Chapter 20

Parallel Coupled Voltage Multiplier for 3 MeV Electron Beam Accelerator

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A 3 MeV, 100 kW DC electron beam accelerator based on parallel multiplier column has been designed for various industrial radiation processing applications. A block schematic of 3 MeV/ 100 kW DC electron accelerator is shown in Fig. 20.1. Two design approaches are considered: (1) existing 3 MeV design dimension with few modifications, and (2) Design as per standard dynamitron dimensions. In design-1, feasibilities of using a subsystem of existing 3 MeV accelerator has been evaluated by detailed design calculations and tabulated. Optimization analysis has been carried out for number of stages, voltage regulations, RF

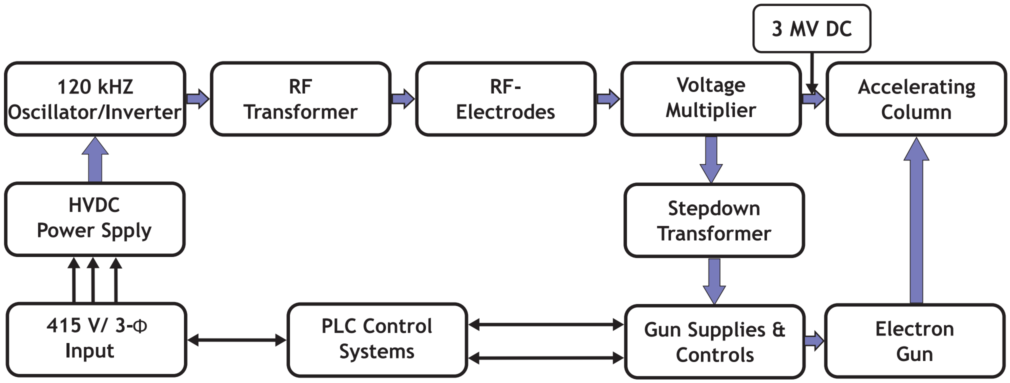

Figure 20.1: Power supply Block schematic of 3 MeV/ 100 kW DC Accelerator.

input required etc. The power loss estimations, input supplies and their ratings required are described in brief.

Table 20.1: Optimization for Number of Stages: Corona Shield (OD) = 970 mm, RFE (ID) = 1630 mm, RFE (H) = 3000 mm, Tank ID = 2120 mm

N	C_{se}, pF	k	RF Input, kV	VR, kV	% VR	Nmin	Rectifier Stack (304 kV PIV) Derating Factor
30	10.35	2.74	300.57	290.91	8.84	28	0.72
35	8.87	3.03	291	358	10.66	32	0.63
40	7.76	3.32	284	427	12.46	35	0.56
45	6.9	3.61	280.52	499	14.26	39	0.51
50	6.21	3.9	278	568	15.92	42	0.47
55	5.65	4.19	277	639	17.56	45	0.43
60	5.18	4.48	277	711	19.16	49	0.41
65	4.78	4.77	278	784	20.72	52	0.38
70	4.44	5.06	279	856	22.2	55	0.36
75	4.14	5.35	280	931	23.68	57	0.34
80	3.88	5.64	282	1005	25.09	60	0.33

20.1 Design Using Existing 3 MeV Design Dimension with Few Modifications

Existing 3 MeV, 10 mA PCVM dimensions (corona guards (OD) = 970 mm, RF Electrode (ID) = 1630 mm, Column Height (h) = 3.0 m, tank (ID) = 2120 mm) has been considered for 3 MeV, 100 kW design. Rectifier stack of 304 kV PIV, 50 ns T_{rr}, 500 mA has been chosen for the design calculations. Table 20.1 shows the optimization for coupling factor (k), voltage regulation (VR), RF input required and diode derating factors with number of stages (N). Figure 20.2 shows the variation of voltage regulations, RF input with number of stages (N). Similarly, Fig. 20.3 shows the effect of number of stages on coupling factor (k value) and diode (rectifier) derating factor.

