Physical Load Model Description

The following describes a physical load model approach based on given P and Q load at 115 kV buses. This type of physical load structure is commonly used by GE in harmonic studies and is considered to be a reasonable approach to use in the NU cable project TOV analysis. The model includes a damped transformer, a resistive load component, a motor load component (locked rotor representation), and power factor correction capacitance. Note that there will always be uncertainty in the load representation because there is very little data (only P,Q) on the actual loads. Also, note that these models do not include non-linearities of transformers nor do they include power electronics based load.

The physical load model structure (Figure A1) and definition are described below.

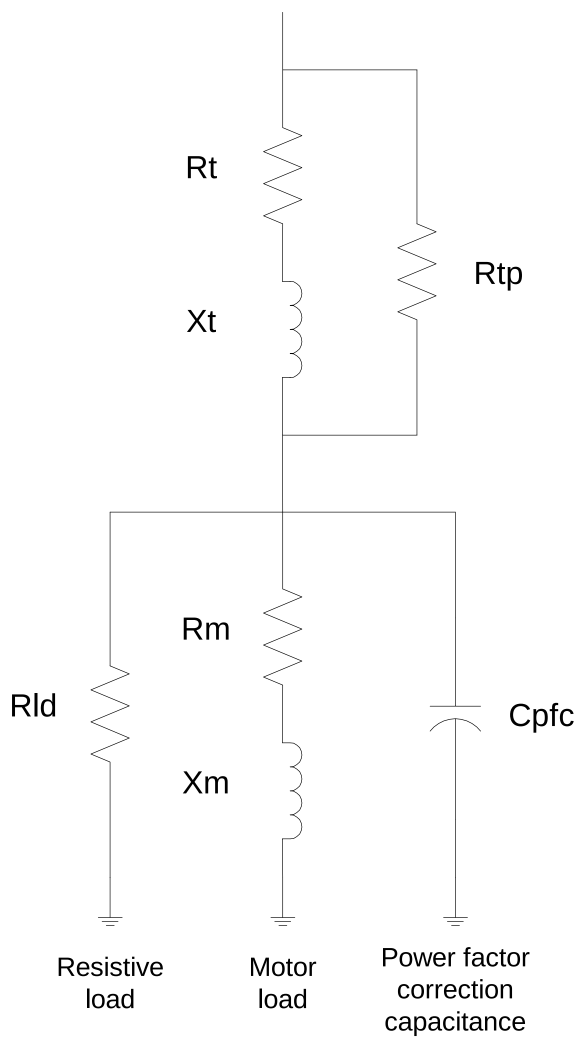


Figure A1. Physical Load Model Structure

Given Data/Definitions	Comments
P100, Q100 at 115 kV buses	P (MW) and Q (MVAR) at 100% load
S100=sqrt(P100^2 + Q100^2)	
kld=0.7	Load level (e.g., 70%, 50%, 40%)
Pload=P100*kld	
Qload=Q100*kld	
Sload=sqrt(Pload^2 + Qload^2)	
pfload=Pload./Sload	Given power factor
Vbase=115	Load bus voltage (kV)

Assumptions/Calculations	Comments
pfunc=0.88	assumed uncompensated power factor (constant for all load buses)
km=0.25	assumed motor load portion
kr=0.333	assumed resistive load portion
xfrmva=S100	load transformer ONAN rating, based on approximate average of loading using some NU load transformer ratings that were known
Zbase= Vbase^2/xfrmva	all impedances in pu on load transformer MVA base
Xt=0.2 pu	transformer leakage reactance, accounts for two transformations and distribution feeder reactance - positive sequence (X0>>X1)
Rt=Xt/20	positive sequence (R0>>R1)
Rtp=100*Xt	positive sequence (R0>>R1)
Ppu=Pload/xfrmva	P in pu of xfrmva
Rld=1/(Ppu*kr)	pu
Xmotor=0.2 pu	Typical motor reactance
Xm=Xmotor/(Ppu*km)	Equivalent motor reactance for given power level
Rm=Xm/2	pu
Qunc=Pload*tan(acos(pfunc))	assumed uncompensated MVAR
Qdiff=(Qunc-Qload)/2	assume half of power factor correction
Xpfc= Vbase^2/Qdiff	Ohms
Bpfc=1/Xpfc	Mhos
Cpfc=Bpfc/377	Farads

