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Generator Models Comparison Results

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Abstract

This memo describes preliminary simulation results indicating that the dynamic responses of the GENROU and GENTPJ models are different from each other, when using the same reactances and time constants on both models, even when magnetic saturation is neglected.

Based on the evidence of these simulations, a few items need to be discussed:

1. moving from GENROU to GENTPJ cannot be done simply using the same parameters as given in an existing GENROU model;
2. if the GENTPJ model is to be used, changes in the parameters should be accepted, when moving from GENROU to GENTPJ, in order to preserve/match the dynamic response of the model; and
3. changing a validated (MOD-026) GENROU model to a GENTPJ model with the same parameters is probably violating the intent of MOD-026, as the GENTPJ model (with the same parameters as the original GENROU model) will result in a different dynamic response, which might no longer match the measured/recorded response of the equipment.

1 Introduction

The generator model is based on the Lambton generator model (555.5 MVA) described in the literature. The magnetic saturation is neglected ($S(1.0) = 0.001$, ($S(1.2) = 0.002$, and $Kis = 0$), so the GENROU and GENROE models provide the same results. Also, the GENTPF and GENTPJ models should provide the same results, but the GENTPF model is not available in PSS/E, so it wasn't tested.

The parameters for the generator model were randomly varied within somewhat typical ranges for round rotor units. Despite the random selection of the values for the reactances, these selected values still respect the following relationships:

$$X_d \geq X_q > X'_q > X'_d > \left(X''_d = X''_q\right) > X_\ell \tag{1.1}$$

The following simulations were performed for each set of generator parameters:

1. reactive power (0 pf) load rejection, with the unit under-excited and operating on manual excitation control (constant field voltage);
2. open circuit (full speed, no load) 2% step in voltage reference setpoint on the automatic voltage regulator (AVR);
3. full load 2% step in voltage reference setpoint on the AVR;
4. 5000 MVA fault at the HV side of the generator step-up (GSU) transformer, cleared in 100 ms with the trip of one (out of three) parallel circuits between the HV side bus and the infinite bus.

The GSU is assumed to have 10% reactance on the generator MVA base, while the three parallel circuits between the GSU HV bus and the infinite system have 30% reactance (on the generator MVA base) each, resulting in an additional equivalent 10% reactance between the HV bus and the infinite bus. Thus, the total external impedance in the online cases is 20% on the generator MVA base.

These simulations were repeated for 1000 different sets of generator parameters. Fig. 1 and Fig. 2 present the calculated total error in terminal voltage E_t (GENROU and GENTPJ models) for the simulations of the reactive power load rejection and the full load 2% step in voltage reference, respectively. The errors from these two figures cannot be directly compared to each other, as the errors are calculated for the total duration of the simulations, which are different. Also, the simulation of the full load 2% step in voltage reference assumes that the AVR is in service, and the presence of the excitation system closed-loop control in the simulation has a significant impact on the overall simulation, somewhat masking the differences between these generator models.

Based on these calculated errors, Table 1 presents the generator parameters for two of these cases, while the simulation results are shown in the following figures. Traces in black correspond to the results with the GENROU model, while the traces in blue are related to the GENTPJ model.

Table 1: Generator Parameters for Shown Cases

Parameter	Case 261	Case 267
T1d0	4.29	4.79
T2d0	0.033	0.074
T1q0	1.35	1.23
T2q0	0.05	0.035
Xd	2.07	2.108
Xq	1.995	2.027
X1d	0.165	0.131
X1q	0.502	0.426
X2d	0.103	0.105
Xl	0.083	0.075
S(1.0)	0.001	0.001
S(1.2)	0.002	0.002
Kis	0	0

2 Conclusions

Using the same generator parameters (same reactances and same time constants, often referred to as the operational parameters of the generator model) for the GENROU and the GENTPJ models lead to different dynamic responses. These differences are very evident in the generator field current, in all cases. For case 261, the differences for the terminal conditions (terminal voltage, active and reactive power) were not very large, but differences in oscillation damping for the online step response and in the time constant associated with the voltage decay following the 0pf load rejection are still clearly observed. On the other hand, the results for case 267 are quite different when using the GENROU or the GENTPJ models, with the same operational parameters.

These two cases are approximately the most extreme cases in terms of the relative errors between the simulations. As seen in Fig. 1 and 2, all 1000 simulations resulted in differences between the results obtained with the GENROU model and the GENTPJ model, so Kestrel believes that replacing a GENROU model by a GENTPJ model using exactly the same operational parameters will result in differences in the dynamic response of the unit and therefore would modify and possibly invalidate a report associated with the model validation (NERC Std. MOD-026) that was based on the GENROU model.

It might be possible to calculate new (different) operational parameters for the GENTPJ model that would result in a match to the dynamic response of the GENROU model, at least for the terminal conditions. But it is important to recognize that changes to the operational parameters (reactances and time constants) might be required.