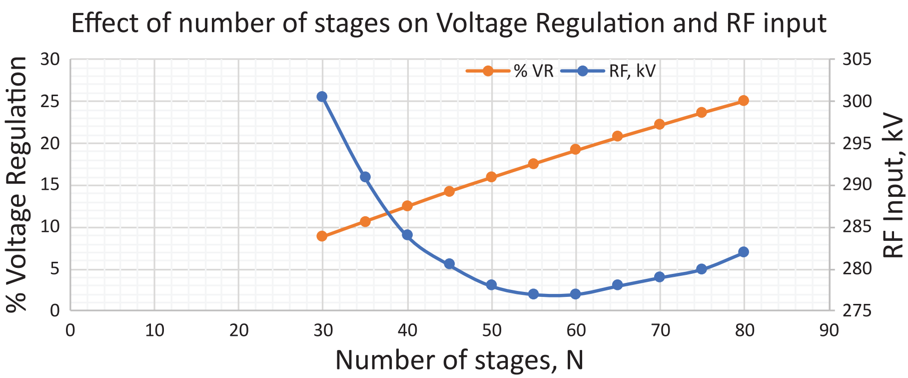

Figure 20.2: Variation of voltage regulation, RF input with number of stages.

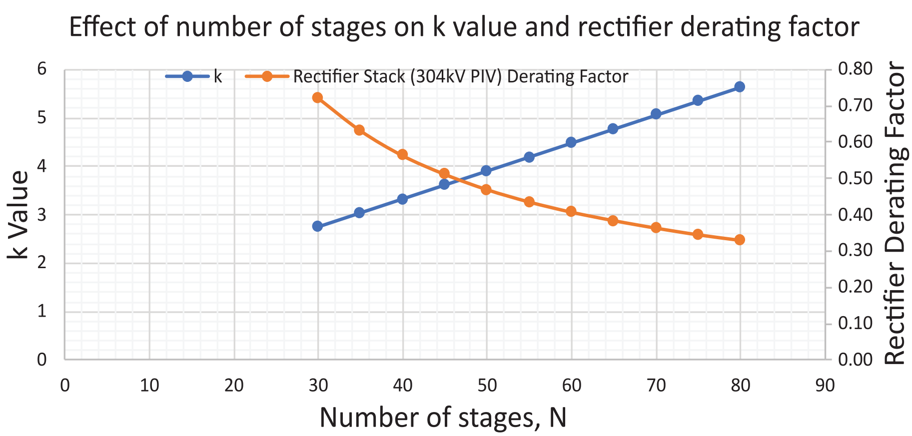

Figure 20.3: Variation of coupling factor and diode derating factor with number of stages.

Based on the above results, two design topologies have been considered:
(a) N = 35, k = 3.03, RF input = 291 kV_p, % Voltage Regulation = 10.88%, Rectifier derating Factor = 0.63;
(b) N = 70, k = 5.06, RF input = 279 kV_p, % Voltage Regulation = 22.2%, Rectifier derating Factor = 0.36.

Table 20.2: (a) Design calculations for N = 35, k = 3.03, RF input = 291 kV_p, % Voltage Regulation = 10.88%, Rectifier derating Factor = 0.63

Input Parameter	**Value**	**Unit**
Dome Voltage in kV, E_0	3000	kV
Beam current in mA, I_0	33	mA
Beam Power, kW	100	kV
Effective Number of stages, N	35	
Value of k	3.03	
Frequency of operation in kHz, f	120	kHz
Value of coupling Capacitance (C_{se}) in pF	8.87	pF
C_{ac} value in pF	4.5	pF
Length of semi cylinder RFE in inch, h	120	inch
Forward bias voltage drop of diode (UXFOB)	12	V
Dynamic resistance of the Diode	22	Ω
Each Diode rating (in kV)	8	kV
Surge Limiter Resistance value per stage	2.1	kΩ
Divider Resistor Value (500 MΩ, 92 Nos. in series)	46	GΩ
Grading Resistor Value (250 MΩ, 180 Nos. in series)	45	GΩ
R_{ac} value of RF Transformer	2.5	Ω
Inductance of the RF Transformer	5	mH

20.2 Design Calculations for Topology–a

Design calculations for topology–a are given in table 20.2.

