Improved MRAS-based Speed Sensorless Control of PMSM Considering Inverter Nonlinearity

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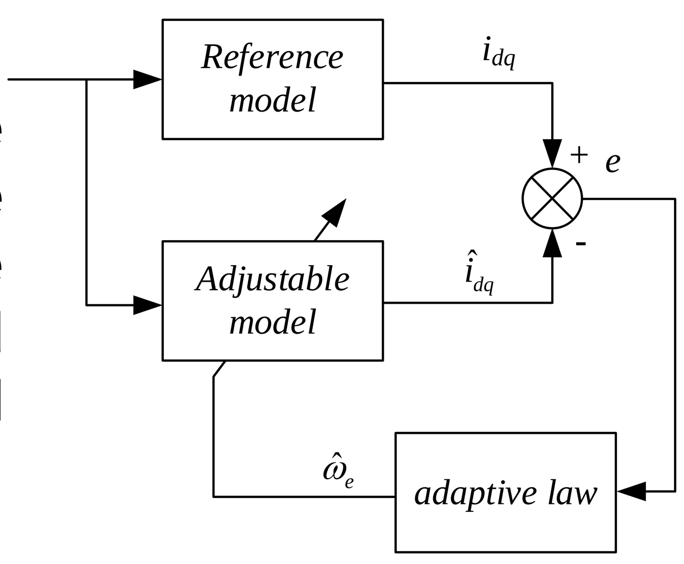
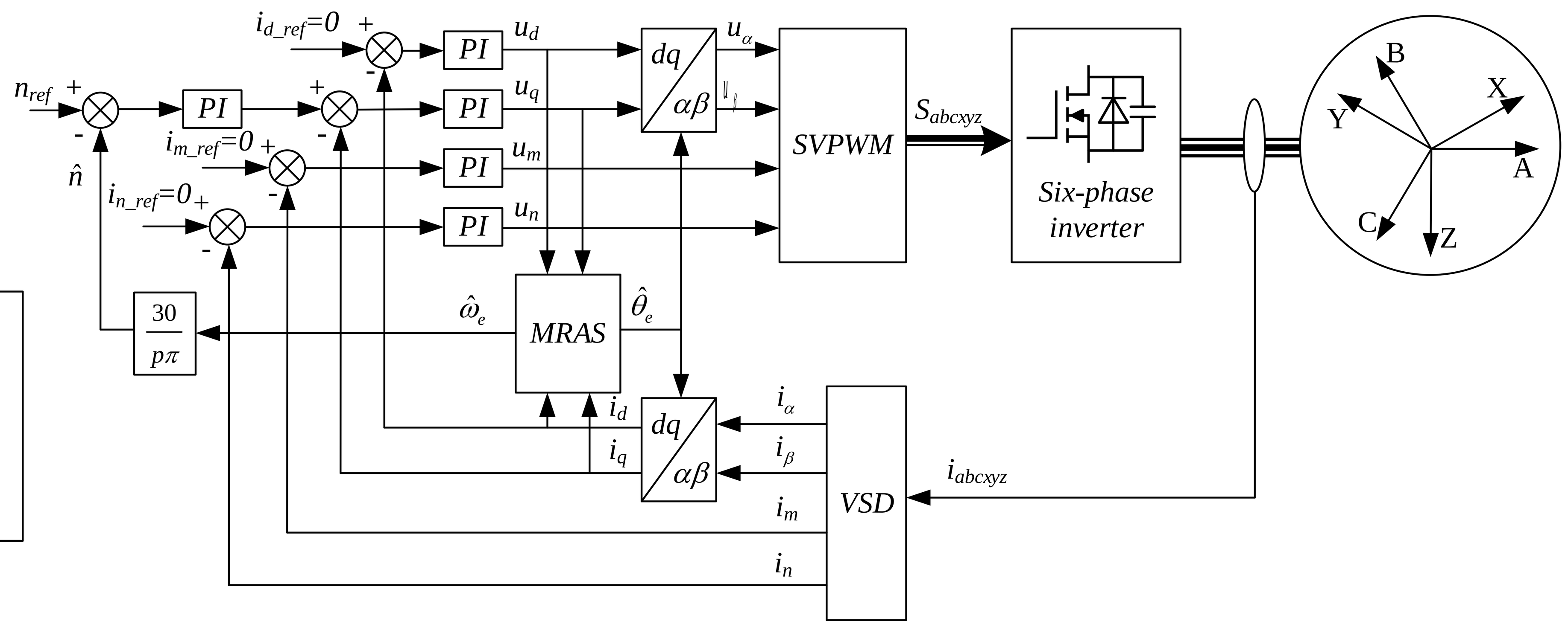
Background and Motivation

- Model Reference Adaptive System (MRAS) is a common method for speed sensorless control. The nonlinear error of the inverter introduces distortion of the motor stator voltage, thereby reducing the estimation performance.
- Generally, themotor terminal voltage is replaced by the reference voltage of the inverter. Therefore, the voltage and current cannot be sampled simultaneously, and the current signal will have hysteresis.



