Central Electricity Authority

(New Delhi)

Dated: 14.05.2026

Draft Amendment – II to the Central Electricity Authority (Manual on Transmission Planning Criteria), 2023

The Central Electricity Authority (CEA) has issued the Manual on Transmission Planning Criteria, 2023. The Manual was effective from 1st April, 2023. To cover the planning procedure, a new chapter (Chapter-7) was added to the Manual vide Amendment-I which was issued on 08.01.2025. In order to include the provision for 1150 kV high voltage AC transmission system the Manual is proposed to be amended. The draft Amendment-II to the CEA (Manual on Transmission Planning Criteria), 2023 is mentioned hereunder. The amended portion are highlighted in yellow color.

1. Amendment to Para 2.1.14 of the Manual

2.1.14 Critical loads such as - railways, metro rail, airports, refineries, underground mines, steel plants, smelter plants, hospitals, [1]data center, etc. shall plan their interconnection with the grid, with 100% redundancy and as far as possible from two different sources of supply.

2. Amendment to Para 3.10.4 of the Manual

The Para 3.10.4 shall be replaced with the following.

"

3.10.4 At the planning stage, a margin of about ± 2% may be kept in the voltage limits and thus the voltages under load flow studies (for 'N-0' and 'N-1' steady-state conditions only) may be maintained within the limits given below:

Voltage (kV_{rms}) (after planning margins)		
Nominal	**Maximum**	**Minimum**
[2]1150	1185 (1.03 pu)	1115 (0.97 pu)
765	785 (1.03 pu)	745 (0.97 pu)
400	412 (1.03 pu)	388 (0.97 pu)
230	240 (1.04 pu)	212 (0.92 pu)
220	240 (1.09 pu)	203 (0.92 pu)
132	142 (1.08 pu)	125 (0.95 pu)
110	119 (1.08 pu)	102 (0.93 pu)
66	70 (1.06 pu)	62 (0.94 pu)

"

3. Amendment to Para 4.3 of the Manual

The Para 4.3 shall be replaced with the following.

[1] Inserted vide Amendment-II

[2] Inserted vide Amendment-II

"

4.3 Voltage limits

a) The steady-state voltage limits are given below. However, at the planning stage a margin as specified at Paragraph: 3.10 may be kept in the voltage limits.

Voltages (kV_{rms})				
	Normal rating		Emergency rating	
Nominal	Maximum	Minimum	Maximum	Minimum
[3]1150(1pu)	1200 (1.04 pu)	1090 (0.95pu)	1200 (1.04pu)	1070 (0.93pu)
765 (1 pu)	800 (1.05 pu)	728 (0.95 pu)	800 (1.05 pu)	713 (0.93 pu)
400 (1 pu)	420 (1.05 pu)	380 (0.95 pu)	420 (1.05 pu)	372 (0.93 pu)
230 (1 pu)	245 (1.07 pu)	207 (0.90 pu)	245 (1.07 pu)	202 (0.88 pu)
220 (1 pu)	245 (1.11 pu)	198 (0.90 pu)	245 (1.11 pu)	194 (0.88 pu)
132 (1 pu)	145 (1.10 pu)	122 (0.92 pu)	145 (1.10 pu)	119 (0.90 pu)
110 (1 pu)	123 (1.12 pu)	99 (0.90 pu)	123 (1.12 pu)	97 (0.88 pu)
66 (1 pu)	72.5 (1.10 pu)	60 (0.91 pu)	72.5 (1.10 pu)	59 (0.89 pu)

b) Temporary over voltage (TOV) limits due to sudden load rejection:

S.No.	System Voltage (kV)	Peak Phase to Neutral Voltage (kV)	TOV (kV)
i).	[4]1200	980	1372 ; (1.4pu)
ii).	800	653	914 ; (1.4pu)
iii).	420	343	515 ; (1.5pu)
iv).	245	200	360 ; (1.8pu)
v).	145	118	212 ; (1.8pu)
vi).	123	100	180 ; (1.8pu)
vii).	72.5	59	112 ; (1.9pu)

c) Switching over voltage (SOV) limits:

S.No.	System Voltage (kV)	Peak Phase to Neutral Voltage (kV)	SOV (kV)
i).	[5]1200	980	1800 ; (1.84pu)
ii).	800	653	1241 ; (1.9pu)
iii).	420	343	858 ; (2.5pu)

4. Amendment to Para 4.4.2.1(a) of the Manual

The Para 4.4.2.1(a) shall be replaced with the following.

"

[3] Inserted vide Amendment-II

[4] Inserted vide Amendment-II

[5] Inserted vide Amendment-II

a) All the equipment in the transmission system shall remain within their normal thermal and voltage ratings after outage / loss of any one of the following elements (called single contingency or 'N-1'), but without load shedding / rescheduling of generation:

- Outage of a 132 kV single circuit,

- Outage of a 220 kV single circuit,

- Outage of a 400 kV single circuit (with or without fixed series capacitor),

- Outage of an Inter-Connecting Transformer (ICT) / power transformer,

- Outage of a 765 kV single circuit

- Outage of one pole of HVDC bipole

- Outage of a 1150 kV single circuit[6]

"

5. Amendment to Para 4.4.2.1 of the Manual

4.4.2.1 Steady-state:

"

a) All the equipment in the transmission system shall remain within their normal thermal and voltage ratings after outage / loss of any one of the following elements (called single contingency or 'N-1'), but without load shedding / rescheduling of generation:

- Outage of a 132 kV single circuit,

- Outage of a 220 kV single circuit,

- Outage of a 400 kV single circuit (with or without fixed series capacitor),

- Outage of an Inter-Connecting Transformer (ICT) / power transformer,

- Outage of a 765 kV single circuit

- Outage of one pole of HVDC bipole

- Outage of one circuit of HVDC line[7]

"

6. Amendment to Para 4.4.2.2 of the Manual

The Para 4.4.2.2 shall be replaced with the following.

"

4.4.2.2 Transient-state:

Usually, perturbation causes a transient that is oscillatory in nature, but if the system is stable, the oscillations will be damped. The system is said to be stable in which synchronous machines, when perturbed, will either return to their original state, if there is no change in exchange of power or will acquire new state asymptotically without losing

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[6] Inserted vide Amendment-II

[7] Inserted vide Amendment-II

synchronism. The transmission system shall be stable after it is subjected to one of the following outage / loss:

a) The system shall be able to survive a permanent three phase to ground fault on a 1150 kV line close to the bus to be cleared in 100 ms.[8]

b) The system shall be able to survive a permanent single phase to ground fault on a 1150 kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.[9]

c) The system shall be able to survive a permanent three phase to ground fault on a 765 kV line close to the bus to be cleared in 100 ms.

d) The system shall be able to survive a permanent single phase to ground fault on a 765 kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

e) The system shall be able to survive a permanent three phase to ground fault on a 400 kV line close to the bus to be cleared in 100 ms.

f) The system shall be able to survive a permanent single phase to ground fault on a 400 kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and unsuccessful re-closure (dead time 1 second) followed by 3-pole opening (100 ms) of the faulted line shall be considered.

g) In case of 220 kV / 132 kV network, the system shall be able to survive a permanent three phase fault on one circuit, close to a bus, with a fault clearing time of 160 ms (8 cycles) assuming 3-pole opening.

h) The system shall be able to survive a fault in HVDC convertor station, resulting in permanent outage of one of the poles of HVDC Bipole.

i) Loss of generation: The system shall remain stable under the loss of single largest generating unit or a critical generating unit (choice of candidate critical generating unit is left to the transmission planner).

j) Loss of largest radial load, connected at single point.

”

7. Amendment to Para 4.4.3.1(a) of the Manual

The Para 4.4.3.1(a) shall be replaced with the following.

“

[8] Inserted vide Amendment-II

[9] Inserted vide Amendment-II

a) The system shall be able to survive a temporary single phase to ground fault on a 765 kV or [10]1150 kV line close to the bus. Accordingly, single pole opening (100 ms) of the faulted phase and successful re-closure (dead time 1 second) shall be considered.

"

8. Amendment to Para 5.1.5 of the Manual

The Para 5.1.5 shall be replaced with the following.

"

5.1.5 The maximum short-circuit level on any new substation bus should not exceed 80% of the rated short circuit capacity of the substation equipment. The 20% margin is intended to take care of the increase in short-circuit levels as the system grows. The rated breaking current capability of switchgear at different voltage levels may be taken as given below:

Voltage Level	Rated Breaking Capacity
[11]1150 kV	50 kA / 63 kA
765 kV	50 kA / 63 kA
400 kV	63 kA / 80 kA
[12]220 kV	50 kA / 63 kA
[13]132 kV	40 kA
66 kV	31.5 kA

Measures such as sectionalisation of bus, series reactor, or any new technology may also be adopted to limit the short circuit levels at existing substations wherever short circuit levels are likely to cross the designed limits.

"

9. Amendment to Para 5.2.2 of the Manual

The Para 5.2.2 shall be replaced with the following.

"

5.2.2 The capacity of any single sub-station at different voltage levels shall not normally exceed as given in column (B) and (C) in the following table:

Voltage Level (A)	Transformation Capacity	
	Load Serving Substation (B)	Generation Pooling substations (C)
[14]1150 kV	12600 MVA	12600 MVA
765 kV	9000 MVA	9000 MVA
400 kV	2500 MVA	5000 MVA
220 kV	1000 MVA	1000 MVA
132 kV	500 MVA	500 MVA

[10] Inserted vide Amendment-II
[11] Inserted vide Amendment-II
[12] Modified vide Amendment-II
[13] Modified vide Amendment-II
[14] Inserted vide Amendment-II

66 kV	160 MVA	160 MVA

10. Amendment to Para 5.4.3.1 of the Manual

The Para 5.4.3.1 shall be replaced with the following.

"

5.4.3.1 Bus reactors shall be provided at substations for controlling voltages within the limits [defined in the Paragraph: 4.3(a)] without resorting to switching-off the lines. The bus reactors may also be provided at generation switchyards to supplement reactive capability of generators. The size of reactors should be such that under steady state condition, switching on and off of the reactors shall not cause a voltage change exceeding 5%. The standard sizes (MVAr) of reactors are:

Voltage Level	Standard sizes of reactors (in MVAr)
132 kV (3-ph unit)	12.5 and 25 (rated at 145 kV)
220 kV (3-ph unit)	50, 25 (rated at 245 kV)
400 kV (3-ph unit)	50, 63, 80,125 and 250 (rated at 420 kV)
765 kV (1-ph unit)	80 and 110 (rated at 765/√3 kV)
[15]1150 kV (1-ph unit)	220 and 300 (rated at 1200/√3 kV)

"

11. Amendment to Para 6.4.1 of the Manual

The Para 6.4.1 shall be replaced with the following.

"

6.4.1 The transmission utilities shall ensure that zone-3 relay settings of the transmission lines is such that they do not trip at extreme loading of line. For this purpose, the extreme loading may be taken as 120% of thermal current loading limit and assuming 0.9 per unit voltage (i.e. 360 kV for 400 kV system, 689 kV for 765 kV system and [16]1035 for 1150 kV system). In case it is not practical to set the Zone-3 in the relay to take care of above, the transmission licensee/owner shall inform CEA, RPCs[17], CTU/STU and RLDC/SLDC along with setting (primary impendence) value of the relay. Mitigating measures shall be taken at the earliest and till such time the permissible line loading for such lines would be limited to as calculated from relay impedance assuming 0.95 pu voltage, provided it is permitted by stability and voltage limit considerations as assessed through appropriate system studies.

"

12. Amendment to Table B under Para 5 of Annexure-I of the Manual

The Table B under Para 5 of Annexure-I shall be replaced with the following.

[15] Inserted vide Amendment-II
[16] Inserted vide Amendment-II
[17] Inserted vide Amendment-I

"

B. Voltage level numbering schema

Voltage Level (kV)	D_3
[18]1150	8
765	7
400	4
230	2
220	2
132	1
110	1
66	0
33	0
11	0

"

13. Amendment to Table in the List-1 of Annexure-I of the Manual

The Table in List-1 of Annexure-I shall be replaced with the following.

"

Data as on Month of the Year						
Sl. No. (Define Bus no)	Name of the S/s or bus - Max. 12 characters	Voltage Level ([19]1150/765/400/230/220/132/110/66/33 kV)	Load Bus (Yes/No)	Generator bus (Yes/No)	Remarks (Existing/ Under construction / Planned)	Year of Commissioning
XXXXXX	AAA	765/400				
XXXXXX	BBB	400/220				
XXXXXX						

"

14. Amendment to Table in the List-2 of Annexure-I of the Manual

The Table in List-2 of Annexure-I shall be replaced with the following.