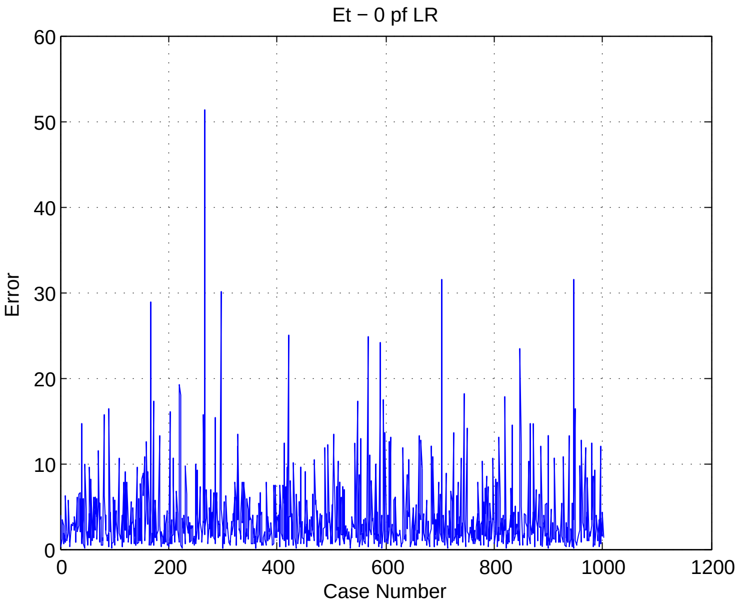

Figure 1: Calculated $\sum\left(E_{t_1} - E_{t_2}\right)^2$ for Reactive Power Load Rejection Simulations

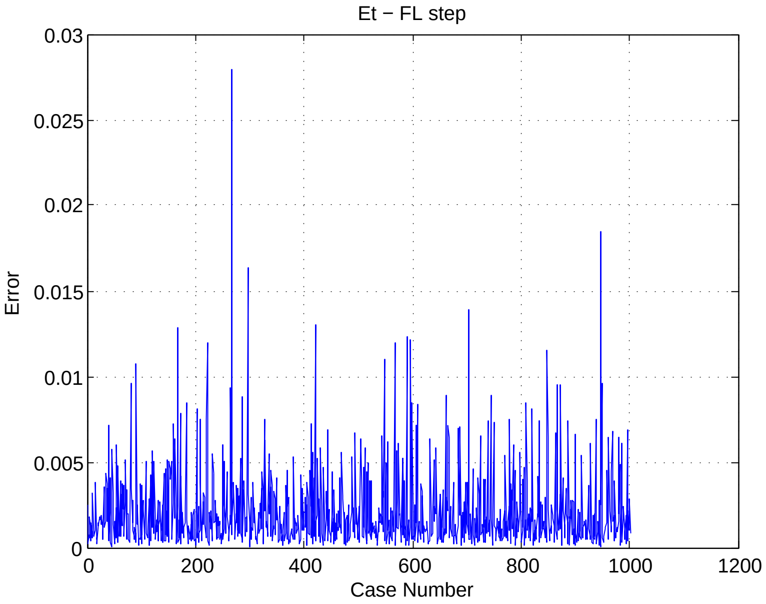

Figure 2: Calculated $\sum\left(E_{t_1} - E_{t_2}\right)^2$ for Online 2% Step Change Simulations

