Design and Performance Analysis of Permanent Magnet High Speed Generator

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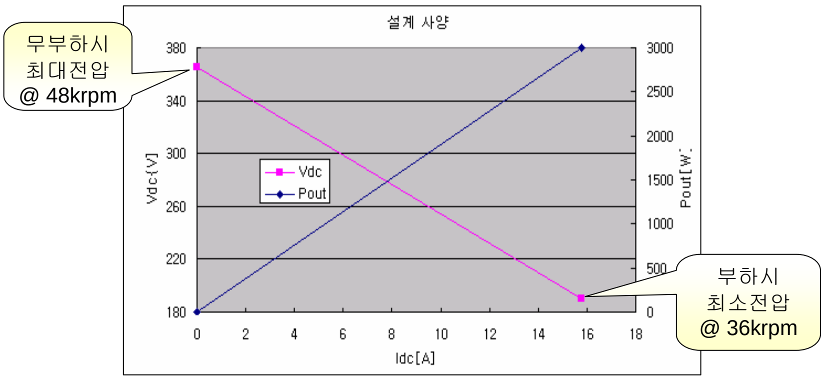
1. 고속 발전기 설계 사양 - 1

항목	사양	단위	비고
형식	PMG	-	Permanent Magnet Generator (정류부 장착)
출력	3000	W	–
속도	48,000	rpm	100% – 75%(48kr – 36kr)
출력 전압	180 – 375	Vdc	모듈 입력 범위
	365	Vdc	무부하 전압(최대전압) @ 48krpm
	190	Vdc	부하 전압(최소전압) @ 36krpm
전류	15.8	Idc	부하 전류 @ 36krpm
극수	4	Pole	–

1. 고속 발전기 설계 사양 - 2



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2. RMxprt를 이용한 초기설계 - 1

Rated Output Power (kW):	3
Rated Power Factor:	1
Rated Voltage (V): (Vdc=330V)	245
Number of Poles:	4
Frequency (Hz):	1600
Frictional and Wind Loss (W):(기계 손, 철손 포함)	200
Rotor Position:	Inner
Operating Temperature (C):	25
Type of Circuit:	Y3

2. RMxprt를 이용한 초기설계 - 2

Number of Stator Slots:	24
Outer Diameter of Stator (mm):	76
Inner Diameter of Stator (mm):	34
Length of Stator Core (mm)	40
Type of Stator Core (Cogent)	NO12
Stator Slot Fill Factor(%)	29
Thickness/Outer Diameter of Sleeve (mm)	0.7/32.2
* 로터 회전 시 선 속도 (m/s)	81
Air gap of Mechanical (mm)	0.9
Type of Magnet	Sm_2Co_{17}

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2. RMxprt를 이용한 초기설계 - 3

Stator Weight (kg)	0.91
Rotor Weight (kg) (Sleeve, Bearing 제외)	0.20
D-Axis Reactance (ohm)	2.09
Q-Axis Reactance (ohm)	2.16
Armature Phase Resistance (ohm)	0.10
Armature Phase Inductance (uH)	211
End Leakage Inductance (uH)	25.6
Number of Turns	40
Equivalent Br (Tesla)	1.09
Estimated Rotor Inertia(kgm^2)	2.76e-5

2. RMxprt를 이용한 초기설계 - 4

RMS Line Current (A)	7.14
Armature Current Density (A/mm^2)	5.50
Frictional, Windage, Core, Rotor Loss (W)	200
Armature Copper Loss (W)	15.3
Total Loss (W)	215.3
Output Power (W)	3,000
Efficiency (%)	93.3
Speed (rpm)	48,000
Rated Torque (N.m)	0.64
Cogging Torque (N.m)	0.031

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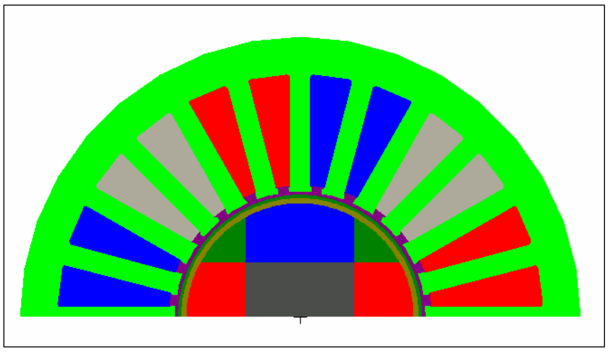
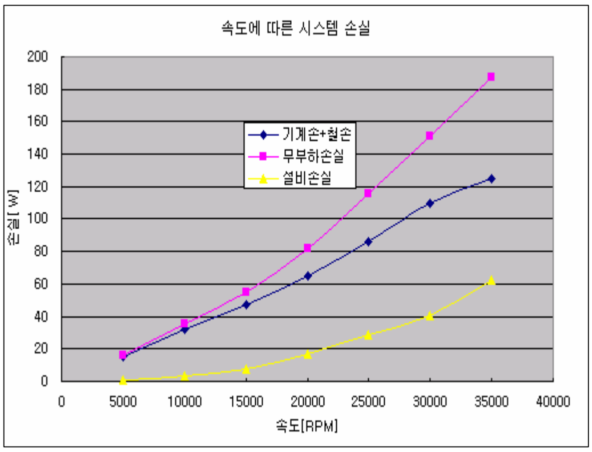
2. RMxprt를 이용한 초기설계 - 5