Example – Ridgefield A 115 kV	Comments
P100=27.4 MW	P (MW) and Q (MVAR) at 100% load
Q100=7 MVAR	
S100=28.28 MVA	
kld=0.7	Load level (70%)
Pload=19.18 MW	
Qload=4.9 MVAR	
Sload=19.8 MVA	
pfload=0.969	Given power factor
Vbase=115	Load bus voltage (kV)
pfunc=0.88	assumed uncompensated power factor (constant for all load buses)
km=0.25	assumed motor load portion
kr=0.333	assumed resistive load portion
xfrmva=28.28 MVA	Actual load transformer ONAN rating at Ridgefield is 25 MVA
Xt=93.53 ohms (Lt=248.1 mH)	positive sequence (X0>>X1)
Rt=4.676 ohms	positive sequence (R0>>R1)
Rtp=9353 ohms	positive sequence (R0>>R1)
Rld=2071 ohms	
Xm=551 ohms (Lm=1463 mH)	
Rm=275.8 ohms	
Bpfc=206.1 micromhos	
Cpfc=0.5468 microFarads	

Above physical load model parameters were based on a more detailed physical load model analysis that included a 115/13.8 kV transformer and two 13.8 kV load buses separated by distribution feeders. The load buses each had another transformer feeding resistive and motor load. Variations of the split between motor load and resistive load were considered in addition to motor parameters and assumed uncompensated power factor. The model given above is a conservative fit of impedance magnitude and a similar angle of the default parameters, as shown in the following figure (Figure A2) for Ridgefield A 70% load (magenta curve is the model given above). The figure includes comparisons with other load models: R-L series, R-L parallel, CIGRE load model (R-L series with L parallel), and a model proposed by Enernex. The angle characteristic indicates level of damping and is important in addition to the impedance magnitude.

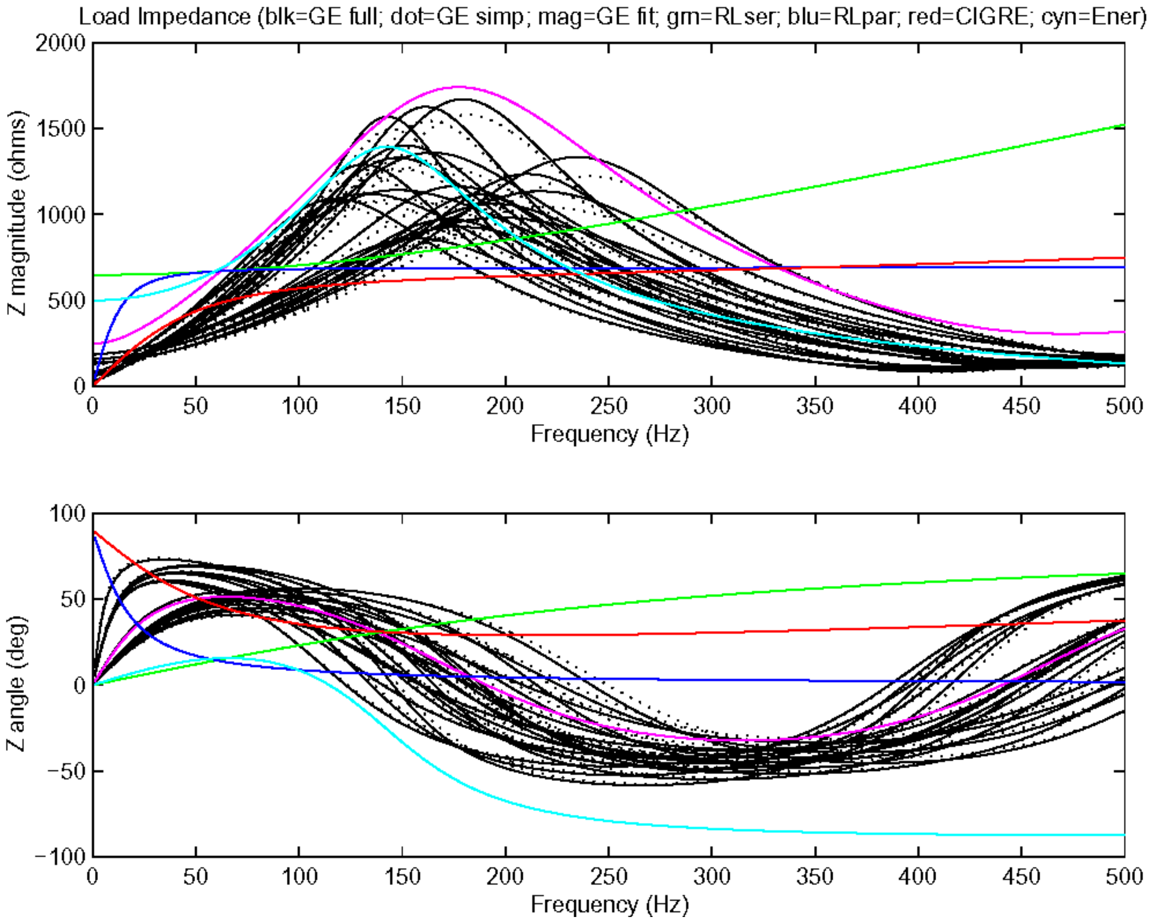


Figure A2. Load Model Impedance at Ridgefield 115 kV

The following plots (Figures A3 and A4) show the driving-point impedance magnitude and angle vs. frequency at Plumtree 345 kV with and without load for two cases:

