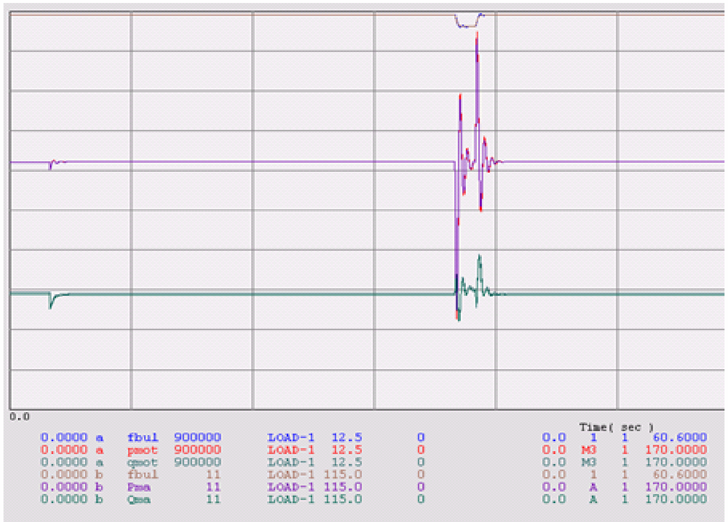
1 motor: Voltage Oscillation



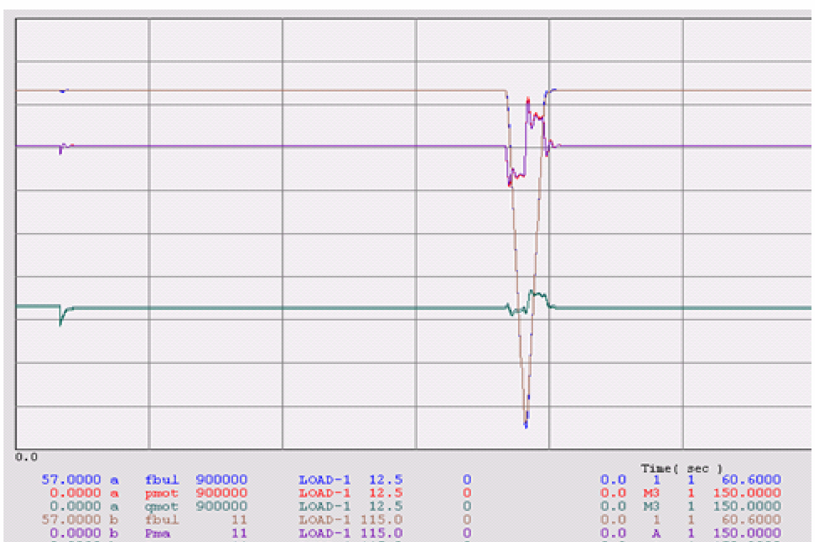
1 motor: Frequency Oscillation



1 motor: Frequency Sag

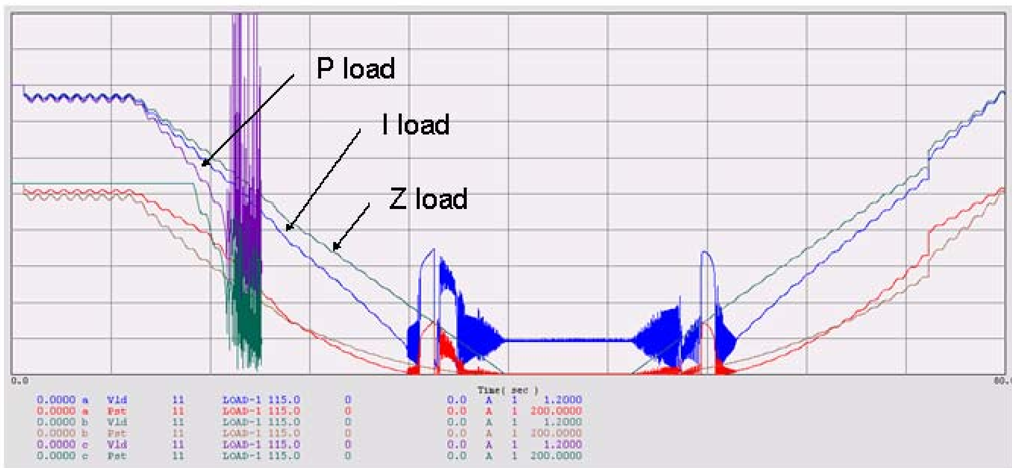


1 motor: Frequency Ramp



Appendix II - Static Load Simulation

Voltage rampdown and rampup



Voltage sags

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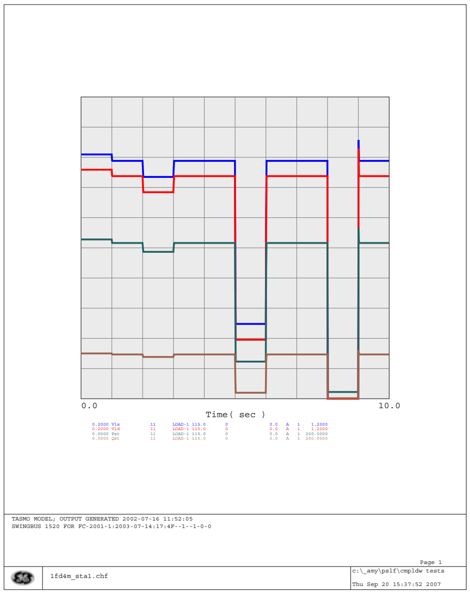
<td>
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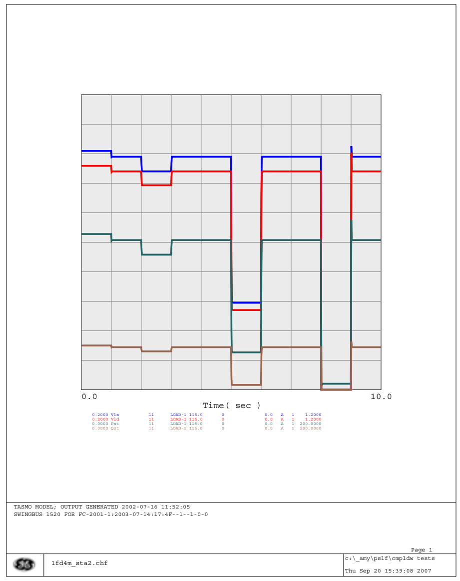
<td>
</td>
</tr>
<tr>
<td>CASE 1: "P1e" 2 "P1c" 0 "P2e" 1 "P2c" 1 "Pfreq" 0 / "Q1e" 2 "Q1c" 0 "Q2e" 1 "Q2c" 1 "Qfreq" 0 /</td>
<td>CASE2: "P1e" 2 "P1c" 1 "P2e" 1 "P2c" 0 "Pfreq" 0 / "Q1e" 2 "Q1c" 1 "Q2e" 1 "Q2c" 0 "Qfreq" 0</td>
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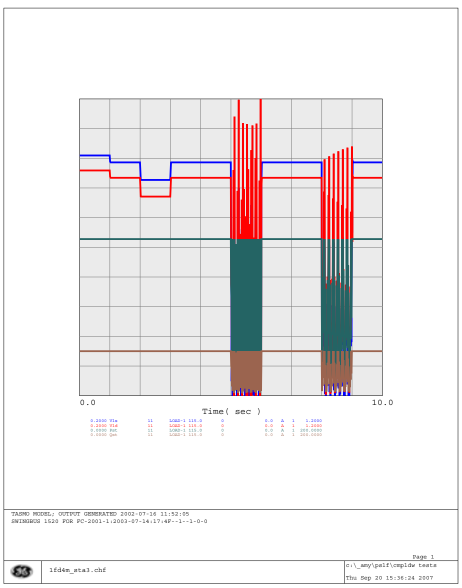
<td>
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<td></td>
</tr>
<tr>
<td>CASE3 "P1e" 2 "P1c" 0 "P2e" 1 "P2c" 0 "Pfreq" 0 / "Q1e" 2 "Q1c" 0 "Q2e" 1 "Q2c" 0 "Qfreq" 0 /</td>
<td></td>
</tr>
</table>