"

Data as on Month of the Year																				
From BUS (Name)	To BUS (Name)	CKT id	Length (km)	Line voltage (kV)	Line Type (S/c or D/c or Multi Ckt)	Conductor type (e.g. AL59/ ACSR MOOSE/ HTLS/Zebra etc.)	Conductor Configuration (Single/Twin /Tripple/ Quad/ Hexa)	Design Ambient/ Conductor Temperature	Either in actuals or in pu on 100MVA base			in MVA	in MVA		in pu on 100MVA base		in pu on 100MVA base		Remarks (Existing/ under construction/ planned)	Year of Commissioning
									R in pu	X in pu	B in pu	Rate A (SIL Loading)	Rate B	Rate C	GI	BI line reactor at from bus end in pu (Fixed / Switchable)	GJ	BI line reactor at To bus end in pu(Fixed / Switchable)		
AAA	BBB	1	400	[20]1150	D/c	Moose	Octa	45/85	XX	XX	XX	5500	12000		XXXXXX	-9 (Fixed)	XXXXXX	-9 (Switchable)		
AAA	BBB	1	291	765	D/c	Zebra	Hexa	45/85	XX	XX	XX	2200	30		XXX	-2.4 (Fixed)	XXX	-2.4 (Switchable)		

[18] Inserted vide Amendment-II
[19] Inserted vide Amendment-II
[20] Inserted vide Amendment-II

													00		XXX		XXX			
AAA	BBB	2	291	765	D/c	Zebra	Hexa		XX	XX	XX	2200	3000			-2.4 (Fixed)		-2.4 (Switchable)		
BBB	CCC	1	208	765	S/c	Bersimis	Quad		XX	XX	XX	2200	3000			0		-2.4 (Switchable)		
DDD	CCC	2	208	765	S/c	Bersimis	Quad		XX	XX	XX	2200	3000			0		-2.4 (Switchable)		
DDD	KKK	1	75	220	D/c	Zebra	Single		XX	XX	XX	130								
CCC	EEE	2	75	220	D/c	Zebra	Single		XX	XX	XX	130								
CCC	FFF	1	77	132	D/c	Panther	Single		XX	XX	XX	65								
GGG	SSS	2	77	132	D/c	Panther	Single		XX	XX	XX	65								
GGG	CCC	1	44	220	D/c	Zebra	Single		XX	XX	XX	130								

"

15. Amendment to Table in the List-5 of Annexure-I of the Manual

The Table in List-5 of Annexure-I shall be replaced with the following.

"

Data as on Month of the Year					
S.No.	**Bus Name (765kV/400kV/230kV/132kV)**	**Voltage level (132kV/ 110kV)**	**Id**	**MVAR**	**Year of Commissioning**
	ZYX	[21]1150	1	-900	
	ABC	765	1	-240	
	DEF	765	2	-240	
	XYZ	765	1	-240	
	TUV	765	2	-240	
	GHI	132	1	100	
	JKL	220	1	150	
	PQR	132	2	70	
	RST	220	1	253	
	MNO	400	1	-80	
	WXY	400	1	-80	

"

16. Amendment to Table in the List-6 of Annexure-I of the Manual

The Table in List-6 of Annexure-I shall be replaced with the following.

"

Data as on Month of the Year										
From BUS No.	**To BUS No.**	**CKT**	**Voltage level (kV) (to bus no)**	**No of taps**	**Voltage change /step**	**Tap Positions**	**MVA Rating (Rate A)**	**Winding MVA Base**	**% Impedance on transformer base**	**Year of Commissioning**

[21] Inserted vide Amendment-II

AAAAA9	AAAAA4	1	[22]1150/400	Tapless	0%	NA	3000	3000	20%	
AAAAA8	AAAAA4	1	765/400	Tapless	0%	NA	1500	1500	12.50%	
BBBBB8	BBBBB4	1	765/400	23	0.5%	12	1500	1500	12.50%	
CCCCC8	CCCCC4	1	765/400	17	1.25%	8	1500	1500	12.50%	
DDDDD8	DDDDD4	1	765/400	17	1.25%	8	1500	1500	12.50%	
EEEEE8	EEEEE4	1	765/400	17	1.25%	8	1500	1500	12.50%	
FFFFF4	FFFFF2	1	400/220	17	1.25%	8	500	1500	12.50%	
GGGGG4	GGGGG2	1	400/220	17	1.25%	8	300	1500	12.50%	
BBBBB1	BBBBB2	1	220/132	17	1.25%	8	100	1500	12.50%	

"

17. Amendment to Table I(a) in the Annexure-II of the Manual

A row section for 1150 kV shall be inserted in the Table-I(a) of Annexure-II. The amended portion is highlighted as under.

"

Voltage (kV)	Config.	Type of conductor	Ckt	Positive sequence			Zero sequence		
				R	X	B	R_0	X_0	B_0
[23]1150	Octa	#ACSR Moose	S/C	5.74000E-7	1.97740E-5	5.89432E-2	1.54840E-5	6.54510E-5	4.00216E-2
	Octa	#ACSR Zebra	S/C	6.95000E-7	1.98420E-5	5.87463E-2	1.56050E-5	6.55190E-5	3.99309E-2
	Octa	#ACSR Bersimis	D/C	4.40000E-7	2.01690E-5	5.71059E-2	1.34180E-5	6.64440E-5	3.37368E-2

"

18. Amendment to Table I(b), I(c), I(d), I(e), I(f) in the Annexure-II of the Manual

The Table I(b), I(c), I(d), I(e), I(f) in the Annexure-II of the replace with the following tables.

Table- I(b)

The resistance data (in Ω/km) for Zebra equivalent size is given in following Table. The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	Stranding/wire diameter (mm)		Overall diameter (mm)	DC Resistance (Ω/km)	AC Resistance values at different temperatures (in Ω/km)		
	Al/Al alloy wire	steel wire		20° C	75 ° C	85 ° C	95 ° C
[24]ACSR	54/3.1	7/3.18	28.62	**0.0677**	0.08564	0.08841	NA

[22] Inserted vide Amendment-II
[23] Inserted vide Amendment-II
[24] Modified vide Amendment-II

	8						
AAAC	61/3.19	NA	28.71	0.06819	0.08269	0.08511	0.08754
AL59	61/3.08	NA	27.72	0.06530	0.07998	0.08243	0.08488

Table- I(c)

The resistance data (in Ω/km) for Bersimis equivalent size is given in following Table. The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	Stranding/wire diameter (mm)		Overall diameter (mm)	DC Resistance (Ω/km)	AC Resistance values at different temperatures (in Ω/km)		
	Al/Al alloy wire	steel wire		20° C	75 ° C	85 ° C	95 ° C
[25]ACSR	42/4.57	7/2.54	35.04	**0.0421**	**0.05412**	**0.05581**	NA
AAAC	61/4.0	NA	36.00	0.04337	0.05350	0.05502	0.05654
AL59	61/4.02	NA	36.18	0.03840	0.04814	0.04955	0.05097

Table- I(d)

The resistance data (in Ω/km) for Moose equivalent size is given in following Table. The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	Stranding/wire diameter (mm)		Overall diameter (mm)	DC Resistance (Ω/km)	AC Resistance values at different temperatures (Ω/km)		
	Al/Al alloy wire	steel wire		20° C	75 ° C	85 ° C	95 ° C
[26]ACSR	54/3.53	7/3.53	31.77	**0.0549**	**0.06969**	**0.07193**	NA
AAAC	61/3.55	NA	31.95	0.05506	0.06719	0.06914	0.07109
AL59	61/3.52	NA	31.70	0.0501	0.06190	0.06377	0.06564
AL59	61/3.31	NA	29.79	0.0566	0.06961	0.07173	0.07385

Table- I(e)

The resistance data (in Ω/km) for Panther equivalent size is given in following Table.

[25] Modified vide Amendment-II
[26] Modified vide Amendment-II

The reactance(X) and susceptance (B) values of line mainly depend on the tower configuration, and therefore the X and B values (in per unit / km / circuit) may be taken from Table I(a) above for similar configuration.

Name of Conductor	Stranding/wire diameter (mm)		Overall diameter (mm)	DC Resistance (Ω/km)	AC Resistance values at different temperatures (Ω/km)		
	Al/Al alloy wire	steel wire		20° C	75 ° C	85 ° C	95 ° C
[27]ACSR	30/3.0	7/3.0	21.00	**0.1363**	**0.16699**	**0.17245**	NA
AAAC	37/3.15	NA	22.05	0.1151	0.13848	0.14261	0.14674
AL59	37/3.08	NA	21.56	0.1075	0.13060	0.13466	0.13873

Table- I(f)

Name of Conductor	Stranding/wire diameter (mm)		Overall diameter (mm)	DC Resistance (Ω/km)	AC Resistance values at different temperatures (Ω/km)		
	Al wire	steel wire		20° C	75 ° C	85 ° C	95 ° C
[28]ACSR Snowbird	42/3.99	7/2.21	30.57	**0.0552**	**0.07029**	**0.07254**	NA
ACSR Lapwing	45/4.78	7/3.18	38.22	0.0358	0.04632	0.04775	NA

19. Amendment to Table II in the Annexure-II of the Manual

The Table II in the Annexure-II of the replace with the following tables.

Table- II

(Thermal Loading Limits of Transmission Lines)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed. Data for some conductors which are equivalent to ACSR Zebra/Bersimis/Moose/Panther are also given in following tables:

Thermal Loading Limits for ACSR Zebra equivalent Conductors:

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (°C)	Ampacity for Maximum Conductor Temperature (°C)			
	Al/Al alloy wire	steel wire		65 ° C	75 ° C	85 ° C	95 ° C
[29]ACSR	54/3.1	7/3.18	40	454	630	761	NA

[27] Modified vide Amendment-II
[28] Modified vide Amendment-II
[29] Modified vide Amendment-II

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (ºC)	Ampacity for Maximum Conductor Temperature (ºC)			
	Al/Al alloy wire	steel wire		65 º C	75 º C	85 º C	95 º C
Zebra	8		45	330	550	699	NA
			48	224	496	658	NA
			50	104	456	630	NA
AAAC	61/3.19	NA	40	461	642	776	887
			45	335	560	713	834
			48	227	505	671	800
			50	104	464	642	776
AL59	61/3.08	NA	40	469	649	783	894
			45	343	567	719	840
			48	237	512	678	806
			50	123	471	648	782

Thermal Loading Limits for ACSR Bersimis equivalent Conductors:

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (ºC)	Ampacity for Maximum Conductor Temperature (ºC)			
	Al/Al alloy wire	steel wire		65 º C	75 º C	85 º C	95 º C
[30]ACSR Bersimis	42/4.57	7/2.54	40	571	819	1000	NA
			45	390	708	915	NA
			48	217	633	860	NA
			50	NA	576	820	NA
AAAC	61/4.0	NA	40	573	827	1013	1166
			45	387	714	926	1093
			48	206	637	870	1047
			50	NA	580	830	1015
AL59	61/4.02	NA	40	604	872	1069	1229
			45	408	754	977	1153
			48	215	672	917	1104
			50	NA	611	875	1070

Thermal Loading Limits for ACSR Moose equivalent Conductors:

[30] Modified vide Amendment-II

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (ºC)	Ampacity for Maximum Conductor Temperature (ºC)			
	Al/Al alloy wire	steel wire		65 º C	75 º C	85 º C	95 º C
[31]ACSR Moose	54/3.53	7/3.53	40	504	710	863	NA
			45	356	618	791	NA
			48	223	554	744	NA
			50	NA	507	711	NA
AAAC	61/3.55	NA	40	512	724	881	1010
			45	361	629	808	948
			48	225	565	760	909
			50	NA	517	726	882
AL59	61/3.52	NA	40	534	754	916	1049
			45	377	655	840	985
			48	237	588	790	944
			50	NA	538	755	916
AL59	61/3.31	NA	40	503	703	852	975
			45	362	613	782	916
			48	239	552	736	878
			50	88	507	704	852

Thermal Loading Limits for ACSR Panther equivalent Conductors:

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (ºC)	Ampacity for Maximum Conductor Temperature (ºC)			
	Al/Al alloy wire	steel wire		65 º C	75 º C	85 º C	95 º C
[32]ACSR Panther	30/3.0	7/3.0	40	320	428	510	NA
			45	247	378	470	NA
			48	189	344	444	NA
			50	137	320	426	NA
AAAC	37/3.15	NA	40	352	474	566	643
			45	269	418	522	605
			48	204	380	493	582
			50	144	353	473	565
AL59	37/3.08	NA	40	362	486	580	658
			45	278	429	535	619
			48	212	390	505	595

[31] Modified vide Amendment-II
[32] Modified vide Amendment-II

			50	152	362	485	578

Thermal Loading Limits for following ACSR Conductors

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (ºC)	Ampacity for Maximum Conductor Temperature (ºC)			
	Al wire	steel wire		65 º C	75 º C	85 º C	95 º C
[33]ACSR Snowbird	42/3.99	7/2.21	40	502	703	852	NA
			45	358	612	782	NA
			48	232	550	736	NA
			50	63	505	703	NA
ACSR Lapwing	45/4.78	7/3.18	40	615	896	1101	NA
			45	405	772	1006	NA
			48	187	686	944	NA
			50	NA	622	899	NA

The above data has been calculated based on following assumptions:

- Elevation above sea level = 0 m
- Solar radiations = 1045 W/m2.
- Wind velocity considering angle between wind & axis of conductor as 90 degrees = 0.56 m/sec
- Solar Absorption Coefficient = 0.8
- Emissivity Coefficient = 0.45
- Effective angle of incidence of sun's rays= 90 deg

Note: Generally, the ambient temperature may be taken as 45 deg Celsius; however, in some areas like hilly areas where ambient temperatures are less, the same may be taken after due calculation given in IS-9676.

