

**Ground Facilities  
and  
Energy-efficient & Alternative Fuel  
Vehicle Drive Systems  
for Urban, Regional and High Speed Train**

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## Preface:

# Electrification Everywhere / Railways

- Railway electrification has a long history and its technology is well known. Here we report on the latest trends.
- Even if railways are considered environmentally friendly, railway operators are aiming carbon reduction considering social demands.
- Expanding mobility for social development, introduction of new rail systems, such as magnetic levitated railway and APM, is attempted.
- In the followings, these trends are explained from the two aspects of ground power supply facilities and on-board drive systems for trains.



# **Modernization of Electric Railways**

## **Part.1 Ground Facilities**

**Energy Management System for Urban Network,  
Energy-efficient Power Supply for High Speed  
Train, Super Speed Maglev System**

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**(Railway Technical Research Institute)**



# 1. Introduction

- In order to meet the social needs for global environmental problems and the demands of passengers such as operational reliability and cost, electric power supply systems for railways have been steadily advanced by utilizing power electronics technology.
- Power supply systems have become increasingly sophisticated to cope with such requirements for environment and customer service.
- The super-speed magnetic levitation train is being introduced with a completely new type of power supply system.



## 2. Power Supply System for Urban Railways

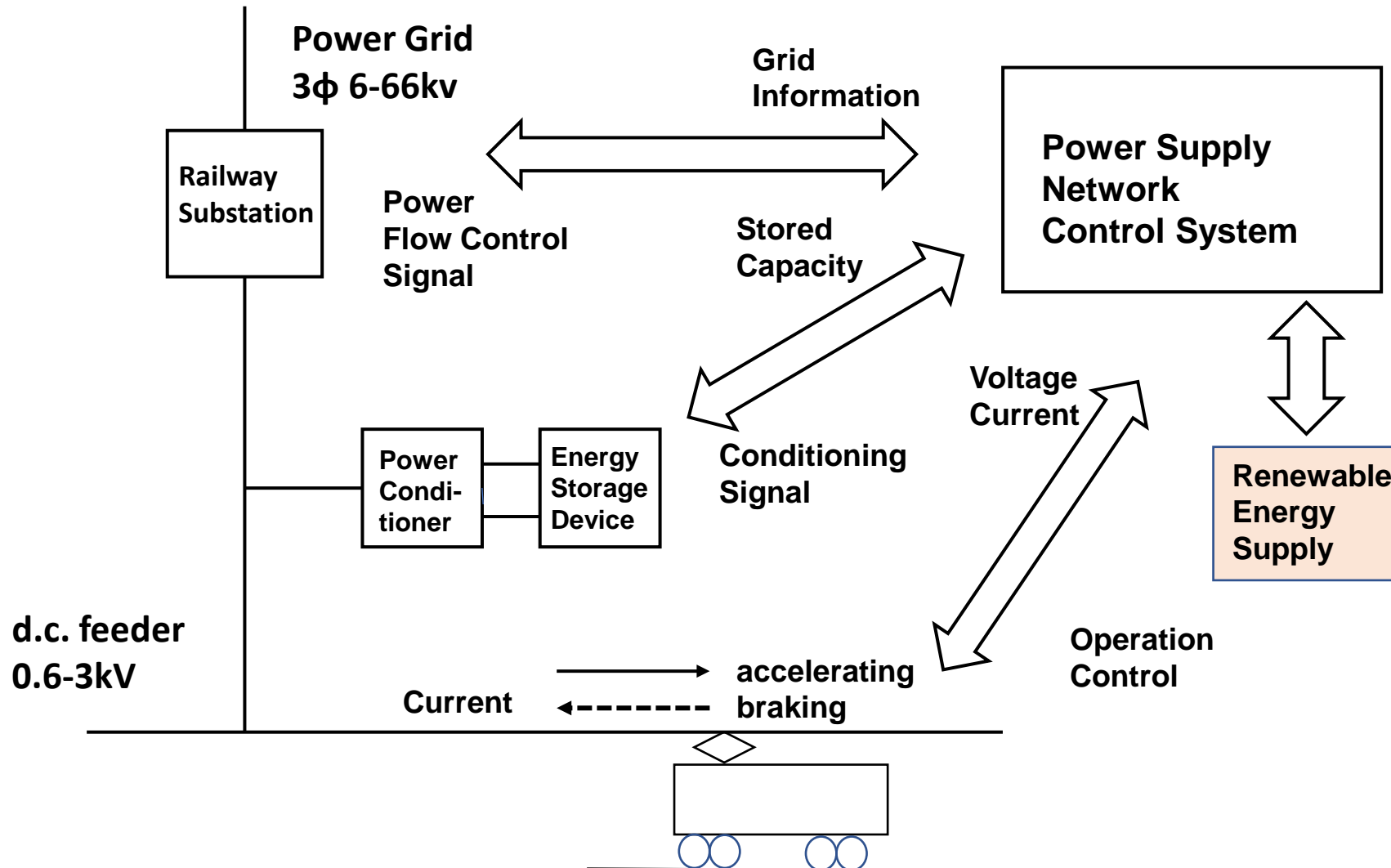
- In order to utilize the regenerative braking energy effectively without accelerating train nearby, the energy storage device is needed in the power supply system or return it to the grid.
- Since all substations are connected to each other by d.c. feeders, the entire power supply system can be operated like a microgrid for the total energy efficiency of the system and the stable train operation.
- The wayside renewable energy supply could be incorporated into this grid system.