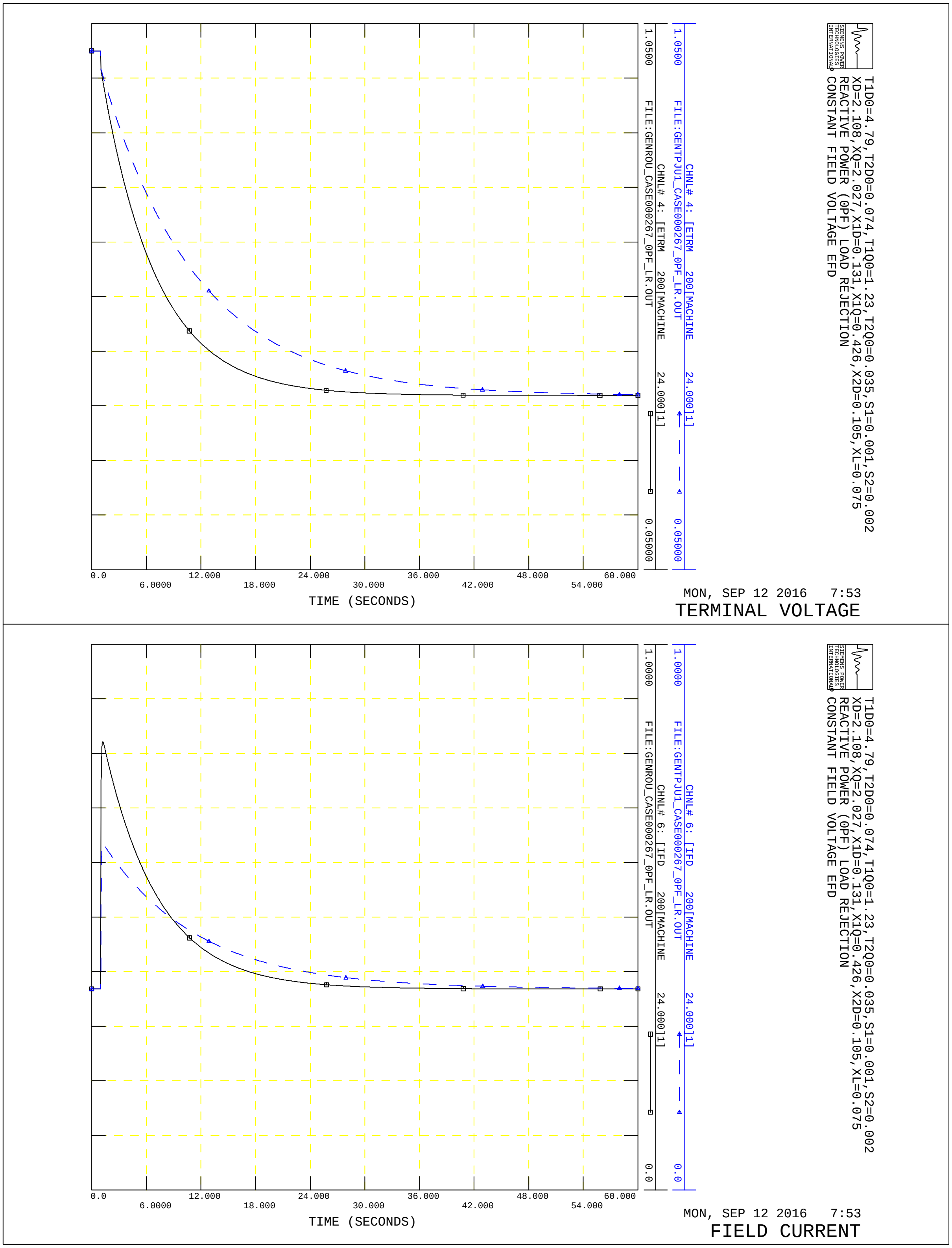

Figure 3: Case 267 - 0pf LR

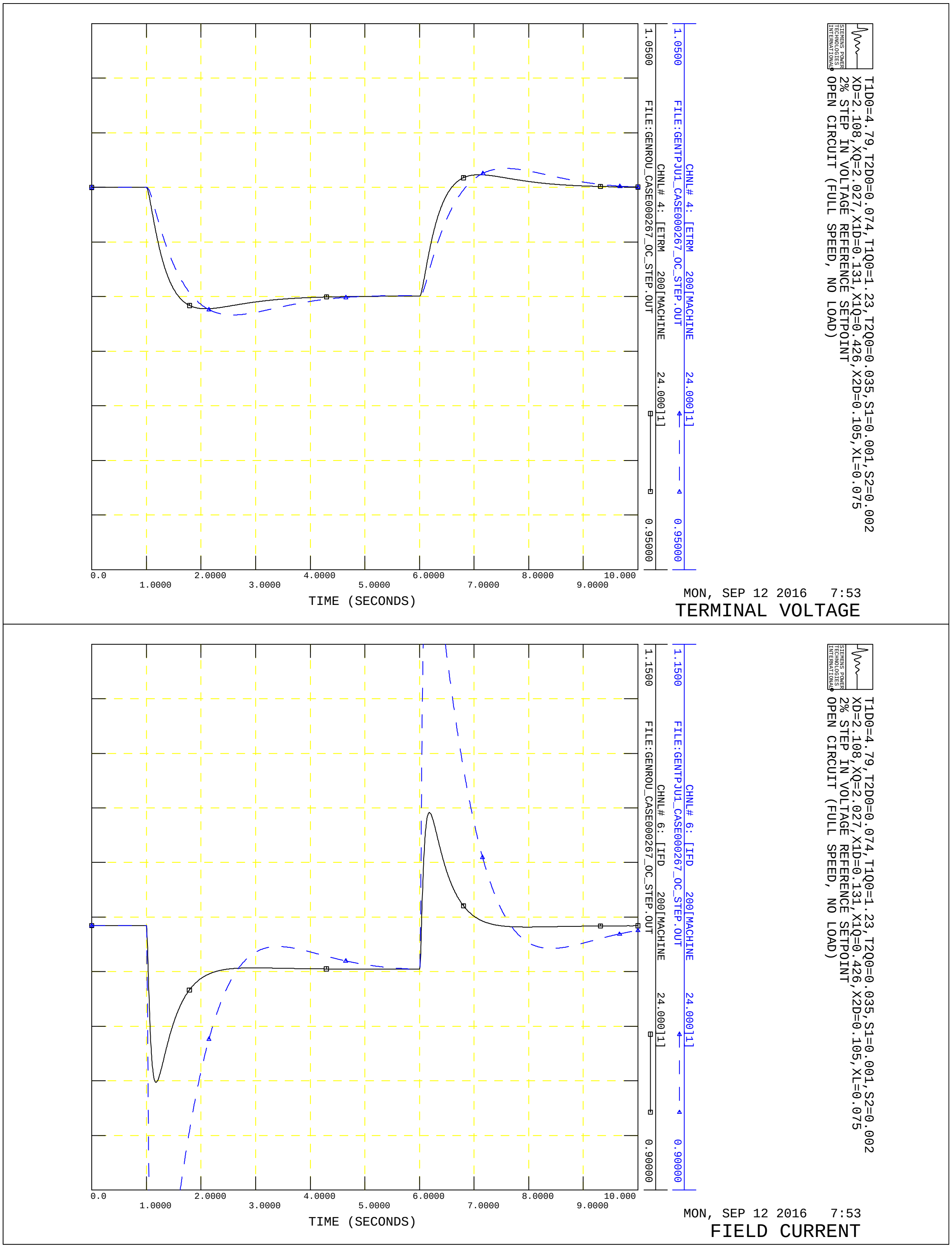

