

회생 제도의 구동 효율 확인

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프로젝트 선정 배경

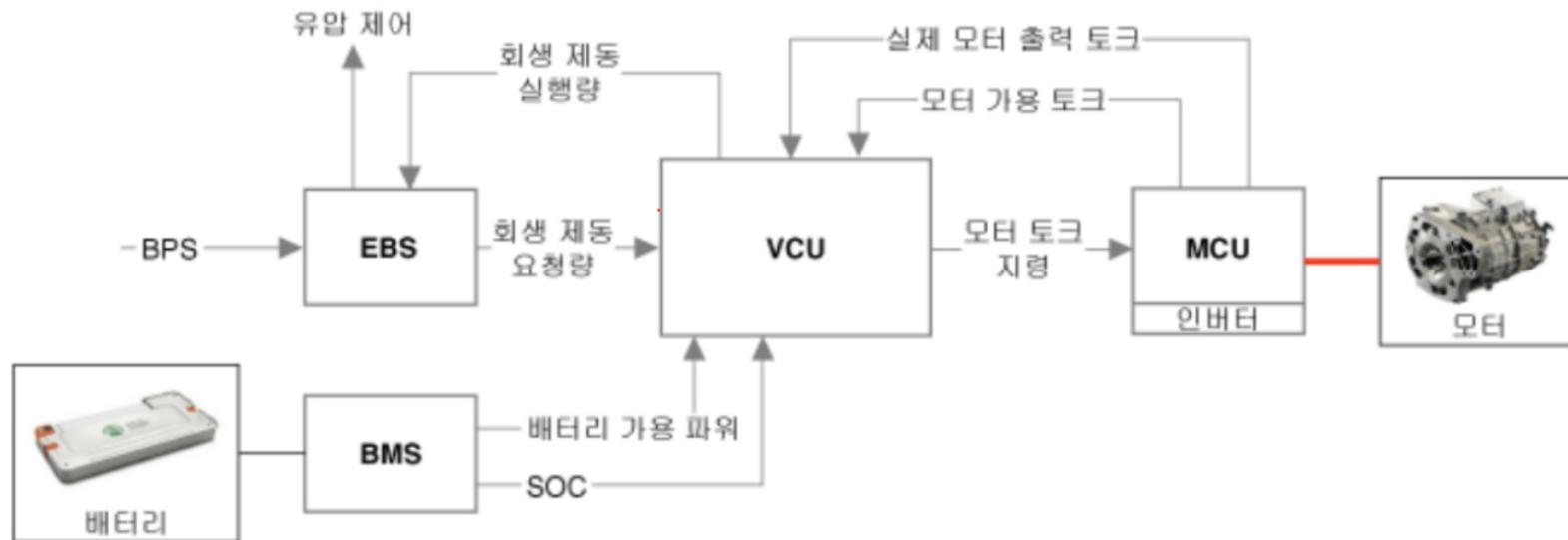
1. 배터리 성능 측면에서, 1회 충전 후 가능한 주행 거리와 충전 시간은 기존 내연 기관 자동차에서 소비자가 기대하는 수준에 미치지 못함

2. 대형화 되는 배터리는 오히려 친환경이라는 장점이 퇴보

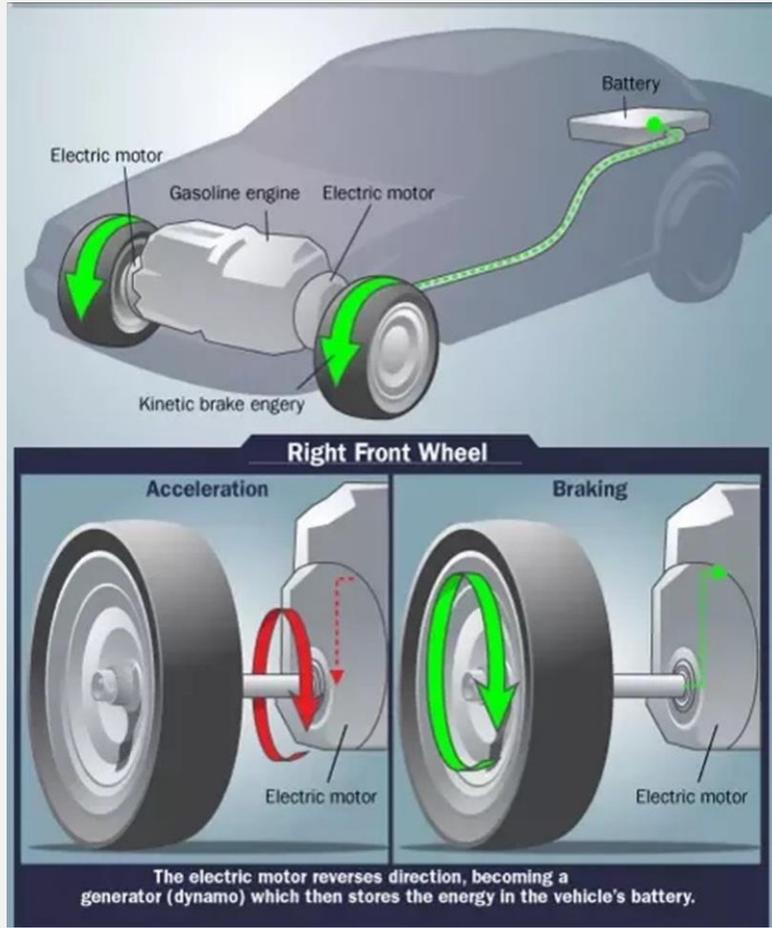
-> 전기차의 효율을 높이기 위한 수단 필요

프로젝트 선정 배경

회생제동 : 가속 페달에서 발을 떼는 순간 운동 에너지를 전기 에너지로 변환해 배터리를 충전하는 시스템



프로젝트 선정 배경



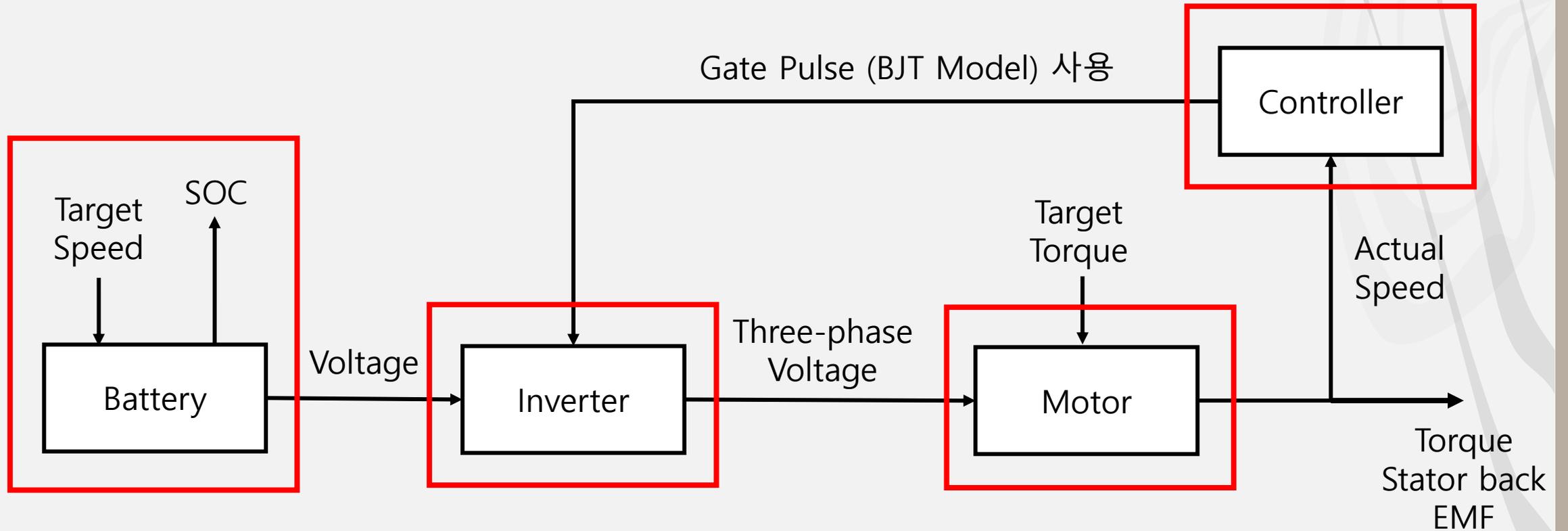
[회생 제동의 장점]