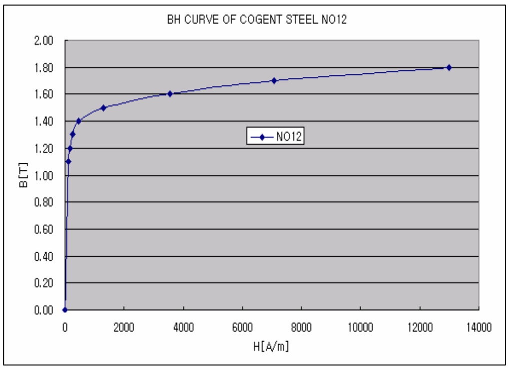
모델링 보완 : **SHAFT, BAND, SLEEVE**

2. RMxprt를 이용한 초기설계 – 6 (손실 고려)

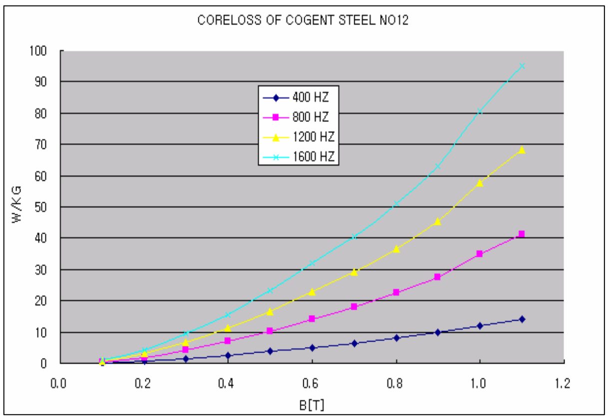


2. RMxprt를 이용한 초기설계 – 7 (Cogent Steel BH Curve)

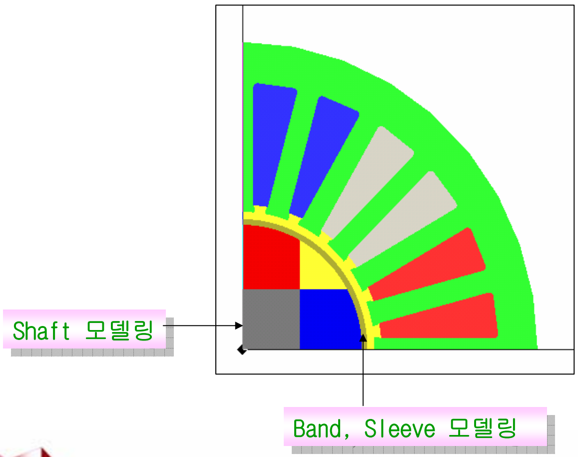
no	B	H
-	[T]	[A/m]
1	0.00	0
2	1.10	124
3	1.20	160
4	1.30	248
5	1.40	470
6	1.50	1290
7	1.60	3550
8	1.70	7070
9	1.80	13000



2. RMxprt를 이용한 초기설계 – 8 (Cogent Steel Coreloss)



3. Maxwell 2D 해석 ¼ 모델 - 1



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3. Maxwell 2D 적용 재질 - 2

명 칭	재 질	특 징	비 고
Shaft	SCM 440/430	고속용 재질에 적합	크롬 몰리브덴강 (자성체)
Magnet	Sm2Co17	온도 특성 우수 (- 0.03 %/C)	항복강도 낮음 (40MPa)
Sleeve	Inconel 718 계열	고속용 재질에 적합	소재강도 (800M~1GPa)
Stator Core	Cogent Steel NO 12	철심 점적율 높음(97%)	소량 구매 가능
Copper	H Class	180 도	

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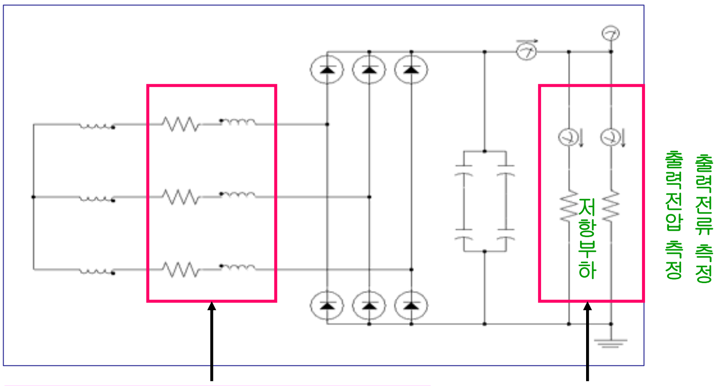
3. Maxwell 2D 적용 외부회로 – 3 (Spice 사용)