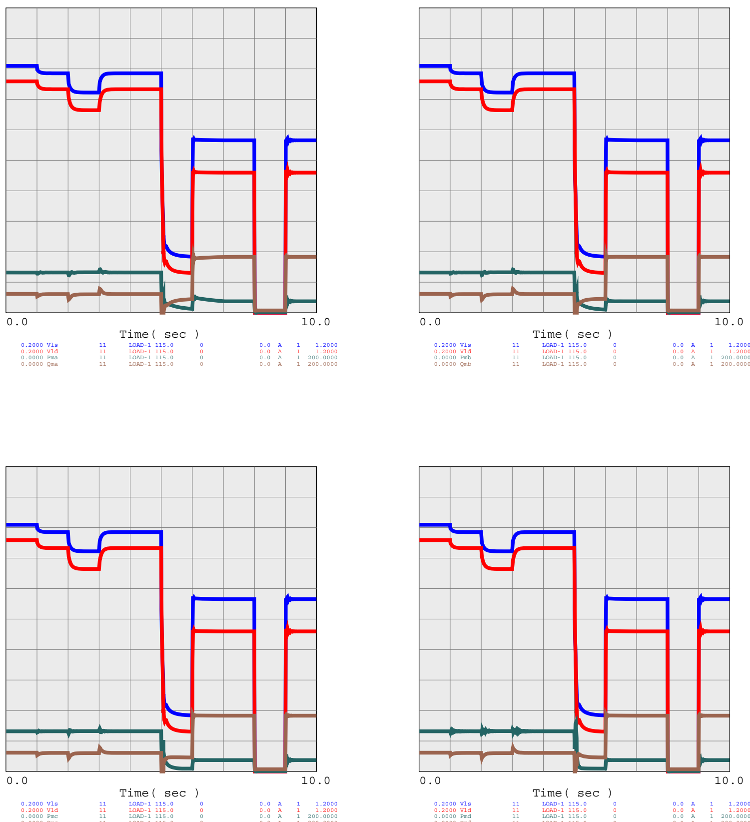
Appendix III - Four Motor Dynamic Simulations