1. 회생제동을 활용하면 손실되는 에너지의 절반 정도 회수 가능
2. 내연 기관 자동차보다 두배 정도 긴 하이브리드나 전기차의 브레이크 패드 교체 주기

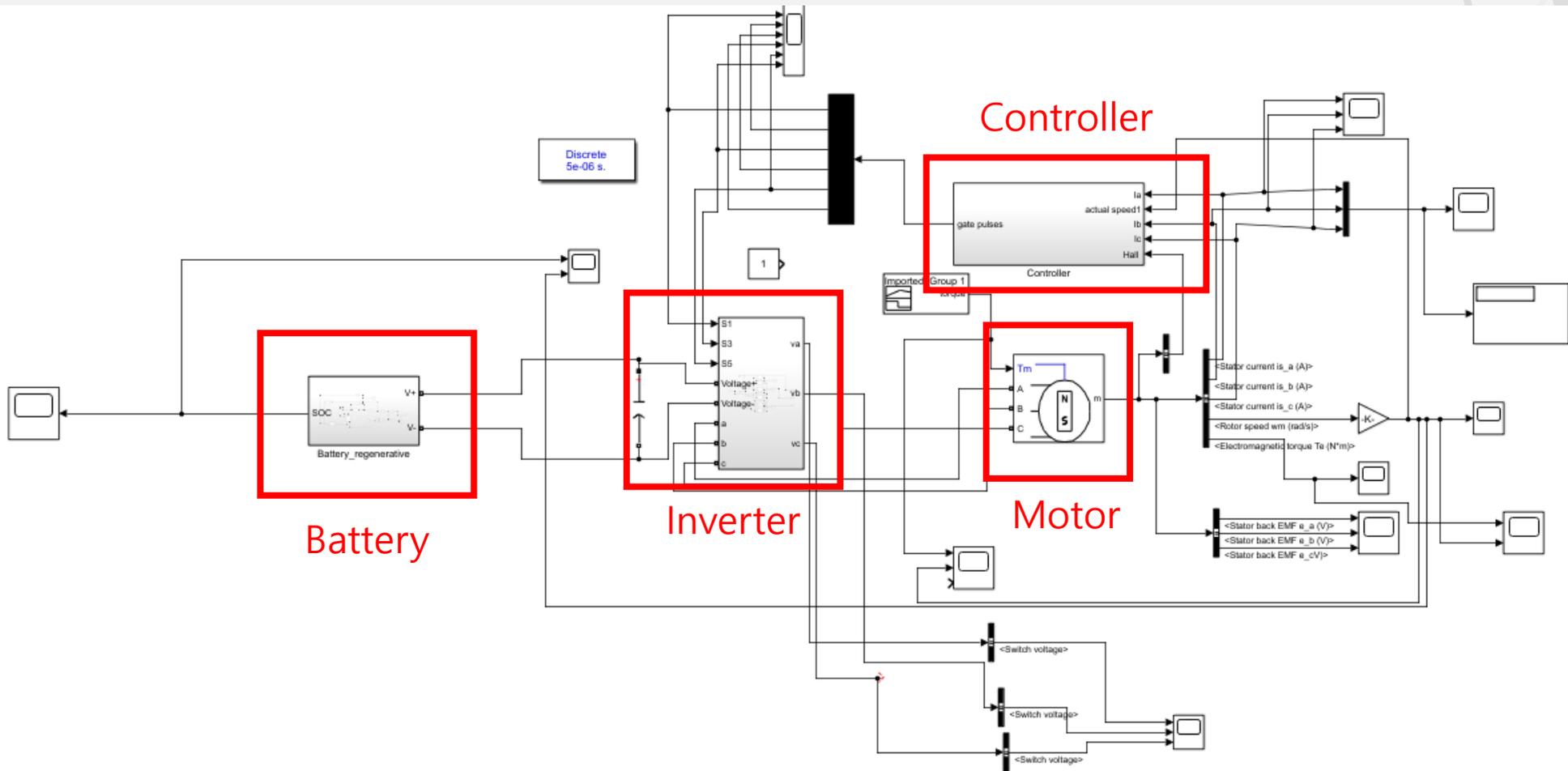
연구 내용 및 목표

1. 일반 주행 상황과 회생 제동 시스템을 적용한 주행 상황에서의 배터리 SOC 비교 (Simulink 통해 구현)
2. 일반 주행 상황과 회생 제동 시스템 내에서의 브레이크 패드에 가해지는 힘 분석 (Matlab 및 Comsol 이용)