Figure 4: Case 267 - Open Circuit 0.02 pu Step in Vref

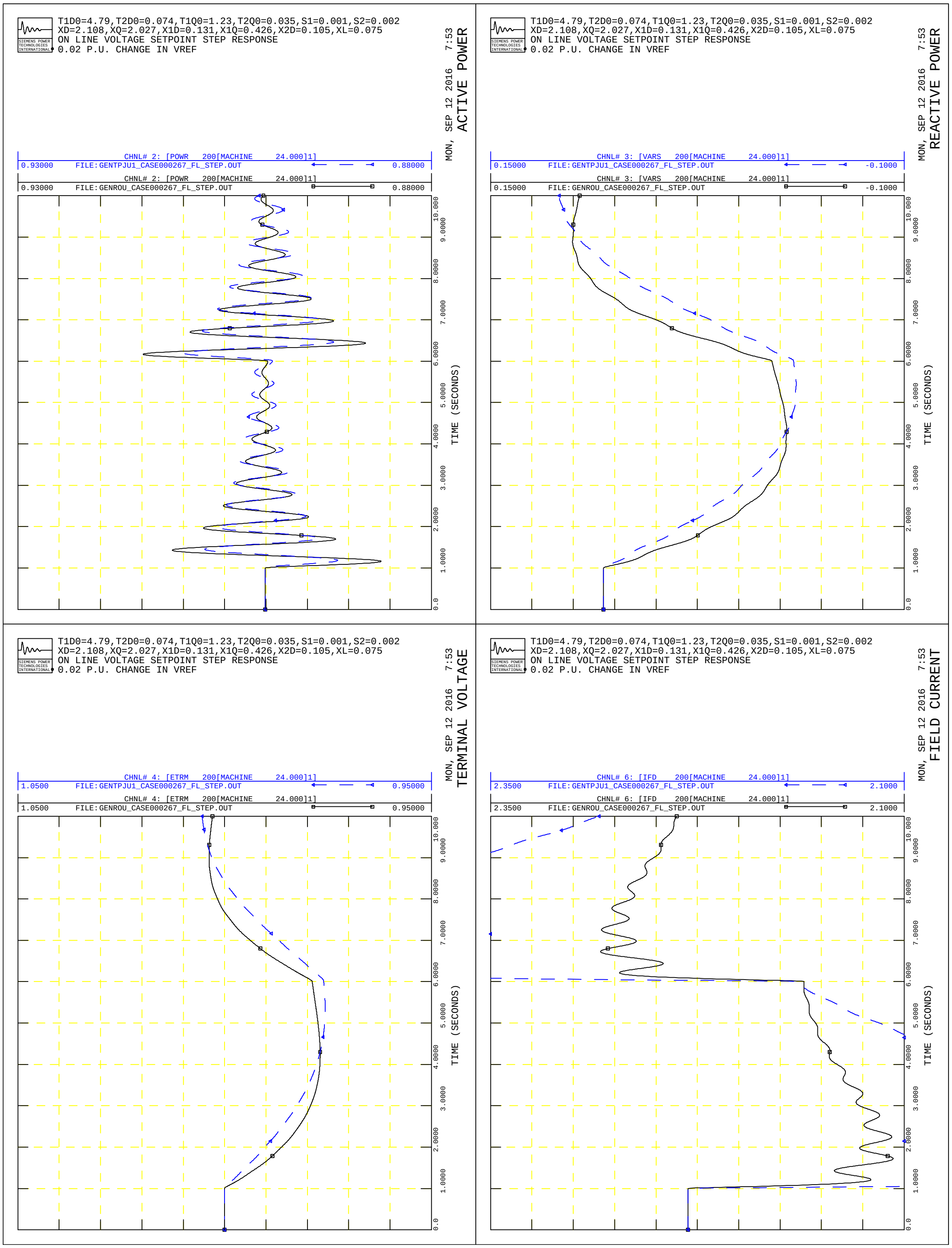

Figure 5: Case 267 - Full Load 0.02 