20.2.1 Design Calculations for HV Multiplier Column

The important design parameters and corresponding specifications are tabulated in table 20.3.

Table 20.3: Design calculations for HV multiplier column.

Input Parameters	***Values***	***Unit***
A. RF Input Required in kV	290.62	kV
B. Regulation Calculation		
Regulation	358.19	kV
Percentage Regulation	10.67	%
C. No load and Load Voltage		

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Table 20.3 – *Continued from previous page*

Input Parameters	***Values***	***Unit***
No Load Voltage	3358.19	kV
Load Voltage	3000	kV
D. Stage Voltage Calculation		
Stage voltage	95.95	kV
E. Diode PIV Calculation		
PIV of multiplier Diode	191.9	kV
F. Ripple Calculation		
Ripple	15.5	kV
	0.46	%
G. Capacitance Calculation		
Number of stages, total (N)	35	
length of semi cylinder in inch(RFE) (h)	120	inch
inner Radius in inch(RFE) (r0)	32.08	inch
outer radius in inch(dome shield) (ri)	19.09	inch
r/R Ratio (ri/ro)	0.59507	
RF Electrode to Corona Guard Capacitance (Cse)	8.87	pF
k	3.03	
H. Electric field calculation for Multiplier (User Input)		
Dome Voltage in kV	3000	kV
Inner radius (RF electrode) in cm	81.5	cm
Outer radius (Dome shield) in cm	48.5	cm
accelerator tank radius in cm	106	cm
Electric Field	119.17	kV/cm
Diode PIV working (in kV)	191.9	kV
Dome voltage required (in kV)	3000	kV
number of stages required	31.27	(approximate)
J. Losses = Diode loss + Resistance loss		
(i) Diode loss Calculation		
number of stages	35	
forward bias voltage drop of diode	12	V
current flowing through diode	33	mA
dynamic resistance of the diode	22	Ω
rms current through dynamic resistors	104.346	**mA**

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Table 20.3 – *Continued from previous page*

Input Parameters	***Values***	***Unit***
power loss per diode dynamic	0.24	**W/Diode**
Power loss per Diode	0.396	**W/Diode**
Number of Diodes per stage Calculation		
Diode PIV working (in kV)	191.9	kV
Diode rating per stage (in kV)	304	kV
Each Diode rating (in kV)	8	kV
Number of Diodes per stage	38	
Power loss in Diode Dynamic per stage	9.1	**W/stage**
Diode power loss per stage	15.05	**W/stage**
Total Power loss in Diode Dynamic	318.59	**W**
Total Diode Power loss	526.68	**W**
Total loss	0.85	**kW**
(ii) Losses in the Surge Limiting Resistor for the protection of Rectifier Stack		
Enter resistance value associated per stage	2.1	kΩ
Current flowing through diodes	33	mA
rms current flowing through resistors	104.346	**mA**
Power loss in Resistance per Stage	**22.86**	**W**
Total Resistive Power loss	**0.8**	**kW**
(iii) Divider Losses		
Dome Voltage	3000	kV
Enter Divider Resistance Value (500 MΩ, 92 Nos.)	46	GΩ
Divider Losses	**0.2**	kW
(iv) Grading Losses		
Dome Voltage	3000	kV
Grading Resistor Value (250 MΩ, 180 Nos.)	45	GΩ
Grading Losses	**0.2**	kW
Total Multiplier Loss [(i) + (ii) + (iii) + (iv)]	**2.04**	kW
K. RF Transformer Power losses		
RF Input Voltage (rms)	205.47	kV
Frequency of operation	120	kHz
Rac Value	2.5	Ω
Inductance value of the transformer	5	mH

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Table 20.3 – *Continued from previous page*

Input Parameters	***Values***	***Unit***
Inductive Impedance of the Transformer	**3768**	Ω
Power loss In Transformer	**7.43**	kW
L. Tank Capacitance Calculations		
RFE (OD)	1.63	m
Tank (ID)	2.12	m
RFE Height	3	m
RFE edge diameter	0.017	m
Distance between RFE edge	0.1	m
Capacitance to tank	634.652	pF
RFE to RFE (edge)	94.1385	pF
RFE Capacitance	346.94	pF