상 저항 : 100 mohm ← From RMxprt
상 인덕턴스 : 211 uH ← From RMxprt

부하조건 모사

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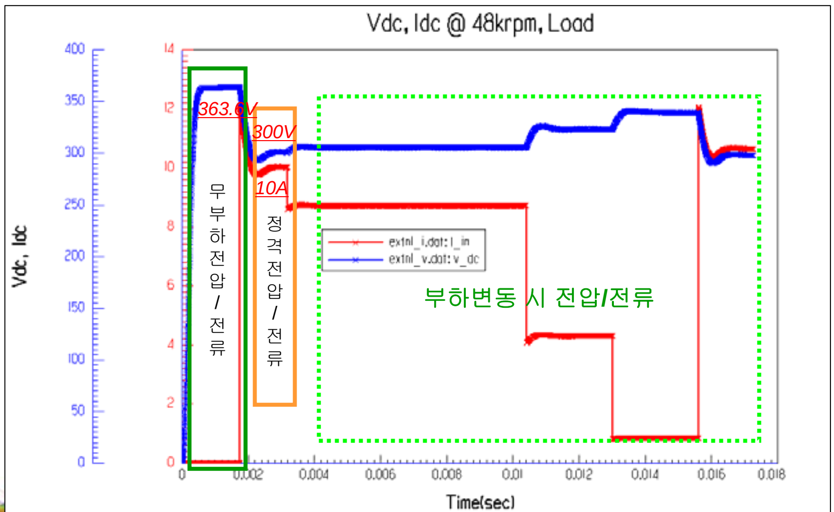
3. Maxwell 2D 적용 해석결과 – 4



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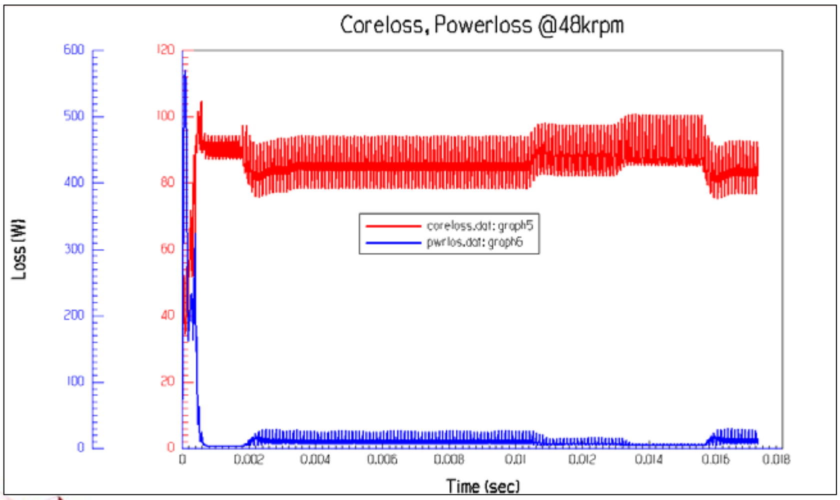
3. Maxwell 2D 적용 해석결과 – 5



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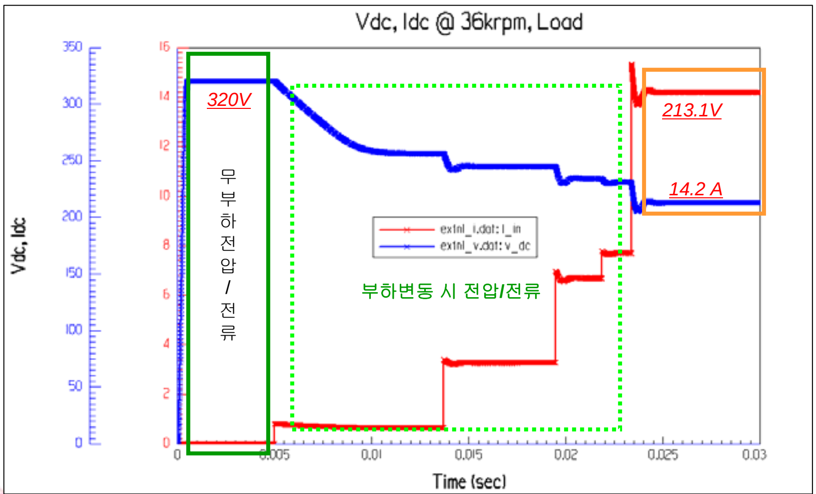
3. Maxwell 2D 적용 해석결과 – 6



