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# Effective Micro Grid Stability Under Excitation Limiters in Islanded and Connected Modes

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**Abstract** In this paper the authors tried to design a under excitation limiter and a power system stabilizer which can operate without any kind of interaction. The under excitation limiter (UEL) is intended to prevent reduction of generator excitation to a level where the steady state stability limit or the stator core end-region heating limit is exceeded. The power system stabilizer (PSS) uses auxiliary stabilizing signals to control the excitation system so as to improve power system dynamic performance.

***Keywords:*** *power system operation, stability, under excitation limiter*

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## 1. Introduction

Stability of power system is one of the most significant issue in power system operation and planning [1,2,3]. Indeed, stability of the power system is involved in many other electrical problems. For instance in power electronics field, the stability of the system is analyzed in [4,5,6]. In power system operation, the stability of system is foci in [7,8]. By adding the renewable energies, the power stability decreased significantly. However, in [9], the stability of power system is solved. In [10,11,12] different methods are used to address the power system stability problems [13-25].

In this paper, coordinated Design of Under-Excitation Limiters and Power System Stabilizers is analyzed. The result proved the high efficiency and performance of the proposed technique. Also, the methods is applied for different stability status. All the simulation and results are done in Matlab software.

To sum up, this paper is organized as follows: Section 2 explained the proposed method to address the problem. In section 3, the simulation results are explained and discussed. Finally, section 4 argued about the conclusion of the research.

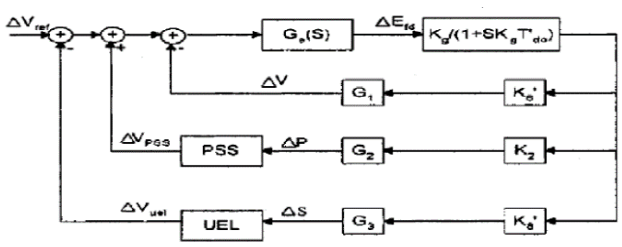


**Figure 1,** A typical bode plot of prior model

## 2. Proposed Method

The simplified Heffron-Phillips model with PSS and UEL control loops were shown in Figure 1. Next figure shows a typical bode plot of prior model.

Also, bode plot for a special case in shown as follows:

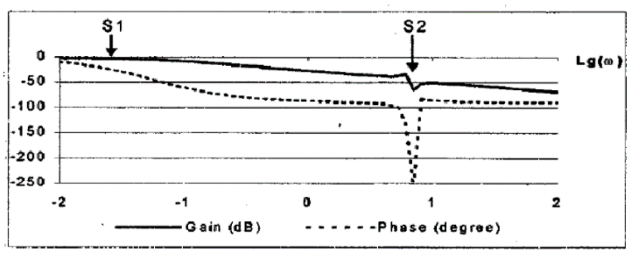


**Figure 2.** A typical bode plot of $\frac{\Delta S}{\Delta E_{fd}}$

In this special case

$$S1 = \frac{1}{Td_0 K_g}$$

$$S1 = \frac{1}{\sqrt{\frac{T_j}{2\pi f_0 K_1}}}.$$

We can see that the two break points (s1, s2) are typically two decades apart. Stability can be assured if the UEL is tuned in such a way that the cross-over frequency (ωc) is somewhere between the two break points.

As the generator heating time-constant is large compared to those associated with the usual electromechanical modes (0.5-2 HZ), it is necessary for the UEL to achieve a fast response characteristic. So (ωc) should be closer to the first break point in order to ensure adequate phase margin. The PSS is introduced so that a damping torque component is produced over a selected frequency range. The frequency range of interest is around the second break point. As this second break point is about two decades away from the first break point, it can be concluded that the proposed UEL tuning method will result in its control action having little effect on the PSS and vice versa [26-31].

