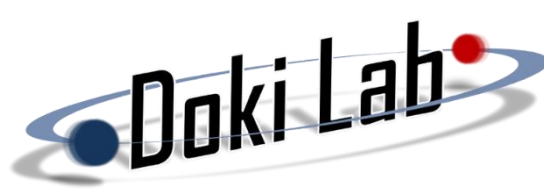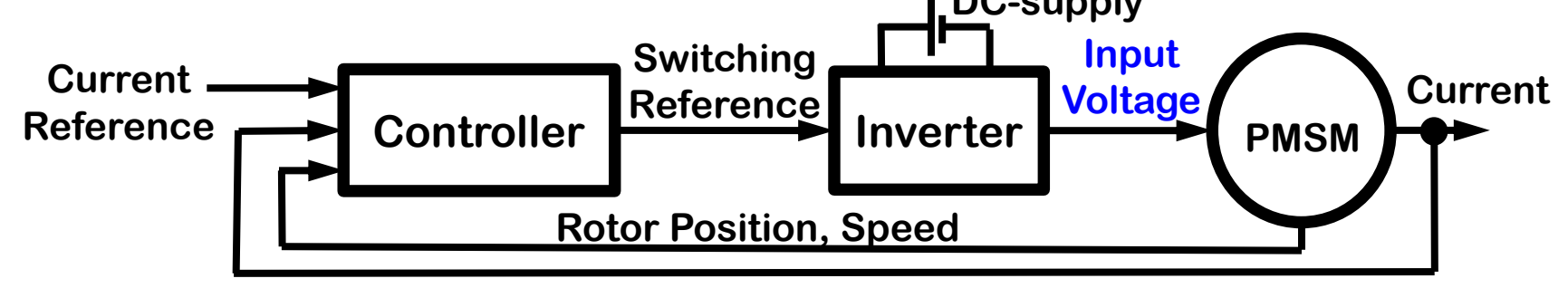# The Steady Current Characteristics of the Voltage Phase Resolution of Model Predictive Modulated Current Vector Control for PMSM

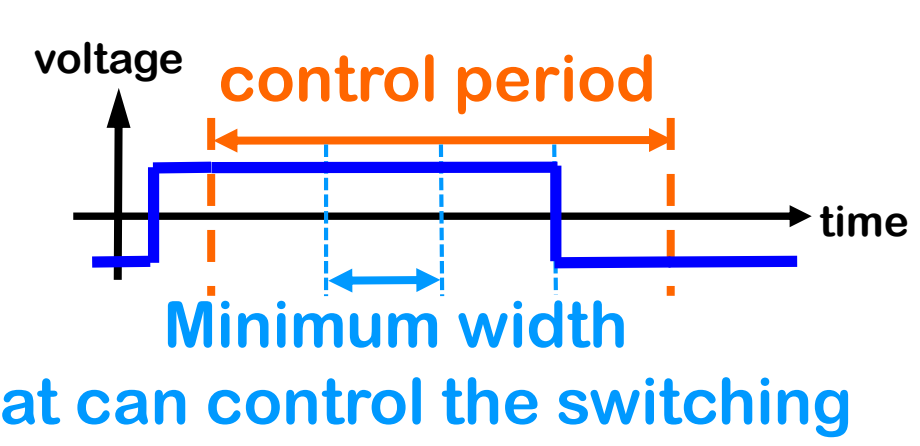Masahiro Shimaoka, Shinji Doki (Nagoya University, Japan)   E-mail : m-shimaoka@nagoya-u.jp, doki@nagoya-u.jp

Doki Lab

Introduction

Motor Drive System has been taken notice
the application of **MPC**(Model Predictive Control)

Current Reference → Controller → Switching Reference → Inverter → Input Voltage → PMSM → Current
DC-supply
Rotor Position, Speed

FCS-MPC decides **Input Voltage** directly
by **Prediction** and **Evaluation**

Key point of this research

Voltage phase resolution

Voltage phase resolution
Angle which rotate during control period

voltage / control period / time
Minimum width that can control the switching

The finer resolution can realize better control

Problem of Conventional FCS-MPC

Steady current control performance is inferior

Reason
- Conventional MPC can't manage voltage phase resolution
- Improvement of resolution is difficult by restriction

We have proposed new MPC based on FCS-MPC which can manage voltage phase resolution

Issue of propose MPC

Calculation amount disturb implementation

Reason
- Resolution of propose MPC has tradeoff relation

laugh ——————— Voltage Phase Resolution ——————→ fine
bad   Control Performance   good
a little   Calculation amount   huge