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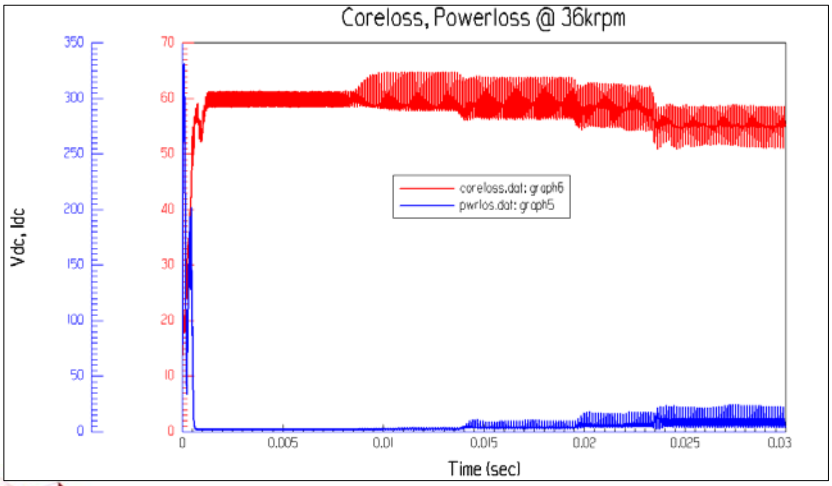
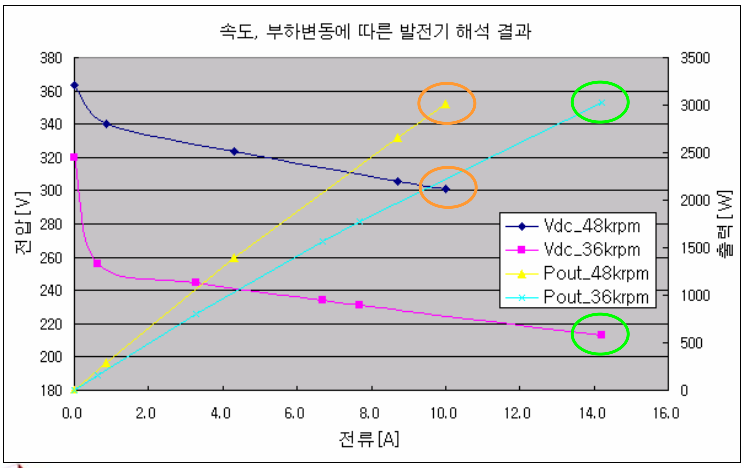
3. Maxwell 2D 적용 해석결과 – 7



3. Maxwell 2D 적용 해석결과 – 8



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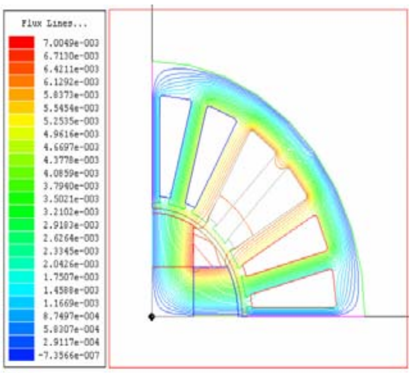
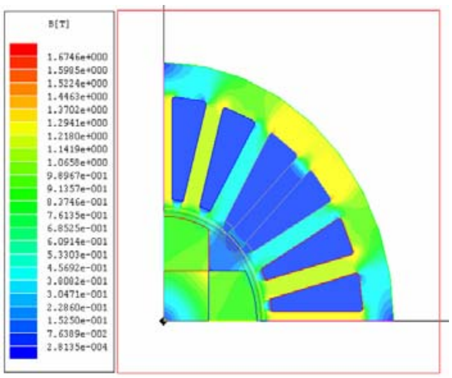
3. Maxwell 2D Post 결과 – 9

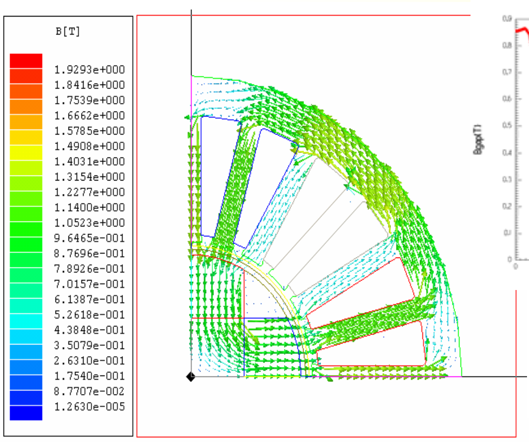
무 부하시 자속 분포와 자속 밀도 분포
(48krpm, t : 0sec)