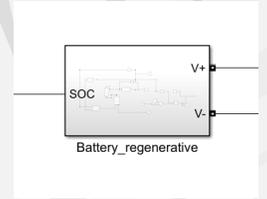
배터리 SOC 분석



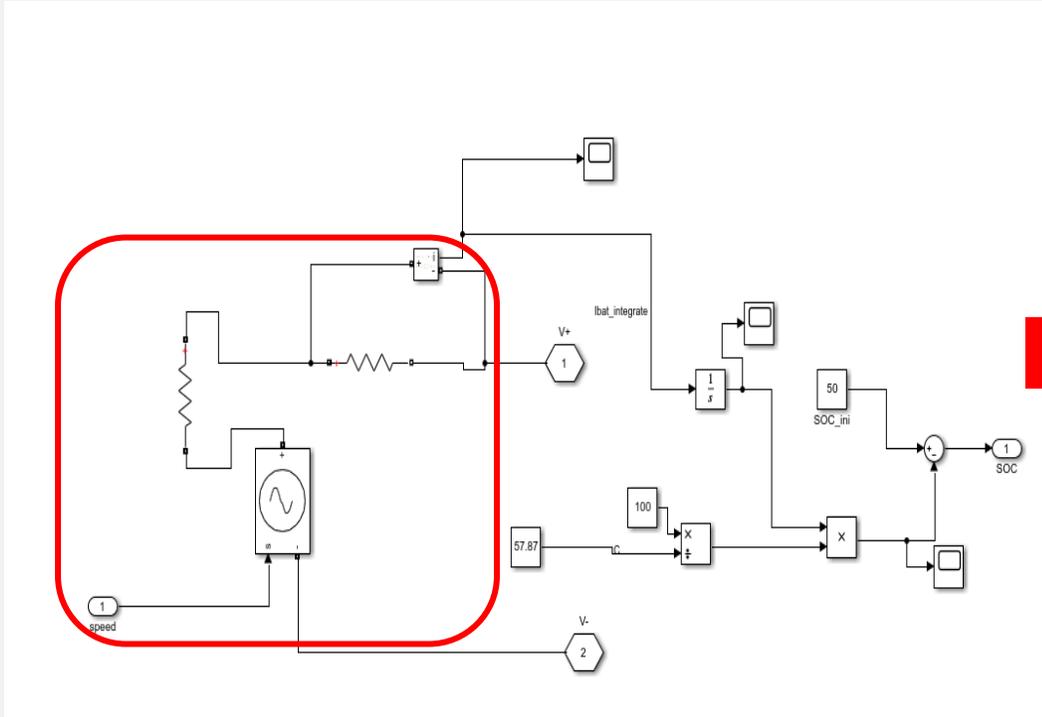
배터리 SOC 분석



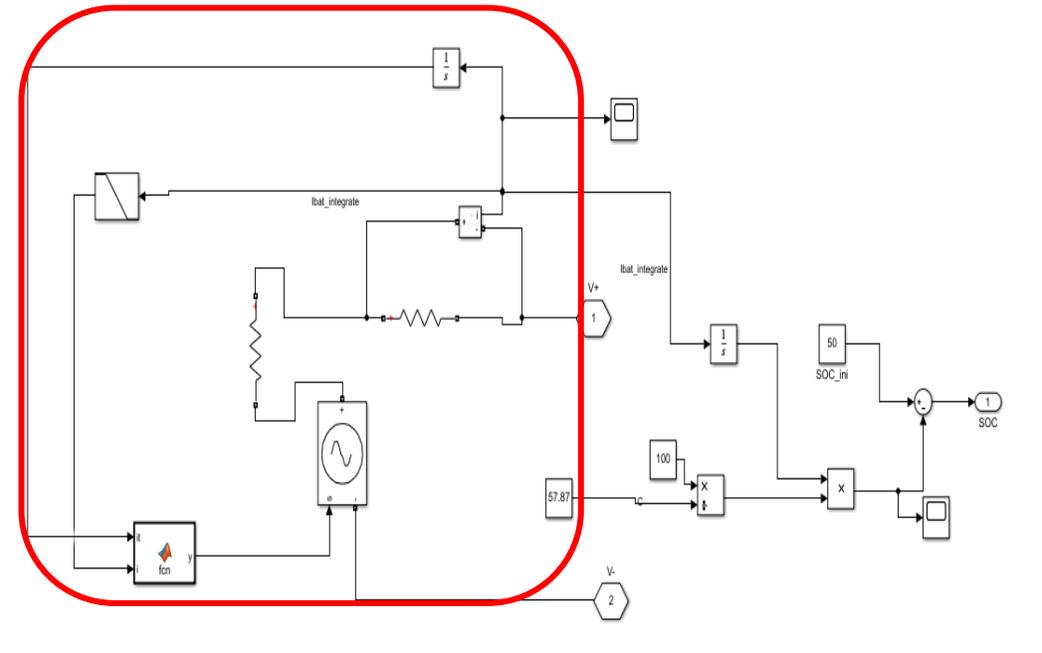
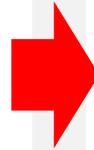
배터리 SOC 분석



Target Speed만 받지 않고
Actual Speed 받아 Battery Voltage 조절

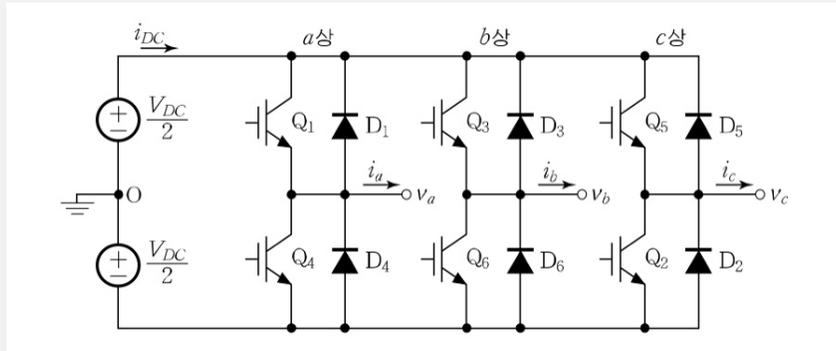


일반 주행 상황에서의
Battery 모델

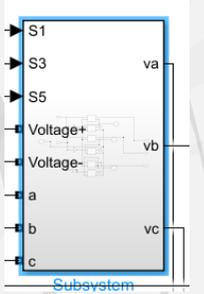
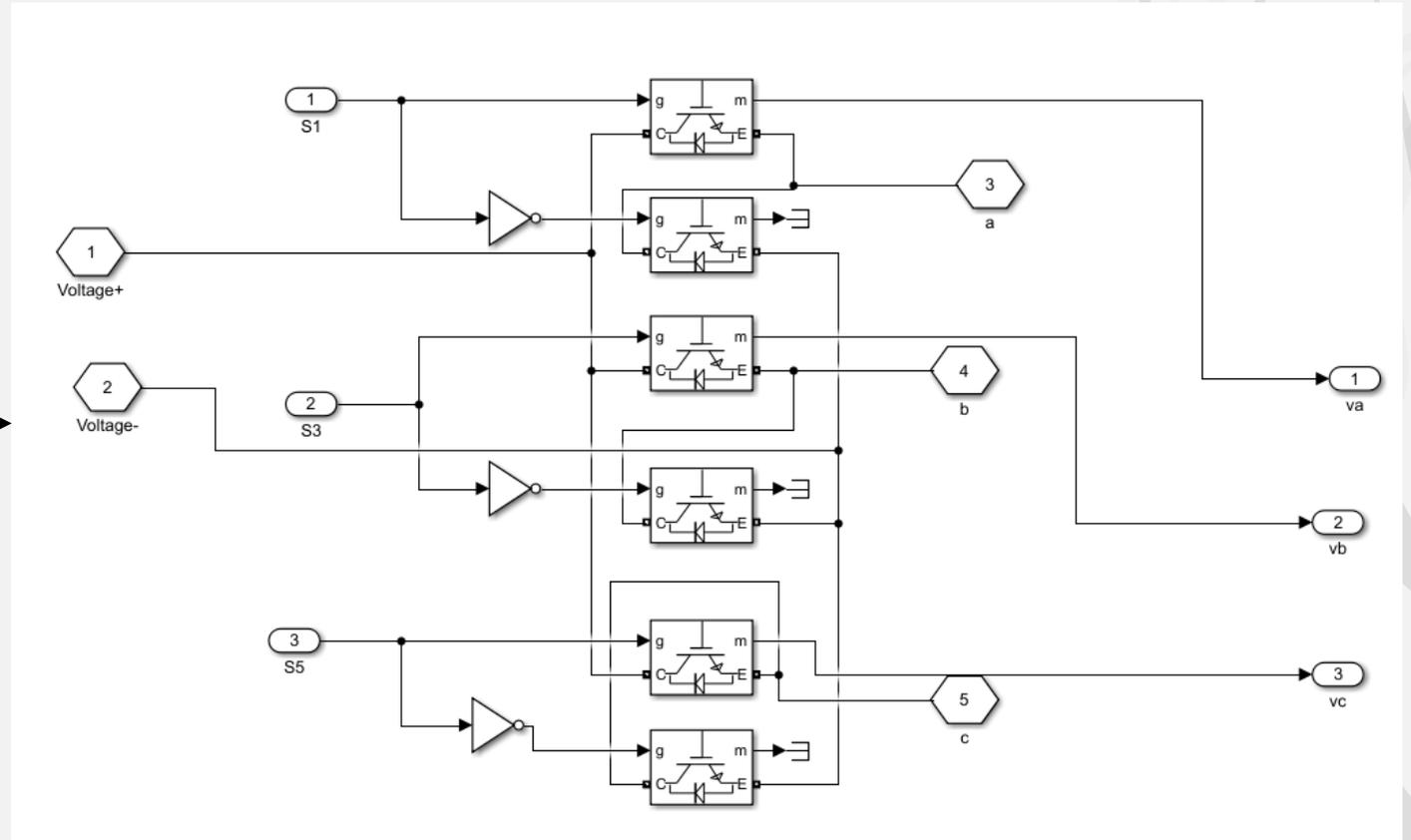


