Lektion 4

4.1

Upg 1

```
l=350000; %m
V=500; %kV
f=50; %Hz
x=0.34; %Ohm/km
y=i*4.5*10^(-6); %S/km

L = x/(2*pi*f);
z= i*x;    % = i*omega*L där omega=2*pi*f
C=y/(i*2*pi*f);
```

a)

```
Zc=sqrt(z/y)
```

```
Zc = 274.8737
```

b)

```
gamma = sqrt(z*y)  % = i*beta
```

```
gamma = 0.0000 + 0.0012i
```

```
beta=imag(gamma);
```

c)

```
% f*lambda=1/(sqrt(LC))
lambda = 1/(f*sqrt(L*C))
```

```
lambda = 5.0797e+03
```

d)

```
SIL=V^2/Zc %MW
```

```
SIL = 909.5086
```

4.2

Upg 2

```
l=300000; %m
V=765000;
Zc=266.1;
lambda=5000000;
Vspu=1;
Vrpu=1;

SIL=V^2/Zc %W
```

```
SIL = 2.1993e+09
```

```
%P=Vspu*Vrpu*SIL*sin(delta)/(sin(2*pi*l/lambda))

delta=deg2rad(90);   %delta=90 ger maximal effektöverföring
P=Vspu*Vrpu*SIL*sin(delta)/(sin(2*pi*l/lambda))
```

```
P = 5.9742e+09
```

4.3

Upg 3

```
f=50; %Hz
S=500*10^6; %VA
V=15000; %V
P=32;
H=2; %p.u
D=0;
```

a)

```
omega_e=2*pi*f
```

```
omega_e = 314.1593
```

b)

$$\frac{2H}{\omega_{e,s}}\frac{d^2\delta_e}{dt^2} = P_{mpu} - P_{epu}$$

c)

```
delta0=deg2rad(10)
```

```
delta0 = 0.1745
```

d) Sätt in i svängekvationen

$$P_{mpu} = 1, P_{epu} = 0$$

e)

```
cycles=3;
t=cycles/f %seconds
```

```
t = 0.0600
```

$$\frac{d\delta(t)}{dt} = \frac{2\pi f}{4}t + 0$$

$$\delta(t) = \frac{2\pi f}{8}t^2 + 0.1745$$

0 och 0175 i slutet av uttrycken fås genom att se till att

begynnelsevillkoren uppfylls, dvs $\frac{d\delta(0)}{dt} = 0$ och $\delta(0) = 0.1745$.

f)

```
delta3cyc=2*pi*f/8 * t^2 + delta0 %rad
```

```
delta3cyc = 0.3159
```

```
rad2deg(delta3cyc)
```

```
ans = 18.1000
```

Lösningsförslag till 4.3e:

Felet inträffar vid $t=0$, allt snurrar ihop och generatorn har $\delta(0)=\delta_0$

Vid $t=0$ är $\omega_e-\omega_{e,s}=0$, Vi kallar $\omega_e-\omega_{e,s}=\Delta\omega$ dvs $\Delta\omega(t)=0$, vid $t=0$

$$\frac{d\Delta\omega}{dt}=\frac{d\omega_e}{dt}-\underbrace{\frac{d\omega_{e,s}}{dt}}_{=0}=\frac{\omega_{e,s}P_{mpu}}{2H}=K \Rightarrow \int_0^{\Delta\omega} d\omega=\int_0^t K\,d\tau \Rightarrow [\omega]_0^{\Delta\omega}=[K\tau]_0^t$$

$\Delta\omega(t)=Kt$, såhär driver vinkelhastigheterna ifrån varandra

$$\frac{d\delta}{dt}=\Delta\omega=Kt \Rightarrow \int_{\delta(0)}^{\delta(t_1)} d\delta=\int_0^{t_1} Kt\,dt \Rightarrow [\delta]_{\delta(0)}^{\delta(t_1)}=\left[\frac{K}{2}t^2\right]_0^{t_1}$$

$\delta(t_1)-\delta(0)=\frac{K}{2}t_1^2-0$ såhär långt har vinklarna drivit isär.

dvs $\delta(t_1)=\delta(0)+\frac{\omega_{e,s}P_{mpu}}{2H}\cdot t_1^2$

4.4

Upg 4

```
pmpu=1;
delta0=deg2rad(23.95)
```

```
delta0 = 0.4180
```

```
H=3; %pu
f=50;
cycles=3;

t=cycles/f
```

```
t = 0.0600
```

a) $$\frac{2H}{\omega_{e,s}}\frac{d^2\delta_e}{dt^2}=P_{mpu}$$

```
delta1=2*pi*f/(4*H) * t^2 + delta0
```

```
delta1 = 0.5123
```

```
rad2deg(delta1)
```

```
ans = 29.3500
```

b)

```
A1=(delta1-delta0)*1
```

```
A1 = 0.0942
```

vid tiden t =0.06 ökar p_e från 0 till sinuskurvan i figuren. p_e fortsätter öka tills att AA=AD, A_1=A_2

c)

```
p_max=2.4638
```

```
p_max = 2.4638
```

$$A_2 = \int_{\delta_1}^{\delta_2} (p_{max} \sin\delta - p_{mpu}) d\delta = A_1$$

$$A_1 = p_{max}[-\cos\delta]_{\delta_1}^{\delta_2} - [\delta]_{\delta_1}^{\delta_2}$$

$$p_{max}\cos\delta_1 + \delta_1 - A_1 = p_{max}\cos\delta_2 + \delta_2$$

```
% Använder fsolve för att lösa ekvationen
% Define the function
equation = @(x) p_max * cos(x) + x - delta1 - p_max*cos(delta1) +A1;

% Initial guess
initial_guess = 0.7;

% Solve the equation
solution = fsolve(equation, initial_guess)
```

```
Equation solved.

fsolve completed because the vector of function values is near zero
as measured by the value of the function tolerance, and
the problem appears regular as measured by the gradient.

<stopping criteria details>
solution = 0.7306
```

```
delta2=rad2deg(solution)
```

```
delta2 = 41.8618
```

Testa sätta in de olika delta_2 för att se vilken som löser ekvationen bäst.

```
delta2= deg2rad(41.86);
p_max * cos(delta2) + delta2 - delta1 - p_max*cos(delta1) + A1
```

```
ans = 2.0271e-05
```

```
delta2= deg2rad(41.23);
p_max * cos(delta2) + delta2 - delta1 - p_max*cos(delta1) + A1
```

```
ans = 0.0070
```

```
delta2= deg2rad(42.87);
p_max * cos(delta2) + delta2 - delta1 - p_max*cos(delta1) + A1
```

```
ans = -0.0116
```