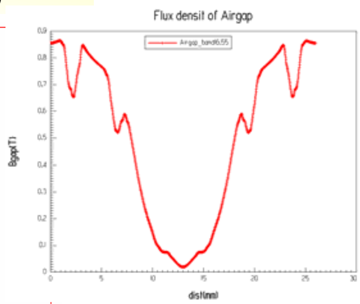




3. Maxwell 2D Post 결과 – 10

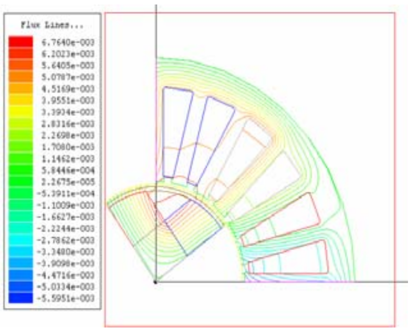
무 부하시 Vector 분포
(48krpm, t : 0sec)

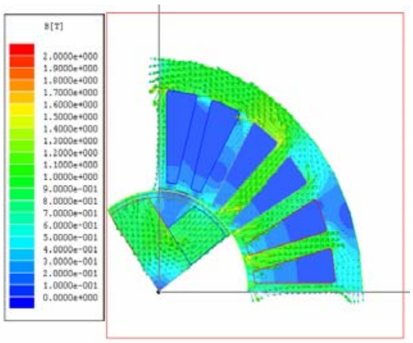




3. Maxwell 2D Post 결과 – 11

무 부하시 자속 분포와 자속 밀도 분포
363.6Vdc @ 1M Load
48krpm, t : 0.01248sec





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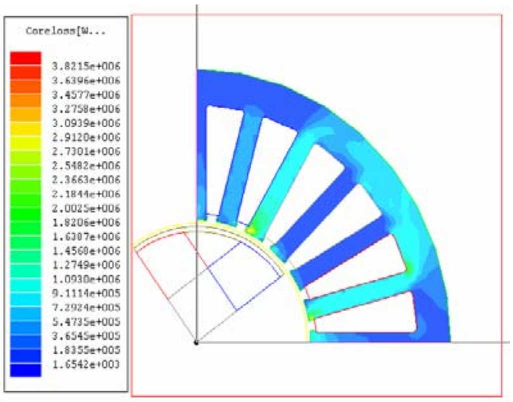
3. Maxwell 2D Post 결과 – 12

무 부하시 Coreloss 분포
363.6Vdc @ 1M Load
48krpm, t : 0.01248sec



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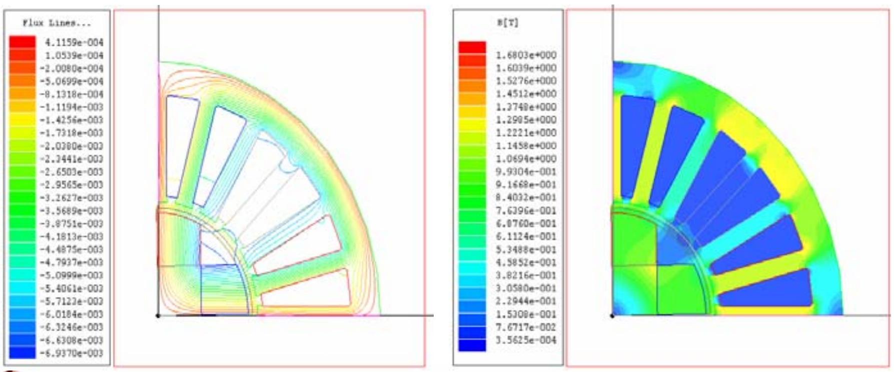
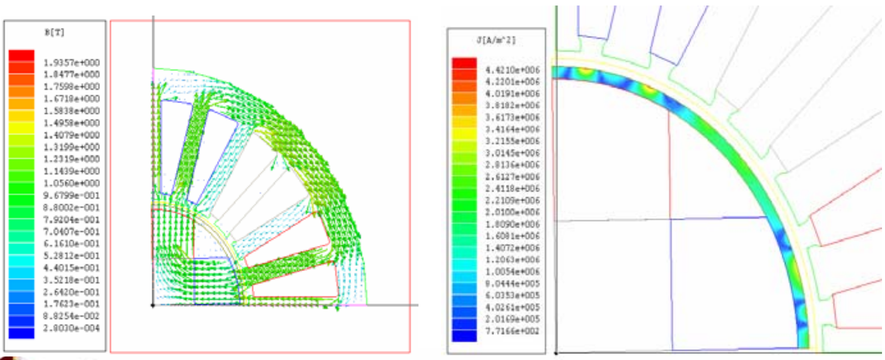
3. Maxwell 2D Post 결과 – 13