20.2.2 RF Parameter Calculations

RF Transformer Secondary Voltage:
145 kV$_p$-0-145 kV$_p$ (150 kV$_p$-0-150 kV$_p$, 120 kHz Chosen);
Input Power to HV Multiplier = 100 kW + 2 kW = 102 kW;
Input Power to RF Transformer = 100 kW + 2 kW + 7.43 kW = 109.43 kW;
Considering Input Power to RF Transformer 120 kW;
Primary Parameter of RF Transformer:
10 kV$_p$/ 24 A, 120 kHz;
15 kV$_p$/ 16 A, 120 kHz;
500 V$_p$/ 480 A, 120 kHz;
Power Oscillator/Inverter Parameter:
A triode tube-based oscillator of rating 10 kV/ 24 A or 15 kV/ 16 A, 120 kW, 120 kHz will be designed and developed. In parallel 500 V$_p$/ 480 A, 120 kHz, 120 kW IGBT based inverter will be developed.

20.2.3 HVDC Source

Output Voltage:
10 kV DC, 16 A DC, 160 kW for triode tube oscillator;
15 kV DC, 10.66 A DC, 160 kW for triode tube oscillator;
500 V DC, 250 A DC, 126 kW for IGBT based Inverter;
Input Mains Power Supply: 3-Φ, 415 V, 50 Hz, 292 A;
(Oscillator)/ 230 A (IGBT Inverter).
Comparison of power supply parameters for Triode Oscillator tube and IGBT Inverter are shown below in table 20.4:

20.2.4 Gun Power Supplies

Anode supply using suitable biasing resistors
Filament Power Supply: 15 V, 20 A

Table 20.4: Comparison of Power supply parameter based on Triode Tube and IGBT.

	Triode Tube Based Oscillator	**IGBT Based Inverter**
RF Transformer		
Secondary	150 kV_p-0-150 kV_p, 120 kHz, 480 mA	150 kV_p-0-150 kV_p, 120 kHz, 480 mA
Primary	10 kV/ 24 A/ 120 kHz or 15 kV/ 16 A/ 120 kHz	500 V_p/480 A, 120 kHz
Oscillator/Inverter		
Ratings	10 kV/ 24 A/ 120 kHz or 15 kV/ 16 A/ 120 kHz, 120 kW	500 V_p/480 A, 120 kHz, 120 kW
Input Power	160 kW	126 kW
HVDC Supply		
Output	10 kV/ 16 A or 15 kV/ 10.66 A	500V/ 252 A
Power Loss	5% (8 kW)	5%(6.3 kW)
Mains	3-Φ, 415 V, 50 Hz, 292A	3-Φ, 415 V, 50 Hz, 230 A
Input Power	168 kW	132.3 kW
Efficiency	59.52%	76%

Number of Accelerating Tubes: 10 Numbers of NEC tube 335 keV each;
Insulation used: 6 kg/cm^2 SF_6 gas.
The design sheet for N = 35 with existing 3 MeV dimensions for 100 kW, 3 MeV DC power supply is given in table 20.5.

Table 20.5: Design sheet for number of stages, N= 35.

Input Parameter	***Value***
HV Multiplier	
Dome Voltage (kV)	3000
Beam Current (mA)	33
RF Input (kV)	290.62
Regulation (kV)	358.19
Percentage Regulation (%)	10.67
Ripple (kV)	15.5
Percentage Ripple (%)	0.46

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Table 20.5 – *Continued from previous page*