[33] Modified vide Amendment-II

High Temperature Low Sag conductors (HTLS)

HTLS conductors are capable of being operated continuously at temperatures as high as 250º C without any degradation in mechanical or electrical properties. However, in such conductors, the increase in sag is not linear at all temperatures because above a certain temperature called 'knee point temperature', the conductor experiences a sag increase due to the expansion of core alone (coefficient of linear expansion of core wires are comparatively lower than the complete conductor). This is because of the higher thermal expansion rate of aluminium which causes all the stress of the conductor to be borne by the core beyond the knee point temperature. Therefore, beyond the knee point temperature, the new expansion coefficient of the conductor will be the same as that of the core, resulting in relatively low sag increase when operated at high temperature.

[34]Indicative parameters of HTLS conductor:

Transmission Line	Ampacity of HTLS per conductor	Minimum Conductor diameter (mm)	Maximum DC Resistance at 20°C (Ω/km)	Sub-conductor Spacing (mm)	Reactance (X)	Susceptance (B)
400kV Transmission line with Twin HTLS conductor	1516 A	28.62	**0.0549**	450		
220 kV transmission line with single HTLS conductor	1092 A	25	**0.0677**	NA		
132 kV transmission line with single HTLS conductor	800 A	18	**0.1363**	NA		

20. Amendment to Table V (c) in the Annexure-III of the Manual

The Typical parameters for Renewable Energy Generation Sources has been added at Table V (c) of Annexure-II.

21. Amendment to Tables in the Annexure-III of the Manual

The indicative model of VSC, Wind Park/Farm, Solar Park/Farm, Renewable Energy Generator Converter, BESS unit, Renewable Electrical Control Model, Renewable

[34] Added vide Amendment-II

Energy Plant Controller, Grid-Forming Droop Based Model, Grid-Forming Virtual synchronous machine and STATCOM have been added at Table VII to XVI of Annexure-II.

Table- VII

[35](Modelling for VSC HVDC)

Actual system data, wherever available, should be used. In cases where data is not available standard data given below can be assumed:

VSC Data: No standardized DC control model has been developed so far as this model is usually built to the load requirements of the DC terminals. Based on the past experience in carrying out stability studies, the following models are suggested for VSC.

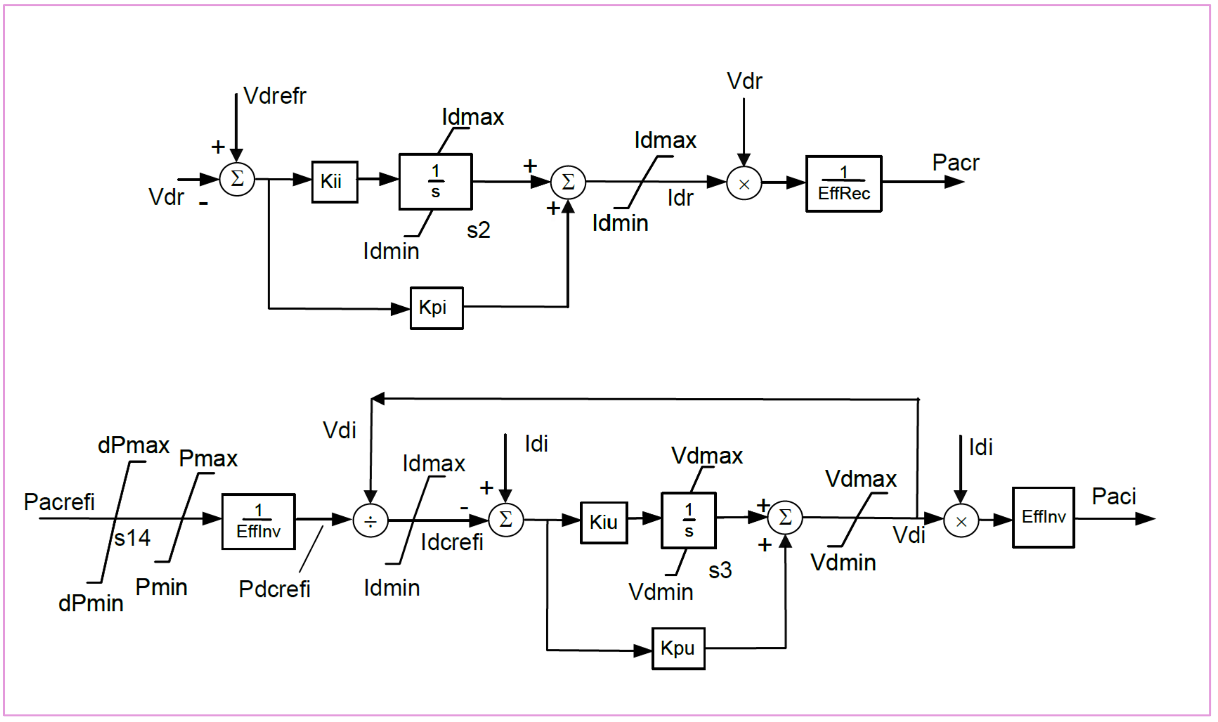


Fig: DC Current and Voltage Controllers (WECC Generic 2-Terminal VSC DC Model) [Source: EPRI/WECC Model guidelines]

Description of the above generic models with typical parameter value is provided at **Exhibit-(i)**

[35] Added vide Amendment-II

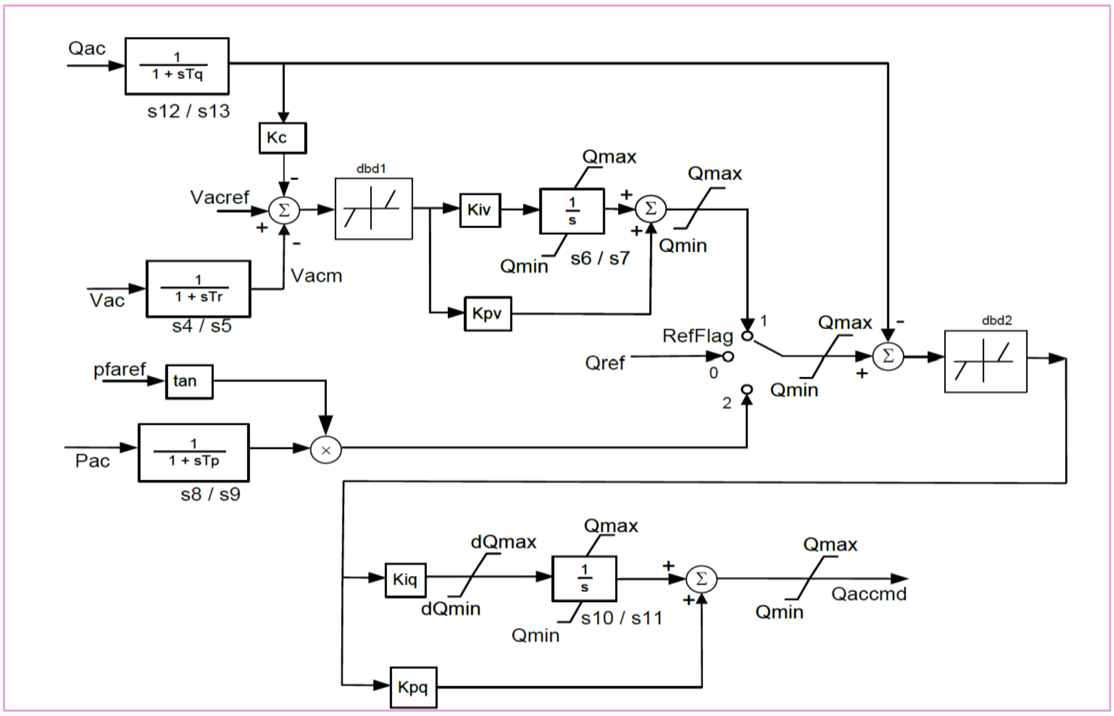


Fig: MVAR Controls for each converter (rectifier & inverter) (WECC Generic 2-Terminal VSC DC Model)
[Source: EPRI/WECC Model guidelines]

[36]Table- VIII

Modelling for Wind Farm

The dynamic components of a wind farm consist of the following elements (illustrated in picture below)

1. Generator or Converter @
2. Electrical control @
3. Drive-Train model #
4. Aerodynamics #
5. Pitch controller #
6. Torque controller #
7. Power Plant Controller (PPC) *
8. Energy storage (As applicable) @

@ Description of the above generic models with typical parameter value is provided at **Exhibit-(ii)**

Description of the above generic models with typical parameter value is provided at **Exhibit-(iii)**

* Description of the above generic models with typical parameter value is provided at **Exhibit-(iv)**

[36] Added vide Amendment-II

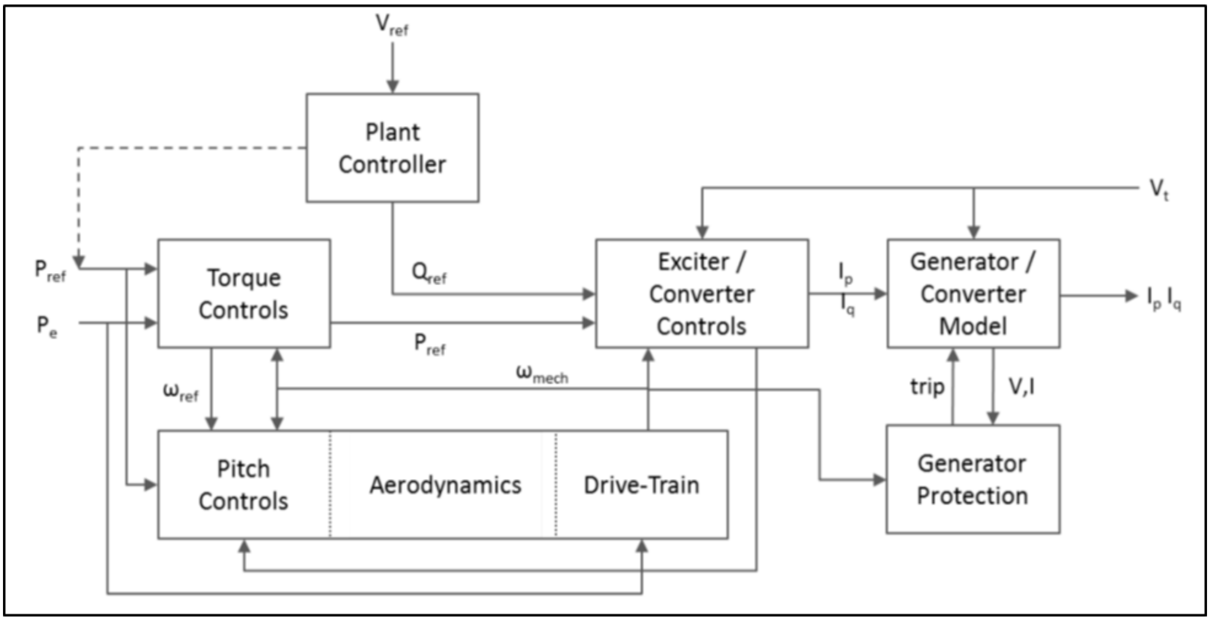


Fig: dynamic components of a wind farm

[37]Table- IX

Modelling for Solar Park/Farm

The dynamic components of a solar farm or park consist of the following elements (illustrated in picture below):