정격 부하시 자속 분포와 자속 밀도 분포
300Vdc @ 10Adc, 30ohm Load
48krpm, t:0.028158sec



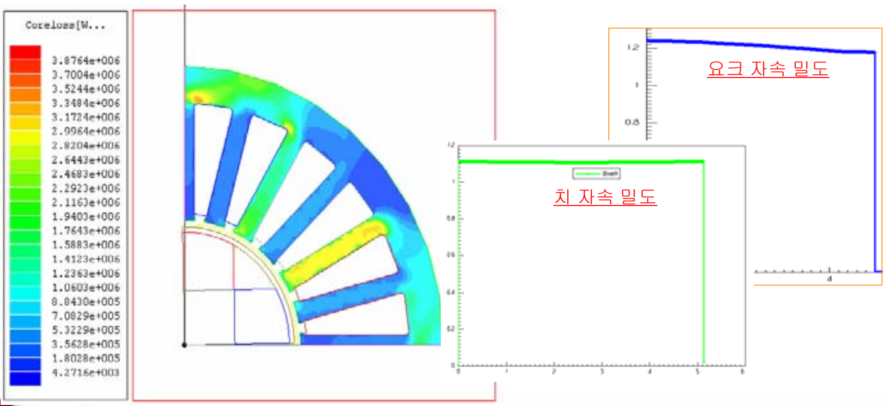
3. Maxwell 2D Post 결과 – 14

정격 부하시 Vector 분포와 Sleeve 전류 밀도 분포
300Vdc @ 10Adc, 30ohm Load
48krpm, t:0.028158sec



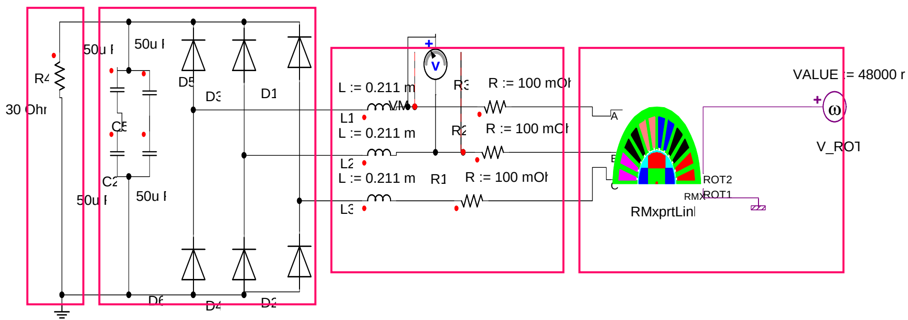
3. Maxwell 2D Post 결과 – 15

정격 부하시 Coreloss 분포
300Vdc @ 10Adc, 30ohm Load
48krpm, t:0.028158sec



4. Simploer 연계 해석 – 1

RMxprt 와 Simplore 연계한 Co-Simulation

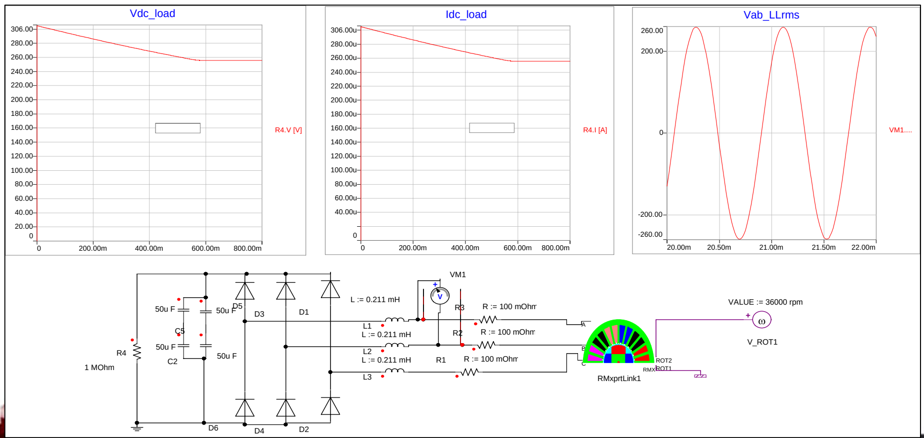


부하 | 정류회로 | 저항, 인덕턴스 | RMxprt

4. Simploer 연계 해석 – 2

RMxprt 와 Simplore 연계한 Co-Simulation

255V, 0A @ 36krpm, 1M ohm



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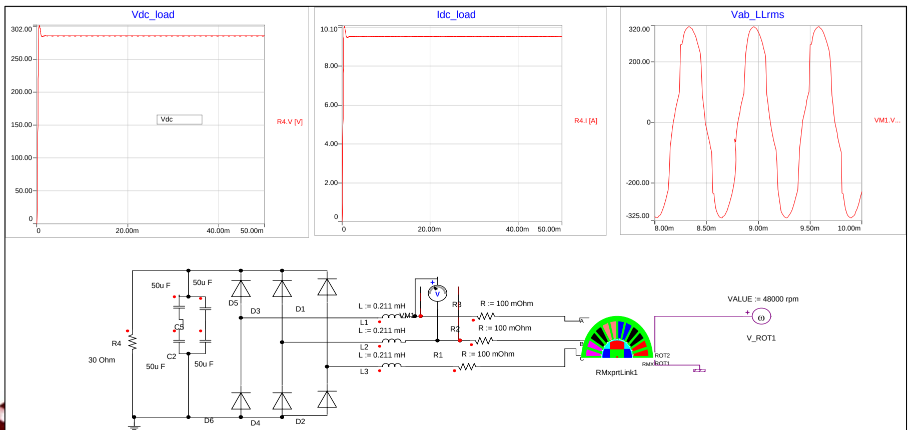
4. Simploer 연계 해석 – 3

