Western System Coordinating Council (WSCC)
3-Machine, 9-Bus System

- All dynamic data and equations of the WSCC 3-machine, 9-bus system depicted in Figure 1 can be found in:

  P. W. Sauer and M. A. Pai, *Power System Dynamics and Stability,* New Jersey: Prentice Hall, 1998

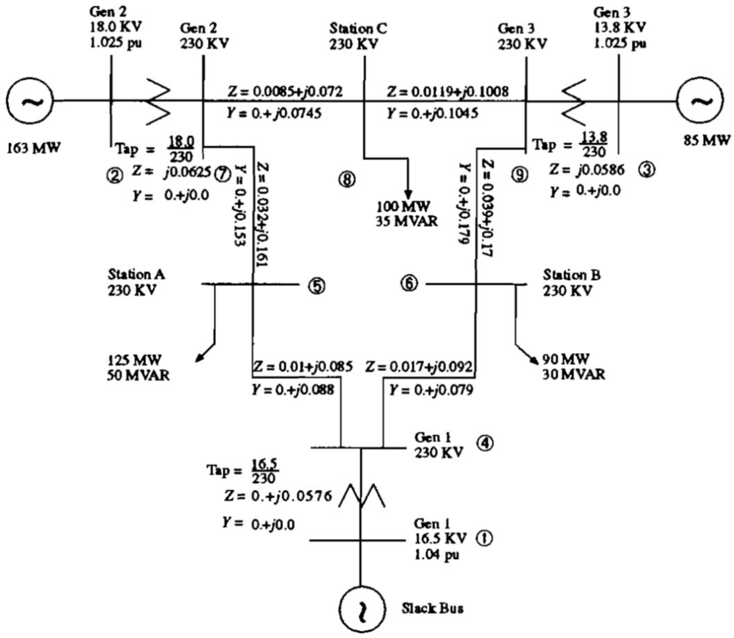

Figure 1. WSCC 3-machine, 9-bus system. Value of Y is half the line charging.

- **System base MVA** is 100, and the **system frequency** is 60 Hz.

- The converged **load-flow data** is given in Table 1.

Table 1. Load-flow results of the WSCC 3-machine, 9-bus system.

	Bus #	Voltage (pu)	P_G (pu)	Q_G (pu)	$-P_L$ (pu)	$-Q_L$ (pu)
1	(swing)	1.04	0.716	0.27	–	–
2	(P-V)	$1.025\angle 9.3^o$	1.63	0.067	–	–
3	(P-V)	$1.025\angle 4.7^o$	0.85	-0.109	–	–
4	(P-Q)	$1.026\angle -2.2^o$	–	–	–	–
5	(")	$0.996\angle\text{-}4.0^o$	–	–	1.25	0.5
6	(")	$1.013\angle -3.7^o$	–	–	0.9	0.3
7	(")	$1.026\angle 3.7^o$	–	–	–	–
8	(")	$1.016\angle 0.7^o$	–	–	1.00	0.35
9	(")	$1.032\angle 2.0^o$	–	–	–	–

- The **impedance matrix**, $\bar{Y}_N$, is shown in Table 2.

Table 2. $\bar{Y}_N$ for the network in Figure 1.

$$
\begin{array}{c|ccccccccc}
 & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 \\
\hline
1 & -j17.361 & 0 & 0 & j17.361 & 0 & 0 & 0 & 0 & 0 \\
2 & 0 & -j16 & 0 & 0 & 0 & 0 & j16 & 0 & 0 \\
3 & 0 & 0 & -j17.065 & 0 & 0 & 0 & 0 & 0 & j17.065 \\
4 & j17.361 & 0 & 0 & \begin{matrix}3.307\\-j39.309\end{matrix} & \begin{matrix}-1.365\\+j11.604\end{matrix} & \begin{matrix}-1.942\\+j10.511\end{matrix} & 0 & 0 & 0 \\
5 & 0 & 0 & 0 & \begin{matrix}-1.365\\+j11.604\end{matrix} & \begin{matrix}2.553\\-j17.338\end{matrix} & 0 & \begin{matrix}-1.188\\+j5.975\end{matrix} & 0 & 0 \\
6 & 0 & 0 & 0 & \begin{matrix}-1.942\\+j10.511\end{matrix} & 0 & \begin{matrix}3.224\\-j15.841\end{matrix} & 0 & 0 & \begin{matrix}-1.282\\+j5.588\end{matrix} \\
7 & 0 & j16 & 0 & 0 & \begin{matrix}-1.188\\+j5.975\end{matrix} & 0 & \begin{matrix}2.805\\-j35.4460\end{matrix} & \begin{matrix}-1.617\\+j13.698\end{matrix} & 0 \\
8 & 0 & 0 & 0 & 0 & 0 & 0 & \begin{matrix}-1.617\\+j13.698\end{matrix} & \begin{matrix}2.772\\-j23.303\end{matrix} & \begin{matrix}-1.155\\+j9.784\end{matrix} \\
9 & 0 & 0 & j17.065 & 0 & 0 & \begin{matrix}-1.282\\+j5.588\end{matrix} & 0 & \begin{matrix}-1.155\\+j9.784\end{matrix} & \begin{matrix}2.437\\-j32.1540\end{matrix}
\end{array}
$$

- The **machine data** are given in Table 3.