1. Generator or Converter @
2. Electrical control including fault ride through @
3. Power Plant Controller (PPC) *
4. Energy storage (i.e. battery), if applicable @

@ Description of the above generic models with typical parameter value is provided at **Exhibit-(ii)**

***** Description of the above generic models with typical parameter value is provided at **Exhibit-(iv)**

[37] Added vide Amendment-II

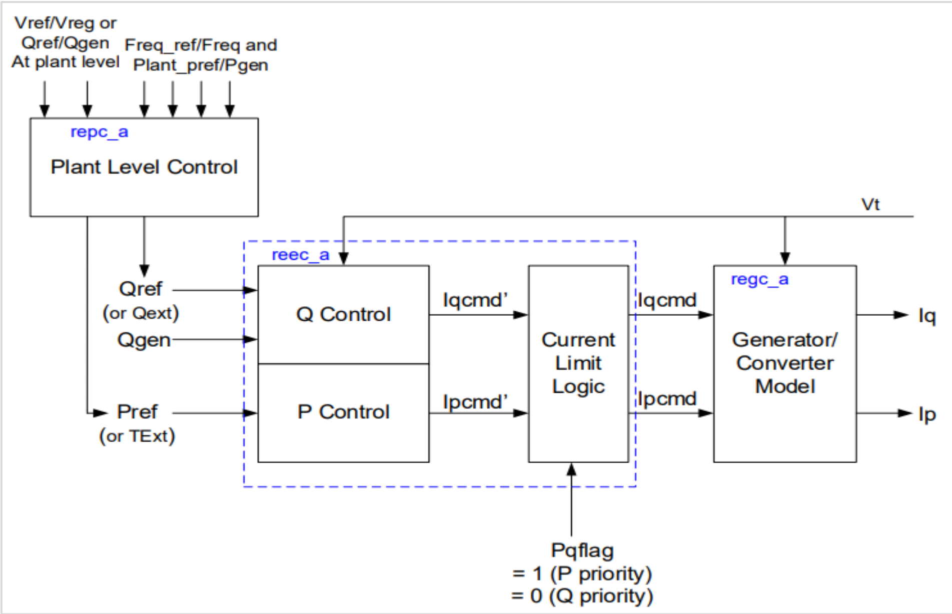


Fig: dynamic components of a Solar park/ farm

[38]Table- X

Modelling of BESS unit

A BESS unit is modelled using generation generic models as shown below.

- Renewable energy generator/converter model: the inverter interface for the BESS unit.
- Renewable energy electrical controls model: BESS inverter controls (representation of the charging/discharging dynamics).

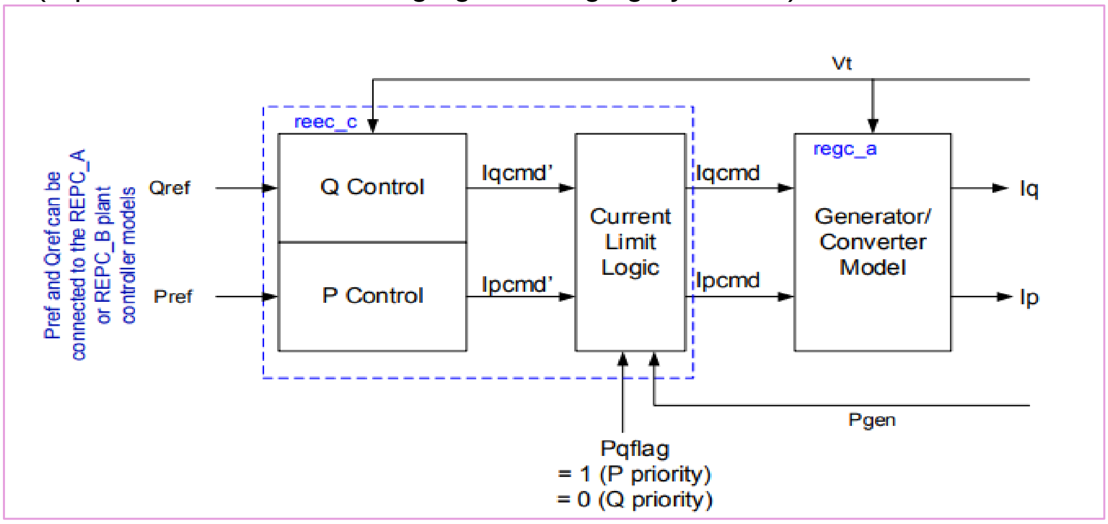


Fig: dynamic components of a BESS unit

Description of the above generic models with typical parameter value is provided at **Exhibit-(ii)**

38 Added vide Amendment-II

[39]Table- XI

Modelling for Renewable Energy Generator Converter Model (REGC_C)

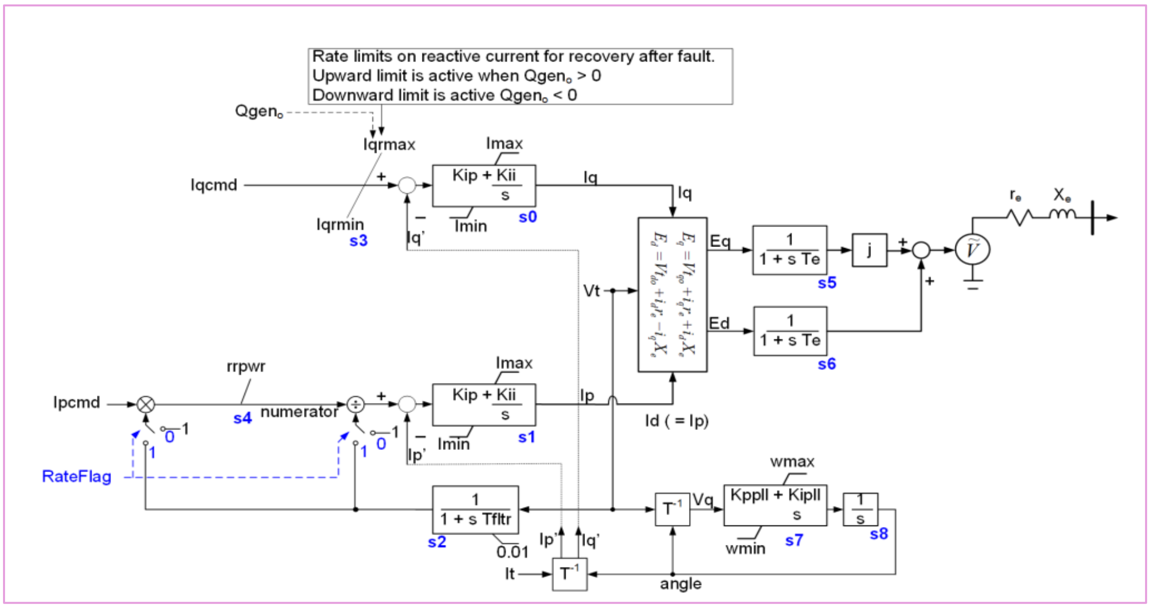
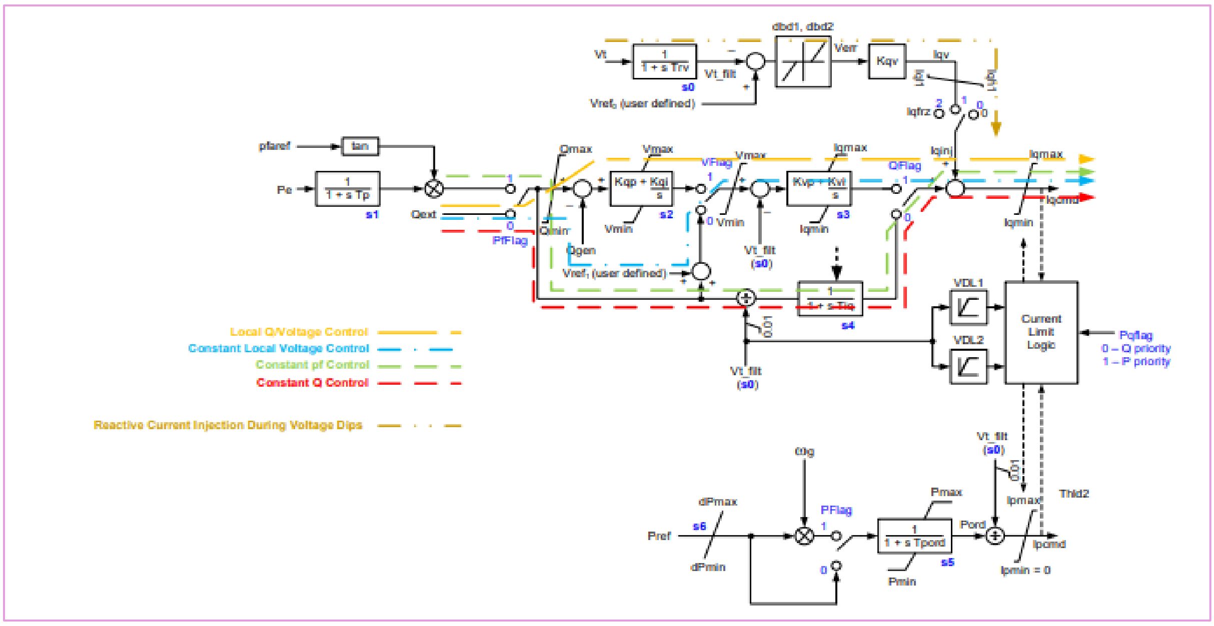


Fig: Control block diagram of Renewable energy generator converter model REGC_C [Source: EPRI/WECC Model guidelines]

Description of the above generic models with typical parameter value is provided at **Exhibit-(ii)**

[40]Table- XII

Modelling for Renewable Electrical Control Model (REEC_D)



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39 Added vide Amendment-II

40 Added vide Amendment-II

Fig: Control block diagram of Renewable Electrical Control Model REEC_D [Source: EPRI/WECC Model guidelines]

Description of the above generic models with typical parameter value is provided at **Exhibit-(ii)**

[41]Table- XIII

Modelling for Renewable Energy Plant Controller (REPC_C)

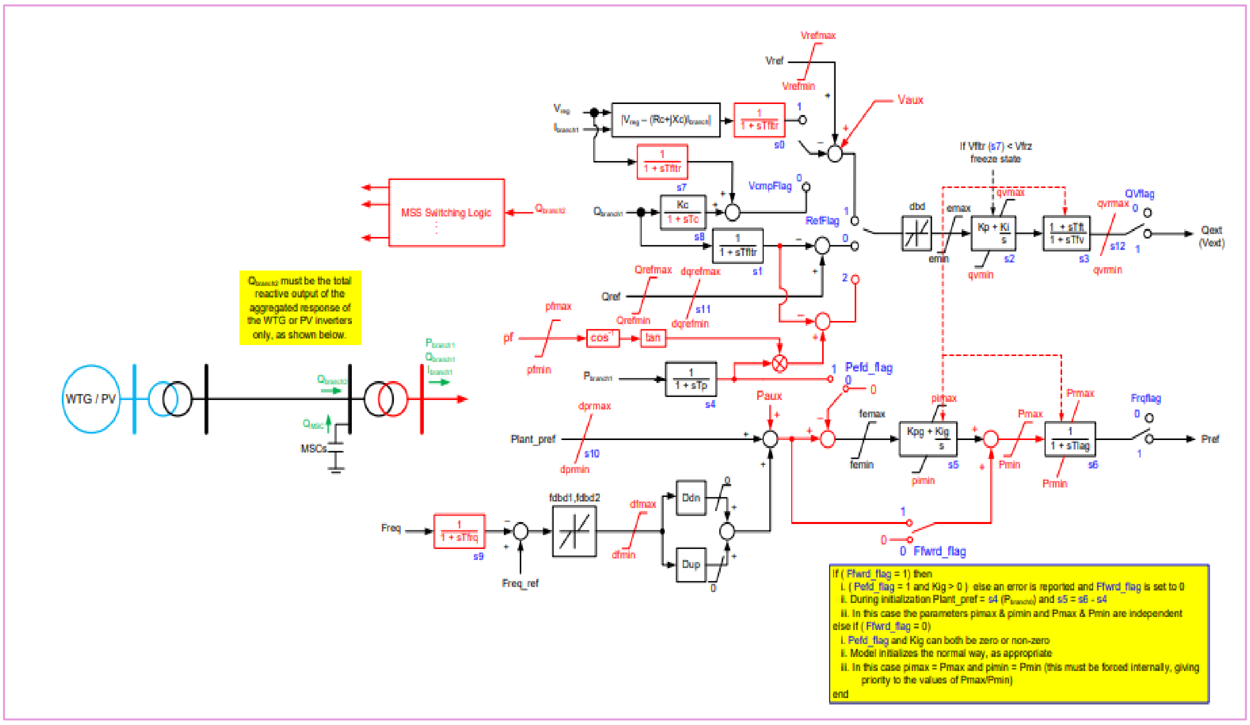

Fig: Control block diagram of Plant Controller Model – REPC_C [Source: EPRI/WECC Model guidelines]