## 3. Case Study and Results

Your paper must use a page size corresponding to A4 which is 210mm wide and 297mm long. The margins are set as follows: top= 15 mm, bottom= 15 mm, right=17.5 mm, left = 20 mm. Your paper must be in two column format with a space of 1.93 characters between columns [12,13,14,15].

The methods for designing UEL and PSS based on famous below diagrams are mentioned in the paper (Figure 4).

Also, the power system stabilize transfer function is shown in the next figure.

The extended excitation system and AVR model were used as shown below (Figure 5).

To simulate the prior blocks it's necessary to calculate (K1-K8) based on steady state power system model. I used of an M-file that shown as below for this matter. The outputs of the below program are K1-K8.

The algorithm in Matlab in defined as follows [16-28]:

```
Vd0=0.978;
Vq0=0.204;
Id0=0.978;
Iq0=0.204;
Vt0=0.999;
Xd=4.53;
Xq=Xd;
X1d=0.4;
X1q=X1d;
XT=0.06;
XL=0.2;
Xe=XT+XL;Ku=2;
Tj=6.11;
K1=(Vd0-X1d*Iq0)*(Vd0+Xe*Iq0)/(Xe+X1d)+(Vq0-
Xe*Id0)*(Vq0+X1q*Id0)/(Xe+X1q);
K2=(Vd0+Xe*Iq0)/(Xe+X1d);
K3=(Xe+X1d)/(Xe+Xd);
K4=(Vd0-Xe*Iq0)*(Xd+X1d)/(Xe+X1d);
K5=X1q*Vd0*(Vq0-Xe*Id0)/(Vt0*(Xe+X1q))-
X1d*Vq0*(Vd0-Xe*Iq0)/(Vt0*(Xe+X1d));
K6=Xe*Vq0/(Vt0*(Xe+X1d));
K7=(Vd0*Iq0*(X1d-Xe)+Iq0^2*X1d*Xe-
Vd0^2)/(Ku*(Xe+X1d))+(Vq0*Id0*(X1q+Xe)+Id0^2*X1q
*Xe-Vq0^2)/(Ku*(Xe+X1q))-
((Vd0*Id0+Vq0*Iq0)*(X1d*X1q-
Xe^2))/((Xe+X1d)*(Xe+X1q))-
((Vd0*Vq0+Iq0*Id0*Xe^2)*(X1d-
X1q))/((Xe+X1d)*(Xe+X1q));
K8=(Vq0+Xe*Id0)/(Xe+X1d)-
(Vd0+Xe*Iq0)/(Ku*(Xe+X1d));
```

Where K7 & K8 & K18 & C depend on Ku

```
K16=K6-K2*K5/K1;
K18=K8-K2*K7/K1;
Kg=K1*K3/(K1-K2*K3*K4);
A=Tj/(2*pi*60*K1);
B=K1*K6/(K1*K6-K2*K5);
C=K1*K8/(K1*K8-K2*K7);
```

By using the Simulink/MATLAB and the prior information these results could be achieve. From Figure 7 and Figure 8 we understand that the frequency region of the PSS operation is about mid frequency. And also, from Figure 9 it's clear that the frequency region of the UEL operation is about low frequency. Therefore the designed UEL does not have any interaction with designed PSS. Hence the example serves to illustrate the fact that design of the UEL and PSS can be considered separately as each of the control devices is effective over a different frequency range. Figure 10 describes the effect of the UEL slope Ku on system performance.

This is shown on Figure 10, where it's clear that changes in Ku have no effect on the low frequency region. When Ku exceeds 6, the changing of Ku does not improve the gain margin significantly. It is desirable to set Ku to as large a value as possible to ensure adequate damping.

For showing the effect of the UEL on the time response characteristic of the generator the following simulation with PSCAD/EMTDC was done. The simulation shows a reactor tripping in 2 sec.

From the prior results, it's clear that the designed UEL have a suitable effect on the generator stability.