RMxprt 와 Simplore 연계한 Co-Simulation

286V, 9.52A @ 48krpm, 30 ohm



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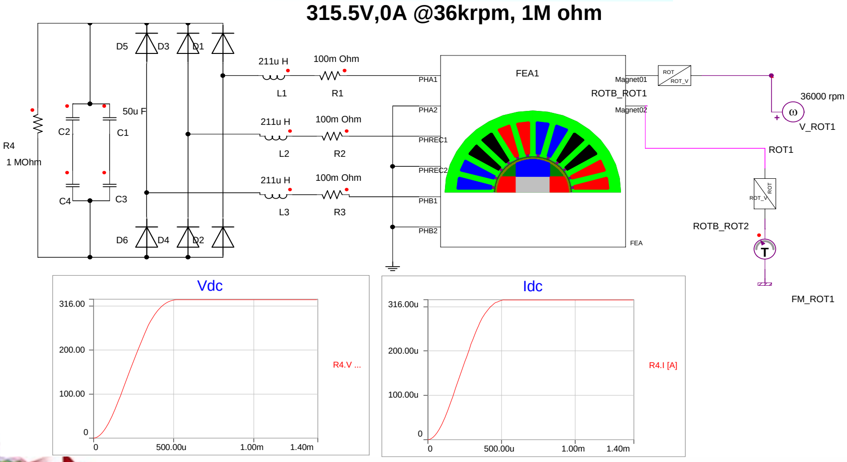
4. Simploer 연계 해석 – 4

Maxwell 2D 와 Simplore 연계한 Co-Simulation

315.5V,0A @36krpm, 1M ohm



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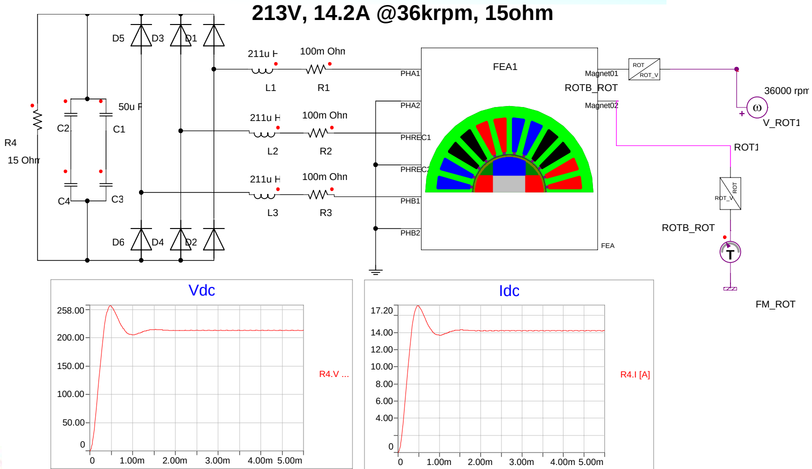
4. Simploer 연계 해석 – 5

Maxwell 2D 와 Simplore 연계한 Co-Simulation

213V, 14.2A @36krpm, 15ohm



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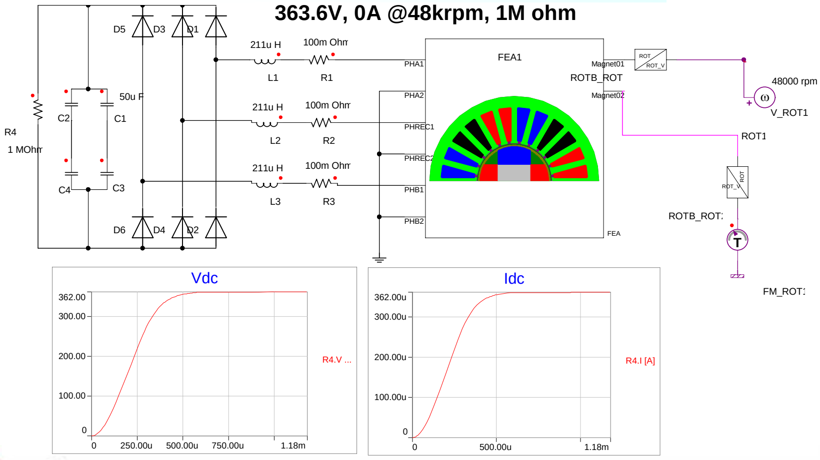
4. Simploer 연계 해석 – 6