Description of the above generic models with typical parameter value is provided at **Exhibit-(iv)**

[42]Table- XIV

41 Added vide Amendment-II

42 Added vide Amendment-II

Modelling for Grid-Forming Droop Based Model

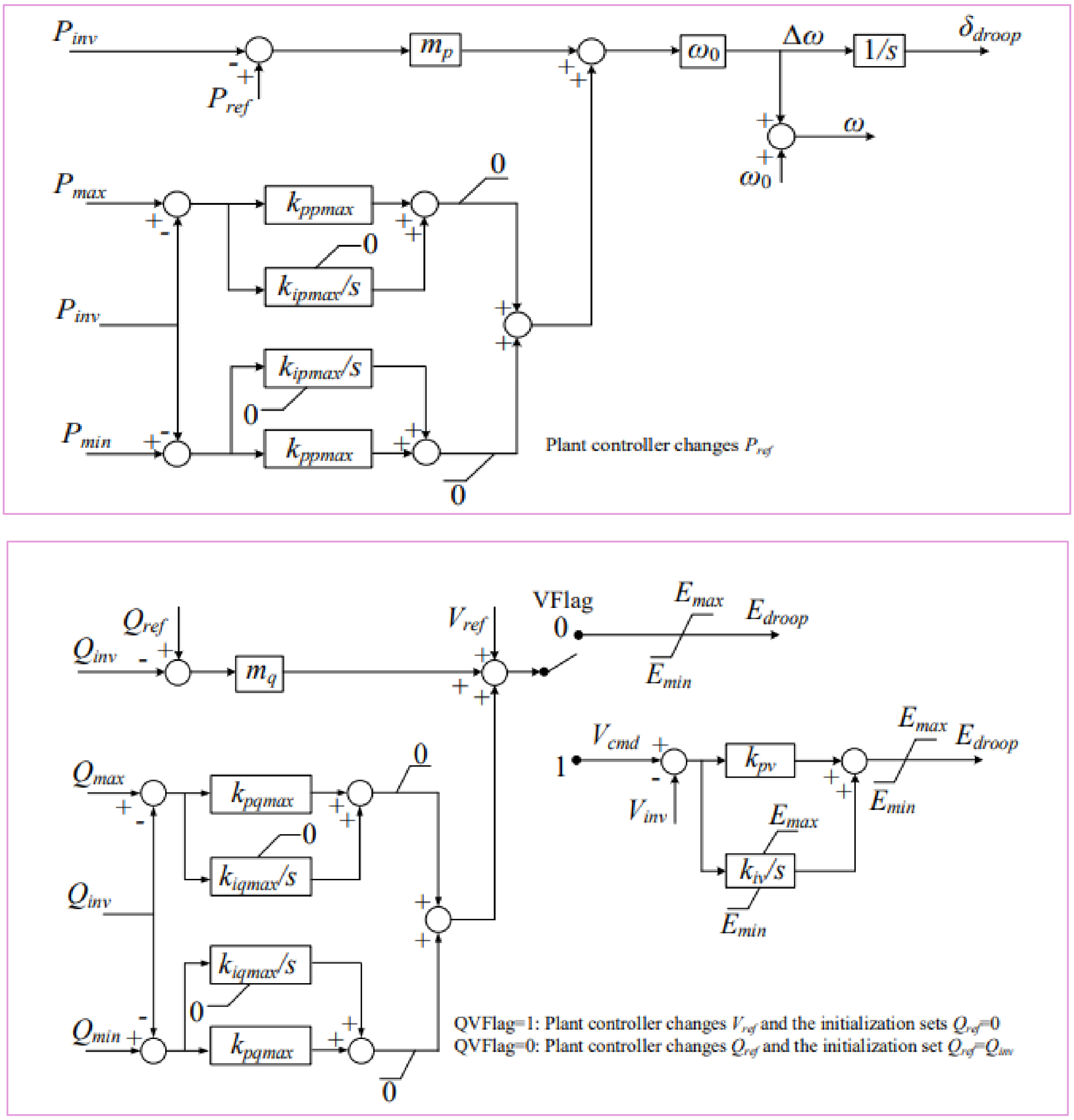

Fig: Control block diagram of Grid forming Droop Based Model REGFM_A1 [source: PNNL Model Specification]

Description of the above generic models with typical parameter value is provided at **Exhibit-(v)**

[43]Table- XV

Modelling for Grid-Forming Virtual synchronous machine-based Model

43 Added vide Amendment-II

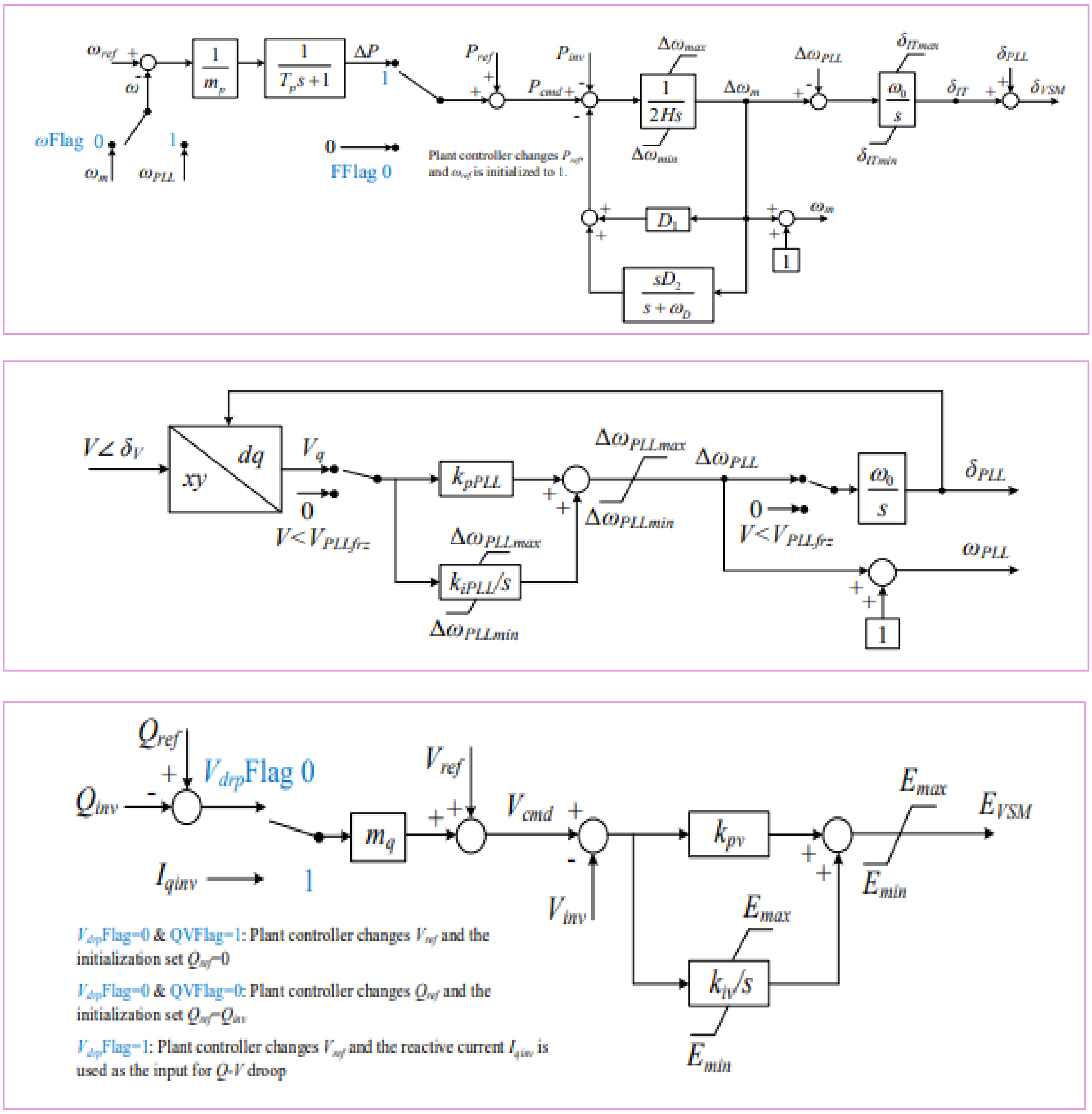

Fig: Control block diagram of Grid forming Virtual synchronous machine Based Model REGFM_B1 [source: PNNL Model Specification]

Description of the above generic models with typical parameter value is provided at **Exhibit-(v)**

[44]Table- XVI

Modelling for STATCOM Model

[44] Added vide Amendment-II

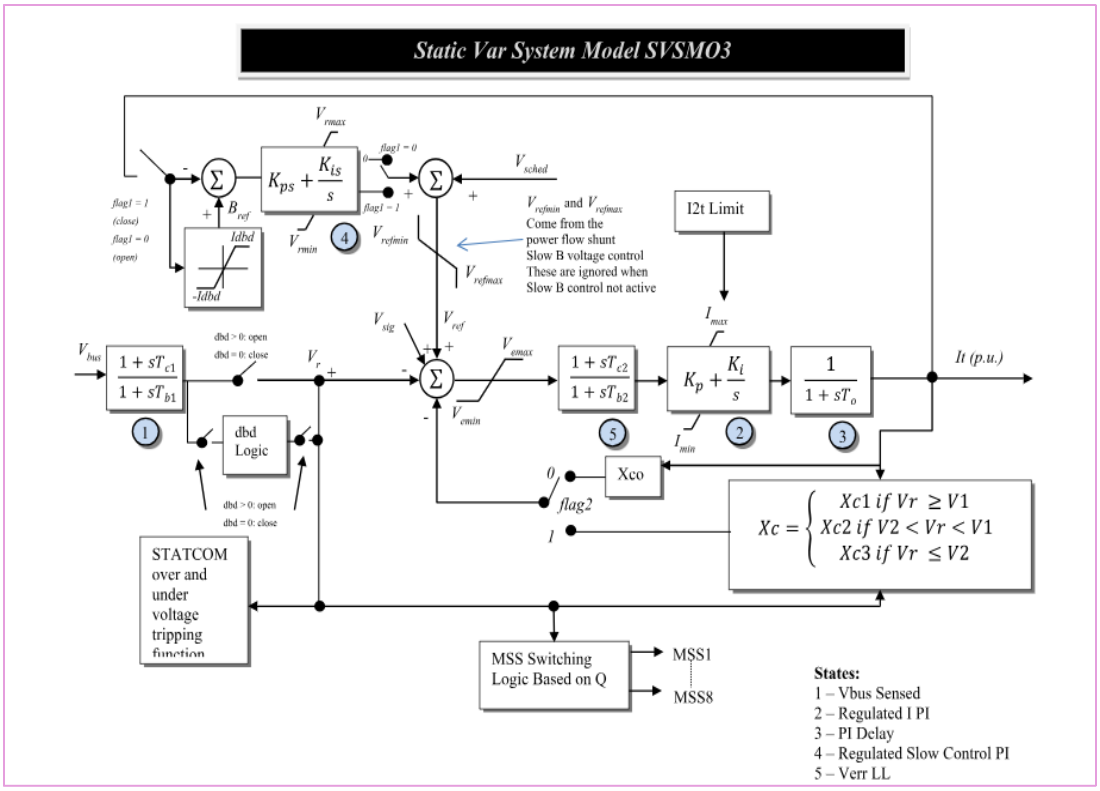

Fig: Control block diagram of STATCOM model SVSMO3T2 [Source: Power world model guidelines]

Description of the above generic models with typical parameter value is provided at **Exhibit-(vi)**

[45]Table- XVII
Modelling of Load

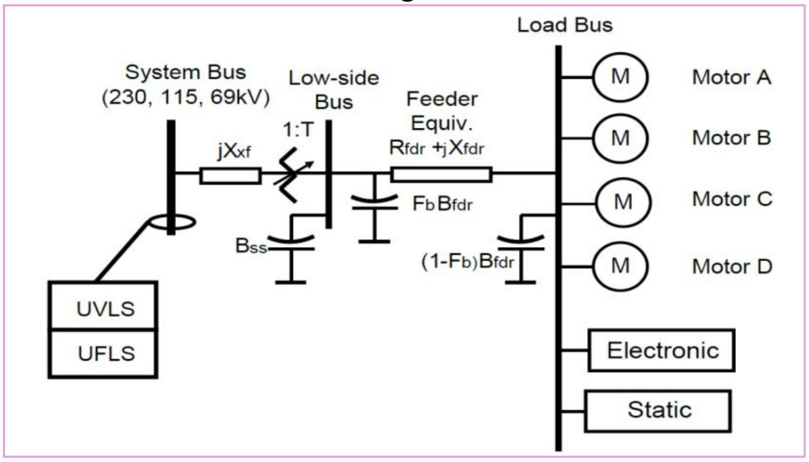

Fig. Composite load model structure CMLDXXU2 for residential and commercial load [WECC Model Specification]

Description of the above generic models with typical parameter value is provided at **Exhibit-(vii)**

[45] Added vide Amendment-II

22. Amendment to Table I in the Annexure-III of the Manual

The Load factors mentioned at Table I Annexure-III are amended as under.