MA: HA=0.6, etrqA=0

MB: HB=0.4, etrqB=0

MC: HC=0.2, etrqC=0

MD: HD=0.05, etrqD=0



TASMO MODEL; OUTPUT GENERATED 2002-07-16 11:52:05
SWINGBUS 1520 FOR FC-2001-1:2003-07-14:17:4F--1--1-0-0

Page 1

1fd4m_H.chf

c:_amy\pslf\cmpldw tests

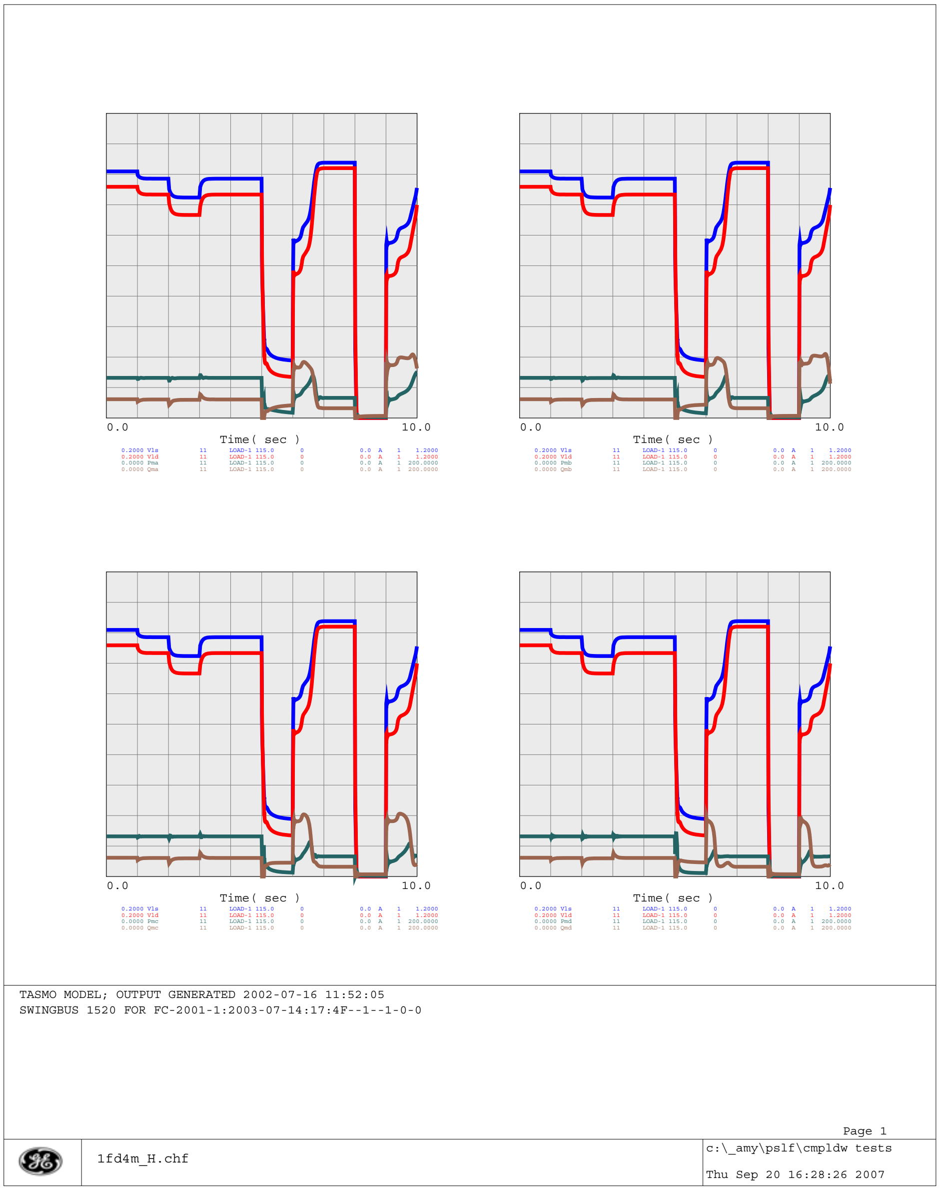
Thu Sep 20 16:32:25 2007

MA: HA=0.6, etrqA=2

MB: HB=0.4, etrqB=2

MC: HC=0.2, etrqC=2

MD: HD=0.05, etrqD=2

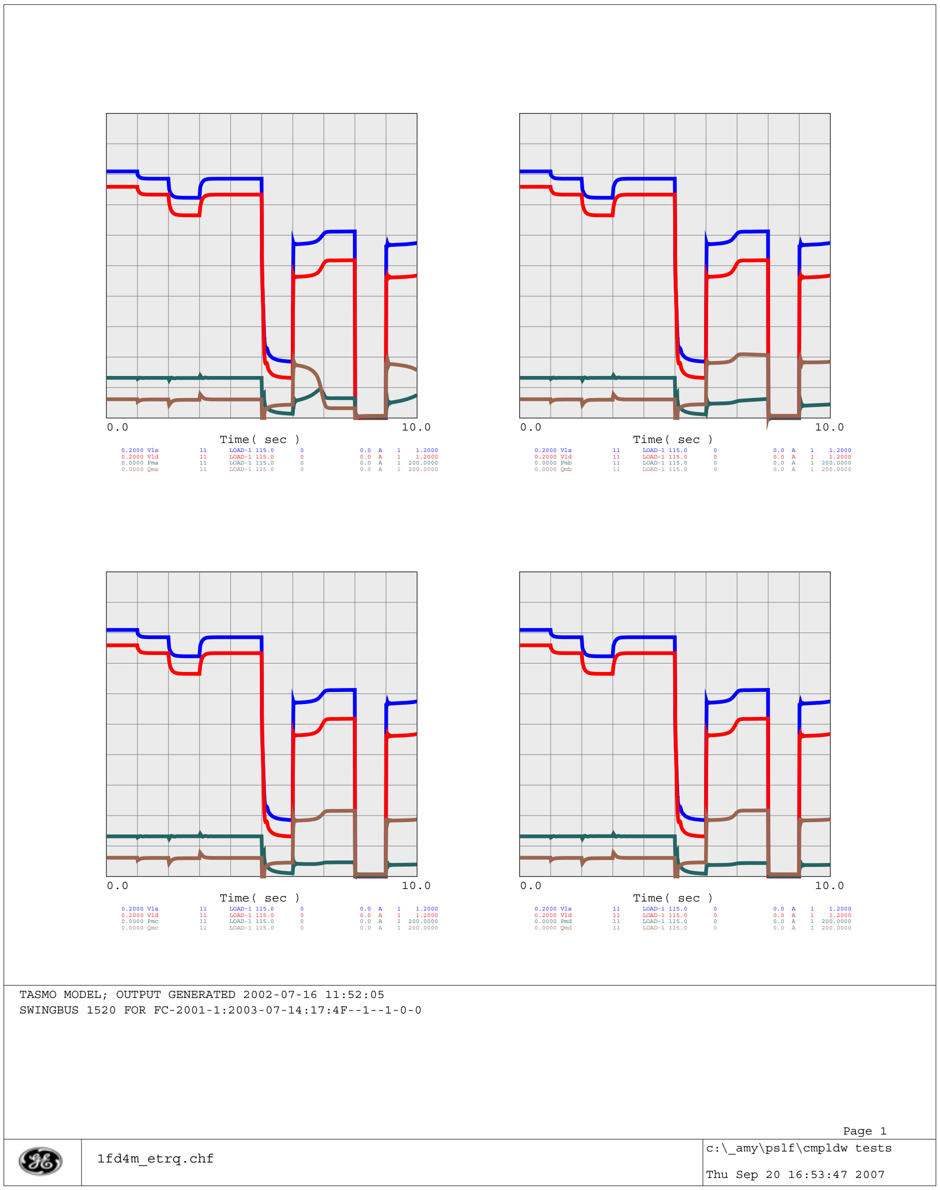


MA: HA=0.3, etrqA=2