TABLE [1]  
[[Current application of Fixed Energy Storage System in Japan (2019)]]

Railway company	Kind of energy unit	Built age	Number
Keihin kyuko	Flywheel	1987	1
JR West	Lithium ion battery	2006, 2018	2
Kobe city	Lithium ion battery	2007	1
Kagoshima city	Lithium ion battery	2007	2
Seibu	Supercapacitor	2007, 2016	3
Osaka metro	Nickel-metal hydride battery	2010-	7
	Lithium ion battery	2013	1
Tobu	Lithium ion battery	2012, 2015	2
Tokyo metro	Lithium ion battery	2016	4
Keio	Lithium ion battery	2015	1
Tokyo monorail	Nickel-metal hydride battery	2013, 2014	2
Sapporo city	Nickel-metal hydride battery	2015	2
	Lithium ion battery	2017	1
Yokohama city	Nickel-metal hydride battery	2015	1
JR East	Lithium ion battery	2013-	3
	Nickel-metal hydride battery	2018	1
Tama monorail	Lithium ion battery	2017	1
Odakyu	Lithium ion battery	2018	1
JR Kyushu	Lithium ion battery	2018	1
Nankai	Lithium ion battery	2018	1

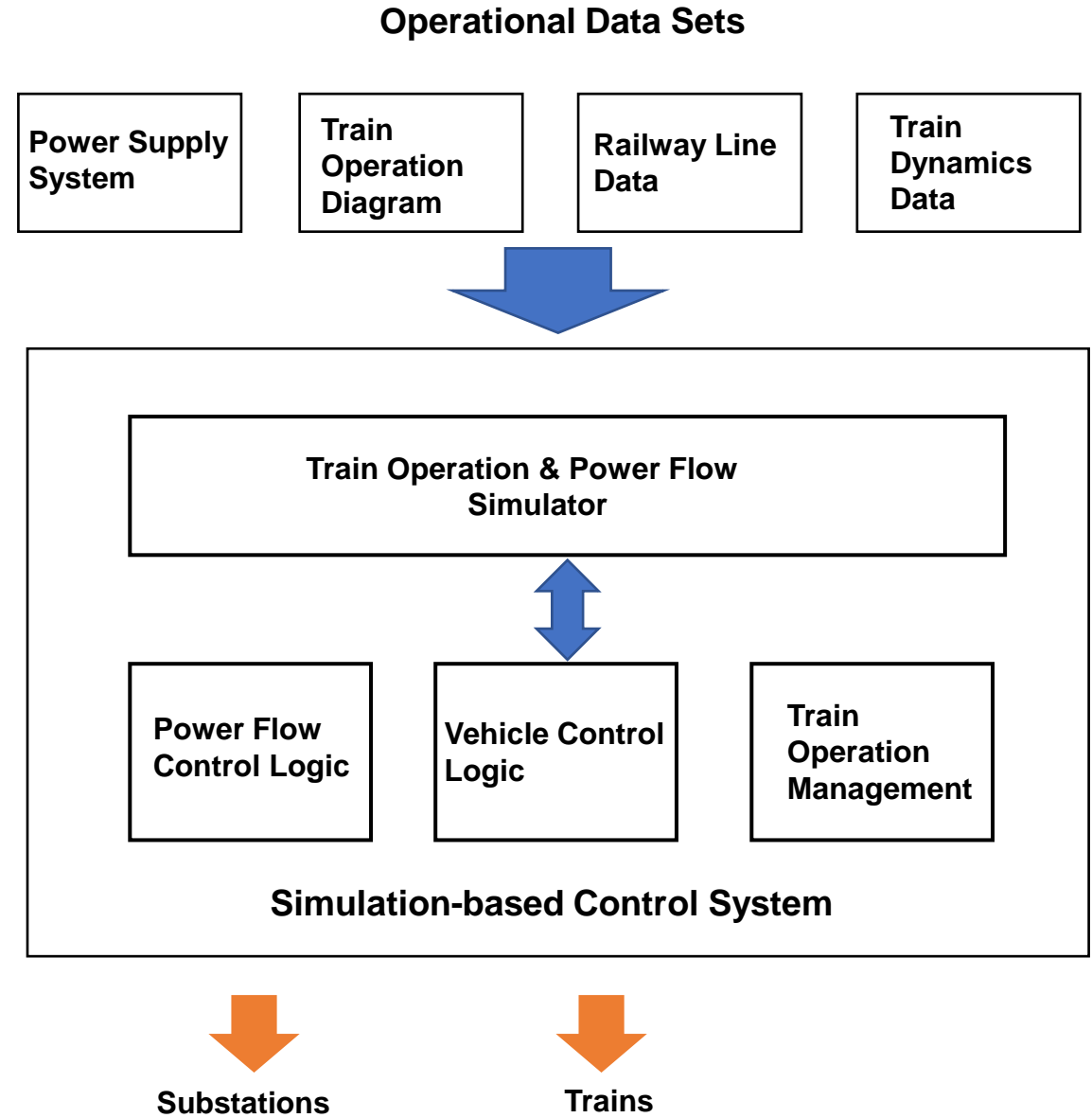




## Energy management system for Urban Railway Network

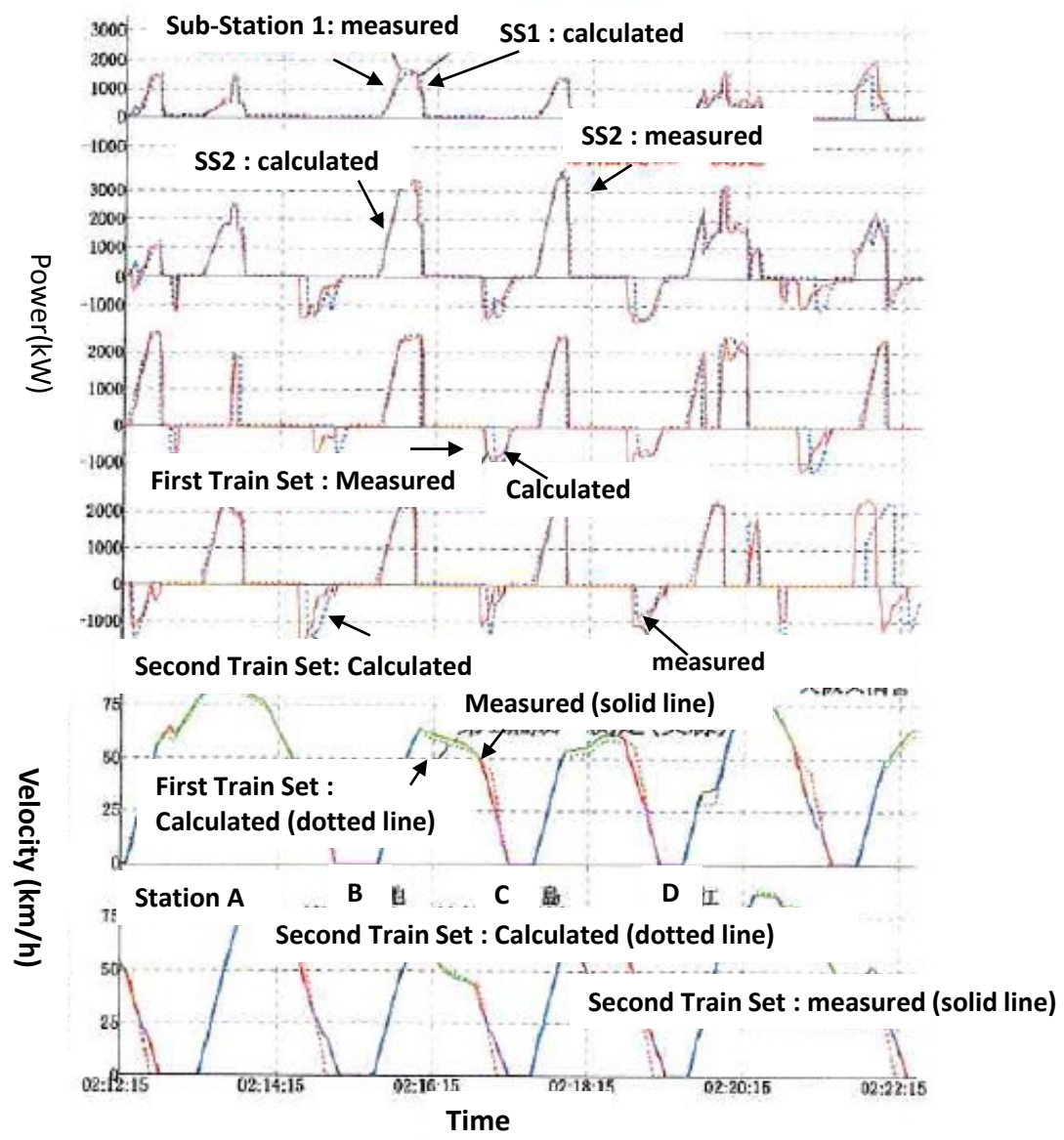


**Basic Scheme of Simulation-based Control System for Urban Network Energy Saving**





**Results of power flow simulation fits well with actual operation data.  
The simulation-based control system for an urban network is under development.**



### 3. Power Supply System for High Speed Railways

- High-speed railway networks are steadily expanding as a means of transportation that supports the active mobility demanded by modern society.
- Since the voltage phase of supplied power from substations varies from point to point, feeders are divided into sections by region.
- Railway operators have introduced power conditioning functions at substations for power costs, carbon reduction and security of power supply to trains.