pu Step in Vref

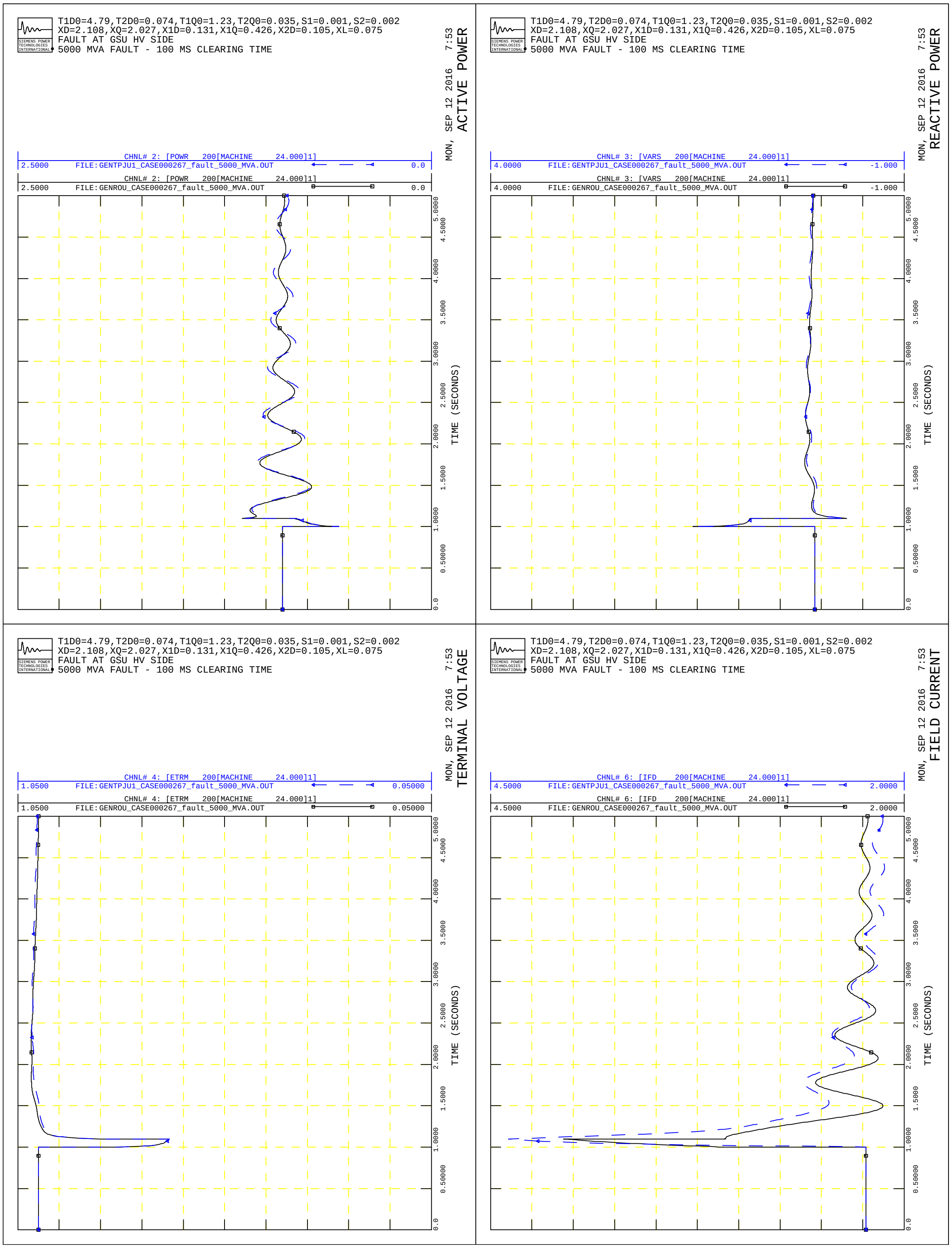

Figure 6: Case 267 - 5000 MVA Fault at GSU High-Voltage Side

