Development of the "New Energy Train -hybrid type-"

ne@train
new energy train

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Development of the NE Train

Purpose

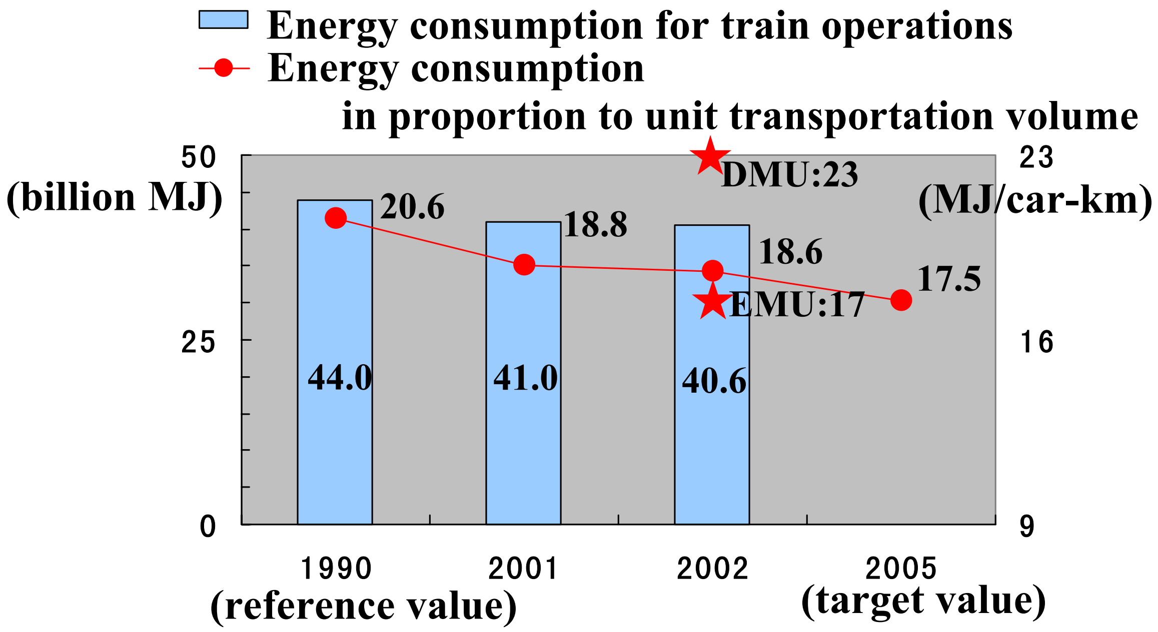
1. Background of the NE Train project
2. Outline of development
    2-1 Concept
    2-2 Overview of NE Train
    2-3 Energy control system
3. Evaluation test
4. Conclusion

Background of the project

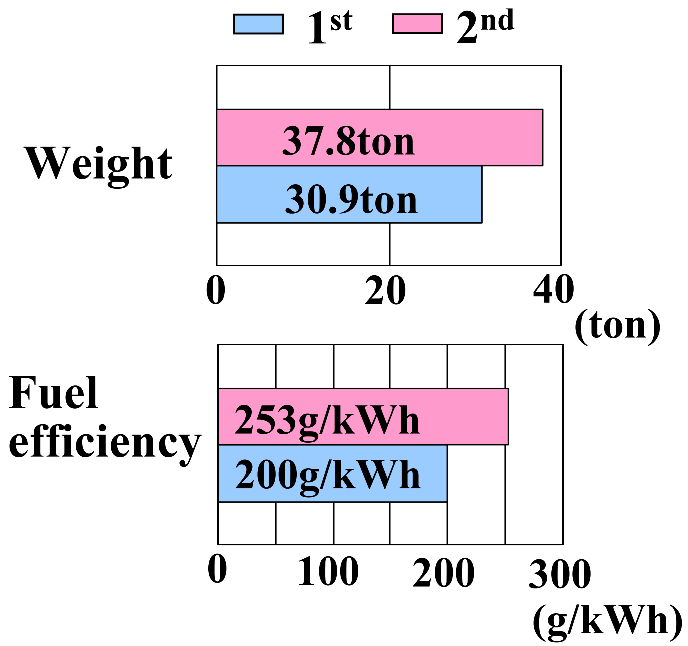
DMU Problem

=A JR East's DMU : 530cars=

- Low energy efficiency
- Pollution and Noise
- High maintenance
- Poor acceleration and deceleration



- Energy consumed for train operations and transported volume



- 2nd generation diesel railcars

Concept of the NE Train project

Purpose

- Reduce environmental load of railcars through innovation of propulsion system.