MB: HB=0.3, etrqB=1

MC: HC=0.3, etrqC=0.5

MD: HD=0.3, etrqD=0

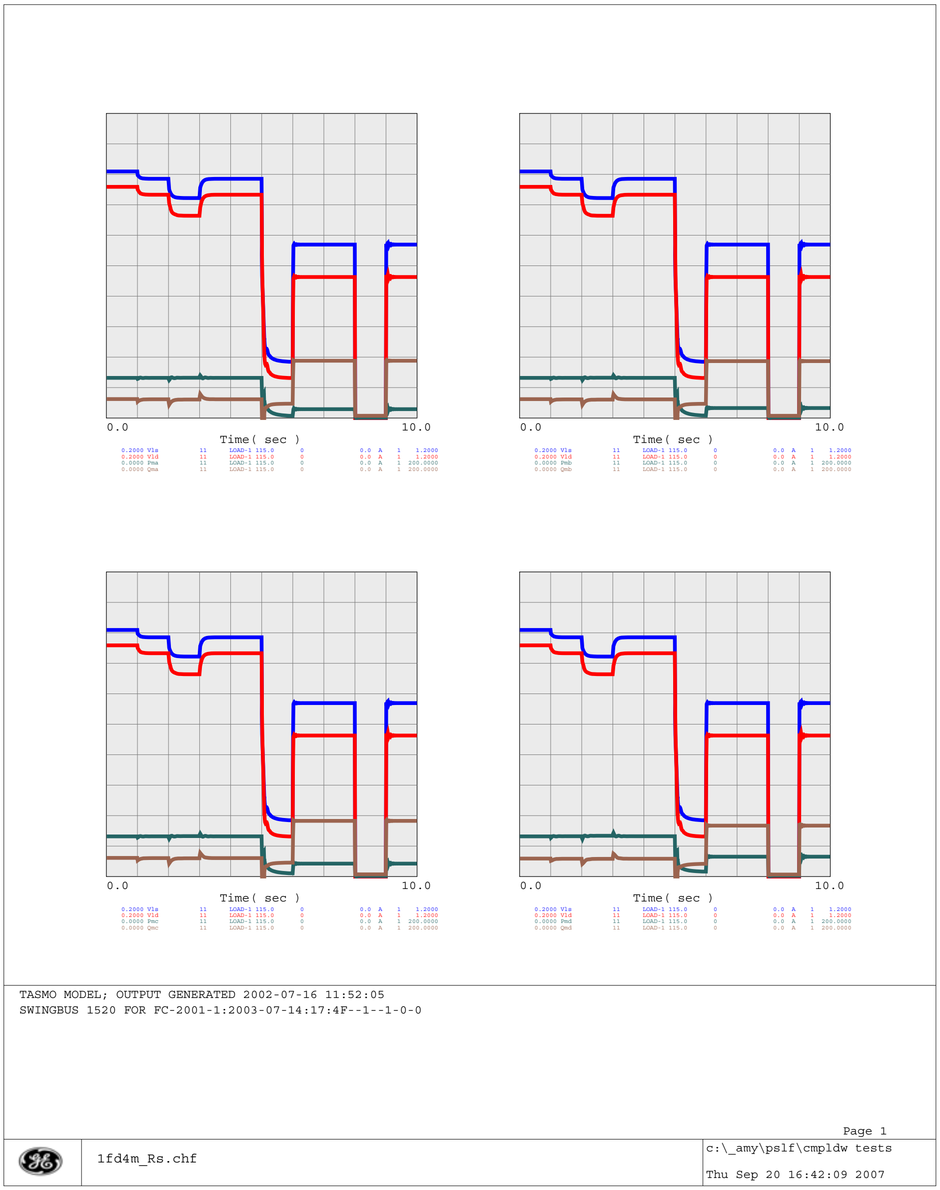


MA: RsA=0.0113

MB: RsB=0.015

MC: RsC=0.025

MD: RsD=0.053

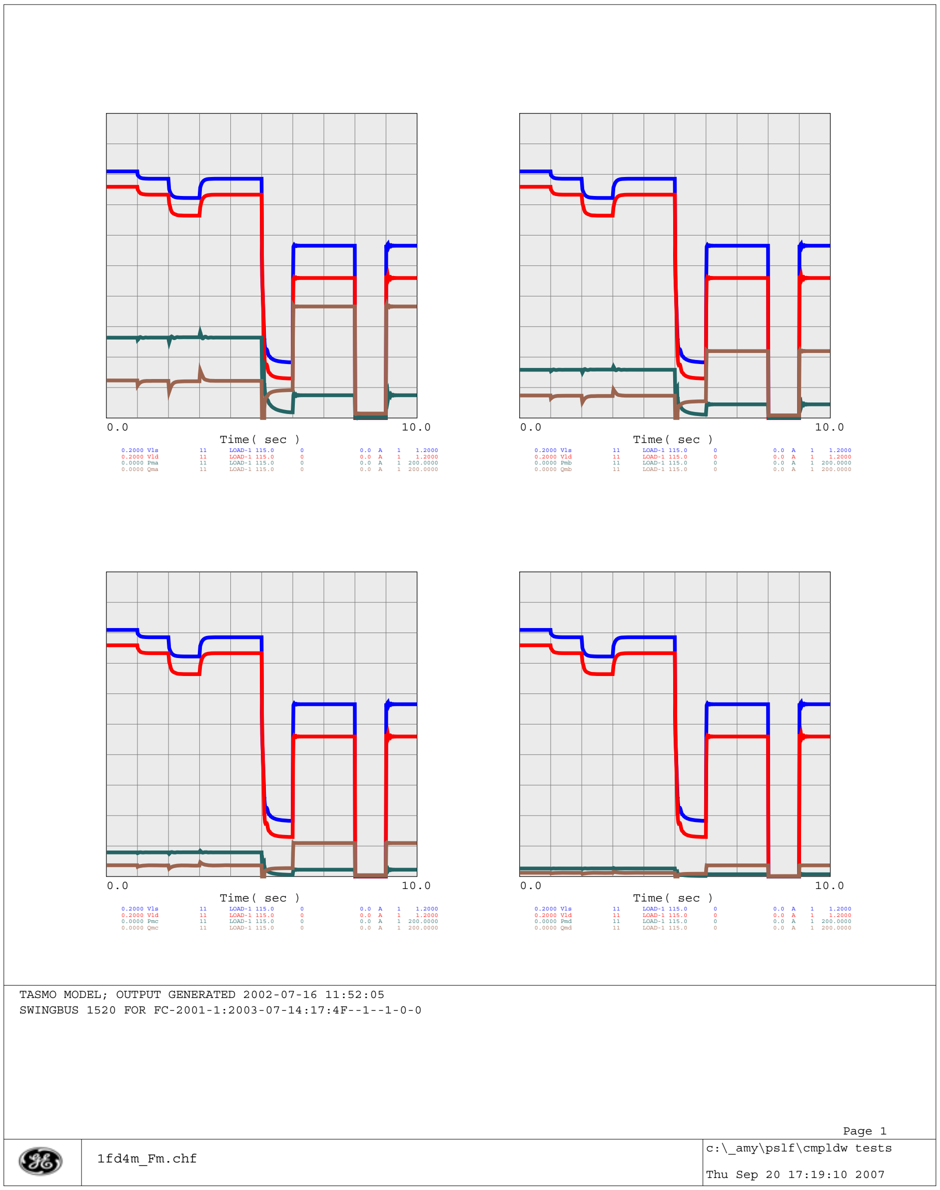


MA: Fma=0.5

MB: Fmb=0.3

MC: Fmc=0.15

MD: Fmd=0.05

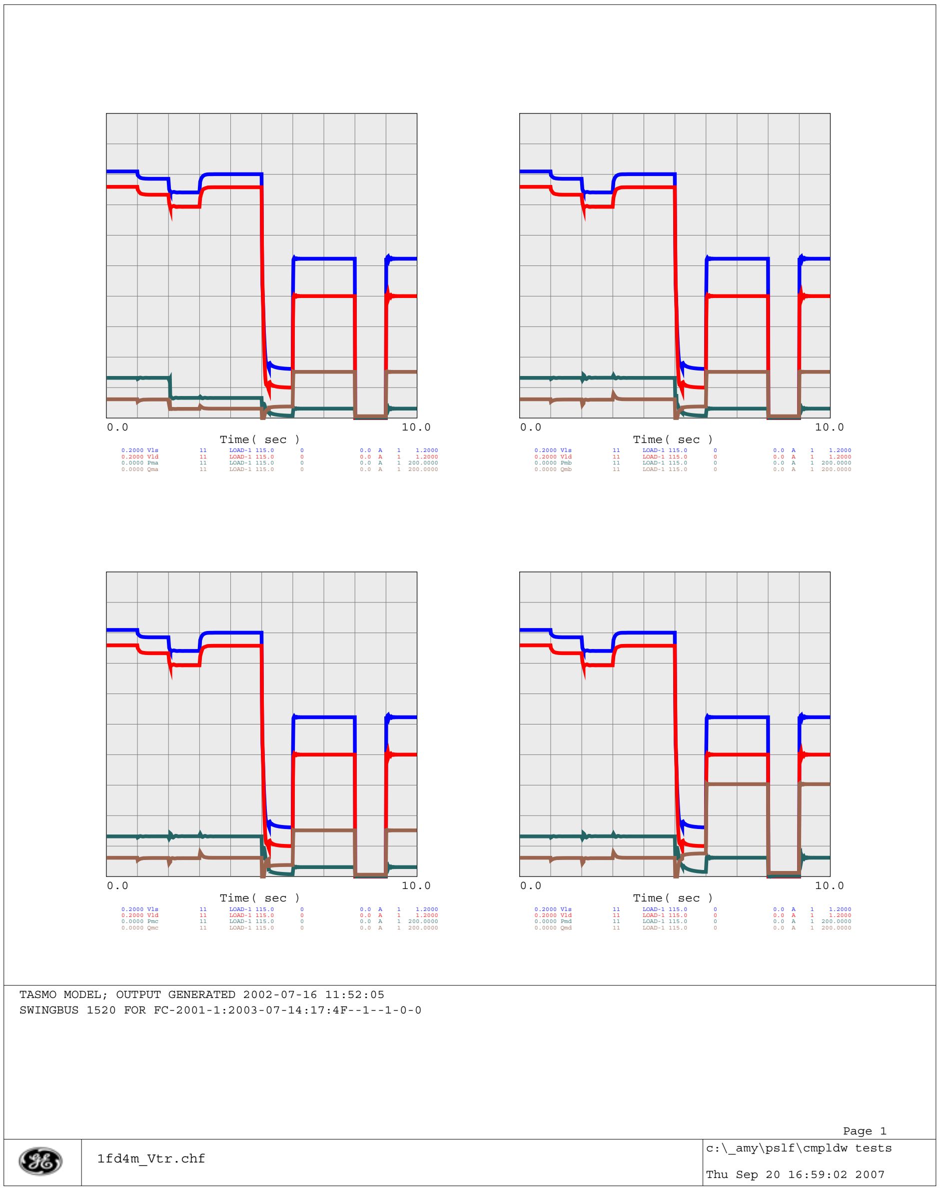


MA: Vtr2A=0.9

MB: Vtr2B=0.6

MC: Vtr2C=0.3

MD: Vtr2D=0.1

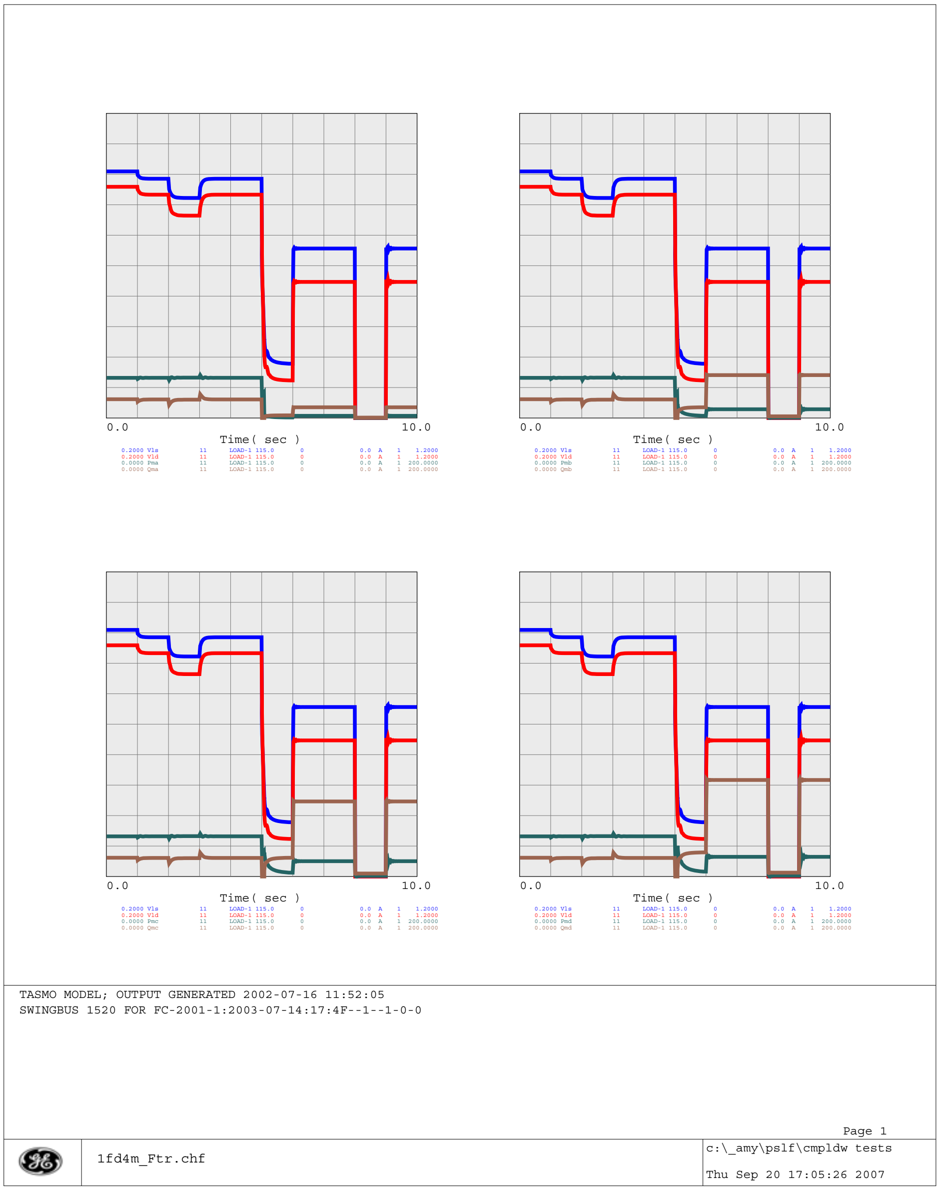


MA: Ftr2A=0.9

MB: Ftr2B=0.6