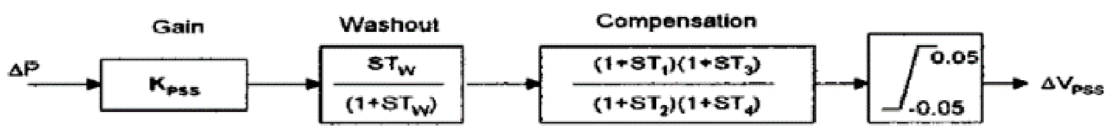


**Figure 3.** A power system stabilizer transfer function

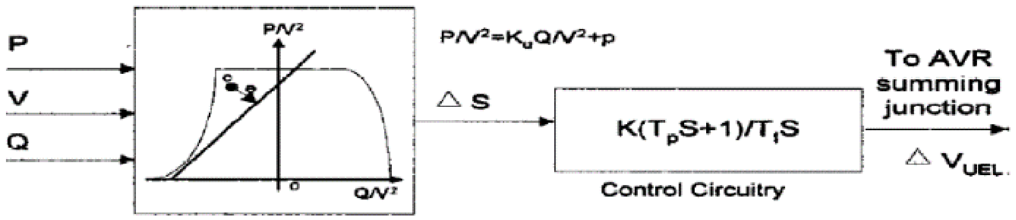


**Figure 4.** UEL Scheme

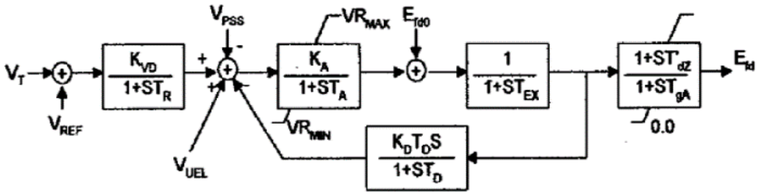


**Figure 5.** AVR model of G1

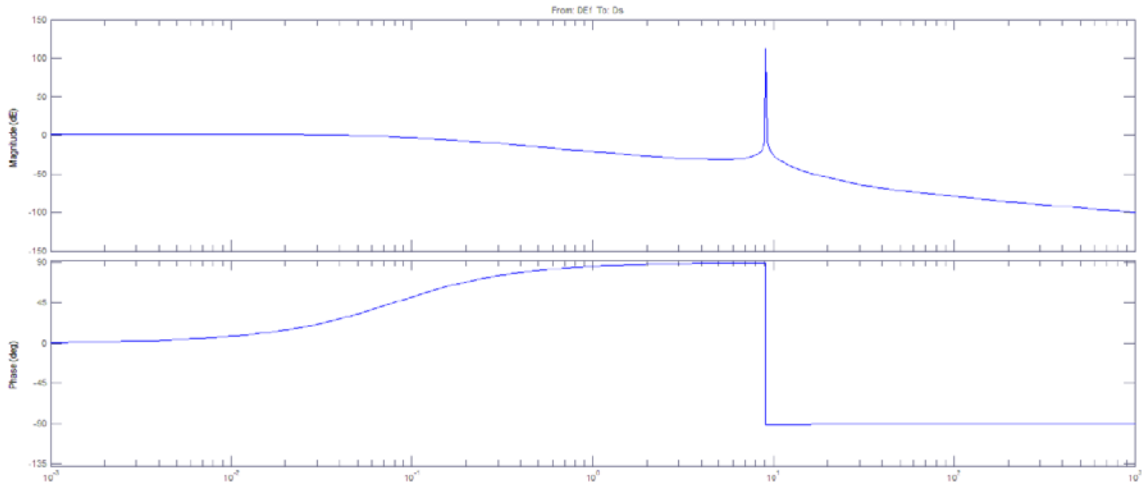