회생 제동 상황에서의
Battery Model

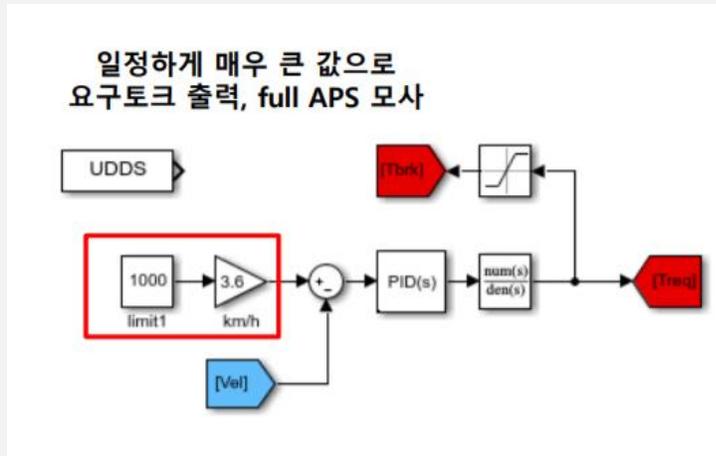
배터리 SOC 분석



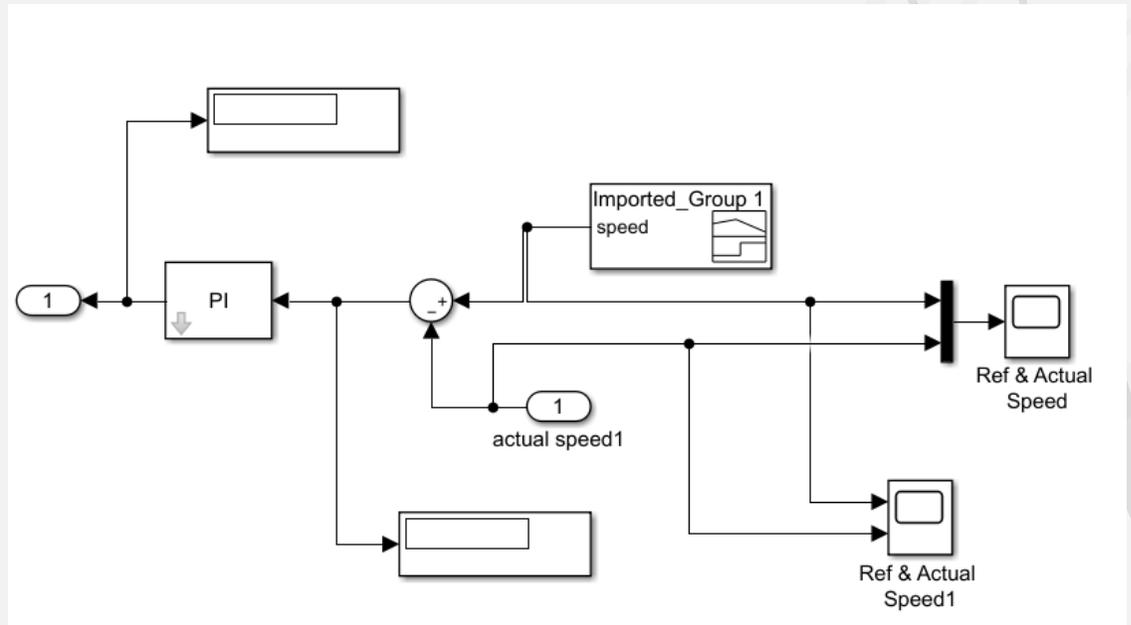
IGBT/Diode 모델 이용하여
Inverter 회로 구성



배터리 SOC 분석

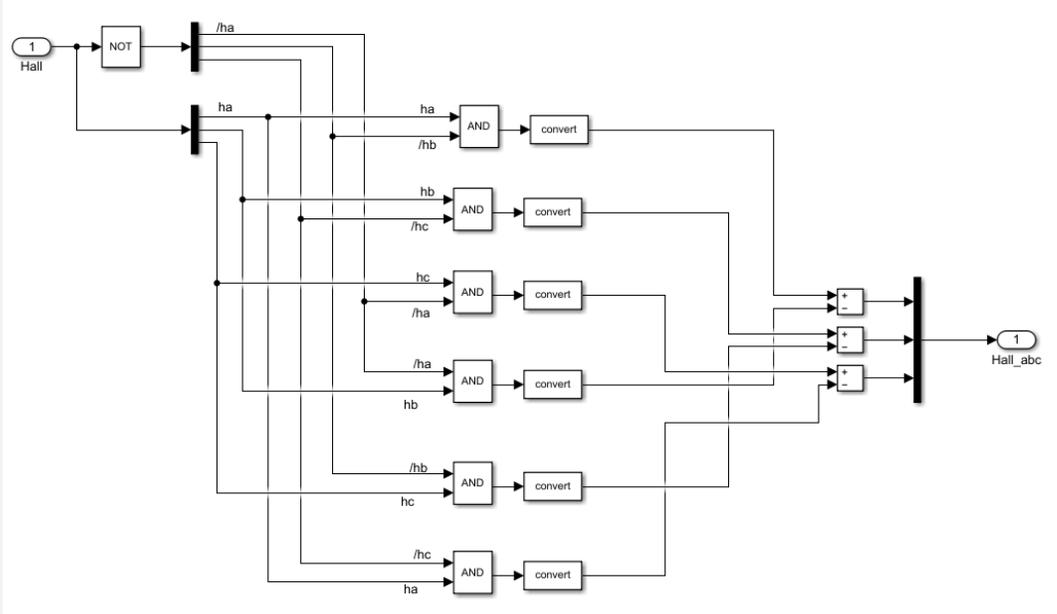
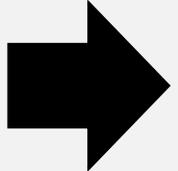
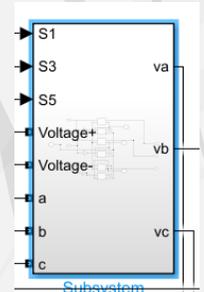
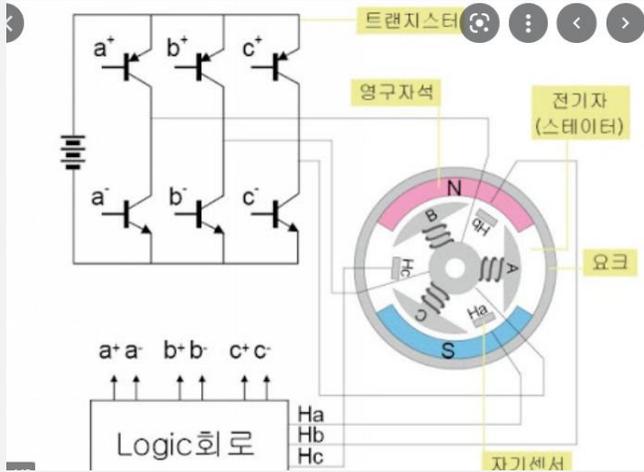


$$Velocity = Target Speed - Actual Speed$$



Speed Controller 구성
(Speed Input 값 주기 위한 회로도 구성)

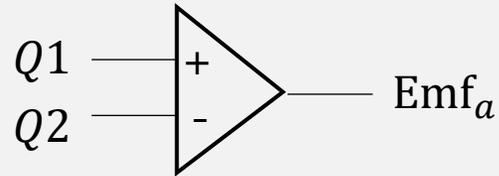
배터리 SOC 분석



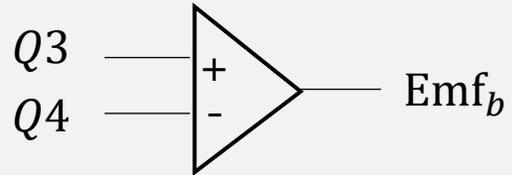
Ha	Hb	Hc	Emf_a	Emf_b	Emf_c
0	0	0	0	0	0
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1
1	1	1	0	0	0