MC: Ftr2C=0.3

MD: Ftr2D=0.1

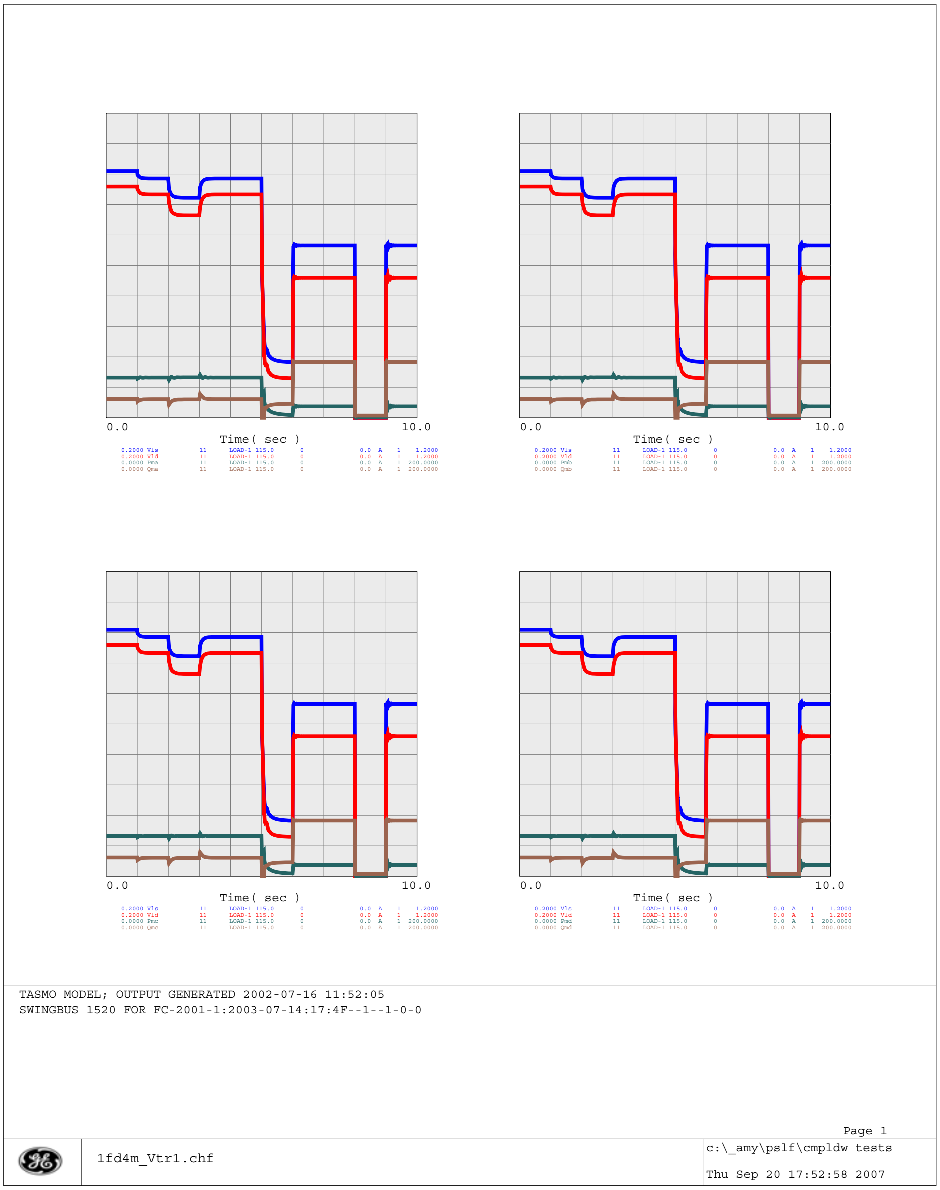


MA: Vtr1A= 0.9, Ttr1A= 2

MB: Vtr1B= 0.6, Ttr1B= 2

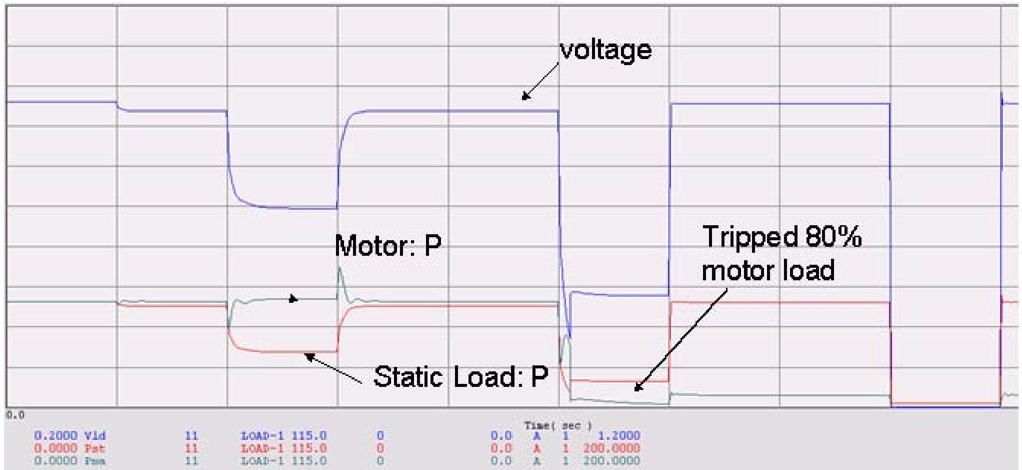
MC: Vtr1C= 0.3, Ttr1C= 2

MD: Vtr1D= 0.1, Ttr1D= 2



Appendix IV - One motor plus one static load

Voltage Sags



Appendix V - WECC Composite Load Model (CMPLDW) Specifications

WECC Composite Load Model (CMPLDW) Specifications
By Bill Price, GE Energy
June 8, 2007