Input Parameter	***Value***
No Load Voltage (kV)	3358.19
Diode Losses (kW)	0.85
SLR Losses (kW)	0.8
Divider Losses (kW)	0.2
Grading Losses (kW)	0.2
Total Multiplier Losses (kW)	2.04
RFT losses (kW)	7.43
Stage Voltage	95.95
PIV of each stage	191.896362
Electric Field (kV/cm)	119.17
Insulation	SF_6 at 6 kg/cm^2
RF Electrode to Corona Guard Capacitance (pF)	8.87
k value	3.03
RF Transformer	
Primary Voltage	10 kV$_p$ or 15 kV$_p$ or 500 V$_p$
Secondary Voltage	150 kV$_p$-0-150 kV$_p$
Frequency	120 kHz
Power Oscillator/Inverter	
Voltage	10 kV or 15 kV or 500 V
Current	24 A or 16 A, 480 A
Power	120 kW
HVDC supply	
Output	10 kV/ 16 A or 15 kV/ 10.66 A or 500 V/ 252 A
Input	3-Φ, 415 V, 50 Hz, 168 kVA or 132 kVA
Accelerating Tubes	NEC Tubes 10 Nos.
Gun Power Supply	
Anode with resistive biasing Filament	15 V, 20 A

20.3 Design Calculations for Topology–b

The design calculations for Topology–b are tabulated in table 20.6.

Table 20.6: (b) Design Calculations for N = 70, k = 5.06, RF input = 279 kV_p, % Voltage Regulation = 22.2%, Rectifier derating Factor = 0.36.

Input Parameter	**Value**	**Unit**
Dome Voltage in kV, E_0	3000	kV
Beam current in mA, I_0	33	mA
Effective Number of stages, N	70	
Value of k chosen	5.06	
Frequency of operation in kHz, f	120	kHz
Value of C_{se} in pF	4.44	pF
C_{ac} value in pF	4.5	pF
length of semi cylinder in inch, h	120	inch
Forward bias voltage drop of diode	12	V
Dynamic resistance of the Diode	22	Ω
each Diode rating (in kV)	8	kV
resistance value per stage	2.1	kΩ
Divider Resistor Value	46	GΩ
Grading Resistor Value	45	GΩ
R_{ac} value of Transformer	2.5	Ω
Inductance of the Transformer	5	mH

20.3.1 Design Calculations for HV Multiplier Column

The design calculations for HV Multiplier Column are tabulated in table 20.7.

20.3.2 RF Parameter Calculations

RF Transformer Secondary Voltage:
140 kV_p-0-140 kV_p (**150 kV_p-0-150 kV_p, 120 kHz Chosen**);
Input Power to HV Multiplier = 100 kW + 3.69 kW = 103.69 kW;
Input Power to RF Transformer = 100 kW + 3.69 kW + 6.84 kW = 110.53 kW.
Considering Input Power to RF Transformer 120 kW

Primary Parameter of RF Transformer:
10 kV_p/ 24 A, 120 kHz
15 kV_p/ 16 A, 120 kHz
500 V_p/ 480 A, 120 kHz
Power Oscillator/Inverter Parameter:
A triode tube-based oscillator of rating 10 kV/ 24 A, 120 kW, 120 kHz will be designed and developed. In parallel 500 V_p/ 480 A, 120 kHz, 120 kW IGBT based inverter will be developed.

Table 20.7: Design Calculations for HV Multiplier Column.

Input Parameter	*Value*	*Unit*
A. RF Input Required in kV	**278.77**	**kV**
B. Regulation Calculation		
Regulation	**858.01**	**kV**
Percentage Regulation	**22.24**	**%**
C. No load and Load Voltage		
No Load Voltage	**3858.01**	**kV**
Load Voltage	**3000**	**kV**
D. Stage Voltage Calculation		
Stage voltage	**55.11**	**kV**
E. Diode PIV Calculation		
PIV of multiplier Diode	**110.23**	**kV**
F. Ripple Calculation		
Ripple	**31**	**kV**
	0.80	**%**
G.Capacitance Calculation	**User Input**	
Number of stages, total	70	
length of semi cylinder in inch (RFE)	120	inch
inner Radius in inch (RFE)	32.08	inch
outer radius in inch(dome shield)	19.09	inch
r/R Ratio	0.59507	
RF Electrode to Corona Guard Capacitance	**4.44**	**pF**
k	**5.06**	
H. Electric field calculation for Multiplier	**User Input**	
Dome Voltage in kV	3000	kV
Inner radius (RF electrode) in cm	81.5	cm
Outer radius (Dome shield) in cm	48.5	cm
Accelerator tank radius in cm	106	cm
Electric Field	**119.17**	**kV/cm**
I. Number of stages required		
Diode PIV working (in kV)	110.23	kV
Dome voltage required (in kV)	3000	kV
number of stages required	**54.43**	(approximate)
J. Losses = Diode loss + Resistance loss		