- Plumtree-Long Mountain line and E. Devon-Beseck line out, 70% load conditions
- All lines in, 50% load conditions

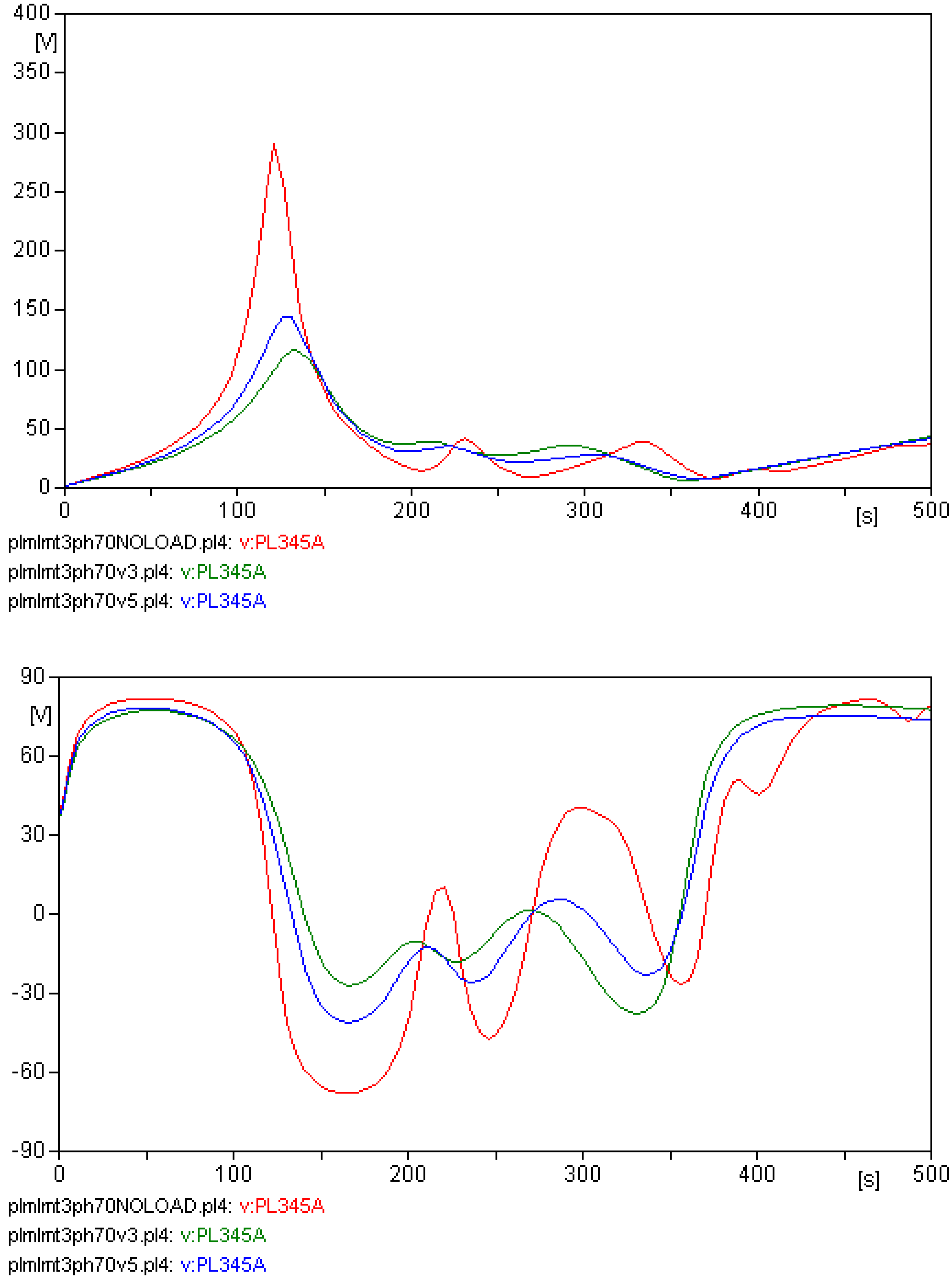
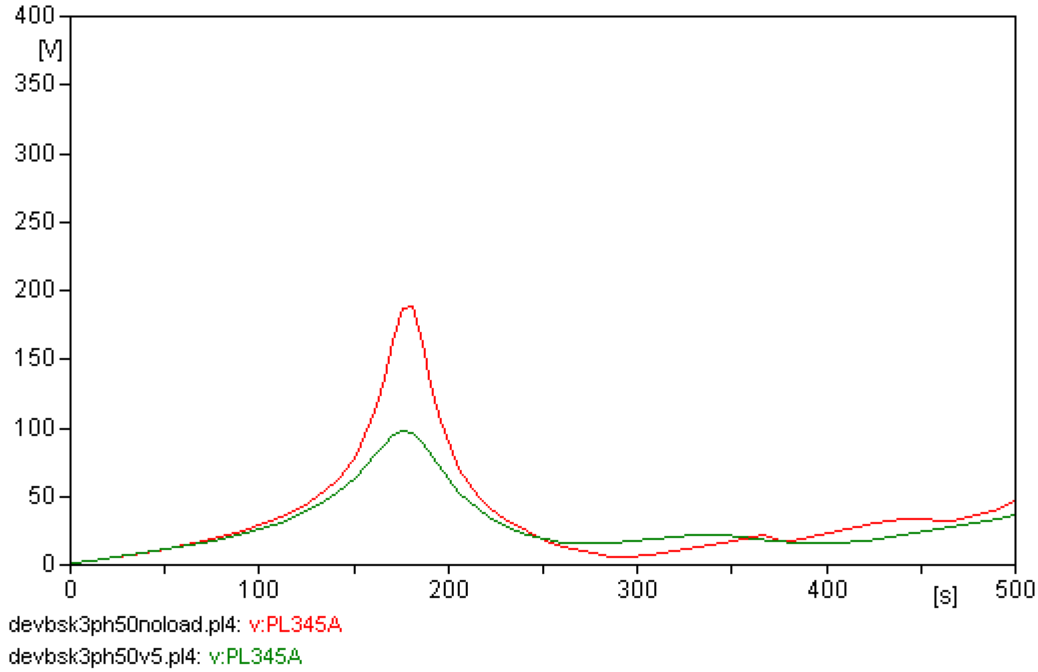