- **Changes from previous (Feb. 8) specification version are in red.**
- **Features that are not yet implemented in PSLF V16.1 are in green.**
- **Overall Specifications**
  - **The overall structure of the CMPLDW model is shown in Figure 1.**

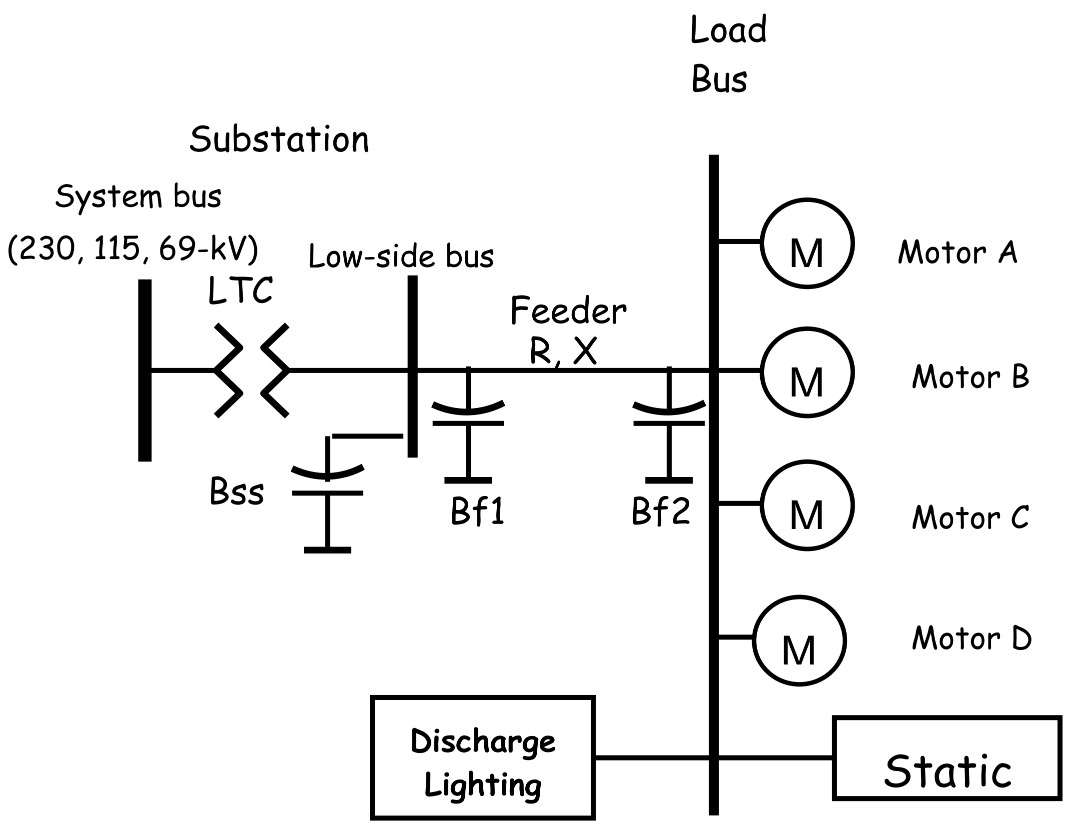


Figure 1 CMPLDW Model Structure

- **Any load can be represented in dynamic simulations by a CMPLDW model. All of the P and Q of the load will be included in the CMPLDW model.**