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Table 20.7 – *Continued from previous page*

Input Parameter	***Value***	***Unit***
(i) Diode loss Calculation		
Number of stages	70	
Forward bias voltage drop of diode	12	V
current flowing through diode	33	mA
Dynamic resistance of the Diode	22	Ω
rms current through dynamic resistors	**104.346**	**mA**
power loss per diode dynamic	**0.24**	**W/Diode**
Power loss per Diode	**0.396**	**W/Diode**
Number of Diodes per stage Calculation		
Diode PIV working (in kv)	191.9	kV
Diode rating per stage (in kv) (for safety purpose)	304	kV
Each Diode rating (in kV)	8	kV
Number of Diodes per stage	**38**	
Power loss in Diode Dynamic per stage	**9.1**	**W/stage**
Diode power loss per stage	**15.05**	**W/stage**
Total Power loss in Diode Dynamic	**637.17**	**W**
Total Diode Power loss	**1053.36**	**W**
Total loss	**1.69**	**kW**
(ii) Losses in the Surge Limiting Resistor for the protection of Rectifier Stack		
Enter resistance value associated per stage	2.1	kΩ
Current flowing through diodes	33	mA
rms current flowing through resistors	**104.346**	**mA**
Power loss in Resistance per Stage	**22.86**	**W**
Total Resistive Power loss	**1.6**	**kW**
(iii) Divider Losses		
Dome Voltage	3000	kV
Enter Divider Resistance Value (500 MΩ, 92 Nos.)	46	GΩ
Divider Losses	**0.2**	**kW**
(iv) Grading Losses		
Dome Voltage	3000	kV
Grading Resistor Value (250 MΩ, 180 Nos.)	45	GΩ
Grading Losses	**0.2**	**kW**
Total Multiplier Loss ((i) + (ii) + (iii) + (iv))	**3.69**	**kW**

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Table 20.7 – *Continued from previous page*

Input Parameter	***Value***	***Unit***
K. RF Transformer Power losses		
RF Input Voltage (rms)	197.09	kV
Frequency of operation	120	kHz
R_{ac} Value	2.5	Ω
Inductance value of the transformer	5	mH
Inductive Impedance of the Transformer	**3768**	**Ω**
Power loss In Transformer	**6.84**	**kW**

20.3.3 HVDC Source

Output Voltage:
10 kV DC, 16 A DC, 160 kW
15 kV DC, 10.66 A DC, 160 kW
500 V DC, 250 A DC, 126 kW
Input Mains Power Supply: 3-Φ, 415 V, 50 Hz, 292 A/ 230 A. Comparison of power supply parameters for Triode tube and IGBT are shown in table 20.8.

Table 20.8: Comparison of Power supply parameter based on Triode Tube and IGBT.

	Triode Tube Based Oscillator	**IGBT Based Inverter**
RF Transformer		
Secondary	150 kV_p-0-150 kV_p, 120 kHz, 480 mA	150 kV_p-0-150 kV_p, 120 kHz, 480 mA
Primary	10 kV/24A/120 kHz or 15 kV/16 A/120 kHz	500 V_p/480 A, 120 kHz
Oscillator/Inverter		
	10 kV/24 A/120 kHz or 15 kV/16 A/120 kHz	500 V_p/480 A, 120 kHz
Input Power	160 kW	126 kW
HVDC		
Output	10 kV/16 A or 15 kV/10.66 A	500 V/252 A
Power Loss	5% (8 kW)	5% (6.3 kW)
Mains	3-Φ, 415 V, 50 Hz, 292 A	3-Φ, 415 V, 50 Hz, 230 A
Input Power	168 kW	132.3 kW
Efficiency	59.52% (64%)	76% (82%)

20.3.4 Gun Power Supplies

Anode supply using suitable biasing resistors
Filament Power Supply: 15 V, 20 A;
Number of Accelerating Tubes: 10 Numbers of NEC tube 335 keV each;
Insulation used: 6 kg/cm^2 SF_6 gas; The design sheet for N = 70 with existing 3 MeV dimensions for 100 kW, 3 MeV DC power supply are given in table 20.9.

