

Supplementary file for:

Small signal stability analysis of a four machine system with placement of multi-terminal high voltage direct current link

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Table 1: Multiterminal high voltage direct current data.

Parameter	Rect-1	Rect-2	Invtr
Rated/Actual power (MW)	300/198	1000/460	1200/700
Rated/Actual DC current (kA)	0.3/0.2	1.0/0.5	1.2/0.75
α for rectifier, γ_0 for inverter	14.8	18	15
Transformer per 6 pulse thyristor			
Rating (MVA)	350	1000	1200
Voltage (kV)	230/500	230/500	500/230
Leakage reactance (pu)	0.18	0.18	0.18
PI controller			
Proportional gain	1.0989	1.5363	1.5363
Integral time constant (s)	0.01092	0.01524	0.01524
VDCOL			
Threshold input	0.4-1.0	0.4-0.9	0.4-0.9
Threshold output	0.55-1.5	0.55-1.0	0.55-1.0

Table 2: Synchronous machine data.

Generator data		AVR and PSS	
ra	0.0025 pu	<i>Input signal</i>	Speed
xl or xp	0.130 pu	T_R	0.01 sec
xd	1.81 pu	V_{imax}	10 pu
$x'd$	0.3 pu	V_{imin}	-10 pu
$x''d$	0.25 pu	K_A	200 pu
$T'd0$	8.0 sec	E_{fmax}	7.0 pu
$T''d0$	0.03 (s)	E_{fmin}	-6.4 pu
xq	1.7 pu	K_{STAB}	20
$x'q$	0.55 pu	T_W	10 sec
$x''q0$	0.25 pu	T_1	0.05 sec
$T'q0$	0.4 (s)	T_2	0.02 sec
$T''q0$	0.03 (s)	V_{stmax}	0.2
H	6.5 A1, 6.177 A2	V_{stmin}	-0.2

Table 3: Transmission line data

DC Transmission line (T-model) data	
R(Ω /km)	0.01
Reactor (H)	0.5968
DC filter (μ F)	15
AC Transmission line data	
r (pu/km)	1e-4
x_L (pu/km)	1e-3
b_c (pu/km)	1.75e-3

Nomenclature

H	Inertia constant in s
K_D	Machine load damping coefficient
r_a	Armature resistance in p.u
x_d	Unsaturated d axis synchronous reactance in p.u
x_q	Unsaturated q axis synchronous reactance in p.u
x'_d	Unsaturated d axis transient reactance in p.u
x'_q	Unsaturated q axis transient reactance in p.u
x''_d	Unsaturated d axis sub transient reactance in p.u
x''_q	Unsaturated q axis sub transient reactance in p.u
x_l or x_p	Leakage or Potier reactance in p.u
T'_{d0}	d axis transient open-circuit time constant in s
T''_{d0}	d axis sub transient open-circuit time constant in s
T'_{q0}	q axis transient open-circuit time constant in s
T''_{q0}	q axis sub transient open-circuit time constant in s
T_e	Exciter time constant in s
P_{max}	Maximum turbine output in p.u
K_{STAB}	Stabilising gain,
T_1	First lead time constant,
T_2	First lag time constant,
T_w	Washout time constant,
K_A	Regulator integral gain,
T_R	Transducer time constant,
$\Delta\omega_r$	Change in angular speed,
E_{fd}	Exciter output voltage,
V_{stmax}, V_{stmin}	Minimum and maximum regulator outputs,

V_{ref}	Reference voltage regulator,
V_s	Combined power system stabiliser and possibly discontinuous control output after any limits or switching,
E_t	Terminal voltage of transducer and load compensation elements
R	Direct current line resistance in Ω/km
r	Alternating current line resistance in pu/km
x_L	Alternating current line reactance in pu/km
bc	Alternating current line capacitive impedance in pu/km
pu	Per unit
PI	Proportional and integral
Rect-1	Rectifier 2
Rect-2	Rectifier 1
Invtr	Inverter
VDCOL	Voltage dependent current order limiter
PSS	Power system stabiliser
AVR	Automatic voltage regulator
AC	Alternating current
DC	Direct current
α	Firing angle for rectifier
γ_0	Initial extinction angle for inverter
MW	Active power in mega watt
MVA	Apparent power in mega volt ampere
KV	Kilo-volt
KA	Kilo-ampere
s	Second