1st step: Hybrid system   2nd step: Fuel cell system

Concept & Target

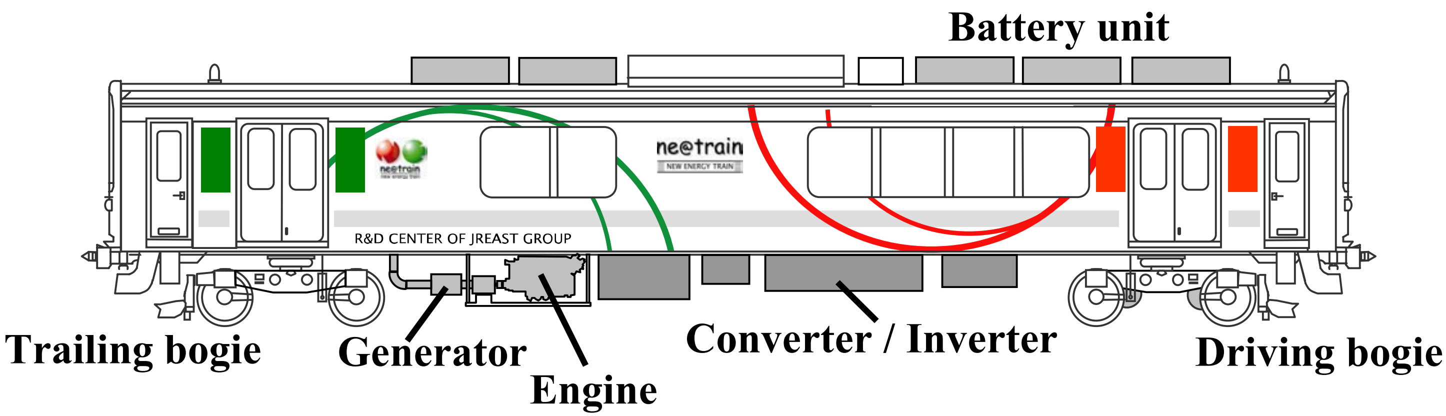
= Environmental friendliness =

- Energy saving
- Reduction of pollutants and noise

= Conversion to electric railcar technology =

- Labor saving maintenance
- Improvement of driving performance

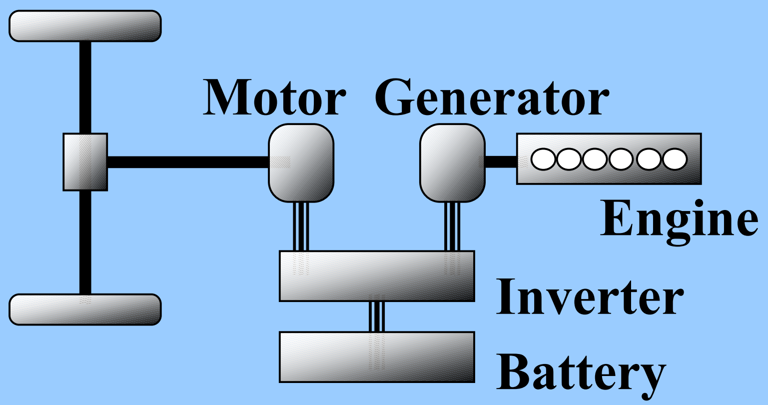
NE Train Overview



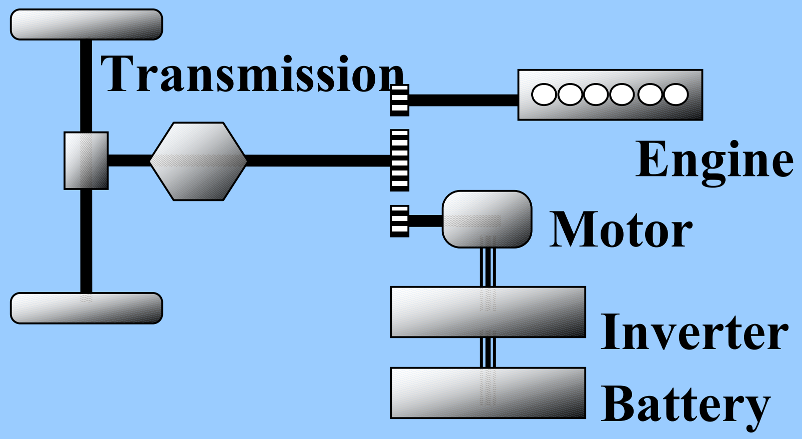
Body	Stainless steel （Length:20 m）
Max. speed	100km/h
Power unit	• Hybrid type: Series type • Main controller: VVVF inverter (IGBT) • Main motor: Induction motor(120kW × 2) • Main battery: Lithium-ion battery（10kWh） • Main generator: Induction motor(180kW) • Engine: Diesel engine(330kW/2100rpm)
Bogie	Bolsterless Bogie
Brake system	Electric command air brake system with regenerative braking