**Figure 6.** bode plot of $\Delta s/\Delta E_{fd}$

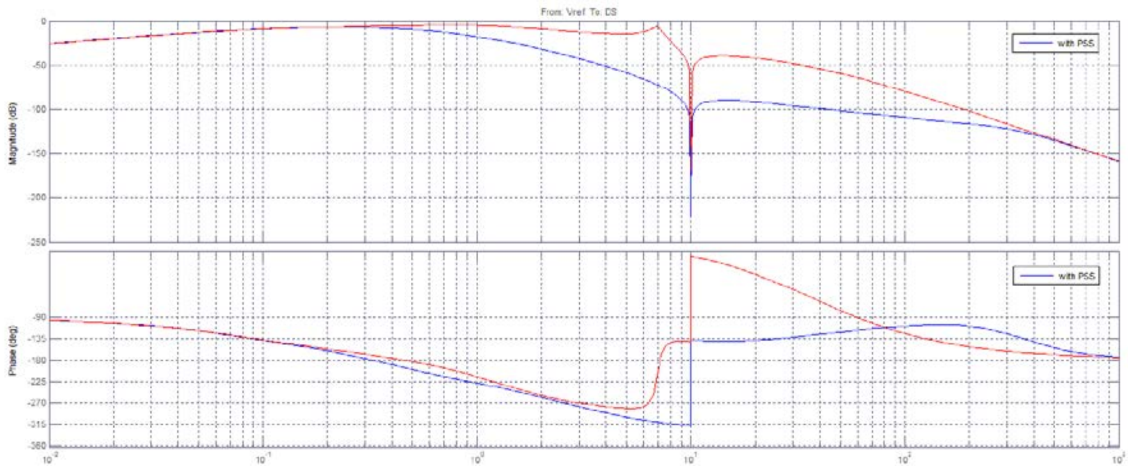


**Figure 7.** Body plot when XL=1

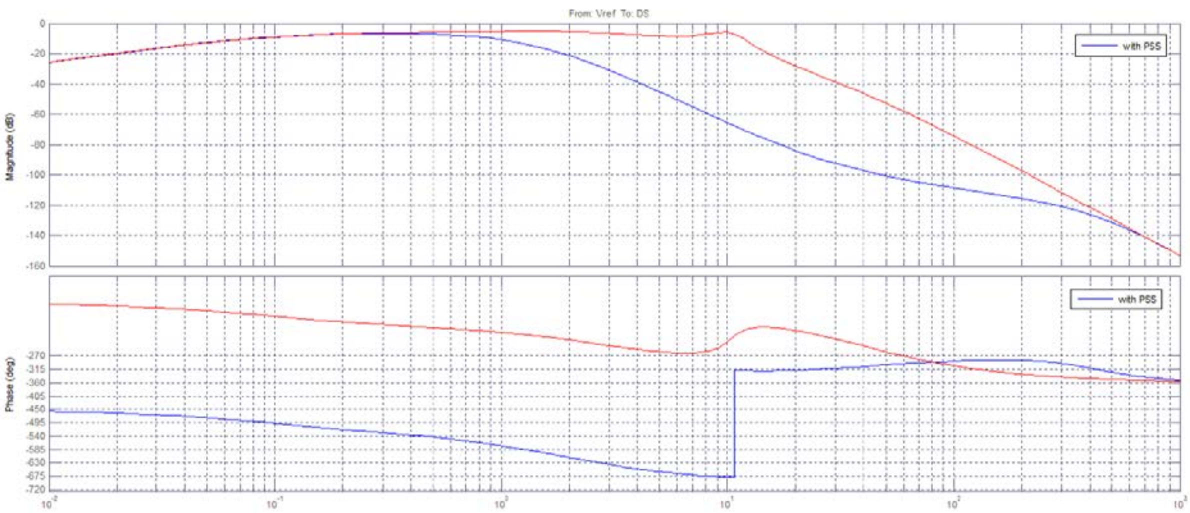


**Figure 8.** Body plot when XL=0.1

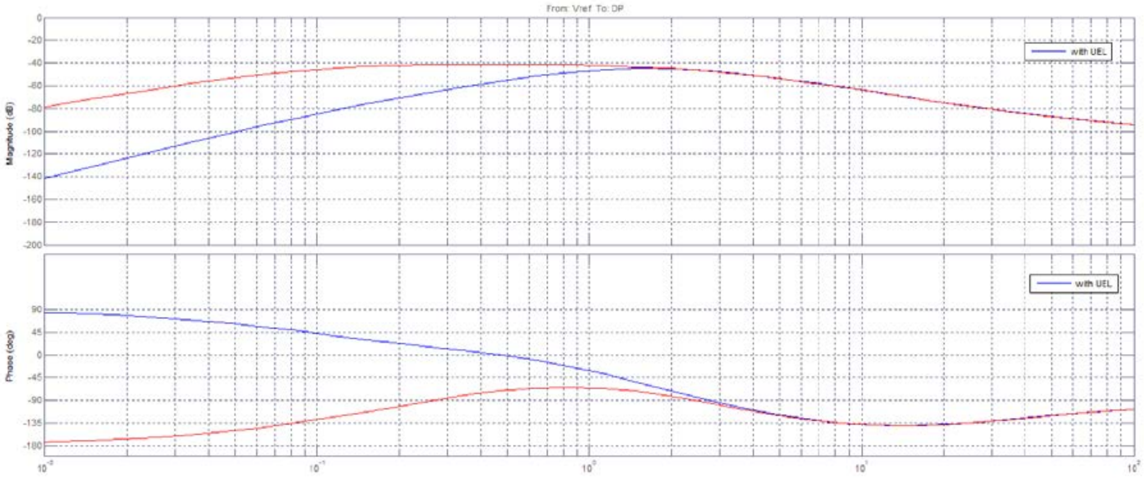