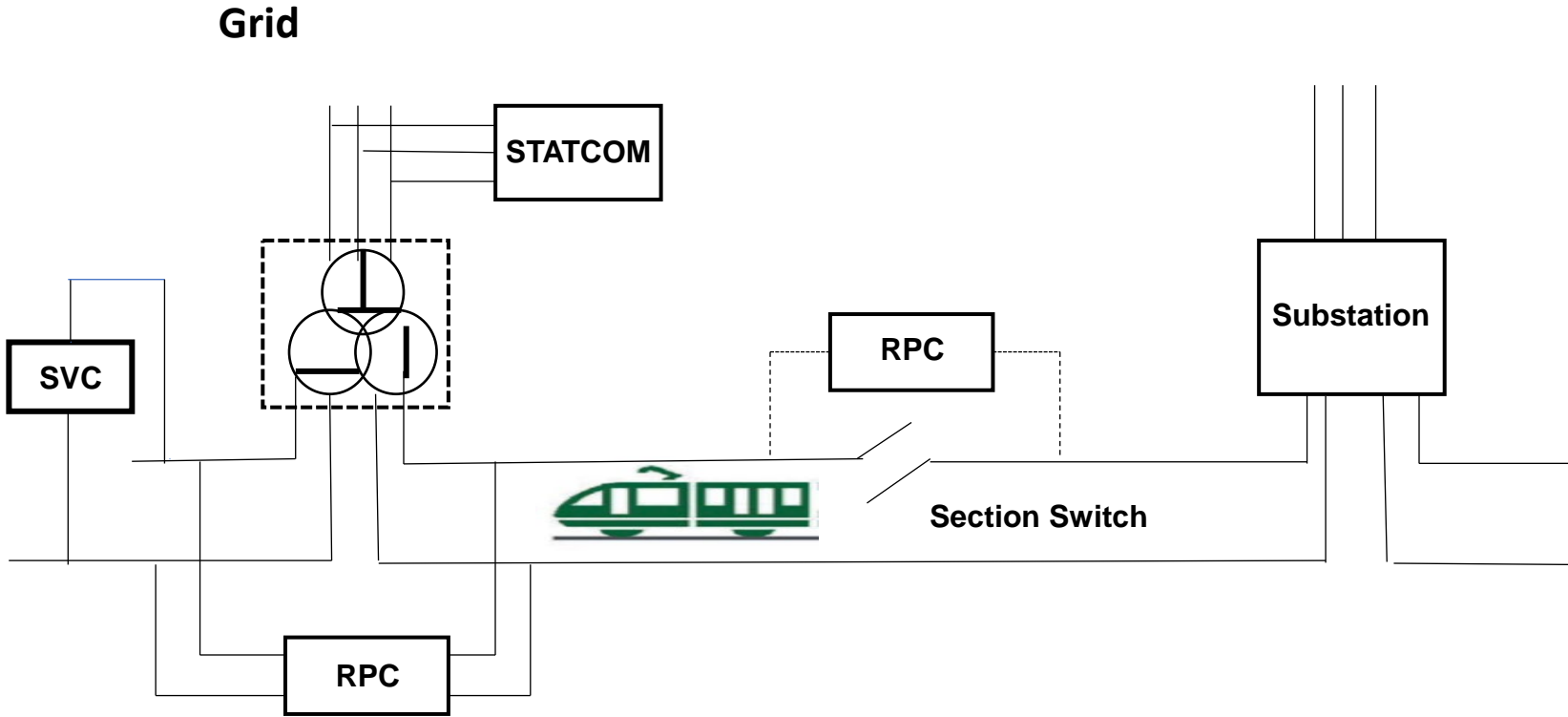


# Power Conditioning in Substation

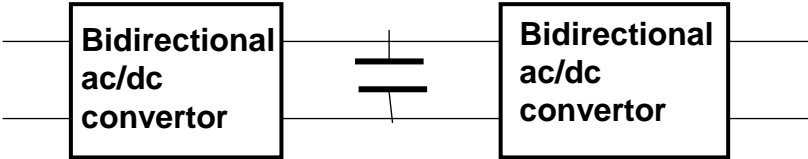
- Power conditioning devices are required for suppressing large power fluctuation to and sustaining power quality (unbalanced, harmonics) for the supplying power grid against high-speed train operations.
- The Railway static Power Conditioner(RPC) is utilized as the all-purpose conditioning equipment in Shinkansen, which also transfers power between different feeding sections to use regenerative braking effectively and to secure power supply against failures.