Hybrid system

2 types of hybrid system



(a) Series-hybrid system



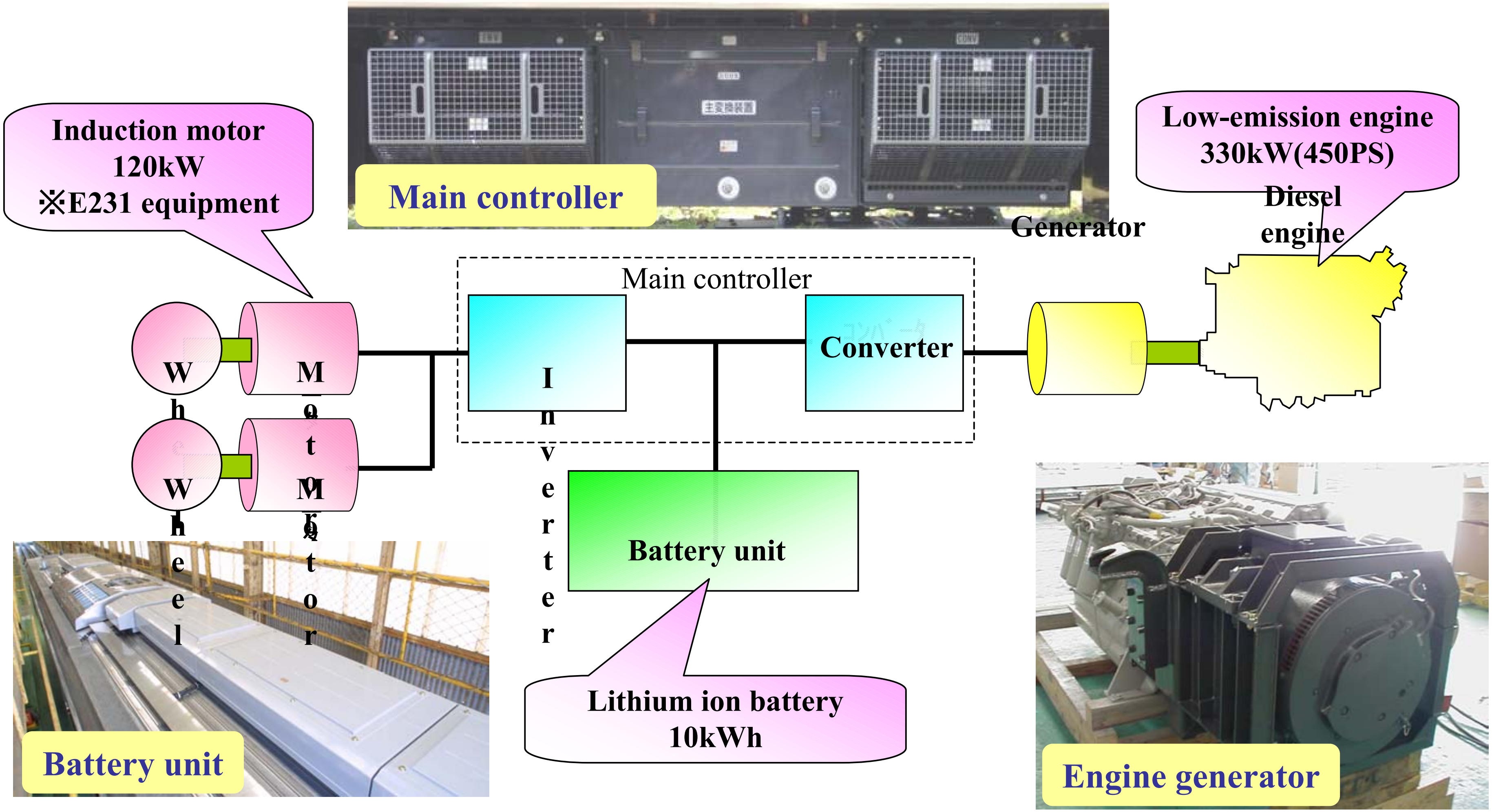
(b) Parallel-hybrid system

Requirements demanded of NE Train

- Advance and sternway used equally.
- Adoption of fuel cell system in future.
- Effective use of latest EMU technology.
- Achieve high performance equivalent to EMU.

Hybrid system Overview

- **Effective use of latest EMU technology and equipments**



Selection of power equipment

Main motor

60km/h on $25^{0}/_{00}$ slope (equal to EMU) 120kW x 2

Engine & Generator

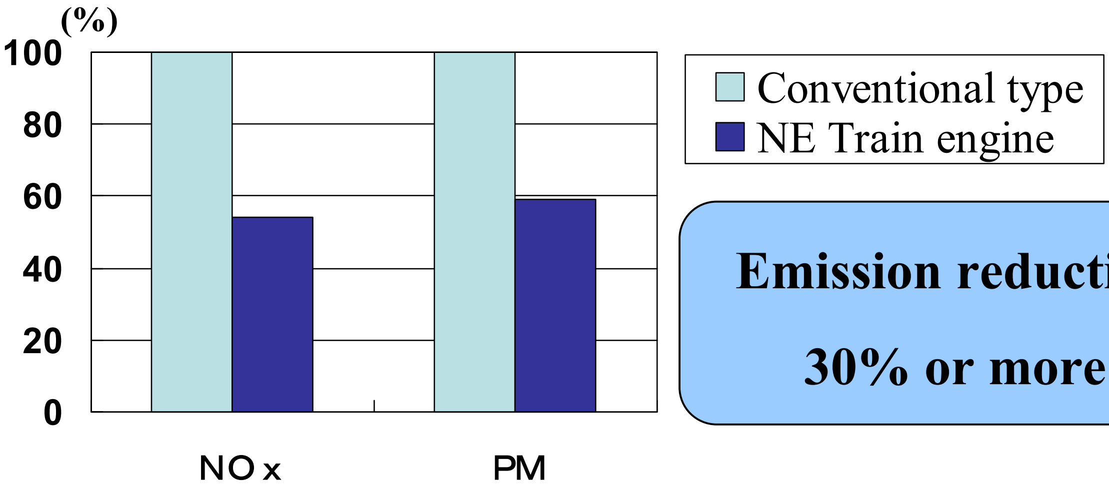
60km/h on $25^{0}/_{00}$ slope 250kW

Power supply for service equipment 50kW

(Air conditioner etc.)

Total 300kW or more

Engine with reduced emissions



Emission reduction

30% or more

Selection of battery unit

Capacity

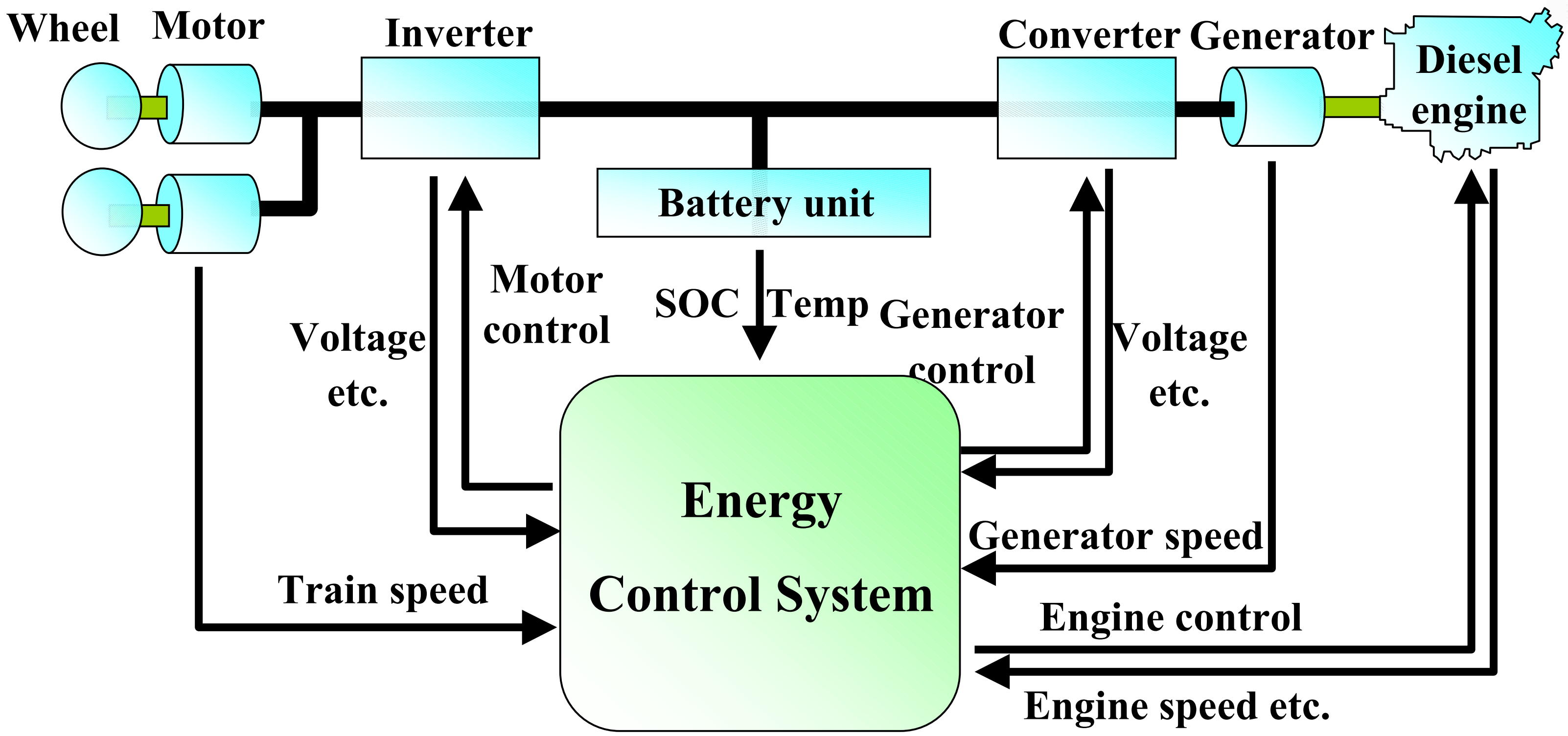
Regeneration energy per 1 stop 1kWh
5km running by Battery only 3kWh
Optimal operation range 40%