**Figure 9.** Body plot when $\Delta P/\Delta V_{ref}$

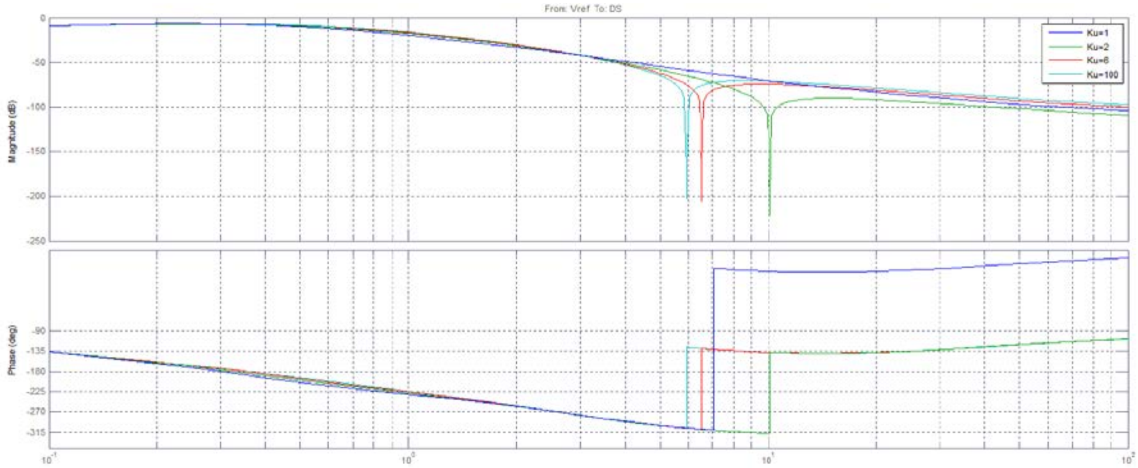


**Figure 10.** Body plot when $\Delta S/\Delta V_{ref}$ (effect of KU)

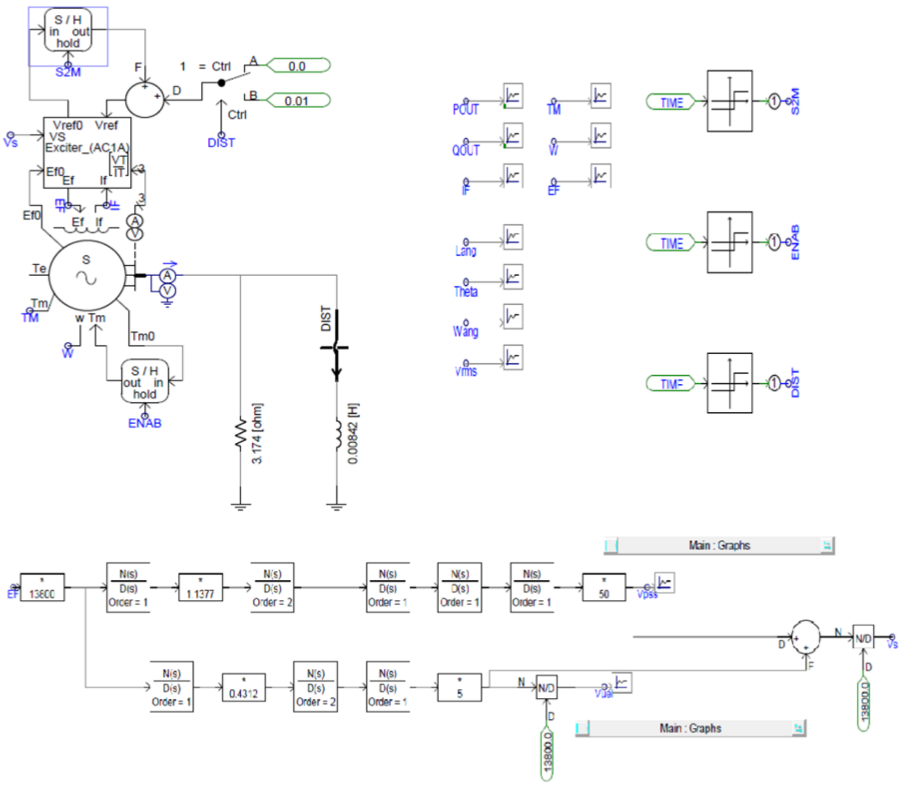