- Fractions of the load can be tripped by relay action via the load shed signal. Such tripping will simulate tripping an equivalent amount of aggregate feeder and of each load element, but not the substation transformer or capacitor (Bss).
- Static Load Model equations:

  $P = Po * (P1c * V/Vo^{P1e} + P2c * V/Vo^{P2e} + P3) * (1 + Pf * \Delta f)$

  $Q = Qo * (Q1c * V/Vo^{Q1e} + Q2c * V/Vo^{Q2e} + Q3) * (1 + Qf * \Delta f)$

  $Po = Pload\,(1. - Fma - Fmb - Fmc - Fmd)$

  $Qo = Po * \tan(\mathrm{acos}(PFs)) = Po * \mathrm{sqrt}(PFs^{-2} - 1.)$

  $P3 = 1. - P1c - P2c$

  $Q3 = 1. - Q1c - Q2c$

  Convert to constant G, B below specified V (solpar.vlbrk)

- Motor Mechanical Load Model:

  $Tm = Tmo * (a * \omega^2 + b * \omega + c + d * \omega^e)$

  $c = 1. - a - b - d$

  [WWP - Suggest replacing with $Pm = Pmo * \omega^e$ for consistency with motorw and fewer input parameters.]

- Shunt capacitance – The feeder capacitors (Bf1 and Bf2) will be computed during initialization of the dynamic simulation to produce the total Q at the system bus. Calculation of Bf1 uses input parameter fb (fraction of B at substation) based on assumed motor power factor of 0.8. After motor initialization, Bf2 is set to remaining required B.
- If LTC data is present for substation transformer, initial tap is set to put low side voltage approximately in middle of Vmin to Vmax range.

- For each composite load model, input data will be:
  - Location – bus number, (name, kV), load ID
  - MVA=xxx – feeder & xfmr MVA base
    - if xxx > 0., xxx is the MVA base.
    - if xxx < 0, abs. value = loading factor = load MW / MVA base
    - if xxx = 0., loading factor = default value (0.8)
  - Bss - Substation shunt B (pu of MVA base)
  - Feeder
    - Rfdr - Feeder R (pu of MVA base)

- Xfdr - Feeder X (pu of MVA base)
- Fb –fraction of feeder reactive compensation applied at the substation end of the feeder

If Xfdr = 0., feeder is omitted, but feeder capacitor is included.

- **Substation transformer**

  If (xxf > jumper threshold), include the following:
  - Xxf – transformer reactiance – p.u. of xfmr MVA base
  - Tfixhs – High-side fixed xfmr tap
  - Tfixls – Low-side fixed xfmr tap
  - LTC – LTC flag – (1=active; 0=inactive)
  - Tmin - LTC min tap (on low side)
  - Tmax - LTC max tap (on low side)
  - Step - LTC Tstep (on low side)
  - Vmin - LTC Vmin (low side pu)
  - Vmax - LTC Vmax (low side pu)
  - Tdel - LTC Control time delay (sec.)
  - Ttap - LTC Tap adjustment time delay (sec.)
  - Rcmp - LTC Rcomp (pu of xfmr MVA base)
  - Xcmp - LTC Xcomp (pu of xfmr MVA base)
- **Load composition**
  - Fma - Motor A fraction
  - Fmb - Motor B fraction
  - Fmc - Motor C fraction
  - Fmd - Motor D fraction
  - Fdl – Discharge Lighting fraction
  - NOTE: If sum < 1., remainder is static load; if sum > 1, fractions are nomalized to 1. and there will be no static load.
- **Static load parameters**
  - PFs - Power factor
  - P1e - P1 exponent
  - P1c - P1 coefficient
  - P2e - P2 exponent
  - P2c - P2 coefficient
  - Pfrq – frequency sensitivity
  - Q1e - Q1 exponent
  - Q1c - Q1 coefficient
  - Q2e - Q2 exponent
  - Q2c - Q2 coefficient
  - Qfrq – frequency sensitivity
- **Motor A parameters (omit if Motor A fraction = 0.)**

- **Motor B parameters (omit if Motor B fraction = 0.)**
- **Motor C parameters (omit if Motor C fraction = 0.)**
- **Motor D parameters (omit if Motor D fraction = 0.)**
- **For each motor (x) that has positive fraction:**
  - Mtypx - Motor type (3=3-phase; 1=single-phase non-restarting; 2=single-phase restarting)
  - LFmx - Loading factor (MW / MVA rating)
  - Ra
  - Lsx
  - Lpx
  - Lppx
  - Tpox
  - Tppox
  - Hx
  - atrqx Torque coeff. for w^2
  - btrqx Torque coeff. for w
  - dtrqx Torque coeff. for w^e
  - etrqx Torque speed exponent
  - Vtr1x - U/V Trip1 V (pu)
  - Ttr1x - U/V Trip1 Time (sec)
  - Ftr1x - U/V Trip1 fraction
  - Vrc1x - U/V Trip1 reclose V (pu)
  - Trc1x – U/V Trip1 reclose Time (sec)
  - Vtr2x - U/V Trip2 V (pu)
  - Ttr2x - U/V Trip2 Time (sec)
  - Ftr2x - U/V Trip2 fraction
  - Vrc2x - U/V Trip2 reclose V (pu)
  - Trc2x – U/V Trip2 reclose Time (sec)
  - NOTE: Reclosing a partially tripped motor will add tripped portion but will not model restarting; Reclosing a fully tripped motor will model restarting.
- If motor type = 1: [Details may change]
  - Vstx - Stall voltage (pu)
  - Gstx - Stall G (pu of motor MVA rating)
  - Bstx - Stall B (pu of motor MVA rating)
  - I2tx - Trip level after stall – Integral of I^2(?) (pu I^2-sec)
- If motor type = 2: [Details may change]
  - Vstx - Stall voltage (pu)
  - Gstx - Stall G (pu of motor MVA rating)
  - Bstx - Stall B (pu of motor MVA rating)
  - Vrstx - Restart voltage (pu)