→ **10kWh**

Comparison of electricity storage equipment

	Energy density (Wh/kg)	Power density (W/kg)	Life span (cycle)	Cost
Ultra Capacitor	6	500	Infinity	High
Lead Acid Battery	40	300	500	Low
Nickel-Metal Hydride Battery	40～70	200～700	1000	Average
Lithium-Ion Battery	**30～130**	**30～1400**	**1000**	High
Flywheel	～50	1000～	Infinity	Average

Power control system



Requirements demanded of system

= Energy saving =

- Effective storage of brake generation energy
- Operation of engine at optimal rpm.

= Reduction of pollutants and noise =

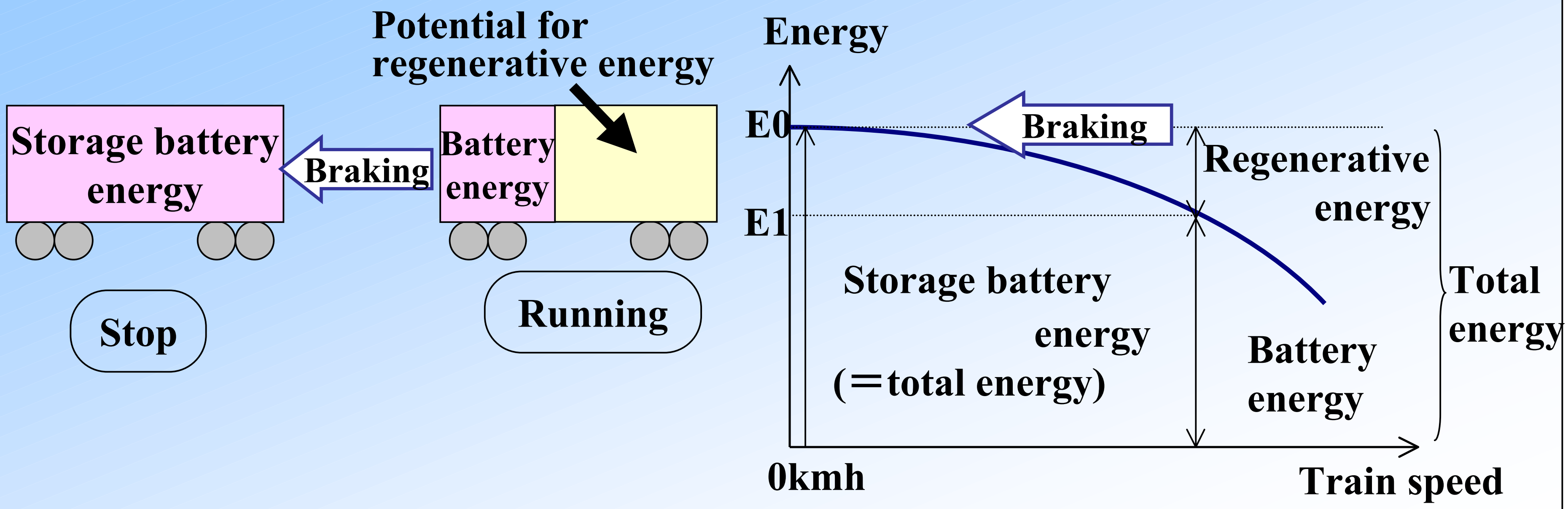
- Use of battery as power source at station