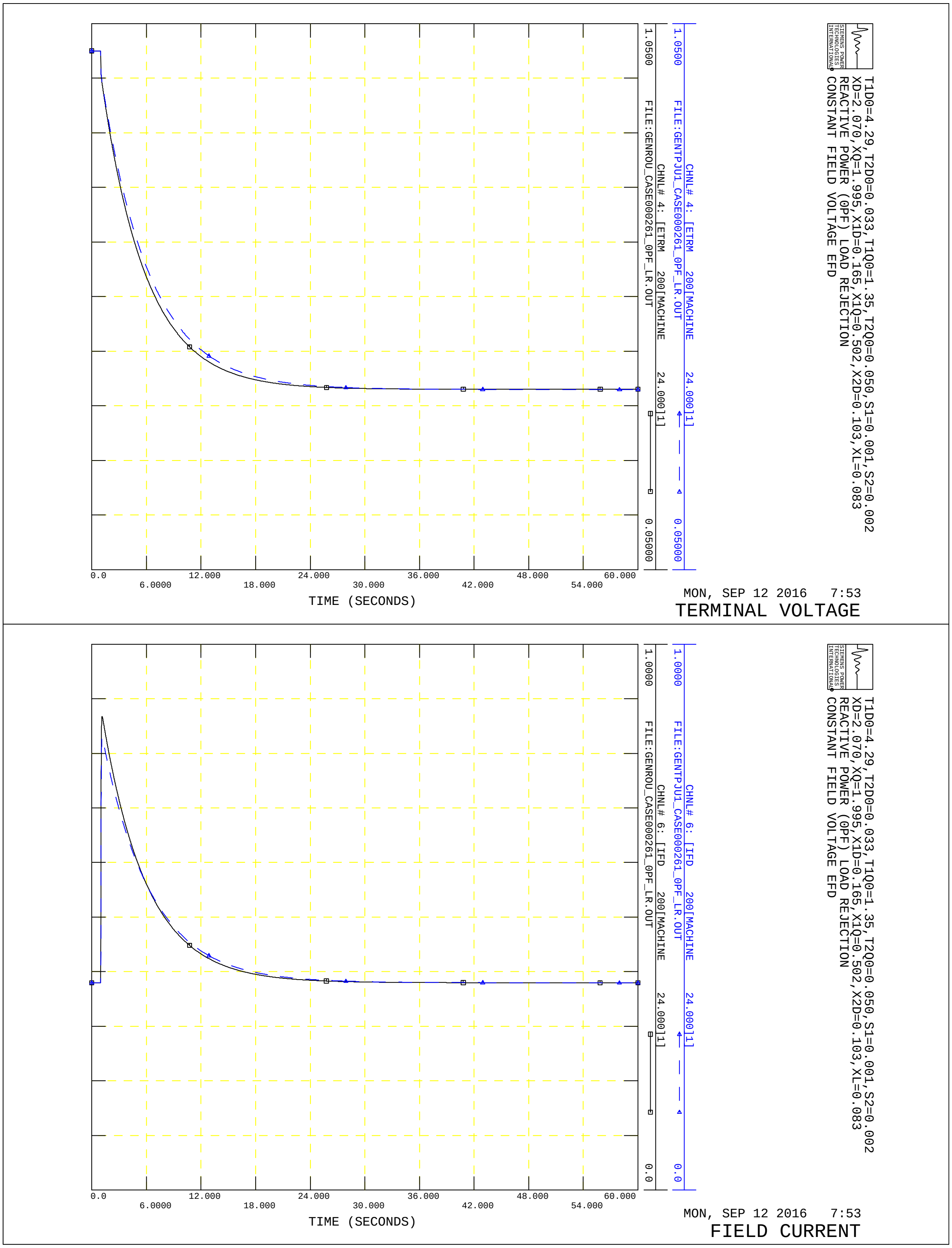

Figure 7: Case 261 - 0pf LR

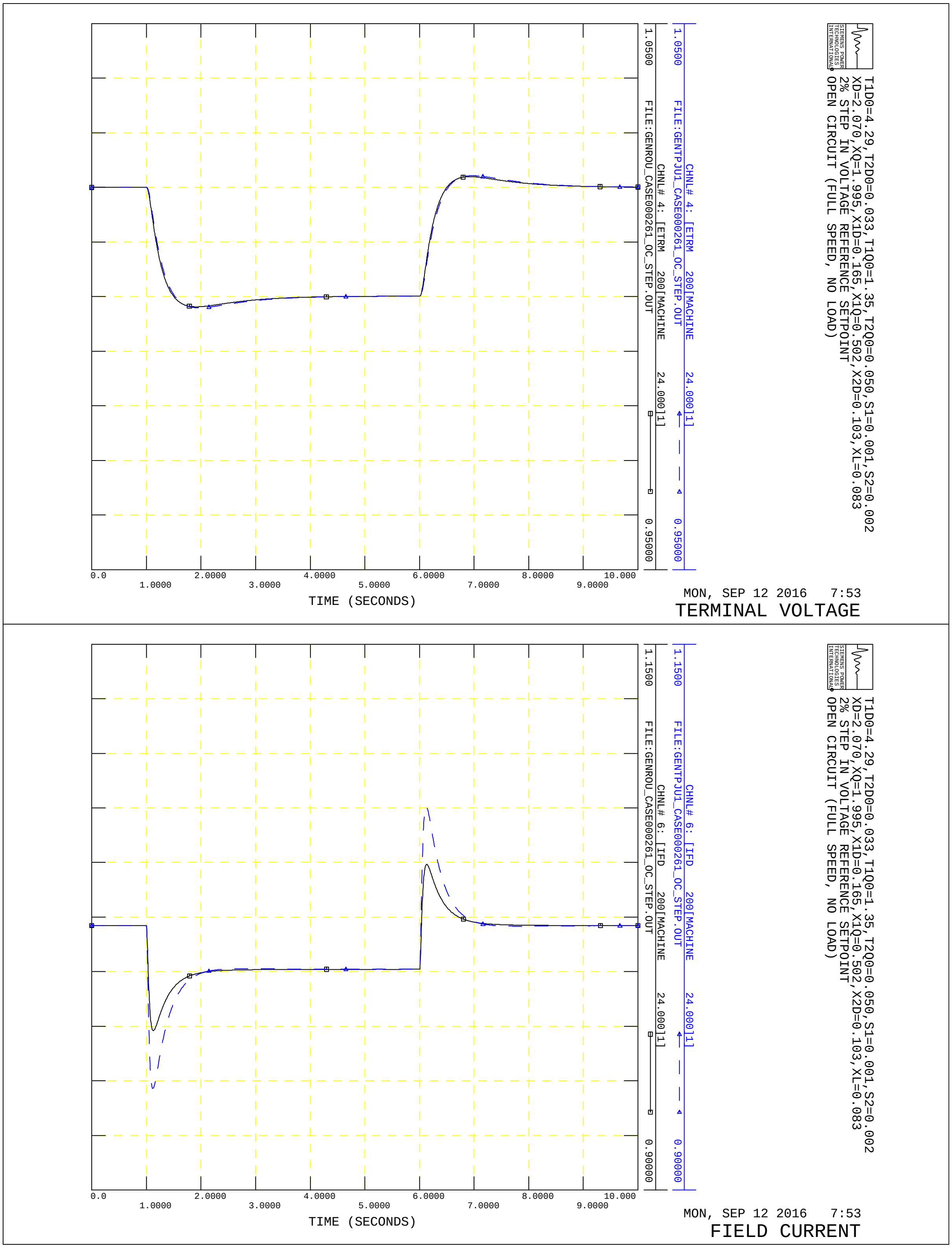

