1 Introduction

The Power System Toolbox (PST) is a Matlab-based power-system simulation software package available from Cherry Tree Scientific Software. It was originally written by Professor Joe Chow of RPI and Graham Rogers. Both are pioneers in power system dynamics. The software is now widely used by researchers. Many researchers have added to options. You can do the following analysis with the software:

- Power flow
- Transient simulation
- Eigenanalysis (linear analysis)

2 Power Flow

To run the power flow, you must create two matrices:
bus = contains all the bus data.
line = contains all the impedance data

2.1 The format for the bus matrix is:

```
% column 1 = bus number (does not have to be sequential)
% column 2 = voltage magnitude(pu)
% column 3 = voltage angle(degree)
% column 4 = p_gen(pu)
% column 5 = q_gen(pu),
% column 6 = p_load(pu)
% column 7 = q_load(pu)
% column 8 = G shunt(pu)
% column 9 = B shunt(pu)
% column 10 = bus_type
%      bus_type    - 1, swing bus
%                  - 2, generator bus (PV bus)
%                  - 3, load bus (PQ bus)
% column 11 = q_gen_max(pu)
% column 12 = q_gen_min(pu)
% column 13 = v_rated (kV)
% column 14 = v_max  pu
% column 15 = v_min  pu
```

2.2 The format for the line matrix is

```
% columns 1 and 2 = from bus, to bus
% column 3 = resistance(pu)
% column 4 = reactance(pu)
% column 5 = line charging(pu)
% column 6 = tap ratio (1.0 nominal)
% column 7 = tap phase (0 nominal)
% column 8 – 10 = tapmax, tapmin, tapsize (0 nominal)
```

These matrices are stored in a file termed d*.m. Use the function lfdemo.m to run the load flow.

3 Transient simulation

To conduct a transient simulation, you need the following additional matrices:

- mac_con = machine data (required)
- exc_con = exciter data (optional)
- pss_con = pss data (optional)
- tg_con = turbine governor data (optional)
- load_con = load data (optional)
- sw_con = switching data (required)

Other data matrices are allowed for special analysis.

3.1 The format for mac_con

Salient pole machines (typically connected to hydro turbines) have no T'_qo. In PST, model this by making T'_qo = 0; then PST will set it to 999 effectively taking it out of the simulation. For a transient model, set all double-prime terms to zero.

```
%   Column
%     1. machine number (may be different from bus number),
%     2. bus number,
%     3. machine base mva,
%     4. leakage reactance x_l(pu),
%     5. resistance r_a(pu),
%     6. d-axis sychronous reactance x_d(pu),
%     7. d-axis transient reactance x'_d(pu),
%     8. d-axis subtransient reactance x"_d(pu),
%     9. d-axis open-circuit time constant T'_do(sec),
%    10. d-axis open-circuit subtransient time constant
%          T"_do(sec),
%    11. q-axis sychronous reactance x_q(pu),
%    12. q-axis transient reactance x'_q(pu),
%    13. q-axis subtransient reactance x"_q(pu),
%    14. q-axis open-circuit time constant T'_qo(sec),
%    15. q-axis open circuit subtransient time constant
%          T"_qo(sec),
%    16. inertia constant H(sec),
%    17. damping coefficient d_o(pu),
%    18. dampling coefficient d_1(pu), (not used?)
%    19. bus number
```

3.2 The sw_con matrix is

```
%Switching file defines the simulation control
% row 1 col1  simulation start time (s) (cols 2 to 6 = zeros)
%       col7  initial time step (s)
% row 2 col1  fault application time (s)
%       col2  bus number at which fault is applied
%       col3  bus number defining far end of faulted line
%       col4  zero sequence impedance in pu on system base
%       col5  negative sequence impedance in pu on system base
%       col6  type of fault  - 0 three phase
%                  - 1 line to ground
%                  - 2 line-to-line to ground
%                  - 3 line-to-line
%                  - 4 loss of line with no fault
%                  - 5 loss of load at bus
%       col7  time step for fault period (s)
% row 3 col1  near end fault clearing time (s) (cols 2 to 6 zeros)
%       col7  time step for second part of fault (s)
% row 4 col1  far end fault clearing time (s) (cols 2 to 6 zeros)
%       col7  time step for fault cleared simulation (s)
% row 5 col1  time to change step length (s)
%       col7  time step (s)
%
```

3.3 The exc_con matrix format

A fast static (power electronic based) exciter can be modeled as a type 0 (**NOTE: TA MUST NOT BE ZERO)**:

```
%column
%  1    exciter type (=0 for static)
%  2    machine number
%  3    transducer filter time constant (T_R - sec) -- not used?
%  4    voltage regulator gain (K_A)
%  5    voltage regulator time constant (T_A - sec)
%  6    transient gain reduction time constant (T_B - sec) denominator
%  7    transient gain reduction time constnat (T_C - sec) numerator
%  8    max voltage regulator output (V_Rmax - pu)
%  9    min voltage regulator output (V_Rmin - pu)
```