Energy control system

1. Keep the sum of kinetic energy and storage battery energy.

2. Control engine for charging a battery efficiently

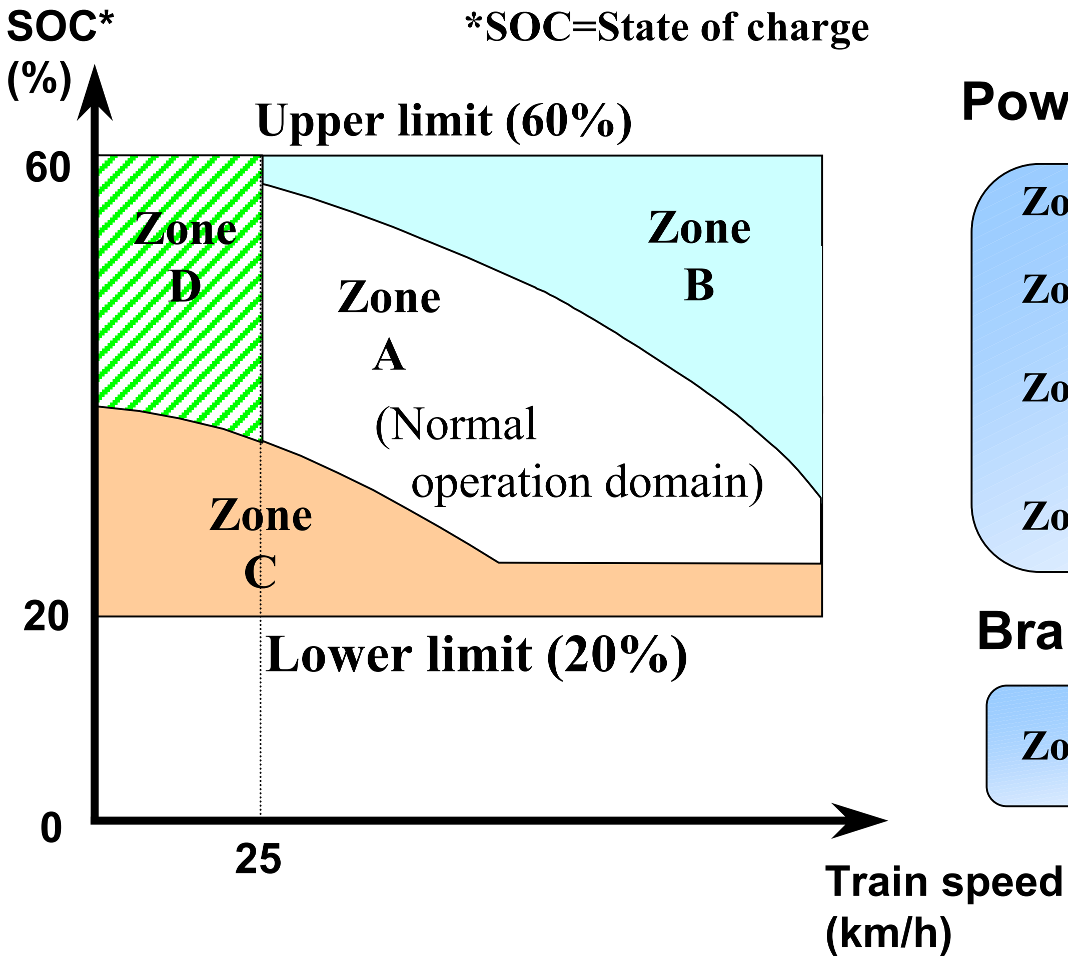
Basic principle



Energy control system

4 energy management zones

Engine controlled by "Train speed" ,"Battery charged level SOC"



Power running

Zone A :Engine highest efficiency (Engine 2N:200kW)

Zone B : Engine idling

Zone C : Engine maximum power (Engine 3N:300kW)