Table 3. Machine data.

Machine Data

Parameters	M/C 1	M/C 2	M/C 3
H(secs)	23.64	6.4	3.01
X_d(pu)	0.146	0.8958	1.3125
X'_d(pu)	0.0608	0.1198	0.1813
X_q(pu)	0.0969	0.8645	1.2578
X'_q(pu)	0.0969	0.1969	0.25
T'_{do}(sec)	8.96	6.0	5.89
T'_{qo}(sec)	0.31	0.535	0.6

- The **exciter**, depicted in Figure 2, is assumed to be identical for all the machines, and is of the IEEE-Type 1. Exciter data are given in Table 4.

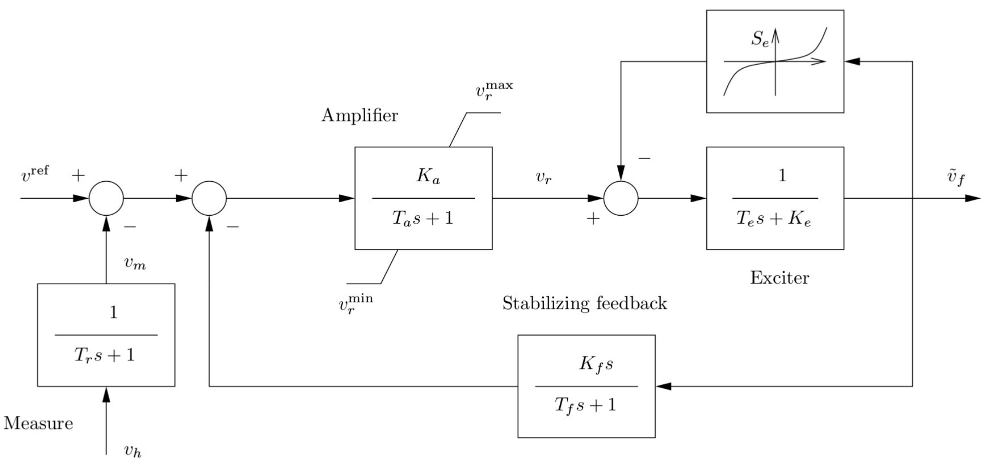

Figure 2. Scheme of an IEEE-Type 1 exciter.

Table 4. Exciter data.

Parameters	Exciter 1	Exciter 2	Exciter 3
K_A	20	20	20
T_A(sec)	0.2	0.2	0.2
K_E	1.0	1.0	1.0
T_E(sec)	0.314	0.314	0.314
K_F	0.063	0.063	0.063
T_F(sec)	0.35	0.35	0.35

$S_{Ei}(E_{f\,di}) = 0.0039e^{1.555E_{f\,di}} \quad i = 1, 2, 3$

- The scheme of the **turbine governor**, responsible of the primary frequency regulation of the machines, is depicted in Figure 3. Turbine governor data is given in Table 5.

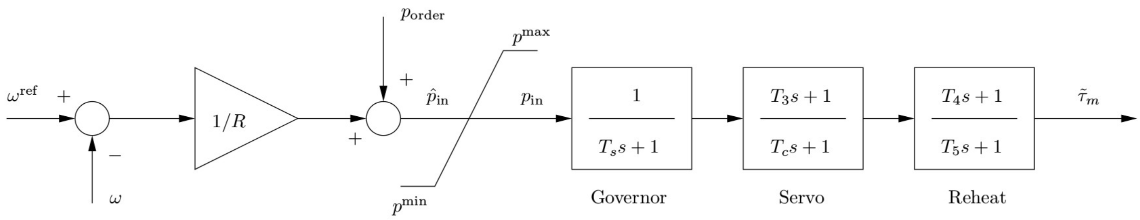

Figure 3. Scheme of a turbine governor.

Table 5. Turbine governor data.

Parameters	T. Governor 1	T. Governor 2	T. Governor 3
R (p.u.[MW])	0.05	0.05	0.05
$p^{\max}$ (p.u.[MW])	1.6	3.2	1.7
$p^{\min}$ (p.u.[MW])	0.0	0.0	0.0
T_s (sec)	0.1	0.1	0.1
T_c (sec)	0.45	0.45	0.45
T_3 (sec)	0.0	0.0	0.0
T_4 (sec)	0.0	0.0	0.0
T_5 (sec)	50.0	50.0	50.0

- The contingency is a **three-phase fault**, located at bus 7. The fault, with a reactance of 10^{-5} p.u. (Ω), is cleared after 70 ms by means of the opening of the line that connects buses 5 and 7. The rotor speeds of the synchronous machines of the system after the fault are plotted in Figure 4.