**Figure 11.** The main structure of the problem

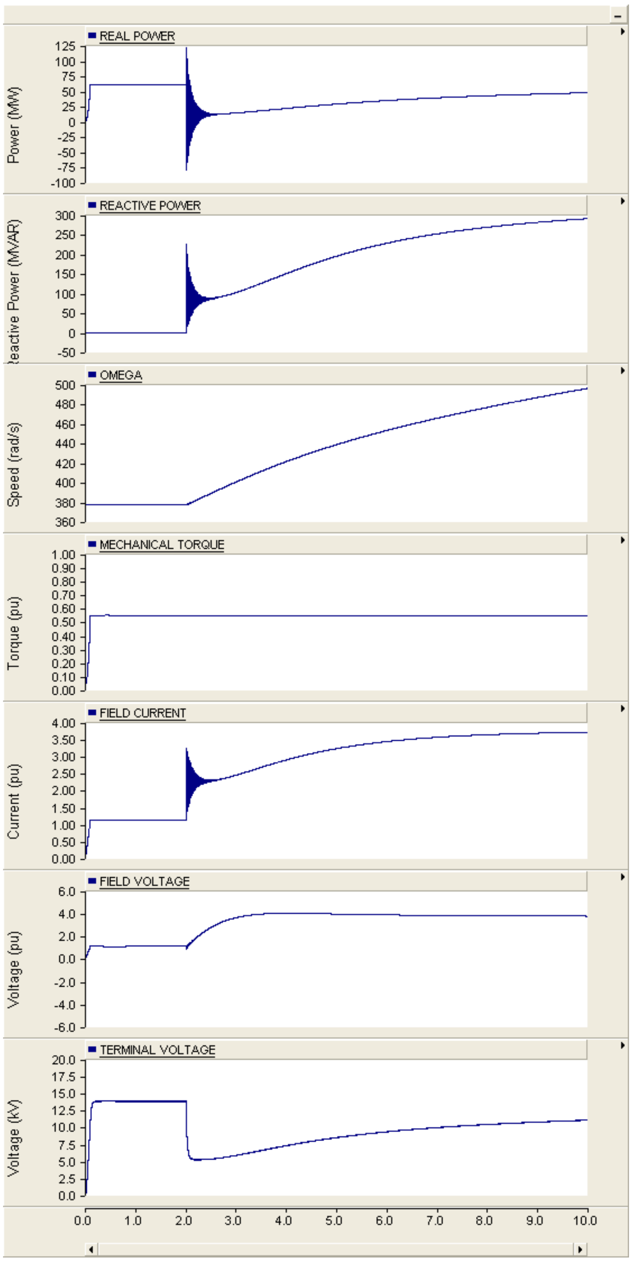


**Figure 12.** Time Response without UEL

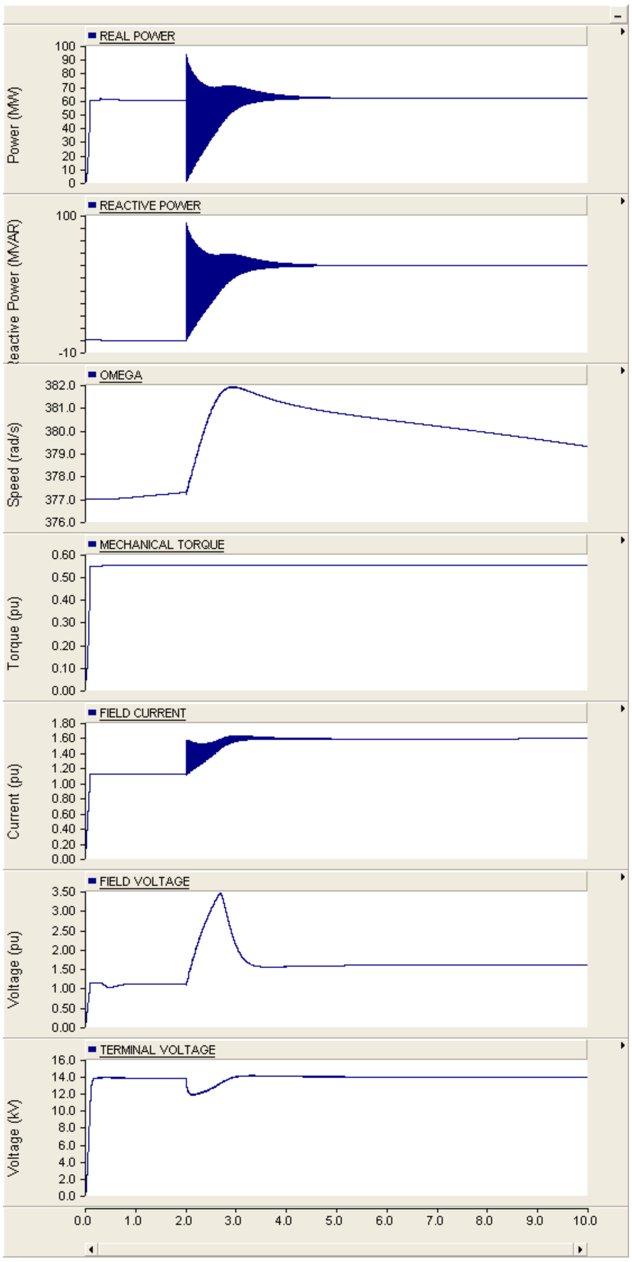


**Figure 13.** Time response with UEL

# 4. Conclusion

It has been shown that the tuning of the UEL and PSS can be carried out separately and without having to consider inter action between the two control loops. Effective control action of the UEL can be achieved by having Ku set to the highest value possible.

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