# Power Conditioning System for High Speed Rail



SVC : Static Var Compensator  
(Thyristor Controlled Reactor)

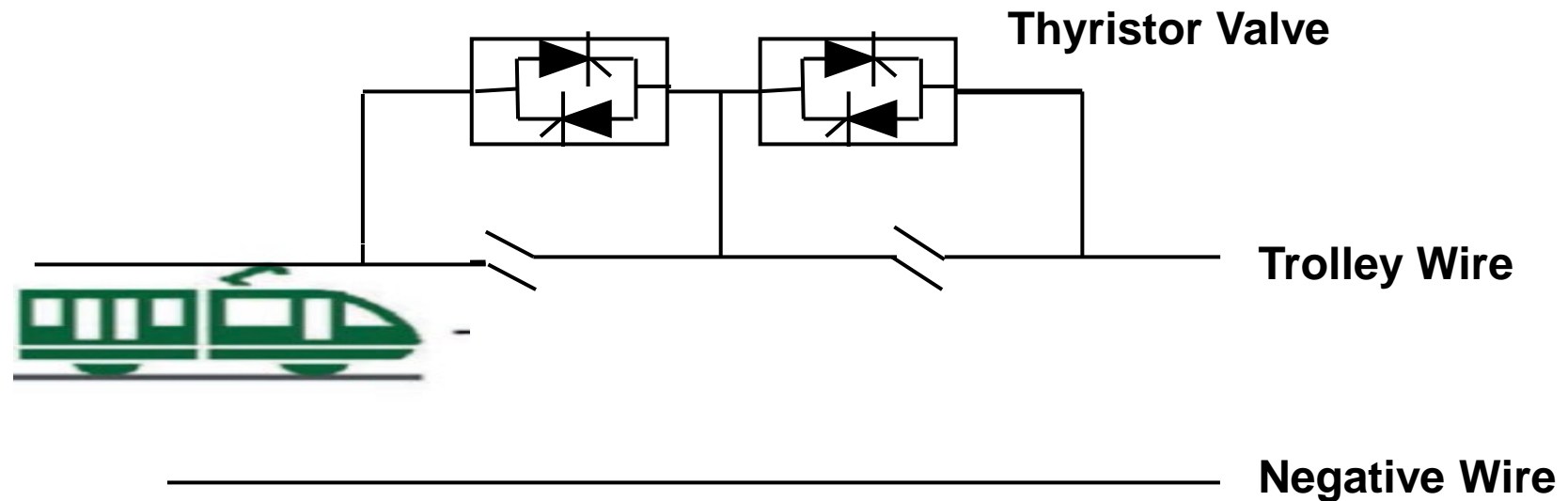


RPC  
Railway static Power Conditioner



# Static Section Transfer Switch

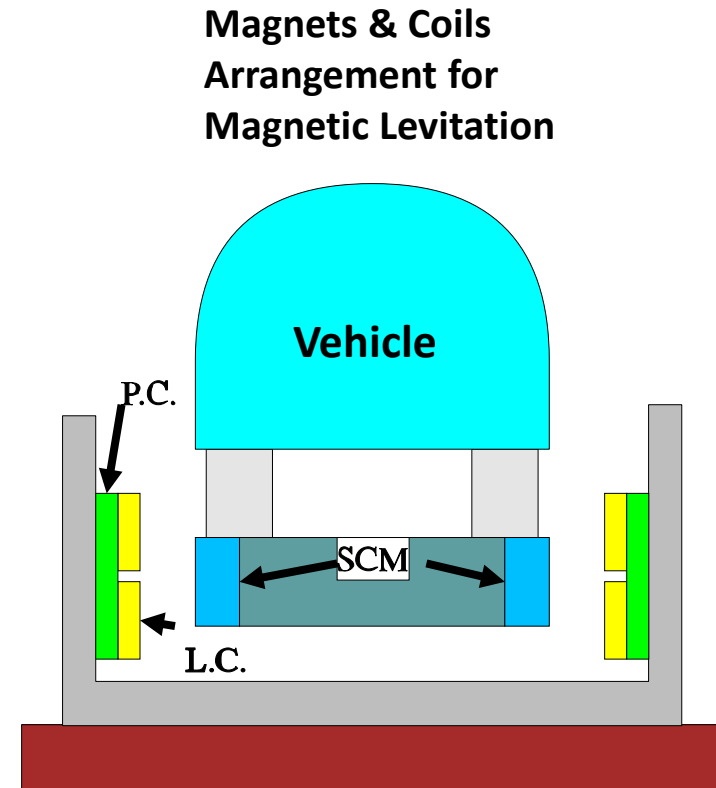
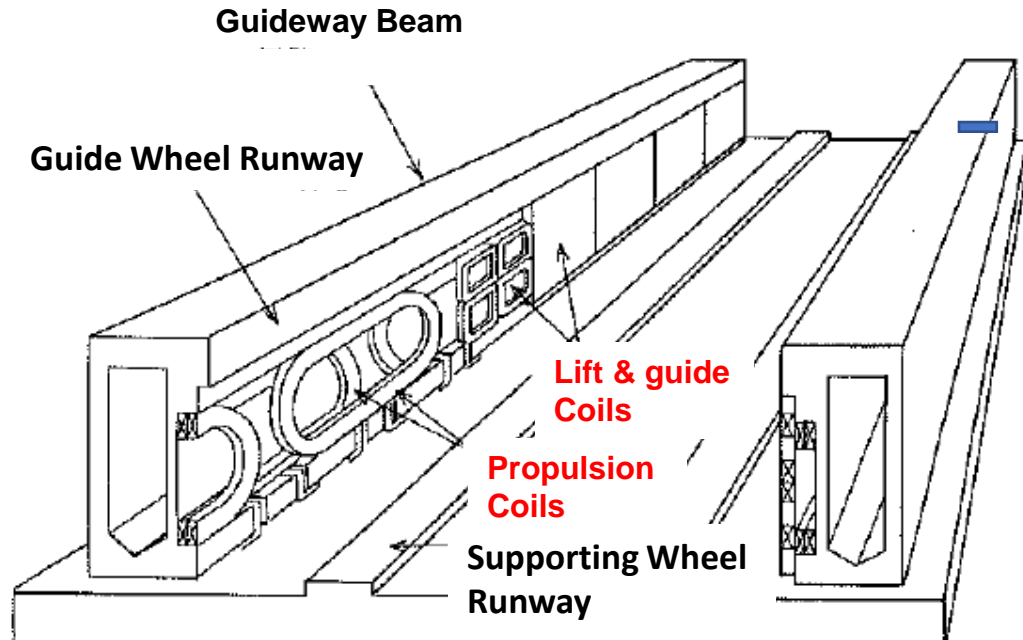
- **Medium Voltage High Current Semiconductor A.C.Switch**



## 4. Power Supply for Super Speed Maglev Train

- The driving force of the super-speed Maglev train is all supplied from the coils of the track-side on ground, and the vehicle has only magnets for levitation.
- The power supply to Maglev trains is a variable voltage and variable frequency 3 phase a.c. system which supplies the current synchronized with the train running.
- Wireless power supply with electromagnetic induction is used for magnets and auxiliaries on board.