Table-I

[46](Load Factors)

Season	Monsoon			Summer			Winter		
Scenarios	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak
Region	%	%	%	%	%	%	%	%	%
All India	95%	93%	71%	100%	98%	74%	98%	87%	62%
NR	89%	90%	55%	100%	97%	59%	76%	67%	39%
WR	87%	85%	60%	87%	83%	64%	99%	89%	68%
SR	91%	75%	47%	83%	77%	51%	98%	81%	61%
ER	87%	95%	67%	96%	99%	63%	71%	74%	50%
NER	81%	93%	44%	84%	95%	29%	60%	68%	32%

23. Amendment to Table II in the Annexure-III of the Manual

The Capacity factors for RE sources mentioned at Table II (a) and II (b) at Annexure-III are amended as under.

Table-II

(Capacity Factors – for Renewable Energy Source (wind/solar) generation)

Capacity factor, considering diversity in wind/solar generation, is the ratio of maximum generation available at an aggregation point to the algebraic sum of capacity of each wind machine / solar panel connected to that grid point. Actual data, wherever available, should be used. In cases where data is not available the Capacity factor (in %) may be calculated using following factors:

Table-II(a)

[47]Capacity Factor for Solar Generation

Season	Monsoon			Summer			Winter		
Scenarios	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak

[46] Modified vide Amendment-II

[47] Modified vide Amendment-II

Region	%	%	%	%	%	%	%	%	%
NR	99%	0%	0%	100%	0%	0%	99%	0%	0%
WR	99%	0%	0%	100%	0%	0%	99%	0%	0%
SR	80%	0%	0%	95%	0%	0%	95%	0%	0%
ER	80%	0%	0%	85%	0%	0%	90%	0%	0%
NER	80%	0%	0%	85%	0%	0%	90%	0%	0%

Table-II(b)

[48]Capacity Factor for Wind Generation

Season	Monsoon			Summer			Winter		
Scenarios	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak	Day Peak	Evening Peak	Night off-Peak
Region	%	%	%	%	%	%	%	%	%
NR	50%	70%	60%	50%	70%	60%	41%	50%	50%
WR	90%	90%	90%	90%	90%	85%	75%	80%	80%
SR	75%	75%	65%	65%	75%	65%	50%	45%	45%
ER	0%	0%	0%	0%	0%	0%	0%	0%	0%
NER	0%	0%	0%	0%	0%	0%	0%	0%	0%

Note: The above factors may be revised from time to time.

[48] Modified vide Amendment-II

Exhibit-(i)

[49]Description of the Generic Model for VSC based HVDC with typical parameter value is as under.

Category	Parameter Description	Typical Value
VSC based HVDC Model (VHVDC1)		
VSC based HVDC Model (VHVDC1) (Refer Table-VII of Annexure -III)	Description	Value
	MWrate, MW rating of the VSC DC line (> 0)	2500
	Kpi (kA/kV), Proportional gain for DC current control	0.05
	Kii (kA/kV/s), Integral gain for DC current control (> 0)	50
	Kpu (kV/kA), proportional gain for dc voltage control	1
	Kiu (kV/kA/s), proportional gain for dc voltage control (> 0)	100
	Idmax (kA), Maximum DC current reference	4.05
	Idmin (kA), Minimum DC current reference	0
	Vdmax (kV), Maximum DC voltage reference	510
	Vdmin (kV), Minimum DC voltage reference	0
	Imax (pu of MWrate), Maximum Converter Current (> 0)	1.5
	Pmax (pu of MWrate), Maximum AC power	1.05
	Pmin (pu of MWrate), Minimum AC power	0
	L (mH), DC line/cable inductance (> 0)	60
	C (µF), DC line/cable capacitance (> 0)	20
	P1 (pu of MWrate), Point on the V-P curve	0.5
	P2 (pu of MWrate), Point on the V-P curve (P2 > P1)	0.75
	P3 (pu of MWrate), Point on the V-P curve (P3 > P2)	0.9
	P4 (pu of MWrate), Point on the V-P curve (P4 > P3)	1.01
	V1 (pu AC voltage), Point on the V-P curve	0.5
	V2 (pu AC voltage), Point on the V-P curve (V2 > V1)	0.75
	V3 (pu AC voltage), Point on the V-P curve (V3 > V2)	0.9
	V4 (pu AC voltage), Point on the V-P curve (V4 > V3)	0.95
	V5 (pu AC voltage), Point on the V-P curve (V5 > V4)	1.1
	V6 (pu AC voltage), Point on the V-P curve (V6 > V5)	1.3
	Tr (s), AC voltage measurement transducer time constant	0.02
	VblkR (pu), AC Voltage below which rectifier blocks	0.25
	VblkI (pu), AC voltage below which inverter blocks	0.3
	Description	Value
	Tpll (s), PLL recovery delay after blocking	0.15
	Vunblk (pu), AC voltage above which converter unblocks	0.8
	Ipmax1 (pu on MWrate), Point on the D-curve (Q into the system) (>0), (Ipmax1 < Imax)	0.9

[49] Added vide Amendment-II

	Ipmax2 (pu on MWrate), Point on the D-curve (Q into the system) (>0), (Ipmax2 < Ipmax1)	0.5
	Ipmax3 (pu on MWrate), Point on the D-curve (Q into the system) (>0), (Ipmax3 < Ipmax2)	0.3
	Iqmax2 (pu on MWrate), Point on the D-curve (Q into the system) (>0), (Imax2 < Imax)	0.5
	Iqmax3 (pu on MWrate), Point on the D-curve (Q into the system), (Iqmax3 < Iqmax2)	0.75
	Ipmin1 (pu on MWrate), Point on the D-curve (Q from the system) (>0), (Ipmin1 < Imax)	0.9
	Ipmin2 (pu on MWrate), Point on the D-curve (Q from the system), (Ipmin2 < Ipmin1)	0.5
	Ipmin3 (pu on MWrate), Point on the D-curve (Q from the system), (Ipmin3 < Ipmin2)	0.3
	Iqmin2 (pu on MWrate), Point on the D-curve (Q from the system) (<0)	-0.5
	Iqmin3 (pu on MWrate), Point on the D-curve (Q from the system) (<0), (ABS(Iqmin3) > ABS(Iqmin2))	-0.75
	Tp (s), real power measurement time constant	0.1
	Tq (s), reactive power measurement time constant	0.1
	dbd1r (pu), rectifier voltage control deadband (≥0)	0
	dbd1i (pu), inverter voltage control deadband (≥0)	0
	Kcr (pu/MVAR), Rectifier reactive droop	0
	Kci (pu/MVAR), Inverter reactive droop	0
	dbd2r (MVAR), rectifier Q control deadband (≥0)	0
	dbd2i (MVAR), inverter Q control deadband (≥0)	0
	Kpvr (MVAR/pu), Rectifier voltage control proportional gain	200
	Kivr (MVAR/pu/s), Rectifier voltage control integral gain (>0)	500
	Kpqr (MVAR/MVAR), Rectifier Q control proportional gain	0
	Kiqr (MVAR/MVAR/s), Rectifier Q control integral gain (>0)	10
	Kpvi (MVAR/pu), Inverter voltage control proportional gain	200
	Kivi (MVAR/pu/s), Inverter voltage control integral gain (>0)	500
	Kpqi (MVAR/MVAR), Inverter Q control proportional gain	0
	Kiqi (MVAR/MVAR/s), Inverter Q control integral gain (>0)	10
	dQmax (MVAR/s), Maximum rate of change of Qac (>0)	999
	dQmin (MVAR/s), Minimum rate of change of Qac (<0)	-999
	dPmax (MW/s), Maximum rate of change of Pacref (>0)	1000
	dPmin (MW/s), Minimum rate of change of Pacref (<0)	-999

Exhibit-(ii)

[50]Description of the Generic Generator model and Electric control model with typical parameter value is as under.

Category	Parameter Description	Typical Value
Generator Model		
	Imax (pu), Maximum current rating of the converter (>0)	1.3
REGCC (For Type-3 and Type-4 Wind turbines, Solar PV & BESS (Refer Table-IX, X, XI of Annexure-III)	Iqrmax, maximum rate limit on Iqcmd (>0)	9999
	Iqrmin, minimum rate limit on Iqcmd (<0)	-9999
	Tfltr (s), terminal voltage filter constant	0.01
	Rrpwr (pu/s), rate of recovery of active current or power (>0)	100
	Imax (pu), maximum converter current rating	1.2
	Te (s), delay in converter control (>0)	0.01
	Kip (pu), inner current control loop proportional gain	0.5
	Ki (1/s), inner current control loop integral gain	5
	Kppll (rad/pu·s), PLL proportional gain	20
	Kipll (rad/pu), PLL integral gain	100
	Wmax (rad/s), upper PLL rate limit	100
	Wmin (rad/s), lower PLL rate limit	-100
	Vpllfrz (pu), voltage below which PLL integrator (state s7) is frozen	0.09
Category	**Parameter Description**	**Typical Value**
Electrical Control model		
REEC_D (For Type-3 and Type-4 Wind turbines, Solar PV & BESS (Refer Table-XII of Annexure-III)	Vdip (pu), low-voltage threshold to activate reactive current injection	0
	Vup (pu), voltage above which reactive current injection logic is activated	1.34
	Trv (s), voltage filter time constant	0.02
	dbd1 (pu), voltage error deadband lower threshold (≤ 0)	-0.05
	dbd2 (pu), voltage error deadband upper threshold (≥ 0)	0.05
	Kqv (pu), reactive current injection gain during over- and under-voltage conditions	2
	Iqh1 (pu), upper limit on reactive current injection	1.1
	Iql1 (pu), lower limit on reactive current injection	-1.05
	Vref0 (pu), user-defined reference (if 0, model initializes to initial terminal voltage)	1
	Iqfrz (pu), value at which Iqcmdbl is held (frozen) for Thld seconds after a voltage dip is over	0.15
	Thld (s), time for which Iqcmdbl is frozen after the voltage dip is over	0
	Thld2 (s ≥ 0), time for which Ipcmd and Ipmax are frozen after the voltage dip is over	0
	Tp (s), filter time constant for electrical power	0.02
	QMax (pu), maximum value of the signal Qext or Vext	0.44
	QMin (pu), minimum value of the signal Qext or Vext	-0.44
	VMAX (pu), maximum limit for voltage control	1.15
	VMIN (pu), minimum limit for voltage control	0.85
	Kqp (pu), reactive power regulator proportional gain	1
	Kqi (pu), reactive power regulator integral gain	0.001
	Kvp (pu), voltage regulator proportional gain	1
	Kvi (pu), voltage regulator integral gain	2
	Vbias (pu), user-defined bias (normally 0)	0
	Tiq (s), time constant on delay for block s4	0.46
	dPmax (pu/s > 0), power reference maximum ramp rate	1
	dPmin (pu/s < 0), power reference minimum ramp rate	-1
	PMAX (pu), maximum power limit	1