Table 20.9: Design sheet for number of stages, N= 70.

Input Parameter	***Value***
Dome Voltage (kV)	**3000**
Beam Current (mA)	**33**
RF Input (kV)	**278.77**
Regulation (kV)	**858.01**
Percentage Regulation (%)	**22.24**
Ripple (kV)	**31**
Percentage Ripple (%)	**0.8**
No Load Voltage (kV)	**3858.01**
Diode Losses (kW)	**1.69**
SLR Losses (kW)	**0.8**
Divider Losses (kW)	**0.2**
Grading Losses (kW)	**0.2**
Total Multiplier Losses (kW)	**3.69**
RFT losses (kW)	**6.84**
Stage Voltage	55.11
PIV of each stage	110.23
Electric Field (kV/cm)	**119.17**
Insulation	**SF_6 at 6 kg/cm^2**
RF Electrode to Corona Guard Capacitance (pF)	**4.44**
k value	5.06
RF Transformer	
Primary Voltage	10 kV$_p$ or 15 kV$_p$ or 500 V$_p$
Secondary Voltage	150 kV$_p$-0-150 kV$_p$
Frequency	120 kHz
Power Oscillator/Inverter	
Voltage	10 kV or 15 kV or 500 V

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Table 20.9 – *Continued from previous page*

Input Parameter	***Value***
Current	24 A or 16 A, 480 A
Power	120 kW
HVDC supply	
Output	10 kV/ 16 A or 15 kV/ 10.66 A or 500 V/ 252 A
Input	3-Φ, 415 V, 50 Hz, 168 kVA or 132 kVA
Gun Power Supply	
Anode with resistive biasing Filament	15 V, 20 A

Comparison of design sheet for N = 35 and N = 70 are in tabulated table 20.10.

Table 20.10: Comparison of Design Sheet for N = 35 & N = 70.

Parameter	***N = 35***	***N = 70***
HV Multiplier		
Dome Voltage (kV)	**3000**	**3000**
Beam Current (mA)	**33**	**33**
RF Input (kV)	**290.62**	**278.77**
Regulation (kV)	**358.19**	**858.01**
Percentage Regulation (%)	**10.67**	**22.24**
Ripple (kV)	**15.5**	**31**
Percentage Ripple (%)	**0.46**	**0.8**
No Load Voltage (kV)	**3358.19**	**3858.01**
Total Multiplier Losses (kW)	**2.04**	**3.69**
RFT losses (kW)	**7.43**	**6.84**
Stage Voltage	95.95	55.11
PIV of each stage	191.896362	110.23
Electric Field (kV/cm)	**119.17**	**119.17**
Insulation	**SF_6 at 6 kg/cm^2**	**SF_6 at 6 kg/cm^2**
RF Electrode to Corona Guard Capacitance (pF)	**8.87**	**4.44**
k value	3.03	5.06
RF Transformer		

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Table 20.10 – *Continued from previous page*

Parameter	***N = 35***	***N = 70***
Primary Voltage	10 kV$_p$ or 15 kV$_p$ or 500 V$_p$	10 kV$_p$ or 15 kV$_p$ or 500 V$_p$
Secondary Voltage	150 kV$_p$-0-150 kV$_p$	150 kV$_p$-0-150 kV$_p$
Frequency	120 kHz	120 kHz
Power Oscillator/Inverter		
Voltage	10 kV or 15 kV or 500V	10 kV or 15 kV or 500V
Current	24 A or 16 A, 480 A	24 A or 16 A, 480 A
Power	120 kW	120 kW
HVDC supply		
Output	10 kV/ 16 A or 15 kV/ 10.66 A or 500 V/ 252 A	10 kV/ 16 A or 15 kV/10.66 A or 500 V/ 252 A
Input	3-Φ, 415 V, 50 Hz, 168 kVA or 132 kVA	3-Φ, 415 V, 50 Hz, 168 kVA or 132 kVA
Accelerating Tubes	NEC Tubes 10 Nos.	NEC Tubes 10 Nos.
Gun Power Supply		
Anode with resistive biasing Filament	15 V, 20 A	15 V, 20 A

Table 20.11: Subsystems of 3 MeV/100 kW Accelerators.