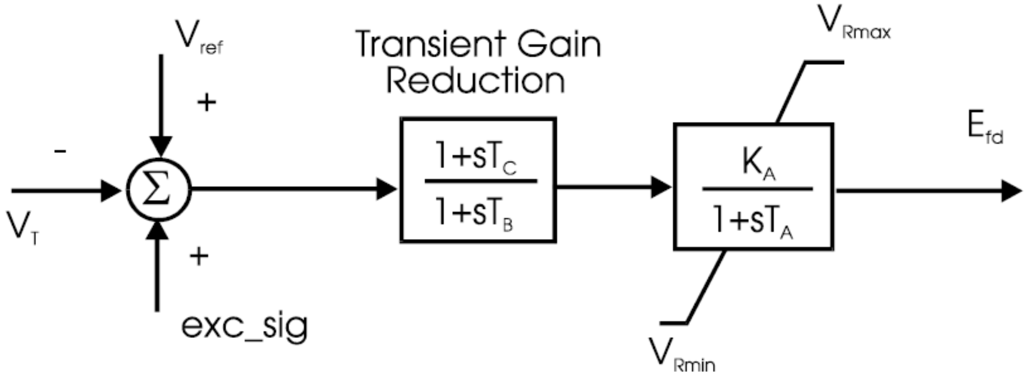


Figure 1: Type 0 (used for fast static exciters).

A DC slower exciter can be modeled as a type 1:

```
%column
%  1    exciter type (=1 for DC type 1)
%  2    machine number
%  3    transducer filter time constant (T_R – sec)
%  4    voltage regulator gain (K_A)
%  5    voltage regulator time constant (T_A - sec)
%  6    transient gain reduction time constant (T_B - sec) denominator
%  7    transient gain reduction time constnat (T_C - sec) numerator
%  8    max voltage regulator output (V_Rmax - pu)
%  9    min voltage regulator output (V_Rmin - pu)
% 10    exciter constant K_E
% 11    exciter time constant (T_E)
% 12    E1(pu)
% 13    saturation function S_E(E1)
% 14    E2 (pu)
% 15    saturation function S_E(E2)
% 16    stabilizer gain K_F
% 17    stabilizer time constant T_F
```

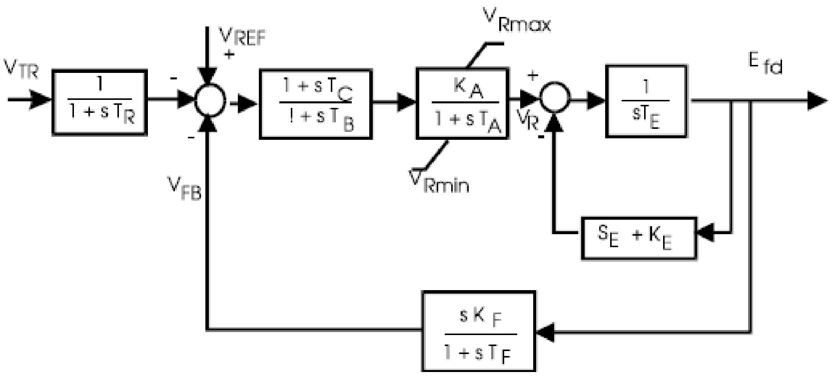
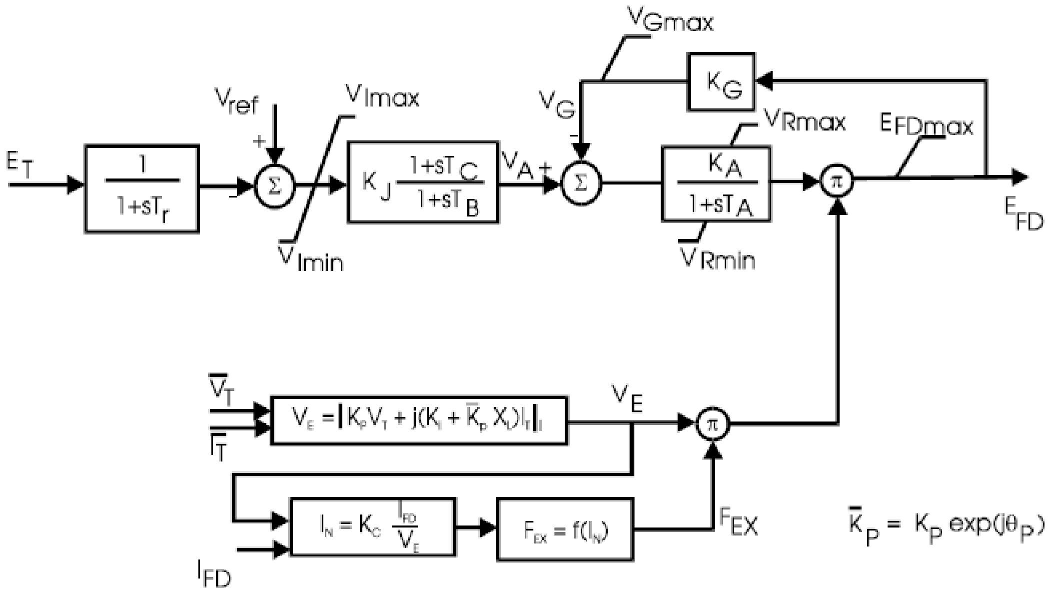


Figure 2: DC exciter type 1.