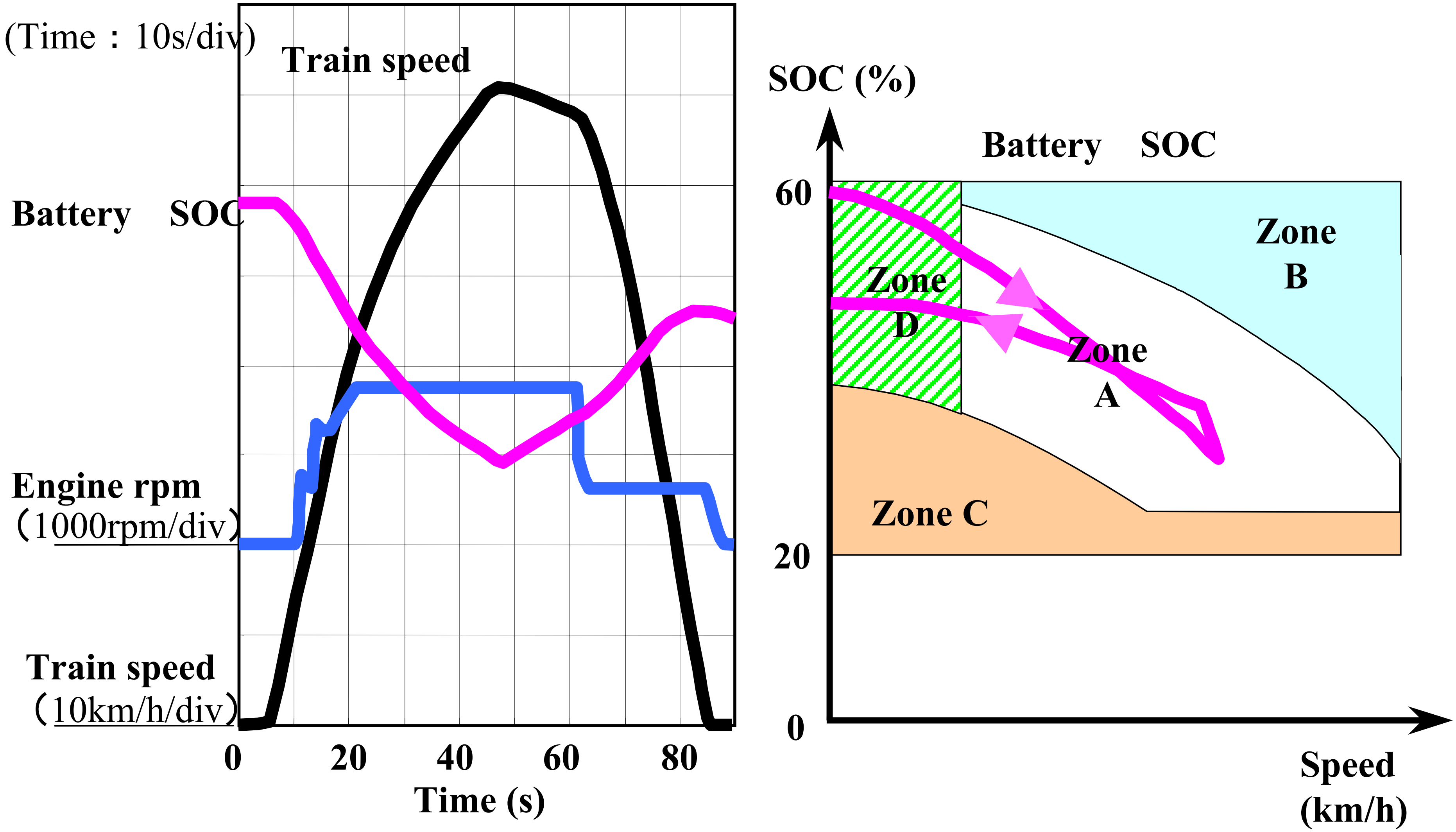
Zone D :Engine stop

Braking

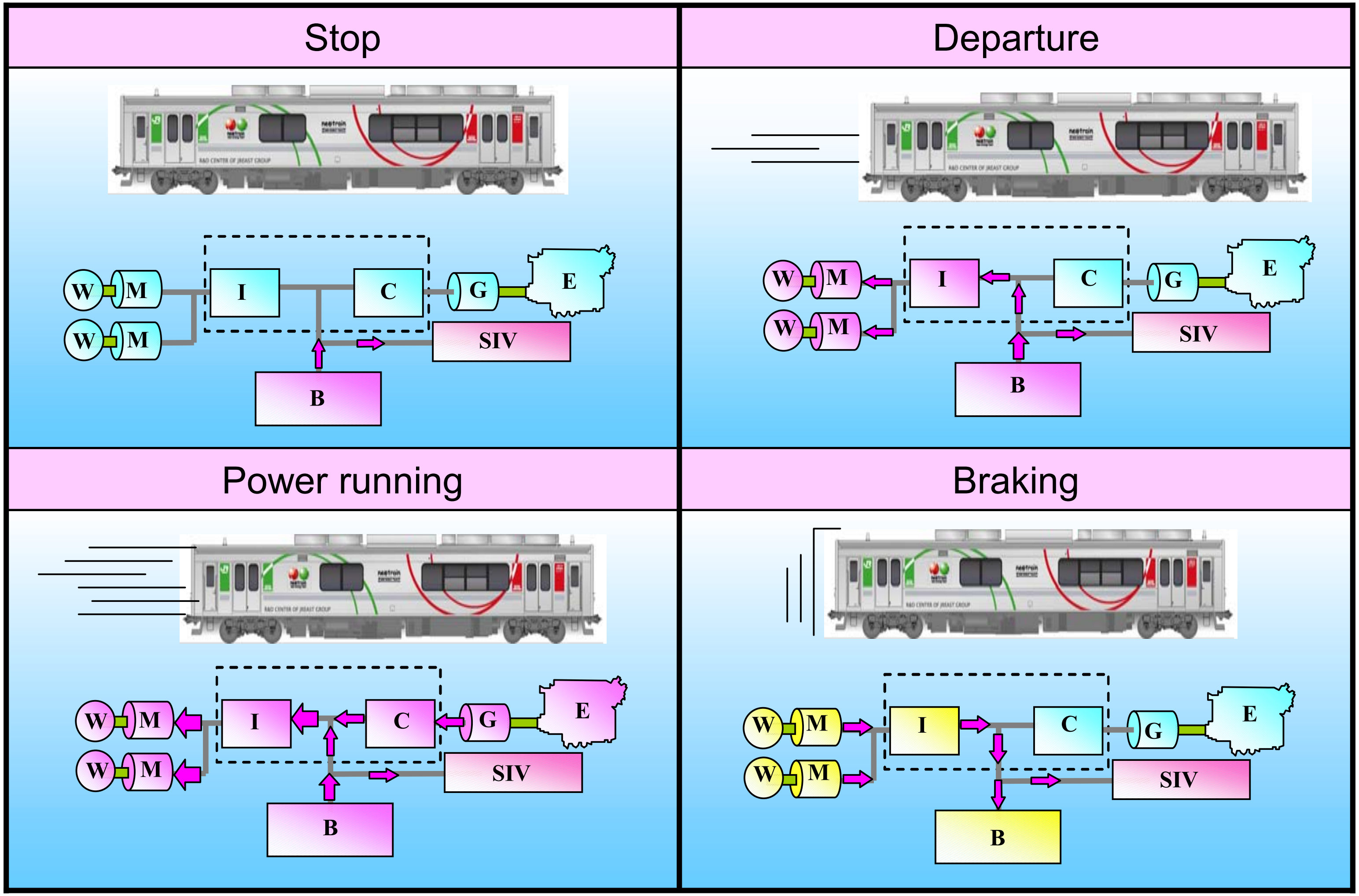
Zone A-D : Engine idling

Management diagram of energy control system

Power running to 70km/h (Engine idling from 25km/h) ➞ Braking



Operation state of hybrid system



E: Engine G: Generator C: Converter SIV: Auxiliary power supply
I: Inverter B: Battery M: Motor W: Wheel

NE Train evaluation test

NE Train test run

Drivers' monitor

Evaluation test

Evaluation by test runs of the NE Train

Schedule : 2003/May. - 2003/Sep.   2003/Nov.-

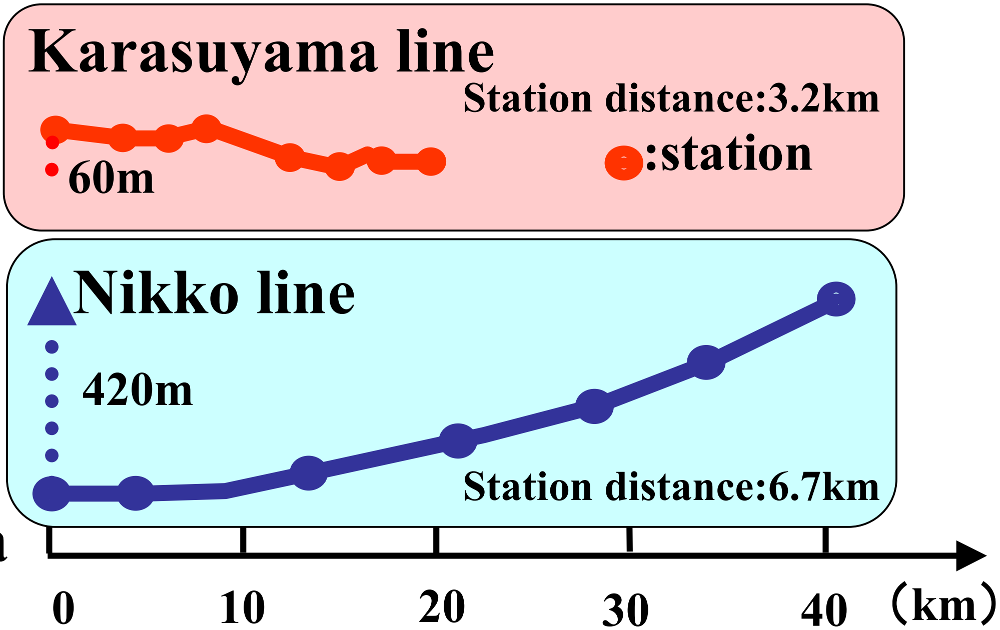
Place : Karasuyama line, Nikko line, Tohoku line