Maxwell 2D 와 Simplore 연계한 Co-Simulation

363.6V, 0A @48krpm, 1M ohm



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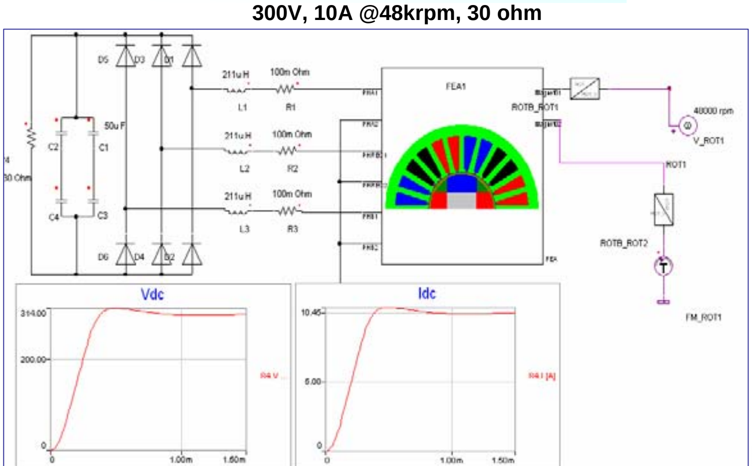
4. Simploer 연계 해석 – 7

Maxwell 2D 와 Simplore 연계한 Co-Simulation

300V, 10A @48krpm, 30 ohm



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5. 결과 정리 - 1

: RMxprt, Maxwell 2D, Simplore 해석 결과 비교

SPEED	Maxwell 2D (Spice)			RMxprt / Simplore			Maxwell / Simplore			Load
	Vdc	Idc	Pout	Vdc	Idc	Pout	Vdc	Idc	Pout	R_load
48 krpm	363.6	0	0	342.4	0	0	362	0	0	1M
	340.0	0.85	289	324.2	0.81	263	344.2	0.86	0	400
	323.4	4.30	1391	308	4.10	1263	323.5	4.3	0	75
	305.4	8.70	2657	290	8.27	2398	304.7	8.7	0	35
	300.0	10.00	3000	286	9.52	2723	300	10.00	3000	30

5. 결과 정리 - 2

: RMxprt, Maxwell 2D, Simplore 해석 결과 비교

SPEED	Maxwell 2D (Spice)			RMxprt-Simplore			Maxwell-Simplore			Load
	Vdc	Idc	Pout	Vdc	Idc	Pout	Vdc	Idc	Pout	R_load
36 krpm	320	0	0	255.5	0	0	315.5	0	0	1M
	256.3	0.64	164	244	0.61	149	256.6	0.64	164	400
	245	3.27	801	234	3.1	725	246	3.27	804	75
	234	6.68	1563	223	6.38	1423	234.4	6.69	1568	35
	231.4	7.7	1782	220	7.34	1615	231.1	7.72	1784	30
	213.1	14.2	3026	202.5	13.5	2734	213	14.2	3025	15

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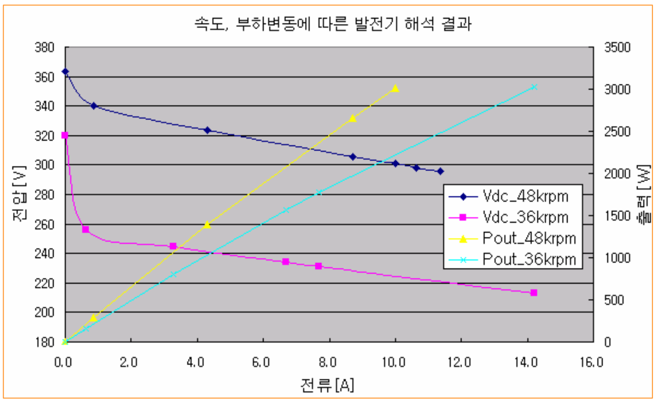
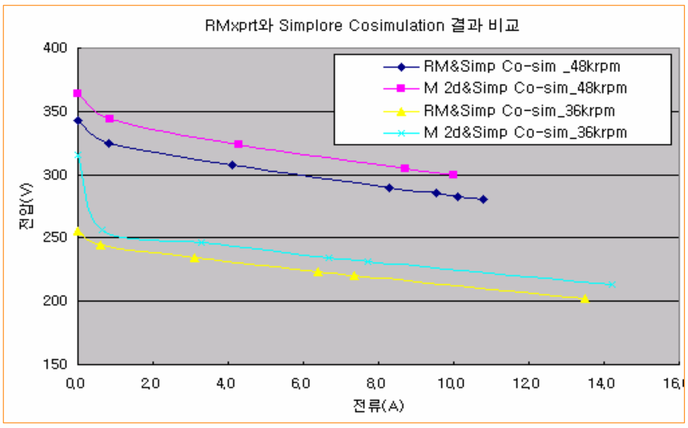
5. 결과 정리 - 3

: Maxwell 2D 외부회로(Spice) 이용한 해석 결과



5. 결과 정리 - 4

: RMxprt와 Simplore 연계 해석 결과



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5. 결과 정리 - 5

: **Maxwell 2D와 Simplore 연계 해석 결과**