Sample dyd records:

```
# Load with LTC transformer, two 3-phase motors
cmpldw  9999 “Bus xyz”  230.0  “L1”  : #3 MVA=0.77 “Bss” 0.2 “Rfdr” 0.02 “Xfdr” 0.1 “Fb” 0. /
 “Xxf”   0.12 “Tfixhs”  0.97  “Tfixls”  1.0  “LTC”   1.   “Tmin”  0.9  “Tmax”  1.1 “step”   0.0625 /
“Vmin”  0.98 “Vmax”  1.02  “Tdel”  30.  “Ttap”  5.   “Rcomp”  0.01  “Xcomp”  0.05 /
“Fma”   0.1  “Fmb”   0.08  “Fmc”   0.4  “Fmd”   0.0 “Fdl” 0.1 /
“Pfs”   0.9  “P1e”  2.  “P1c”  0.5 “P2e”   1.6  “P2c”   0.4  “Pf”    1.  /
             “Q1e”  2.  “Q1c”  0.5 “Q2e”   4.0  “Q2c”   0.4  “Qf”    -1.  /
“MtpA”  3.  “LfmA”  0.8 “RA”  0.02 “LsA”  3.0 “LpA”   0.25  “LppA”  0.15 /
 “TpoA”  0.5 “TppoA” 0.02 “HA”    0.2 “aA”   1.0  “bA”   0.0 “dA”    0.0  “eA”    0.0  /
“Vtr1A” 0.7 “Ttr1A” 0.5  “Ftr1A” 0.5 “Vrc1A” 999. “Trc1A” 999. /
“Vtr2A” 0.5 “Ttr2A” 0.0  “Ftr2A” 1.0 “Vrc2A” 0.65 “Trc2A” 1. /
“MtpB”  3.  “LfmB”  0.8 8 “RB”  0.02 “LsB”  0.9 “LpB”   0.5  “LppB”  0.2 /
 “TpoB”  0.5 “TppoB” 0.02 “HB”    0.2 “aB”   0.0  “bB”   0.0 “dB”    1.0  “eB”    1.2  /
“Vtr1B” 0.7 “Ttr1B” 0.5 “Ftr1B” 0.5 “Vrc1B” 999. “Trc1B” 999. /
“Vtr2B” 0.5 “Ttr2B” 0.0 “Ftr2B” 1.0 “Vrc2B” 0.65 “Trc2B” 1.0  /
#
# Load with no transformer and only one 3-phase motor
cmpldw  9999 “Bus xyz”  230.0  “L2”  : #2 MVA=0.78 “Bss” 0.0 “Rfdr” 0.02 “Xfdr” 0.1 “Fb” 0.3 /
“xxf” 0. “Tfixhs”  0.0  “Tfixls”  0.0  “LTC”   0.   “Tmin”  0.0  “Tmax”  0. “step”   0.0 /
“Vmin”  0.0 “Vmax”  0.  “Tdel”  0.  “Ttap”  0.   “Rcomp”  0.0  “Xcomp”  0.0 /
“Fma”   0.5  “Fmb” 0.0  “Fmc”  0.0  “Fmd”  0.0 “Fdl” 0.05 /
“Pfs”   0.9  “P1e”  2.  “P1c”  0.5 “P2e”   1.6  “P2c”   0.4  “Pf”    1.  /
             “Q1e”  2.  “Q1c”  0.5 “Q2e”   4.0  “Q2c”   0.4  “Qf”    -1.  /
“MtpA”  3.  “LfmA”  0.8 “RA”  0.02 “LsA”  2.5 “LpA”  0.5  “LppA”  0.2  “TpoA”  0.5 “TppoA” 0.02 /
“HA”    0.2 “aA”   1.0  “bA”   0.0 “dA”    0.0  “eA”    0.0  /
“Vtr1A” 0.7 “Ttr1A” 0.5 “Ftr1A” 0.5 “Vrc1A” 999. “Trc1A” 999. /
“Vtr2A” 0.5 “Ttr2A” 0.0 “Ftr2A” 1.0 “Vrc2A” 0.65 “Trc2A” 1.0
```

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- **Output variables will be:**
  - **Level 1**
    - Pld – Total MW at system bus
    - Qld – Total MVAr at system bus
  - **Level 2**
    - Vls – pu voltage at substation low-side bus
    - Vld – pu voltage at load end of feeder
  - **Level 3**
    - Pst – Static load component MW
    - Qst – Static load component MVAr
    - Pma – Motor A MW
    - Qma – Motor A MVAr
    - Pmb – Motor B MW
    - Qmb – Motor B MVAr
    - Pmc – Motor C MW
    - Qmc – Motor C MVAr
    - Pmd – Motor D MW
    - Qmd – Motor D MVAr
    - Pdl – Discharge lighting load MW
    - Qdl – Discharge lighting load MVAr
  - **Level 4**
    - spda – Motor A speed (pu)
    - Tma – Motor A Current (pu)
    - Tea – Motor A speed (pu)
    - spdb – Motor B speed (pu)
    - Tmb – Motor B Current (pu)
    - Teb – Motor B speed (pu)
    - spdc – Motor C speed (pu)
    - Tmc – Motor C Current (pu)
    - Tec – Motor C speed (pu)
    - spdd – Motor D speed (pu)
    - Tmd – Motor D Current (pu)
    - Ted – Motor D speed (pu)
  - **Level 5**
    - Fma – fraction of Motor A in operation
    - Fmb – fraction of Motor B in operation
    - Fmc – fraction of Motor C in operation
    - Fmd – fraction of Motor D in operation
  - **Include "metering" models**
    - Total CMPLDW outputs for zone, area, and whole system

- Total load loss due to motor tripping

- **Initialization process:**
  1. Get total load P & Q, system bus V from load flow
  2. Add low-side bus and load bus to Ymatrix
  3. Add xfmr,feeder, and substation cap. (Bss) to Y matrix
  4. Compute low-side bus voltage.
  5. Adjust LTC tap to put low-side voltage near midpoint of range.
  6. Estimate feeder shunt (Bf) requirement using static load Q and estimated motor Q (based on 0.8 power factor).
  7. If Bf < 0. (inductive), reduce Bss to make Bf = 0.
  8. Set Bf1 = Fb*Bf.
  9. Compute far-end bus voltage.
  10. If far-end voltage is less than 0.95 p.u., or greater than 1.05 p.u., modify feeder X to bring within range. Adjust R to maintain same X/R ratio.
  11. Compute required far-end P and Q to match system bus P and Q accounting for losses in transformer, feeder, and shunts.
  12. Initialize motor models and static load models – obtain total Q of load components.
  13. Set Bf2 to match required Q at far-end bus.
- **Calculations during normal running:**
  - **sorc mode: (before network solution)**
    - Use low-side voltage, load voltage, and frequency from previous network solution
    - Compute current injection at load (far end) bus from motor and static load models.
    - If LTC tap has changed, compute current injections at system and low-side buses to reflect tap change. (Present logic changes tap and refactorizes Y matrix.)
  - **netw mode: (iteration with network solution)**
    - Update current injection at load bus from motor and static load models based on change in load bus voltage.
  - **alge mode: (after network solution)**
    - Check for tripping conditions and modify models as required
  - **rate mode: (diff. equation update)**
    - Update derivatives of state variables in motor models