Test program : 1. Basic performance and functionality

2. Emergency function
(generator disconnected, battery disconnected)

3. Energy-saving effect

4. Effect of temperature (in winter and summer)



Test result

● Functionality and basic performance

(a value equivalent to that of electric railcar)

Acceleration = 2.3km/h/s at 35km/h　Deceleration = 3.6km/h/s

Proper coordination of generative and mechanical brake

● Energy-saving effects

(Target) saving of 20% in energy
compared with diesel railcars

(Result) regeneration ratio is 33%
*Karasuyama line max

● Temperature effects

(Condition) from - 5 degree to 35 degree

Basic performance operated satisfactory

● Noise reduction at stations

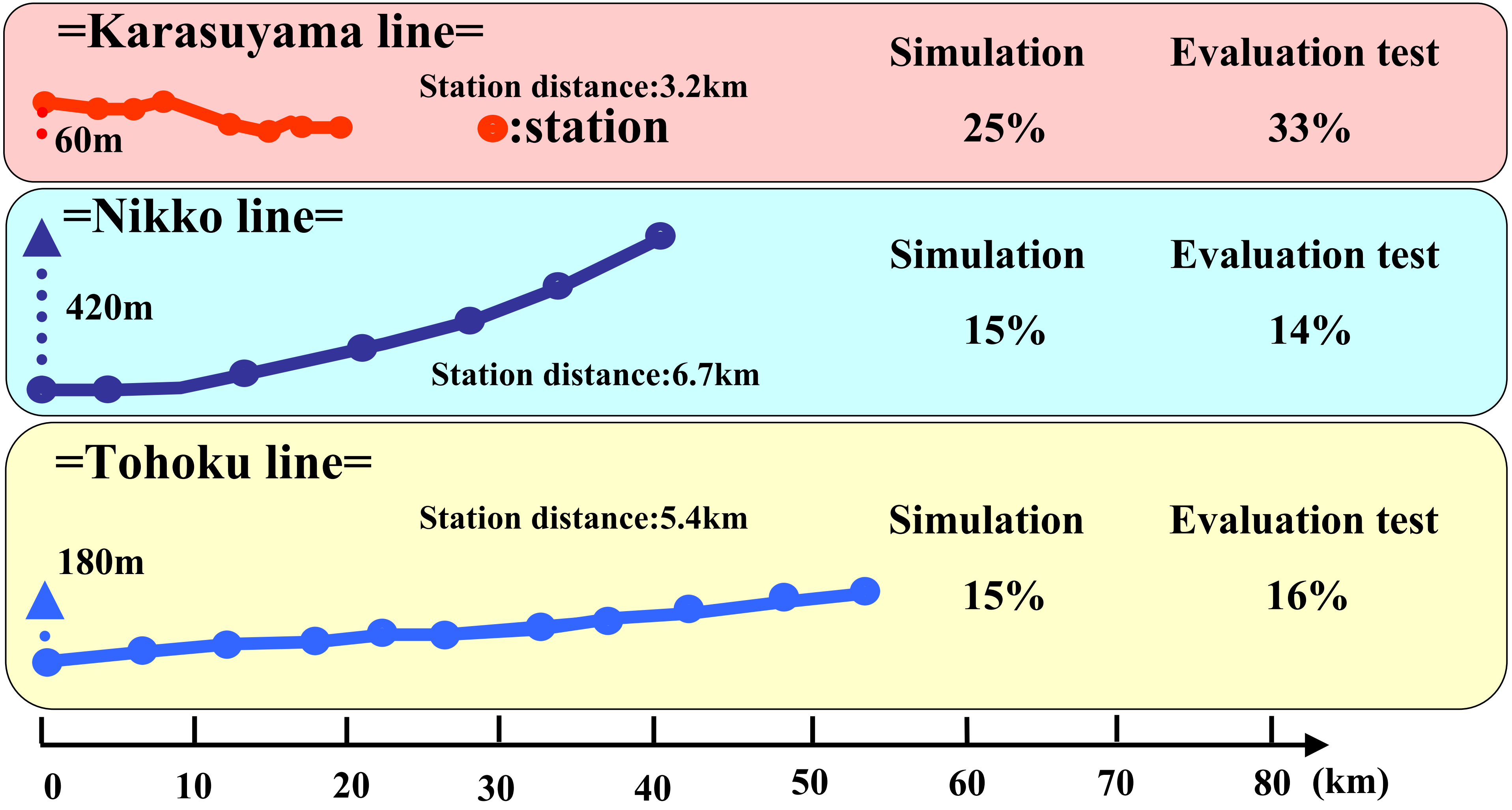
(Target) Engine stop at stations and at a low speed