A static fast exciter can be modeled as a type 3 (NOTE: KA MUST NOT BE ZERO):

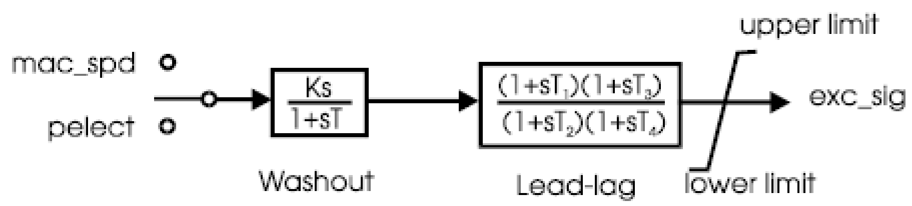
```
%column
%  1    exciter type (=3 for ST3)
%  2    machine number
%  3    transducer filter time constant (T_R – sec)
%  4    voltage regulator gain (K_A)
```

```
%  5    voltage regulator time constant (T_A - sec)
%  6    transient gain reduction time constant (T_B - sec) denominator
%  7    transient gain reduction time constnat (T_C - sec) numerator
%  8    max voltage regulator output (V_Rmax - pu)
%  9    min voltage regulator output (V_Rmin - pu)
% 10    max internal signal VImax
% 11    min internal signal VImin
% 12    first state regulator gain KJ
% 13    potential circuit gain coef Kp
% 14    potential circuit phase angle qp (degrees)
% 15    current circuit gain coef (KI)
% 16    potential source reactance XL (pu)
% 17    rectifier loading factor KC
% 18    max field voltage Efdmax (pu)
% 19    inner loop feedback constant KG
% 20    max inner loop voltage feedback VGmax (pu)
```



3.4 The pss_con matrix format is

```
%column
%  1      Type input (1=spd, 2=power)
%  2      machine number
%  3      gain K
%  4      Washout time const Tw (sec)
%  5      1st lead time const T1 (sec)
%  6      1st lag time const T2 (sec)
%  7      2nd lead time const T3 (sec)
%  8      2nd lag time const T4 (sec)
%  9      max output limit (pu)
%  10     min output limit (pu)
```



3.5 The tg_con matrix format is

```
% tg_con matrix format
%column        data          unit
%  1    turbine model number (=1)
%  2    machine number
%  3    speed set point   wf         pu
%  4    steady state gain 1/R        pu
%  5    maximum power order  Tmax    pu on generator base
%  6    servo time constant   Ts     sec
%  7    governor time constant  Tc   sec
%  8    transient gain time constant T3 sec
%  9    HP section time constant    T4    sec
% 10    reheater time constant    T5    sec
```

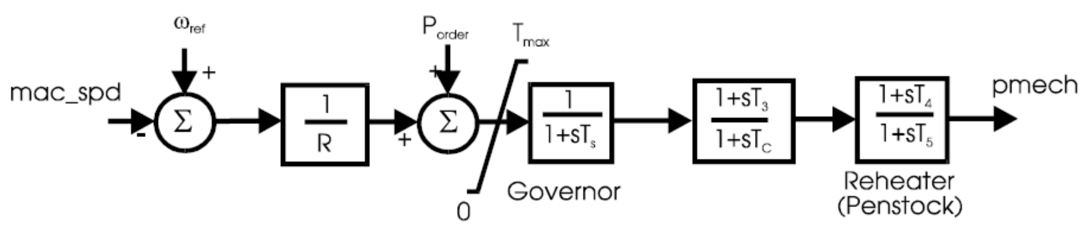


Figure 3: Turbine governor model.

3.6 The load_con matrix format is

```
% col 1       bus number
% col 2       fraction const active power load
% col 3       fraction const reactive power load
% col 4       fraction const active current load
% col 5       fraction const reactive current load
% NOTE:  total fraction is 1.0
```

3.7 Key output variables from the transient simulation are

```
t = row vector of time
bus_v = matrix of bus voltages.  row k corresponds to the kth row of
        the bus matrix.
pelect = matrix of real power output from generators.  Row k corresponds
         to the kth generator as numbered in mac_con.
mac_ang = matrix of machine angles in radians.  Row k corresponds to
         to the kth generator as numbered in mac_con.
mac_spd = matrix of machine speed.  Row k corresponds to the
          kth generator as numbered in mac_con.
```