## Basic Constitution of Superconducting Maglev System

SCM: Superconducting Magnet  
 L.C.: Lift & Guide Coil  
 P.C.: Propulsion Coil

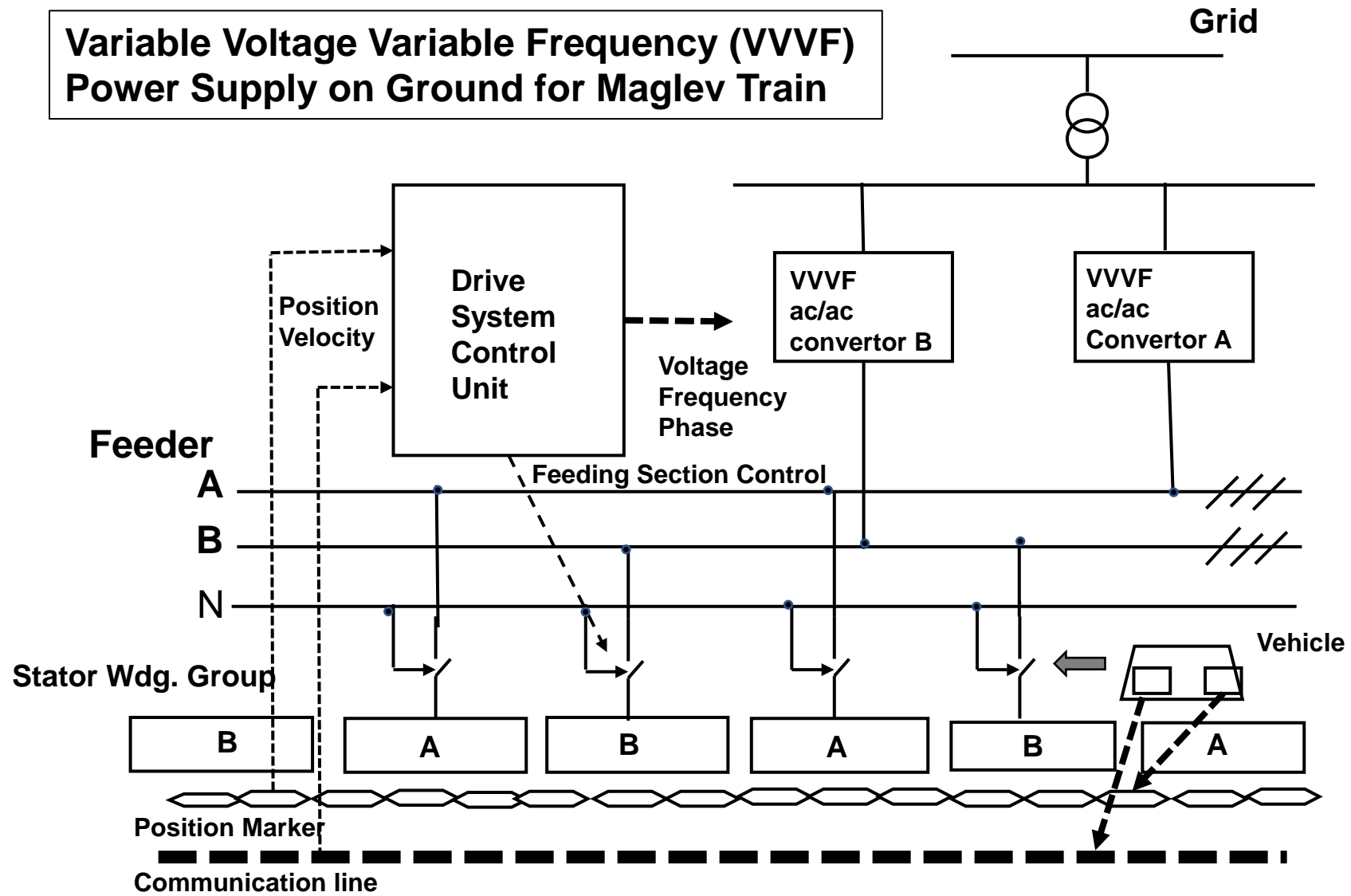


**Operation in Yamanashi  
Test Track**





**Variable Voltage Variable Frequency (VVVF)  
Power Supply on Ground for Maglev Train**



## Summary of Part 1

- **Even in electric railways, highly energy efficient and reliable power supply is strongly required for the mobility of modern society.**
- **The power supply to urban system would be modernized by the integrated control with battery storages, as well as renewable sources.**
- **High speed rail needs power conditioning to the supplying grid with high power electronics equipment.**
- **Super speed maglev is based on the innovative power supply system.**