[50] Added vide Amendment-II

	PMIN (pu), minimum power limit	0
	Imax (pu), maximum limit on total converter current	1
	Tppord (s), power filter time constant	0.0167
	Vq1 (pu), VDL table vq-iq pair (voltage)	-1
	Iq1 (pu), VDL table vq-iq pair (current)	1.3
	Vq2 (pu), VDL table vq-iq pair (voltage), Vq2 > Vq1	2
	Iq2 (pu), VDL table vq-iq pair (current)	1.3
	Vq3 (pu), VDL table vq-iq pair (voltage), Vq3 > Vq2	0
	Iq3 (pu), VDL table vq-iq pair (current)	0
	Vq4 (pu), VDL table vq-iq pair (voltage), Vq4 > Vq3	0
	Iq4 (pu), VDL table vq-iq pair (current)	0
	Vq5 (pu), VDL table vq-iq pair (voltage), Vq5 > Vq4	0
	Iq5 (pu), VDL table vq-iq pair (current)	0
	Vq6 (pu), VDL table vq-iq pair (voltage), Vq6 > Vq5	0
	Iq6 (pu), VDL table vq-iq pair (current)	0
	Vq7 (pu), VDL table vq-iq pair (voltage), Vq7 > Vq6	0
	Iq7 (pu), VDL table vq-iq pair (current)	0
	Vq8 (pu), VDL table vq-iq pair (voltage), Vq8 > Vq7	0
	Iq8 (pu), VDL table vq-iq pair (current)	0
	Vq9 (pu) (Vq9>Vq8), VDL table vq-iq pair (voltage)	0
	Iq9 (pu), VDL table vq–iq pair (current)	0
	Vq10 (pu), Vq10 > Vq9, VDL table vq–iq pair (voltage)	0
	Iq10 (pu), VDL table vq–iq pair (current)	0
	Vp1 (pu), VDL table vp–ip pair (voltage)	-1
	Ip1 (pu), VDL table vp–ip pair (current)	1.3
	Vp2 (pu), Vp2 > Vp1, VDL table vp–ip pair (voltage)	2
	Ip2 (pu), VDL table vp–ip pair (current)	1.3
	Vp3 (pu), Vp3 > Vp2, VDL table vp–ip pair (voltage)	0
	Ip3 (pu), VDL table vp–ip pair (current)	0
	Vp4 (pu), Vp4 > Vp3, VDL table vp–ip pair (voltage)	0
	Ip4 (pu), VDL table vp–ip pair (current)	0
	Vp5 (pu), Vp5 > Vp4, VDL table vp–ip pair (voltage)	0
	Ip5 (pu), VDL table vp–ip pair (current)	0
	Vp6 (pu), Vp6 > Vp5, VDL table vp–ip pair (voltage)	0
	Ip6 (pu), VDL table vp–ip pair (current)	0
	Vp7 (pu), Vp7 > Vp6, VDL table vp–ip pair (voltage)	0
	Ip7 (pu), VDL table vp–ip pair (current)	0
	Vp8 (pu), Vp8 > Vp7, VDL table vp–ip pair (voltage)	0
	Ip8 (pu), VDL table vp–ip pair (current)	0
	Vp9 (pu), Vp9 > Vp8, VDL table vp–ip pair (voltage)	0
	Ip9 (pu), VDL table vp–ip pair (current)	0
	Vp10 (pu), Vp10 > Vp9, VDL table vp–ip pair (voltage)	0
	Ip10 (pu), VDL table vp–ip pair (current)	0
	Rc (pu), current compensation resistance	0
	Xc (pu), current compensation reactance	0.01
	Tr1 (s), time constant for reactive current compensation	0.03
	Kc, reactive current compensation gain	0.01
	Ke, scaling on Ipmin (0 for generator, 0 < Ke ≤ 1 for storage)	0
	Vblk1 (pu), voltage below which converter will block	0.1
	Vblk2 (pu), voltage above which converter will block	1
	Tblk (s), time for which converter remains blocked after voltage is within Vblk1 < Vt < Vblk2	0.05

Exhibit-(iii)

[51]Description of the generic models for dynamic components of a wind farm such as Drive Train, Pitch control, Aerodynamic and Torque controller with typical parameter value of are tabulated below. (**Refer Table-VIII of Annexure-III above**)

Category	Parameter Description	Typical Value
Drive Train model		
Type 3 and Type 4 Wind Machines (WTDTA1)	H, Total inertia constant, sec	5.4900
	DAMP, Machine damping factor, pu P/pu speed	0.0
	Htfrac, Turbine inertia fraction (Hturb/H)1	0.8740
	Freq1, First shaft torsional resonant frequency, Hz	1.1374
	Dshaft, Shaft damping factor (pu)	1.8000

Category	Parameter Description	Typical Value
Pitch Control model [for Type-3 only]		
Generic Pitch Control model for Type-3 : (WTPA1)	Kiw, pitch-control integral gain (pu)	50.0
	Kpw, pitch-control proportional gain (pu)	200.0
	Kic, pitch-compensation integral gain (pu)	0.0
	Kpc, pitch-compensation proportional gain (pu)	0.0
	Kcc (pu)	0.0
	Tp, blade response time constant (s)	0.3000
	TetaMax, maximum pitch angle (degrees)	27.0
	TetaMin, minimum pitch angle (degrees)	0.0
	RTetaMax, maximum pitch angle rate (degrees/s)	10.0
	RTetaMin, minimum pitch angle rate (degrees/s) (<0)	-10.0
Aerodynamic model [For Type-3 only]		
(WTARA1)	Ka, Aerodynamic gain factor (pu/degrees)	0.0070
	Theta 0 Initial pitch angle (degrees)	0.0
Torque Controller model [For Type-3 only]		
Generic Torque Controller for Type-3 wind machines : (WTTQA1)	Kpp, proportional gain in torque regulator (pu)	0.3000
	KIP, integrator gain in torque regulator (pu)	0.6000
	Tp, electrical power filter time constant (s)	0.0500
	Twref, speed-reference time constant (s)	60.0
	Temax, maximum limit in torque regulator (pu)	1.1000
	Temin, minimum limit in torque regulator (pu)	0.0
	p1, power (pu)	0.1500
	spd1, shaft speed for power p1 (pu)	0.8500
	p2, power (pu)	0.2250
	spd2, shaft speed for power p2 (pu)	0.9500
	p3, power (pu)	0.3550
	spd3, shaft speed for power p3 (pu)	1.1000
	p4, power (pu)	0.4580
	spd4, shaft speed for power p4 (pu)	1.2000
	TRATE, total turbine rating (MW)	0.0

[51] Added vide Amendment-II

Exhibit-(iv)

[52]Description of the generic models for Power Plant controller with typical parameter value of are tabulated below

Category	Parameter Description	Typical Value
Power Plant Controller (PPC) model		
Generic Power Plant Controller (PPC) model: REPC_C (Refer Table- VIII, IX of Annexure-III)	Tfltr (s), voltage or reactive power measurement filter time constant	0.02
	Kp (pu), reactive power PI control proportional gain	1
	Ki (pu), reactive power PI control integral gain (>0)	5
	Tft (s), lead time constant	0
	Tfv (s), lag time constant	0.05
	Vfrz (pu), voltage below which State s2 is frozen	0.7
	Rc (pu), line drop compensation resistance	0
	Xc (pu), line drop compensation reactance	0.05
	Kc (pu), reactive current compensation gain	0.02
	emax (pu), upper limit on deadband output	0.05
	emin (pu), lower limit on deadband output	-0.05
	dbd1 (pu), lower threshold for reactive power control deadband (≤ 0)	0
	dbd2 (pu), upper threshold for reactive power control deadband (≥ 0)	0
	qvmax (pu), upper limit on output of V/Q control	0.05
	qvmin (pu), lower limit on output of V/Q control	-0.5
	Kpg (pu), proportional gain for power control	1
	Kig (pu), integral gain for power control	0.1
	Tp (s), real power measurement filter time constant	0.02
	fdbd1 (pu deviation), deadband for frequency control, lower threshold (≤ 0)	-0.0006
	fdbd2 (pu deviation), deadband for frequency control, upper threshold (≥ 0)	0.0006
	Pfremax (pu power), primary frequency response error upper limit	99
	Pfremin (pu power), primary frequency response error lower limit	-99
	Pmax (pu), upper limit on power reference	1
	Pmin (pu), lower limit on power reference	-1
	Tlag (s), power controller lag time constant	0.1
	Ddn (pu), reciprocal of droop for over-frequency conditions (≥ 0)	20
	Dup (pu), reciprocal of droop for under-frequency conditions (≥ 0)	20
	Vrefmax (pu), maximum voltage reference	1.08
	Vrefmin (pu), minimum voltage reference	0.95
	Qrefmax (pu), maximum Q-reference	0.5
	Qrefmin (pu), minimum Q-reference	-0.5
	dqrefmax (pu/s), maximum rate of increase of Q-reference	99
	dqrefmin (pu/s), maximum rate of decrease of Q-reference	-99
	qvrrmax (pu/s), maximum rate of increase of Qcmd (Vcmd) (>0)	0.5
	qvrrmin (pu/s), maximum rate of decrease of Qcmd (Vcmd) (<0)	-0.5
	dprmax (pu/s), maximum rate of increase of plant Pcmd (>0)	99
	dprmin (pu/s), maximum rate of decrease of plant Pcmd (<0)	-99
	pfmax, maximum power factor limit	0.9
	pfmin, minimum power factor limit	-0.9
	dprmax2 (pu/s), maximum rate of increase of Pref	1
	dprmin2 (pu/s), maximum rate of decrease of Pref	-1
	PImax (pu), maximum output of the active power PI controller	0.1
	PImin (pu), minimum output of the active power PI controller	-0.1

[52] Added vide Amendment-II

	Tc (s), reactive-current compensation time constant	0.02
	Qdn1 (pu), first stage of capacitor (reactor) switching OFF (ON)	-0.25
	Qdn2 (pu), second stage of capacitor (reactor) switching OFF (ON), Qdn2 < Qdn1	-0.5
	Qup1 (pu), first stage of capacitor (reactor) switching ON (OFF), Qup1 > 0	0.3
	Qup2 (pu), second stage of capacitor (reactor) switching ON (OFF), Qup2 > Qup1	0.4
	Tdelay1 (s), time delay after which, if Q < Qdn1 or Q > Qup1, MSS logic is initiated	0.5
	Tdelay2 (s), time delay after which, if Q < Qdn2 or Q > Qup2, MSS logic is initiated (Tdelay2 < Tdelay1)	1
	Tmssbrk (s), breaker time to switch ON or OFF a shunt	0.06
	Tout (s), shunt capacitor discharge time after being switched OFF (if a capacitor is switched OFF; that capacitor cannot be switched back ON until Tout seconds have elapsed)	120
	Tfrz (s), delay during which states s2, s3, s5, and s6 remain frozen after the filtered voltage recovers above Vfrz	1
	Tfrq (s), frequency measurement time constant	0.02
	Vfrq (pu), voltage below which measured frequency is set to 1 pu	0.8
	dfmax (pu), frequency error upper limit (> 0)	0.015
	dfmin (pu), frequency error lower limit (< 0)	-0.015

Exhibit-(v)

[53]Description of the generic models for RE generator for Grid forming control with typical parameter value of are tabulated below