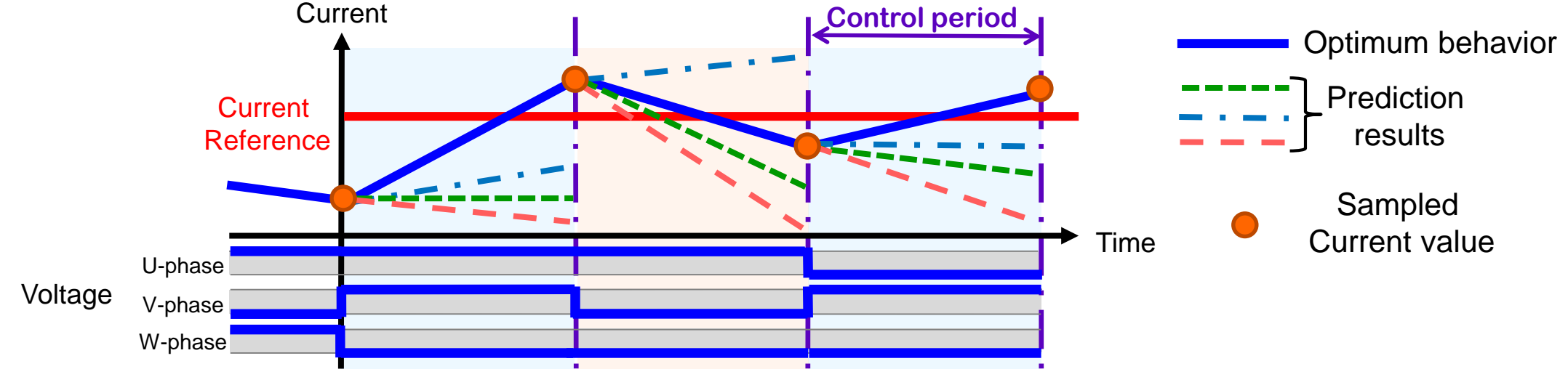**Unlimited shortening of resolution is difficult**

To avoid increasing calculation cost, propose MPC needs to grasp **maximum voltage phase resolution**
which can realize same level performance compared with PI based current vector control with PWM(PI + PWM)

Purpose of research

Understanding the characteristics of MPC's voltage phase resolution

Conventional MPC (CMP-CVC)

CMP-CVC (Conventional Model Predictive Current Vector Control)

Current / Current Reference / Control period / Time
Optimum behavior
Prediction results
Sampled Current value
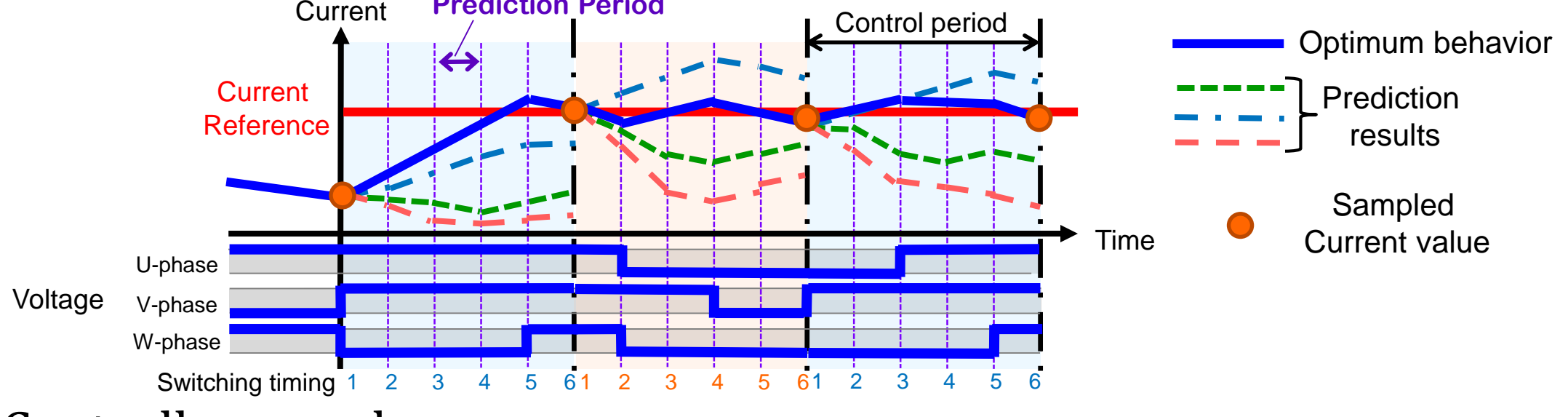Voltage / U-phase / V-phase / W-phase