	N = 35	**N = 70**
HV Multiplier		
Voltage Regulation	10.88%	22.22%
Ripple	0.46%	0.80%
Power Loss	2 kW	3.69 kW
HV column Support Structure	Existing 3 MeV with modification/new design	Existing 3 MeV
Rectifier stack	Existing 3 MeV stacks	Existing 3 MeV Stacks
Corona Guard	Existing 3 MeV with modification/new design	Existing 3 MeV Guards
HV Dome	Existing 3 MeV Dome	Existing 3 MeV Dome
RF Electrode	Existing 3 MeV Electrode	Existing 3 MeV Electrode
Gun Power Supply	Existing 3 MeV	Existing 3 MeV
Multiplier cooling system	Better cooling system for 2 kW/review existing	Better cooling system for 3.69 kW/review existing
Voltage Divider	Existing 3 MeV	Existing 3 MeV
Accelerating Column		
Accelerating Tubes	Existing 3 MeV Tubes	Existing 3 MeV Tubes
Grading Resistors	Existing 3 MeV	Existing 3 MeV
RF Source		
RF Transformer	a. Existing 3 MeV with modifications in primary winding	a. Existing 3 MeV with modifications in primary winding
	b. Existing cooling system	b. Existing cooling systems
Oscillator/Inverter	New design	New Design
HVDC Supply	New Design	New Design
Accelerator Tank	Existing 3 MeV tanks	Existing 3 MeV tanks
Vacuum Systems	Existing 3 MeV	Existing 3 MeV
Insulating Gas	Existing 3 MeV	Existing 3 MeV
Beam Line	Existing 3 MeV	Existing 3 MeV
Scan Horn	New design for 100 kW	New Design for 100 kW
Magnets and Power Supply	New Design for 100 kW	New Design for 100 kW
Cooling systems	To review existing	To review existing
Utilities (fresh air blower/Ozone blower)	To review existing	To review existing

The feasibility of using an existing subsystem of 3 MeV/10 mA accelerator for 3 MeV/100 kW accelerator are summarized in table 20.11.

20.4 Conclusion

1. A design calculation for 3 MeV, 100 kW DC electron beam accelerators based on parallel coupled multiplier column has been done with existing 3 MeV accelerator's dimensions with few modifications on subsystems of HV column.
2. With existing numbers of stages (70), there will not be any change in HV column. However, voltage regulation will be about 22%. No load voltage will be about 3800 kV, which is not desirable for healthiness of the components. With feedback, voltage regulations can be maintained.
3. With 35 number of stages, there will be some modifications on HV column support structures and corona guards. Here voltage regulation will be within permissible limit (10%).
4. For both the designs (N = 35 & 70), RF Transformer to be modified for primary ratings (10 kV or 15 kV for oscillator and 500 V for inverter).
5. For the Triode based RF Source, an Oscillator rated for 10 kV/ 24 A or 15 kV/ 16 A, 120 kW, 120 kHz and HVDC supply rated for 10 kV/ 16 A or 15 kV/ 10.66 A will be developed. A mains power supply required will be 3-Φ, 415 V, 50 Hz, 168 kVA.
6. For Inverters based RF source, an IGBT based inverter rated for 500 V, 480 A, 120 kHz, 120 kW and HVDC supply rated for 500 Vdc, 252 A will be developed.A mains power supply required will be 3-Φ, 415 V, 50 Hz, 132 kVA.
7. Other utilities viz cooling systems, ozone blower, fresh air blower of existing 3 MeV/ 10 mA accelerator need to be reviewed for 3 MeV/ 100 kW design.

Suggestions for Further Reading

a) [104, 105]