(Result) Engine stop
at stations: within 5 minutes; at low speed

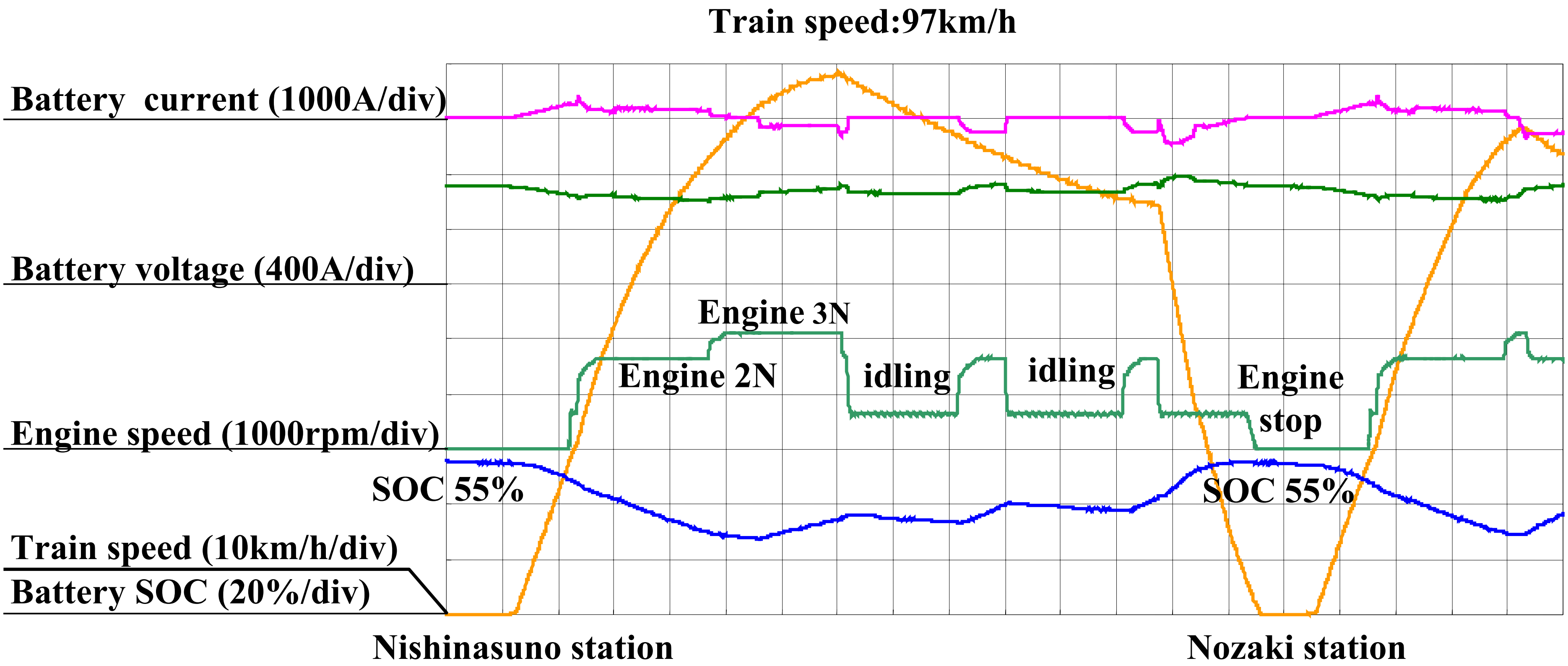
Simulation and evaluation test

energy ratio

	Simulation	Evaluation test
=Karasuyama line=	25%	33%
=Nikko line=	15%	14%
=Tohoku line=	15%	16%

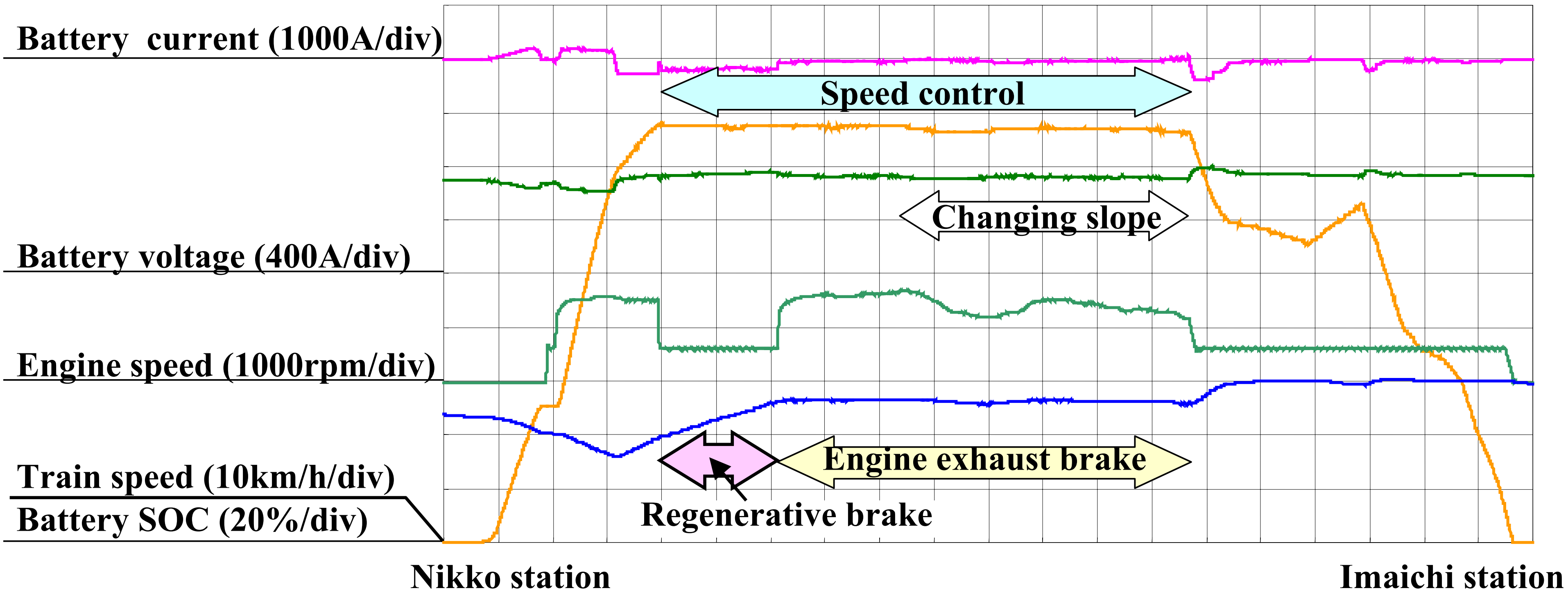


Basic performance (Power running & Braking)



1. Engine stop	Train speed :0-25km/h
2. Engine efficiency control	Engine 2N (about 0-80km/h)
3. Regenerative energy	1.5kWh (one stop, from 60 to 0km/h)

Basic performance (Speed control at a downward slope)



-Speed control at a downward slope-

(Step1) Regenerative brake

(Step2) Engine exhaust brake

Conclusion

- JR East began the NE Train project and developed a prototype with a hybrid system.
- We adopted a series hybrid system with future potential of conversion to fuel cell system.
- We developed an original "Energy Control System" for the control of the hybrid system.
- Results of the test runs demonstrate hybrid system achieved planned performance.
- Test runs on various routes to be conducted henceforth.