Controller searches
optimum voltage vector
during control period

Control set   : Voltage vector
Minimum width   : **Control period**

FCS-MPCVC can't improve steady current control performance enough by restriction of equipment

Propose MPC (MPM-CVC)

MPM-CVC (Model Predictive Modulated Current Vector Control)

Current / Prediction Period / Control period / Time
Current Reference
Optimum behavior
Prediction results
Sampled Current value
Voltage / U-phase / V-phase / W-phase
Switching timing 1 2 3 4 5 6 1 2 3 4 5 6 1 2 3 4 5 6

Controller searches
optimum voltage vector and its switching timing
during control period

Control set   : Time series of voltage vector
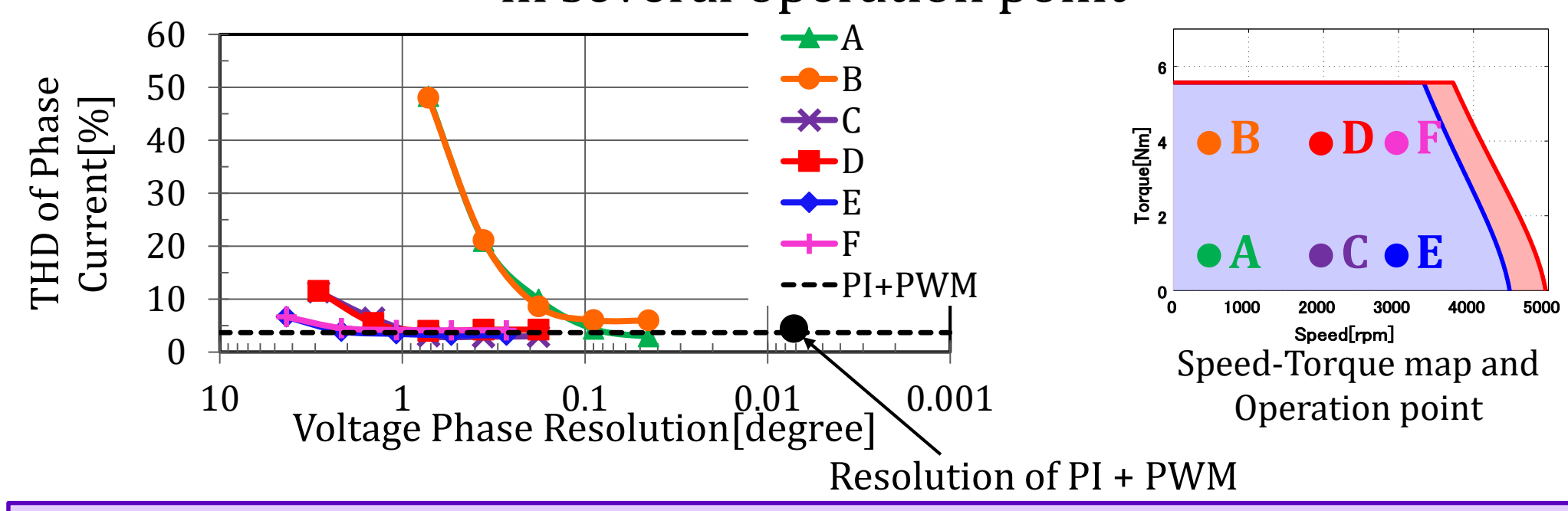Minimum width   : **Prediction period**

MPM-CVC can improve steady current control performance without rising switching frequency

Comparison of each MPC

	Switching frequency	Voltage phase resolution	Control performance
CMP-CVC	Control period	Control period	**Difficult to improve**
MPM-CVC	Control period	Prediction period	**Possible to improve**

Characteristics of Voltage Phase Resolution

Relationships of voltage phase resolution and THD of phase current in several operation point

THD of Phase Current[%] vs Voltage Phase Resolution[degree]
A, B, C, D, E, F, PI+PWM
Resolution of PI + PWM

Speed-Torque map and Operation point
Torque[Nm] vs Speed[rpm]
B, D, F, A, C, E

We confirmed necessary maximum resolution for motor speed

Voltage phase resolution [degree] vs Speed[rpm]