Figure A3. Driving-Point Impedance at Plumtree 345 kV (Magnitude-ohms, Angle-deg)
2 lines out (D-B, P-LM), 70% Load Conditions
__No Load, __GE Physical Model (Default Parameters - Full Detail),
__GE Physical Model (Conservative Fit)



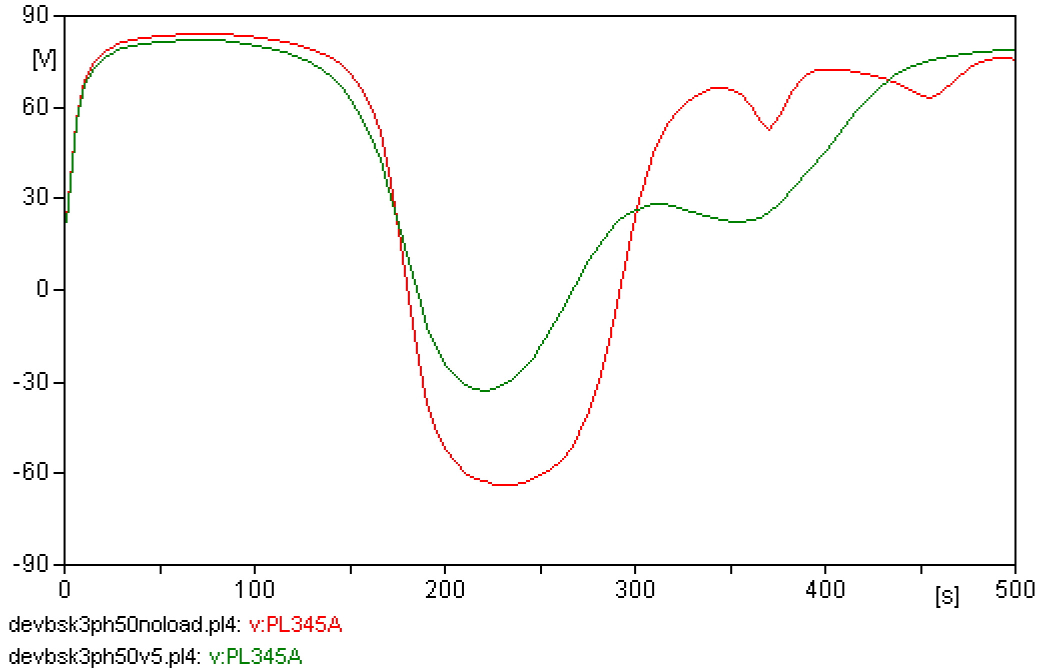


Figure A4. Driving-Point Impedance at Plumtree 345 kV (Magnitude-ohms, Angle-deg)
All Lines In, 50% Load Conditions
__No Load, __GE Physical Model (Conservative Fit)