Hall Sensor 구성
(Hall Seonsor Truth Table 통한 회로 구성)

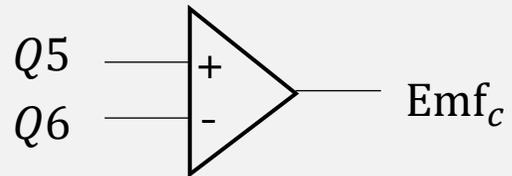
배터리 SOC 분석



$$Q1 - Q2 = Emf_a$$

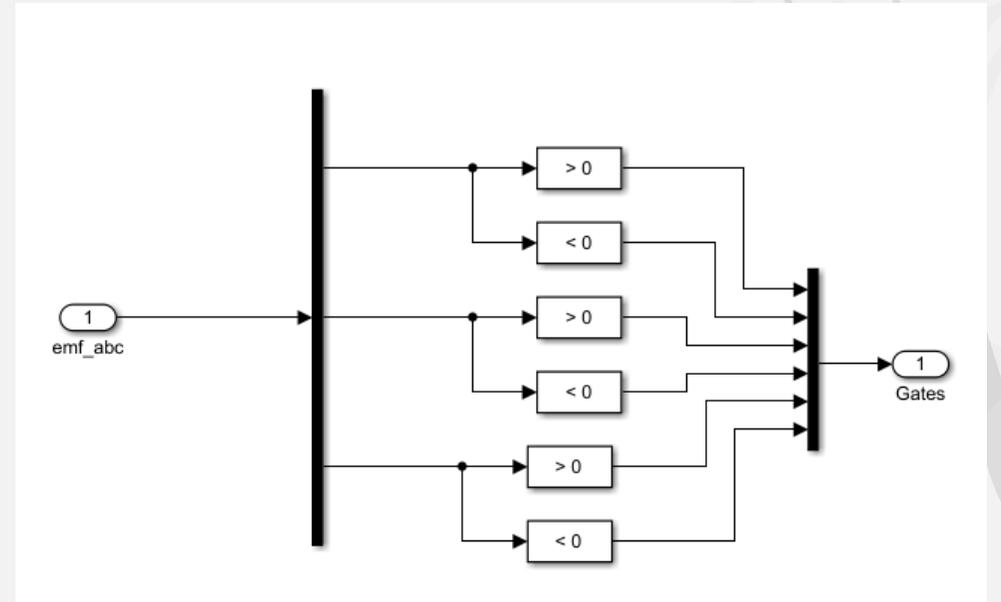
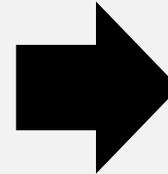