Voltage phase resolution correlates with speed

- In torque change (A-B, C-D, E-F),
  THD is **same value** at identical resolution

- In speed change (A-C-E, B-D-F),
  THD is **difference value** at identical resolution

- MPM-CVC doesn't require voltage phase resolution as fine as PI + PWM

- Resolution doesn't need shortening over necessary value
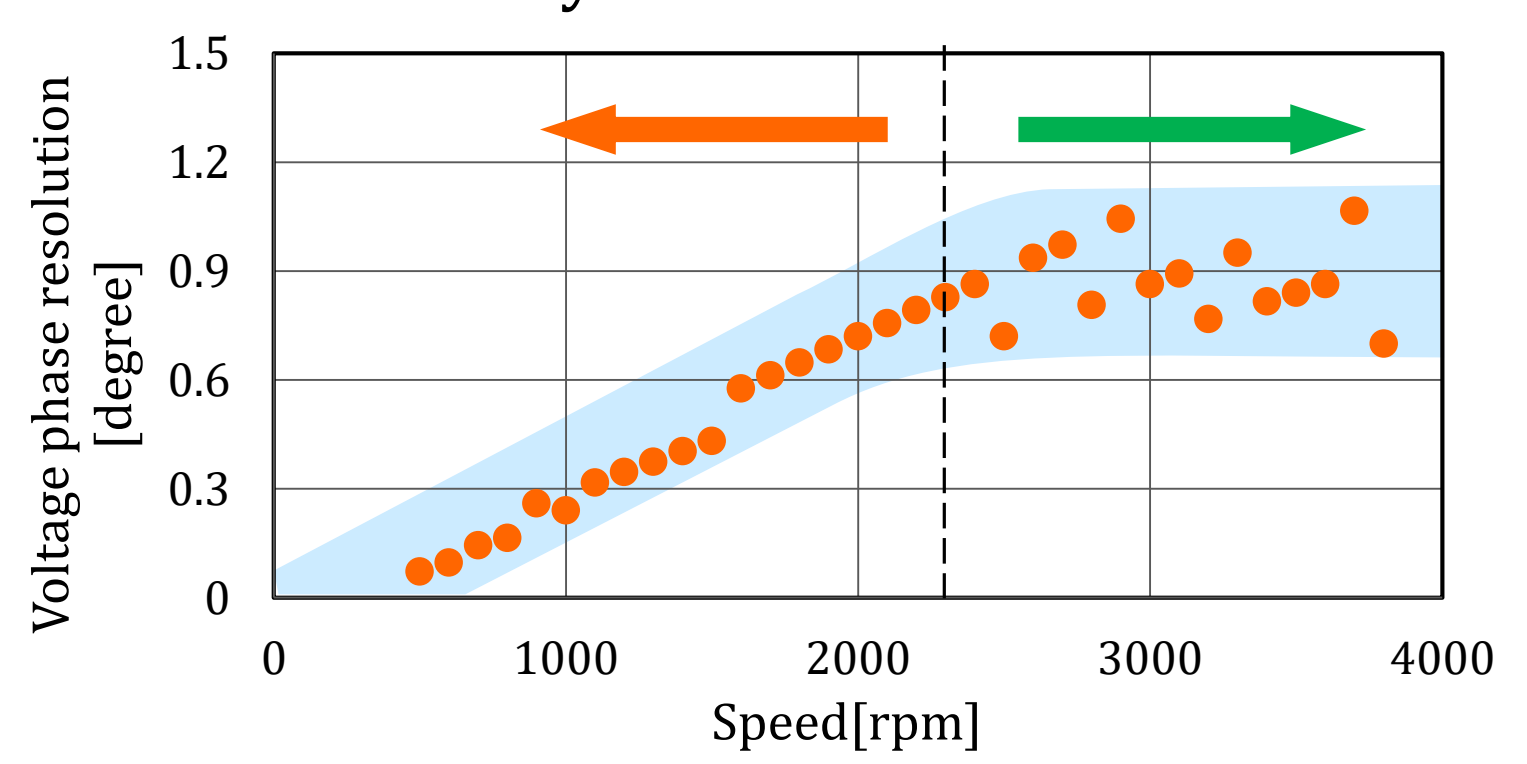
Relationship of speed and resolution is difference at low speed and high speed region

	Low speed region	High speed region
Distribution	**linear distribution**	**roughly same angle**
What to manage	Amplitude of input voltage	Switching timing in suitable phase