Category	Parameter Description	Data
Renewable generator model for Grid Forming Control (Solar/Wind/BESS)		
REGFMA1 (Droop based) (Refer Table-XIV of Annexure-III)	Tp (s), active power filter time constant	0.0100
	Tqf (s), reactive power filter time constant	0.0100
	Tpf (s), terminal voltage filter time constant	0.0100
	Imax (pu), maximum transient converter current	1.5000
	Emax (pu), maximum inverter internal voltage	1.1500
	Emin (pu), minimum inverter internal voltage	0.0
	Pmax (pu), maximum inverter active power output	0.9000
	Pmin (pu), minimum inverter active power output	0.0
	Qmax (pu), maximum inverter reactive power output	0.5000
	Qmin (pu), minimum inverter reactive power output	-0.5000
	mp (pu), P–f droop (> 0)	0.0100
	mq (pu), Q–V droop (> 0)	0.0100
	Kpp (pu), power controller limiter proportional gain	0.0100
	Kip (pu), power controller limiter integral gain (> 0)	0.1000
	Kqp (pu), reactive power controller limiter proportional gain	0.1000
	Kqi (pu), reactive power controller limiter integral gain (> 0)	20.0
	Kvp (pu), voltage controller proportional gain	0.0
	Kvi (pu), voltage controller integral gain (> 0)	5.8600
REGFMB1 (VSM based) (Refer Table-XV)	mq (pu), Q–V droop gain	0.0500
	Kpv (pu), proportional gain Q–V path	0.0
	Kiv (pu/s), integral gain Q–V path (> 0)	5.8600
	mp (pu), power–frequency droop gain (> 0)	0.0100
	DWmax (pu), upper limit of Δωm (≥ 0)	0.1000
	DWmin (pu), lower limit of Δωm (≤ 0)	-0.1000
	KpPLL (pu), PLL proportional gain	0.2650
	KiPLL (pu), PLL integral gain (> 0)	2.6500
	DwPLLmax (pu), PLL upper limit (≥ 0)	0.1000
	DwPLLmin (pu), PLL lower limit (≤ 0)	-0.1000
	Tp (s), filter time constant in the VSM power loop	0.0200
	H (s), VSM inertia constant (> 0)	3.0
	D1 (pu), VSM damping constant	0.0010
	D2 (pu), transient damping	100.0
	Wb (rad/s), washout block angular frequency	50.0
	ImaxSS (pu), steady-state current limit (> 0)	1.0
	Kf, factor to determine Idmax and Iqmax	0.9000
	Ki (pu), integral gain to limit steady active current (> 0)	2.0
	ImaxF (pu), transient fault current limit (ImaxF > ImaxSS)	2.0

[53] Added vide Amendment-II

	Tpf (s), active power measurement filter time constant	0.0200
	Tqf (s), reactive power measurement filter time constant	0.0200
	Tuf (s), voltage measurement filter time constant	0.0200
	Tif (s), current measurement filter time constant	0.0200
	Ke, scaling on Idmax (0 for generator, 0 ≤ Ke ≤ 1 for storage)	1.0
	Kv (pu), voltage control gain (> 0)	0.0500

Exhibit-(vi)

[54]Description of the generic models for STATCOM with typical parameter value of are tabulated below

Category	Parameter Description	Typical Value
	WECC Generic STATCOM based SVC model	
SVSMO3T2 (Refer Table-XVI of Annexure-III)	Xc0, Linear droop	0.0125
	Tc1, Voltage measurement lead time constant	0
	Tv1, Voltage measurement lag time constant	0.05
	Kp, Proportional gain	20
	Ki, Integral gain	5
	Vemax, Voltage error max. (pu)	0.5
	Vemin, Voltage error min. (pu)	-0.5
	T0, Firing sequence control delay (sec)	0.01
	Imax1, Max. continuous current rating (pu on STATCOM BASE MVA (STBASE))	1
	dbd, Deadband in voltage control (pu)	0
	Kdbd, Ratio of outer to inner deadband	0
	Tdbd, Deadband time (sec)	0.1
	Kpr, Proportional gain for slow-reset control	0.001
	Description	Value
	Kir, Integral gain for slow-reset control	0.001
	Idbd, Deadband range for slow-reset control (pu on STBASE)	0.01
	Vrmax, Max. limit on slow-reset control output (pu)	0.1
	Vrmin, Min. limit on slow-reset control output (pu)	-0.1
	Max. short-term current rating as a multiplier of max. continuous current rating	1.25
	UV1, Voltage at which STATCOM limit starts to be reduced linearly (pu)	0.25
	UV2, Voltage below which STATCOM is blocked (pu)	0.25
	OV1, Voltage above which STATCOM limit linearly drops (pu)	1.1
	OV2, Voltage above which STATCOM blocks (pu)	1.25
	Vtrip, Voltage above which STATCOM trips after time delay, Tdelay2 (pu)	1.5
	Tdelay1, duration of short-term rating (sec)	2
	Tdelay2, Trip time for V > Vtrip (sec)	0.1
	Vrefmax, Max. voltage reference limit (pu)	1.1
	Vrefmin, Min. voltage reference limit (pu)	1
	Tc2, lead time constant (sec)	0.01
	Tb2, lag time constant (sec)	0.01
	I2t, short-term limit	0
	Reset, Reset rate for I2t limit	0
	hyst, Width of hysteresis loop for I2t limit	0
	Xc1, Non-linear droop slope 1	0.01
	Xc2, Non-linear droop slope 2	1
	Xc3, Non-linear droop slope 3	0.01
	V1, Non-linear droop upper voltage (pu)	1.025
	V2, Non-linear droop lower voltage (pu)	0.95
	Tmssbrk, time for MSS breaker to operate - typically ignore (sec)	0.1
	Tout, Time MSC should be out before switching back in (sec)	250
	TdelLC, time delay for switching in a MSS (sec)	0.5
	Iupr, Upper threshold for switching MSSs (pu on STBASE)	0.25
	Ilwr, Lower threshold for switching MSSs (pu on STBASE)	0.25
	Sdelay, time for which STATCOM to remain blocked before being unblocked (sec)	0.02
	STBASE (>0), STATCOM base MVA	—

[54] Added vide Amendment-II

Exhibit-(vii)

[55]Description of the generic models for Composite load with typical parameter value of are tabulated below

Category	Parameter Description	Typical Value
CMLDXXU2 (Refer Table-XVII of Annexure-III)	WECC Generic Composite load Model	
	Load MVA base	-1.2
	Substation shunt B (pu on Load MVA base)	0
	Rfdr - Feeder R (pu on Load MVA base)	0.04
	Xfdr - Feeder X (pu on Load MVA base)	0.04
	Fb - Fraction of Feeder Compensation at substation end	0
	Xxf - Transformer Reactance (pu on Load MVA base)	0.08
	Tfixhs - High side fixed transformer tap	1
	Tfixls - Low side fixed transformer tap	1
	LTC flag (1: active during simulation, 0: inactive, -1: init only)	-1
	Tmin - LTC min tap (low side)	0.9
	Tmax - LTC max tap (low side)	1.1
	Step - LTC step (low side)	0.00625
	Vmin - LTC Vmin tap (low side pu)	1.025
	Vmax - LTC Vmax tap (low side pu)	1.04
	TD - LTC control time delay (sec)	30
	TC - LTC tap adjustment delay (sec)	5
	Rcmp - LTC Rcomp (pu on load MVA base)	0
	Xcmp - LTC Xcomp (pu on load MVA base)	0
	FmA - Motor A fraction	1
	FmB - Motor B fraction	0
	FmC - Motor C fraction	0
	FmD - Motor D fraction	0
	Fel - Electronic load fraction	0
	PFel - PF of electronic loads	1
	Vd1 - Voltage at which electronic loads start to drop	0.7
	Vd2 - Voltage at which all electronic loads drop	0.5
	PFs - Static load power factor	1
	P1e - P1 exponent	2
	P1c - P1 coefficient	0.3
	P2e - P2 exponent	1
	P2c - P2 coefficient	0.7
	Pfrq - Frequency sensitivity	0
	Q1e - Q1 exponent	2
	Q1c - Q1 coefficient	1
	Q2e - Q2 exponent	1
	Q2c - Q2 coefficient	1
	Qfrq - Frequency sensitivity	-1
	MtypA - Motor type	3
	LfmA - Loading factor (MW/MVA rating)	0.75
	RaA - Stator resistance	0.04
	LsA - Synchronous reactance	1.8
	LpA - Transient reactance	0.12
	LppA - Sub-transient reactance	0.104
	TpoA - Transient open circuit time constant	0.095
	TppoA - Sub-transient open circuit time constant	0.0027
	HA - Inertia constant	0.1
	etrqA - Torque speed exponent	0
	Vtr1A - UV Trip1 V (pu)	0.7
	Ttr1A - UV Trip1 Time (sec)	0.02
	Ftr1A - UV Trip1 fraction	0.2
	Vrc1A - UV Trip1 reclose V (pu)	1
	Trc1A - UV Trip1 reclose Time (sec)	99999

[55] Added vide Amendment-II

	Vtr2A - UV Trip2 V (pu)	0.5
	Ttr2A - UV Trip2 Time (sec)	0.02
	Ftr2A - UV Trip2 fraction	0.7
	Vrc2A - UV Trip2 reclose V (pu)	0.7
	Trc2A - UV Trip2 reclose Time (sec)	0.1
	MtypB - Motor type	0
	LfmB - Loading factor (MW/MVA rating)	0.75
	RaB - Stator resistance	0.03
	LsB - Synchronous reactance	1.8
	LpB - Transient reactance	0.19
	LppB - Sub-transient reactance	0.14
	TpoB - Transient open circuit time constant	0.2
	TppoB - Sub-transient open circuit time constant	0.0026
	HB - Inertia constant	0.5
	etrqB - Torque speed exponent	2
	Vtr1B - UV Trip1 V (pu)	0.6
	Ttr1B - UV Trip1 Time (sec)	0.02
	Ftr1B - UV Trip1 fraction	0.2
	Vrc1B - UV Trip1 reclose V (pu)	0.75
	Trc1B - UV Trip1 reclose Time (sec)	0.05
	Vtr2B - UV Trip2 V (pu)	0.5
	Ttr2B - UV Trip2 Time (sec)	0.02
	Ftr2B - UV Trip2 fraction	0.3
	Vrc2B - UV Trip2 reclose V (pu)	0.65
	Trc2B - UV Trip2 reclose Time (sec)	0.05
	MtypC - Motor type	0
	LfmC - Loading factor (MW/MVA rating)	0.75
	RaC - Stator resistance	0.03
	LsC - Synchronous reactance	1.8
	LpC - Transient reactance	0.19
	LppC - Sub-transient reactance	0.14
	TpoC - Transient open circuit time constant	0.2
	TppoC - Sub-transient open circuit time constant	0.0026
	HC - Inertia constant	0.1
	etrqC - Torque speed exponent	2
	Vtr1C - UV Trip1 V (pu)	0.65
	Ttr1C - UV Trip1 Time (sec)	0.02
	Ftr1C - UV Trip1 fraction	0.2
	Vrc1C - UV Trip1 reclose V (pu)	1
	Trc1C - UV Trip1 reclose Time (sec)	9999
	Vtr2C - UV Trip2 V (pu)	0.5
	Ttr2C - UV Trip2 Time (sec)	0.02
	Ftr2C - UV Trip2 fraction	0.3
	Vrc2C - UV Trip2 reclose V (pu)	0.65
	Trc2C - UV Trip2 reclose Time (sec)	0.1
	Tstall - Stall delay (sec)	9999
	Trestart - Restart delay (sec)	0.4
	Tv - Voltage input time constant (sec)	0.02
	Tf - Frequency input time constant (sec)	0.05
	CompLF - Compressor load factor (pu of rated power)	1
	CompPF - Compressor power factor at 1.0 pu voltage	0.98
	Vstall - Compressor stall voltage (pu)	0.6
	Rstall - Compressor motor resistance (pu)	0.1
	Xstall - Compressor motor stall reactance (pu)	0.1
	LFadj - Load factor adjustment to stall voltage	0
	Kp1 - Real power constant for running state 1	0
	Np1 - Real power exponent for running state 1	1
	Kq1 - Reactive power constant for running state 1	6
	Nq1 - Reactive power exponent for running state 1	2
	Kp2 - Real power constant for running state 2	12
	Np2 - Real power exponent for running state 2	3.2
	Kq2 - Reactive power constant for running state 2	11
	Nq2 - Reactive power exponent for running state 2	2.5
	Vbrk - Compressor motor "breakdown" voltage (pu)	0.86

	Frst - Fraction of motors capable of restart	0.2
	Vrst - Voltage at which motors can restart (pu)	0.95
	CmpKpf - Real power constant for frequency dependency	1
	CmpKqf - Reactive power constant for frequency dependency	-3.3
	Vc1off - Voltage 1 at which contactors start dropping out (pu)	0.5
	Vc2off - Voltage 2 at which all contactors drop out (pu)	0.4
	Vc1on - Voltage 1 at which all contactors reclose (pu)	0.6
	Vc2on - Voltage 2 at which contactors start reclosing (pu)	0.5
	Tth - Compressor motor heating time constant (sec)	15
	Th1t - Temp at which compressor motor begins tripping	0.7
	Th2t - Temp at which all motors are tripped	1.9
	Fuvr - Fraction of compressor motors with UV relays	0.1
	UVtr1 - 1st voltage pick-up (pu)	0.6
	Ttr1 - 1st definite time voltage pickup (sec)	0.02
	UVtr2 - 2nd voltage pick-up (pu)	1
	Ttr2 - 2nd definite time voltage (sec)	9999
	Fraction of electronic load that can restart	0.8