$$Q3 - Q4 = Emf_b$$



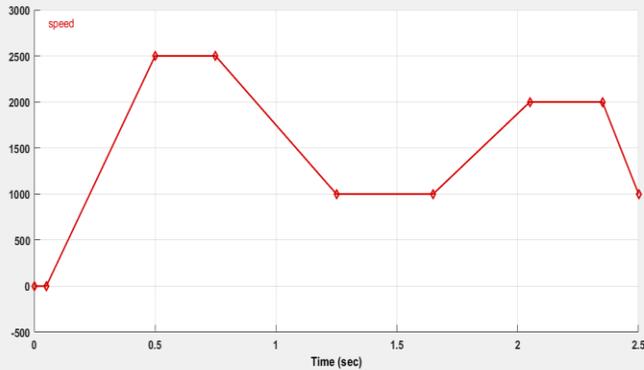
$$Q5 - Q6 = Emf_c$$

Emf_a	Emf_b	Emf_C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

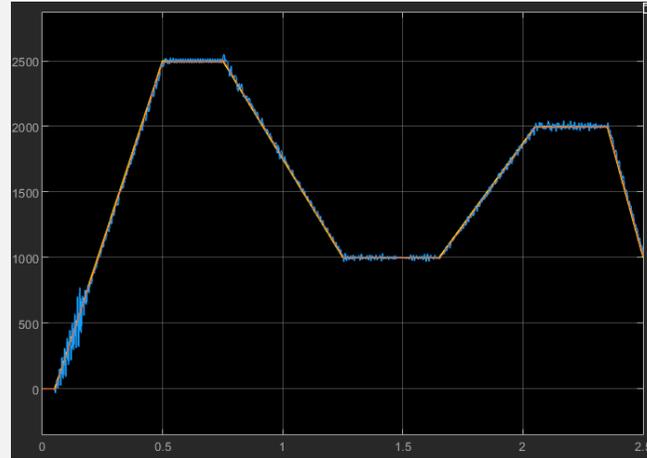


Emf값 통해 gate pulse 출력하는 회로 구성

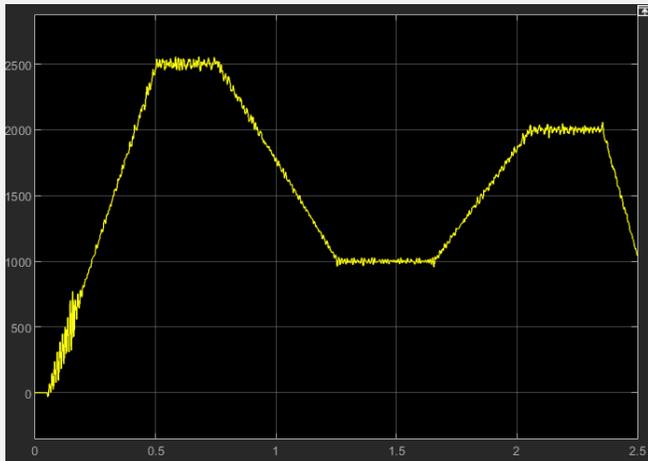
일반 주행 상황 및 회생 제동 시 Speed 분석



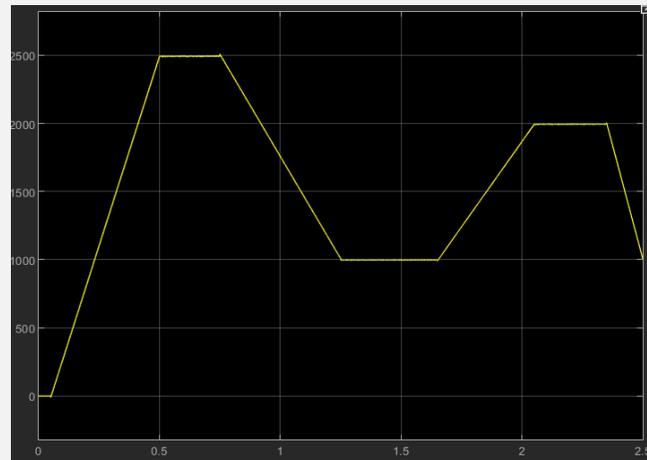
Target Speed Graph



Target Speed 및 Actual Speed



일반 주행 시 Actual Speed

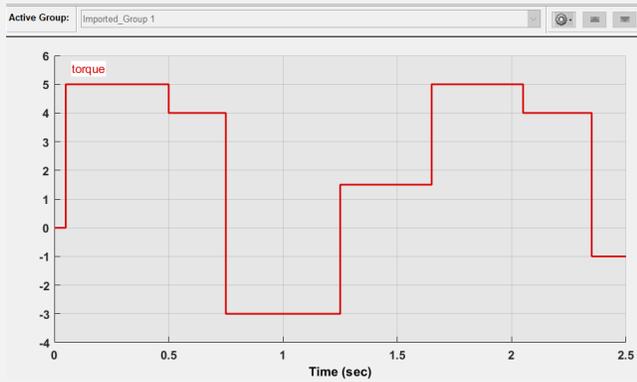


회생 제동 시 Actual Speed

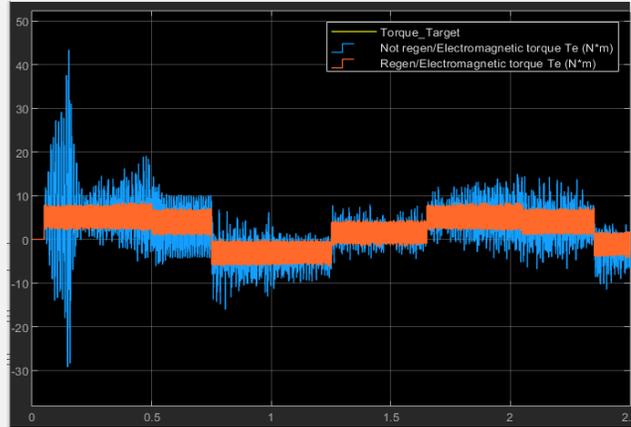


Target Speed 달성

일반 주행 상황 및 회생 제동 시 Motor Torque 분석



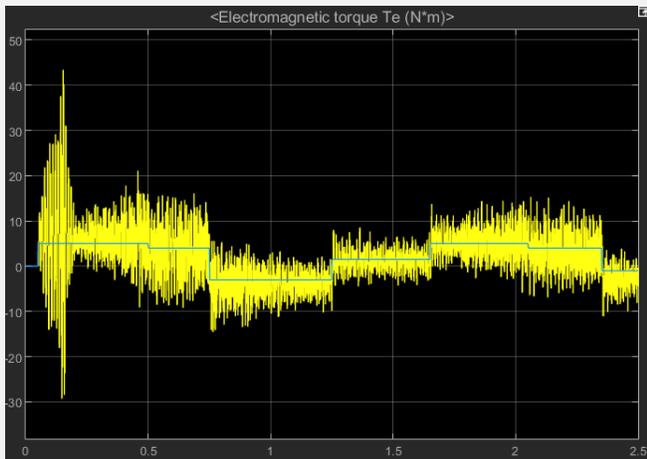
Target Torque Graph



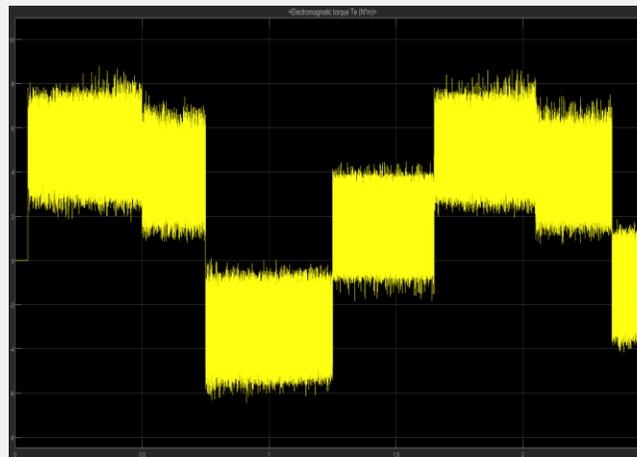
Target Speed 및 Actual Torque



Target Torque 달성

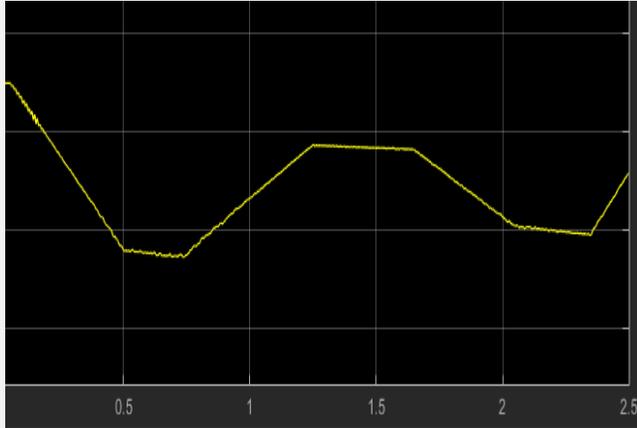


일반 주행 시 Actual Torque

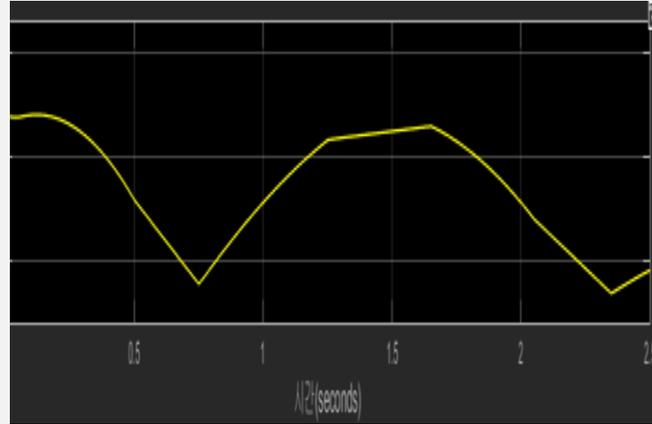


회생 제동 시 Actual Torque

일반 주행 상황 및 회생 제동 시 배터리 SOC 분석

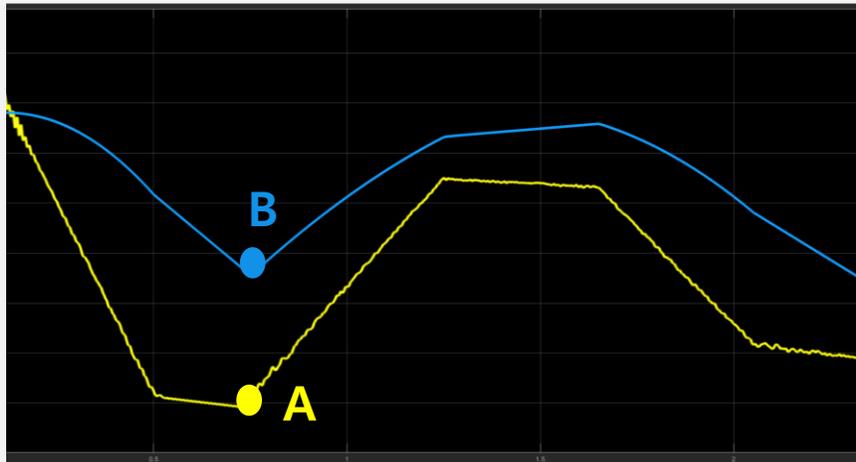


일반 주행 시 SOC 변화율



회생 제동 시 SOC 변화율

같은 주행 조건에서 회생 제동을 사용한 주행에서 더 높은 SOC 결과값



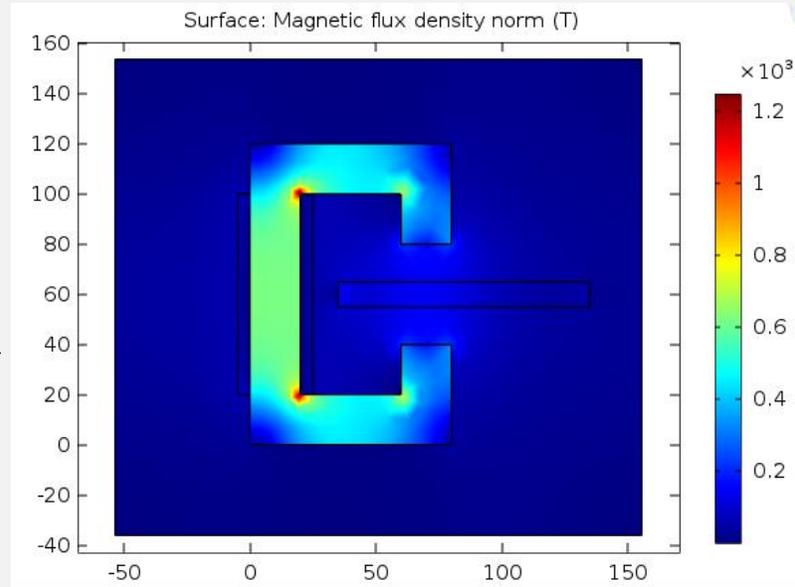
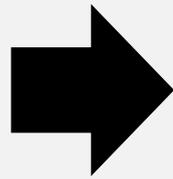
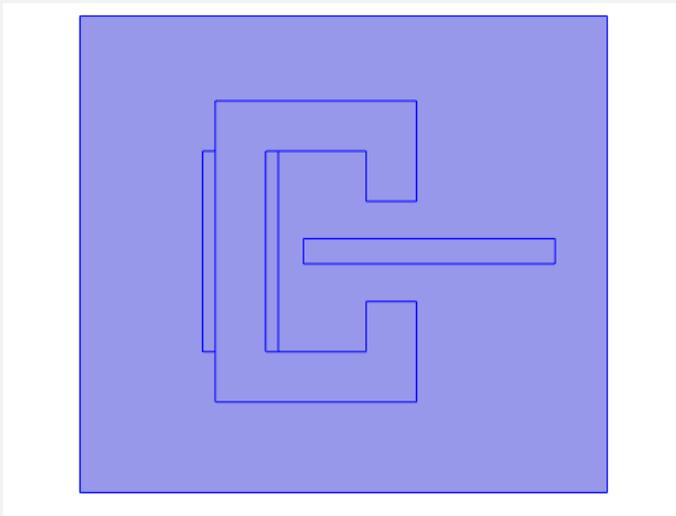