Figure 8: Case 261 - Open Circuit 0.02 pu Step in Vref

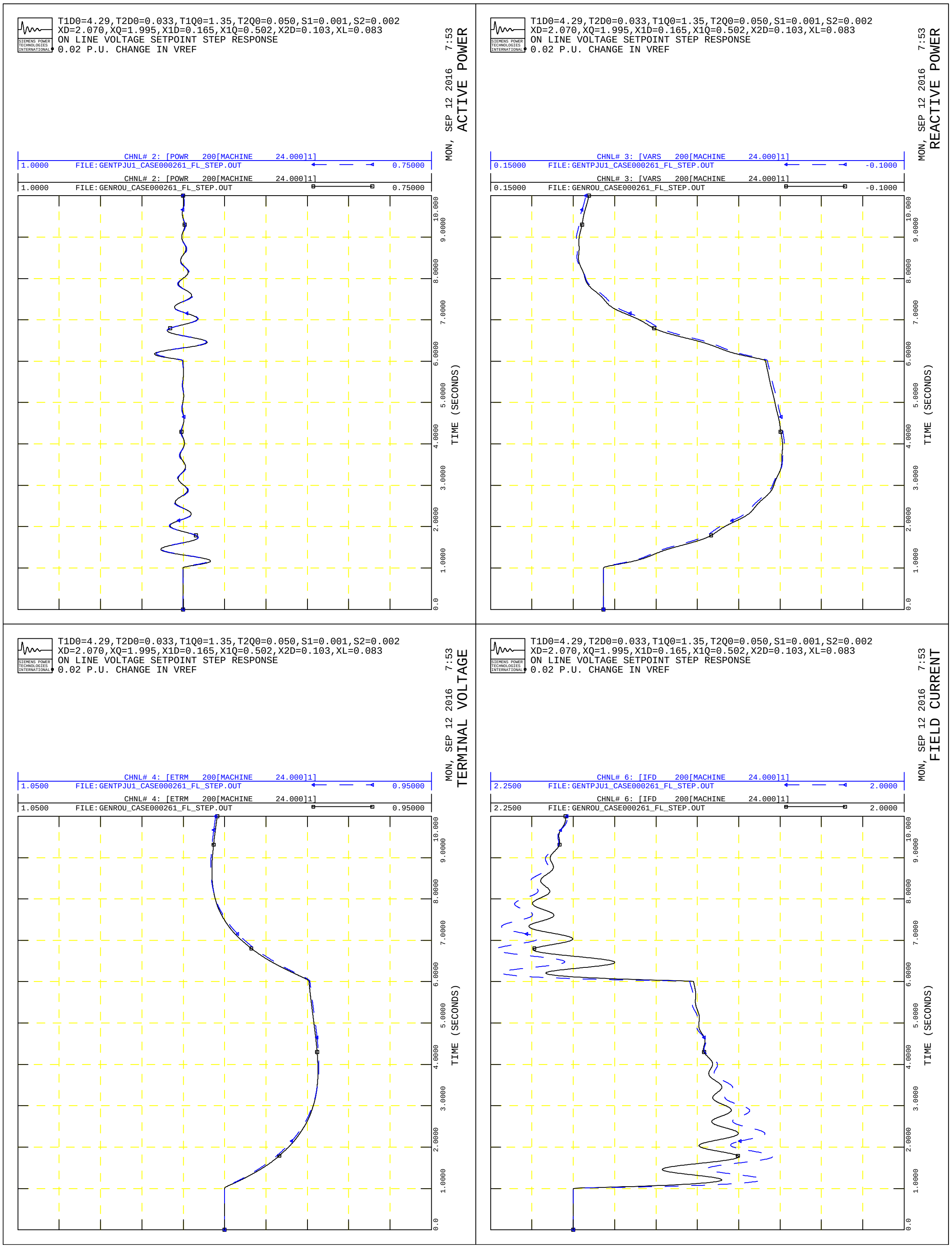

Figure 9: Case 261 - Full Load 