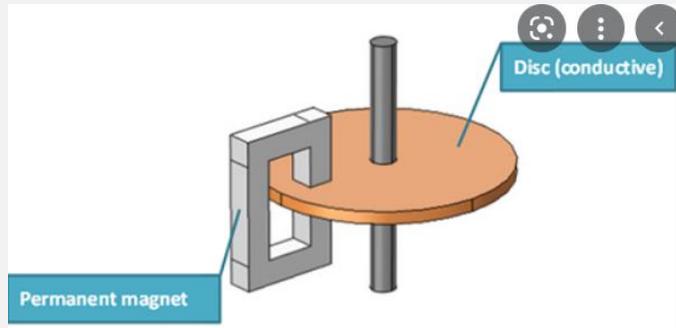
일반 주행 및 회생 제동 시 SOC 변화율

13% 차이 발생

일반 주행 시 SOC 변화율(A)
50% → 14.82%

회생 제동 시 SOC 변화율(B)
50% → 27.89%

브레이크에 가해지는 자기장 분석



x	y	Value
67.256	59.370	144.19

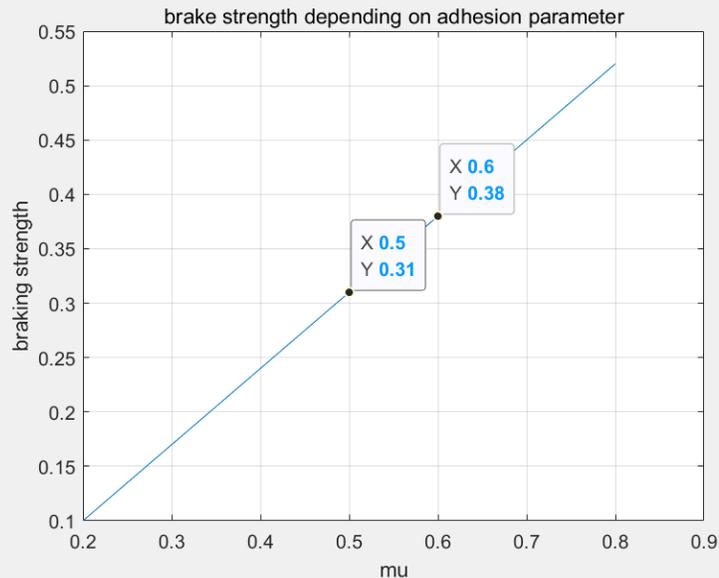
$$B = 144.19T$$

$$B = \frac{2\pi r}{\mu_0} I, J = \frac{I}{A}$$

$$\therefore J = 3.95e^8 A/m^2$$

MATLAB을 이용한 Force 계산

$$z = \frac{\alpha_{dec}}{g} > 0.1 + 0.7(\mu - 0.2)$$



$$\mathfrak{F}_{eddy} = \oint_s J_e dS = J_e dr$$

$$F_{br} = \frac{1}{2} \left[\frac{mg}{H_g} \sqrt{L_b + \frac{4H_g}{mg} F_{bf}} - \left(\frac{mgL_b}{H_g} + 2F_{bf} \right) \right]$$

$$F_{total} = F_{br} - \mathfrak{F}_{eddy}$$

F_{total} : force applied to brake pad

F_{bf} : force applied to one wheel

\mathfrak{F} : magnetic force

F_{br} : brake friction force

L : wheel to wheel length, L_b : center of mass to wheel

H_g : center of mass to ground

m : vehicle mass, g : gravity, z : brake strength, μ : adhesion parameter

The break force generated by friction force:

404.4602

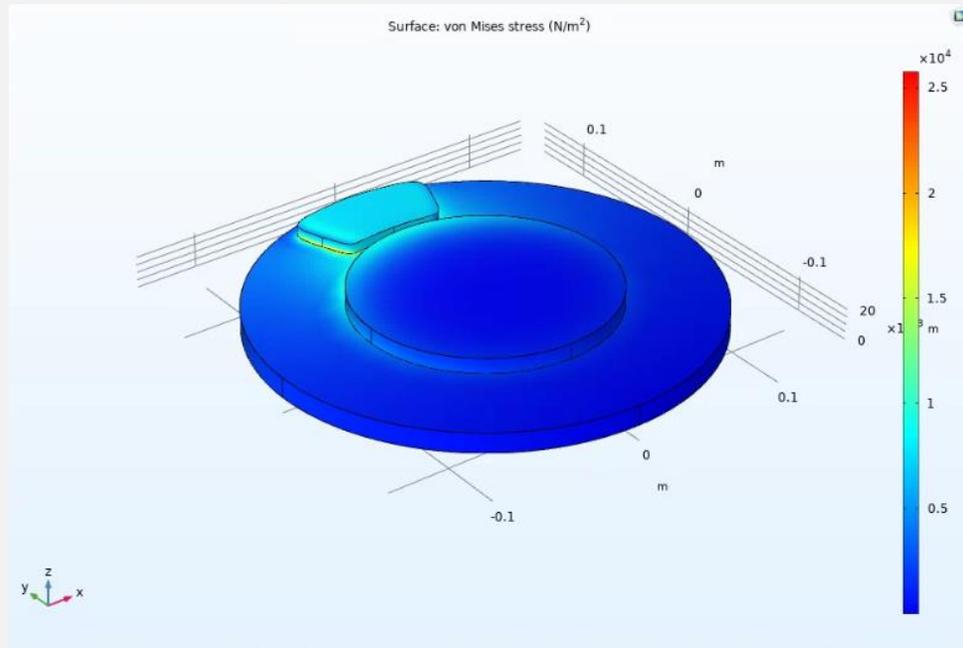
The break force generated by eddy current:

29.6250

The break force needed to stop:

374.8352

브레이크에 가해지는 힘 분석



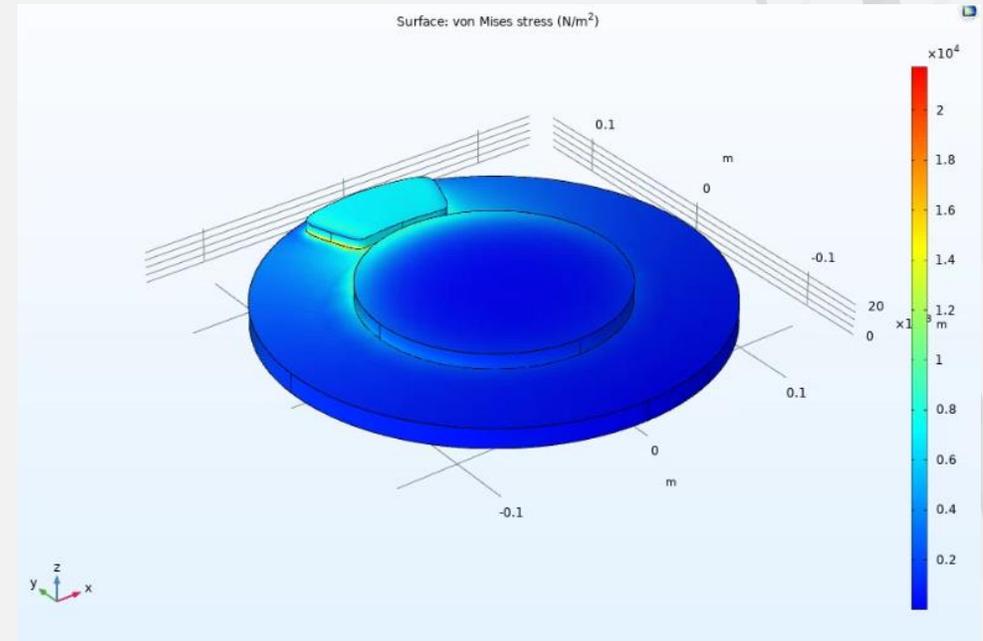
일반 주행 시 정지에 필요한 힘을
인가했을 때 가해지는 응력

$$\sigma = 7356.8 \text{ N/m}^2$$

7356.8



응력
감소



회생 제동 시 정지에 필요한 힘을
인가했을 때 가해지는 응력

$$\sigma = 6815.5 \text{ N/m}^2$$

6815.5

Conclusion

1. 같은 속도와 토크를 가지고 구동할 때, 배터리 방전율 감소
2. 정지 시 Brake Pad에 가해지는 힘 감소

Conclusion: 발전 방향

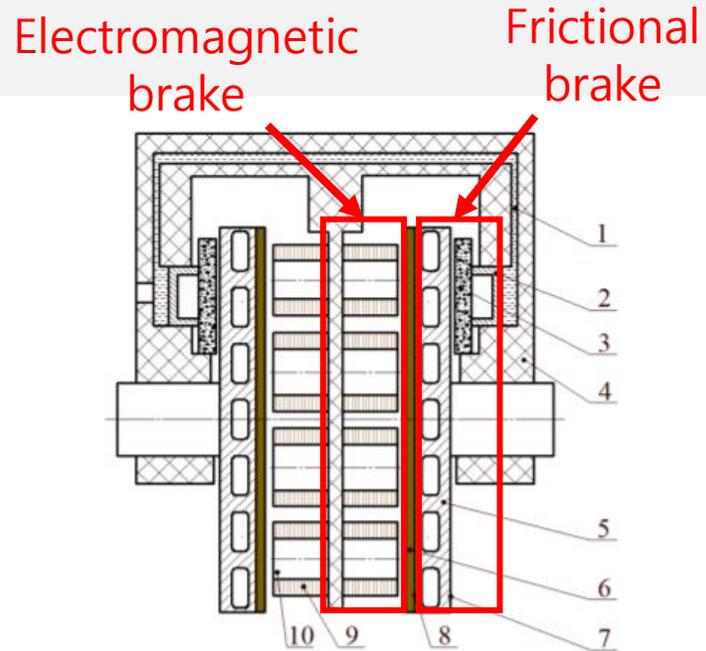
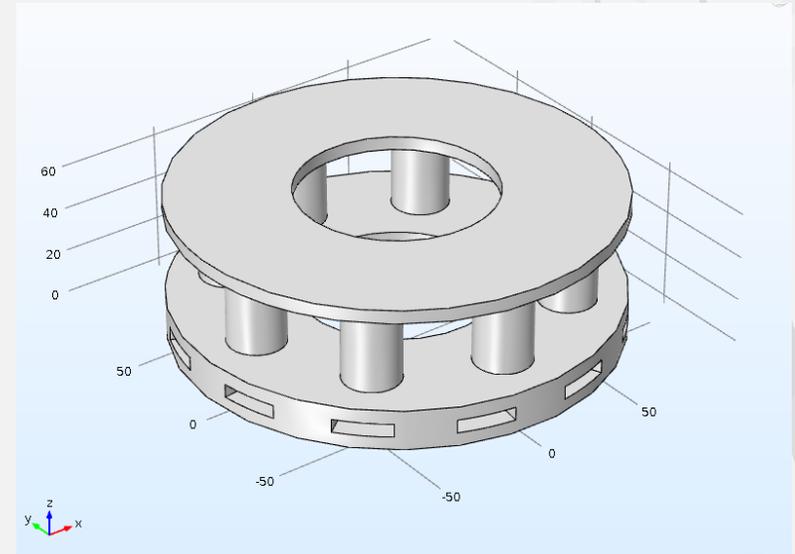


Figure 1. Structural diagram of electromagnetic-frictional integrated brake. 1, brake fluid; 2, brake piston; 3, brake pad; 4, caliper body; 5, integrated brake disc; 6, copper layer; 7, friction brake surface; 8, electromagnetic brake surface; 9, coil; and 10, iron core.



-> 복합된 브레이크의 해석을 통한 온도, 응력 분석

Reference

1. *Matlab, Documentation, Battery(Generic battery model)*
2. *Matlab, Documentation, Brushless DC Motor Fed by Six-Step Inverter*
3. *Kuiyang Wang, 2018, "Performances Analysis of a Novel Electromagnetic-Frictional Integrated Brake Based on Multi-Physiscal Fields Coupling", World Electric Vehicle Journal*
4. *Comsol, Disc Brake Pad Wear*
5. 이은하, 2013, 친환경 자동차의 회생제동 협조 시스템, KSAE
6. 조치훈, "Design and Control of Electronic Brake for Regenerative Braking in Hybrid Electric Vehicle"
, 성균관대학교 기계공학과 박사 논문(pg 33-54)
7. *J.K.AHN, 2007, "Analysis of a Regenerative Braking System for Hybrid Electric Vehicles Using an Electro-Mechanical Brake", International Journal of Automotive Technology*

Reference

8. Alexandre José Rosa Nunes, 2020, "Designing an Eddy Current Brake for Engine Testing", KnowledgeE
9. Boyi Xiao, 2017, "Enhanced Regenerative Braking Strategies for Electric Vehicles: Dynamic Performance and Potential Analysis", energies
10. Yang Yang, 2017, "Regenerative Braking Control Strategy of Electric-Hydraulic Hybrid (EHH) Vehicle", energies
11. Krzysztof POPIOLEK, 2019, "Analysis of Regenerative Braking Strategies", PRZEGLĄD ELEKTROTECHNICZNY
12. CDL, 2021, Powertrain Component Modeling (CAE 수업자료)

THANK YOU

The image features a minimalist design with a white background. A dark green border is visible at the top and bottom. On the right side, there is a light gray, wavy, abstract pattern that resembles a stylized wave or a series of overlapping lines. The text "THANK YOU" is centered in a dark green, sans-serif font.