0.02 pu Step in Vref

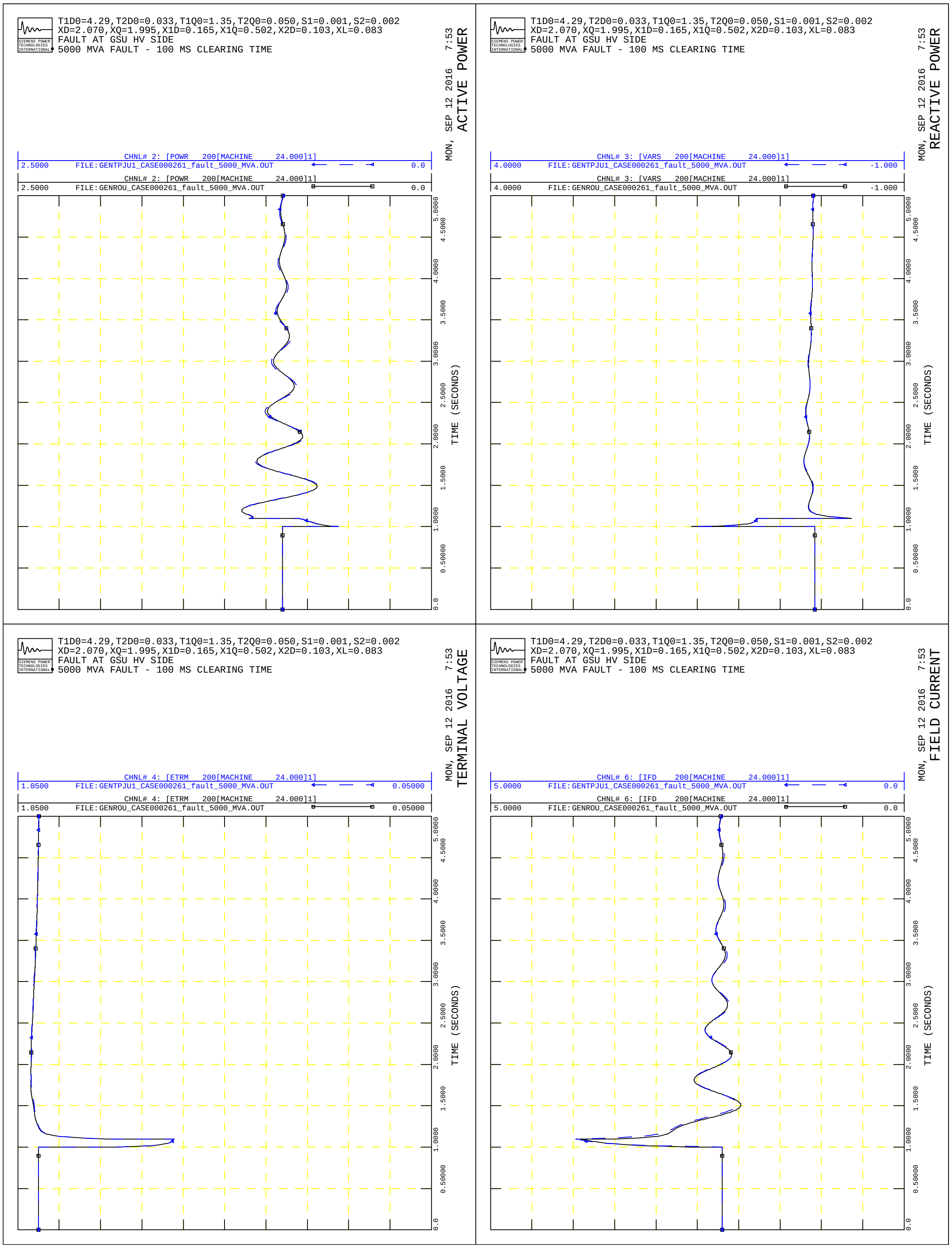

Figure 10: Case 261 - 5000 MVA Fault at GSU High-Voltage Side