The method of MRAS

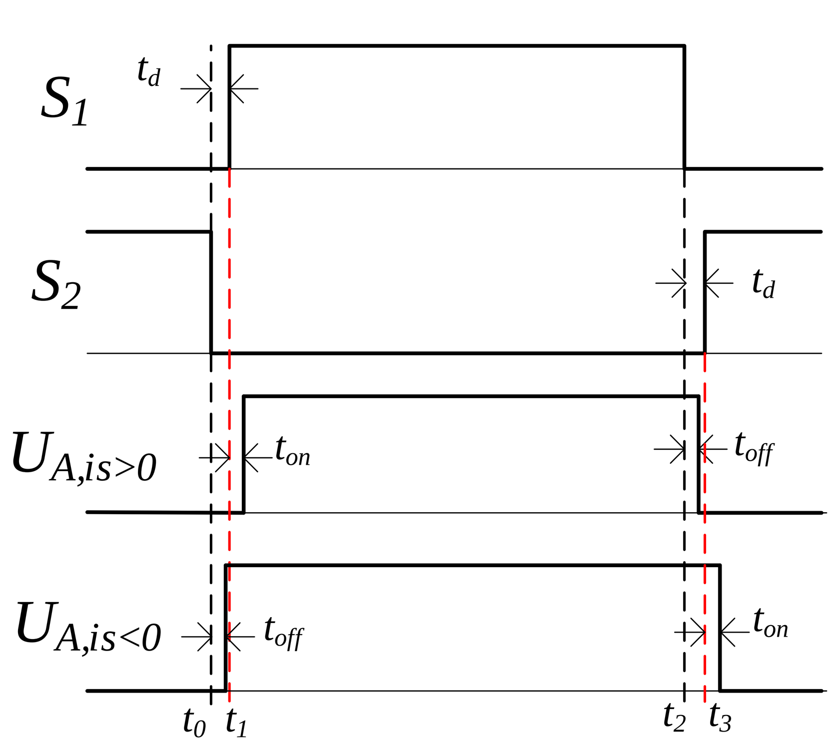
MRAS consists of three main components: reference model, adjustable model, and adaptive law.



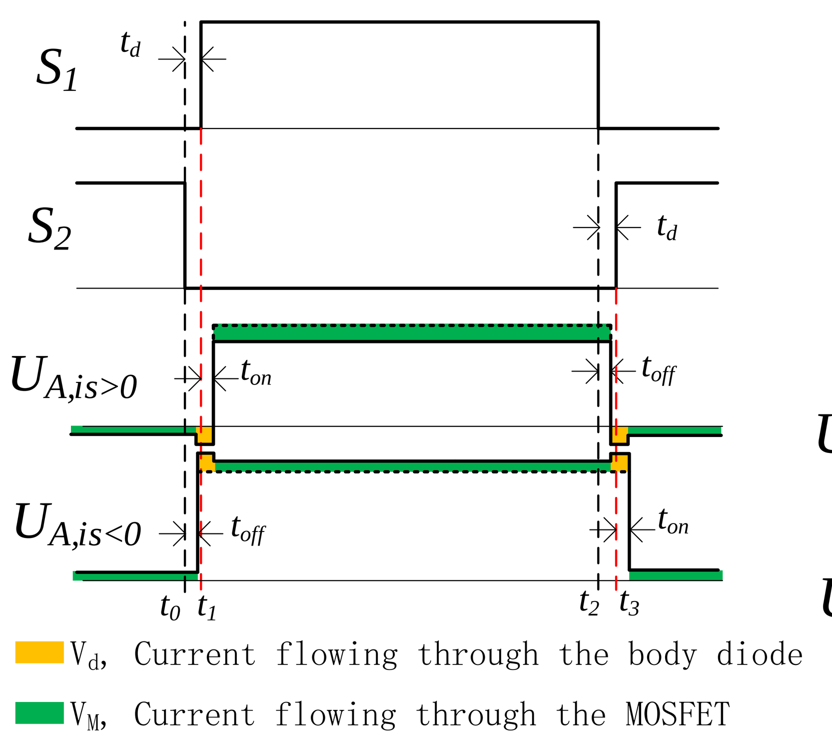
$$\hat{\omega}_e = (k_p + \frac{k_i}{s})[i_d\hat{i}_q\frac{L_q}{L_d} - \hat{i}_d i_q\frac{L_d}{L_q} - \frac{\psi_f}{L_q}(i_q - \hat{i}_q) + (\frac{L_d}{L_q} - \frac{L_q}{L_d})\hat{i}_d\hat{i}_q] \qquad \hat{\theta}_e = \int \hat{\omega}_e dt + \theta_e(0)$$

Analysis of Inverter Nonlinearity Voltage Error

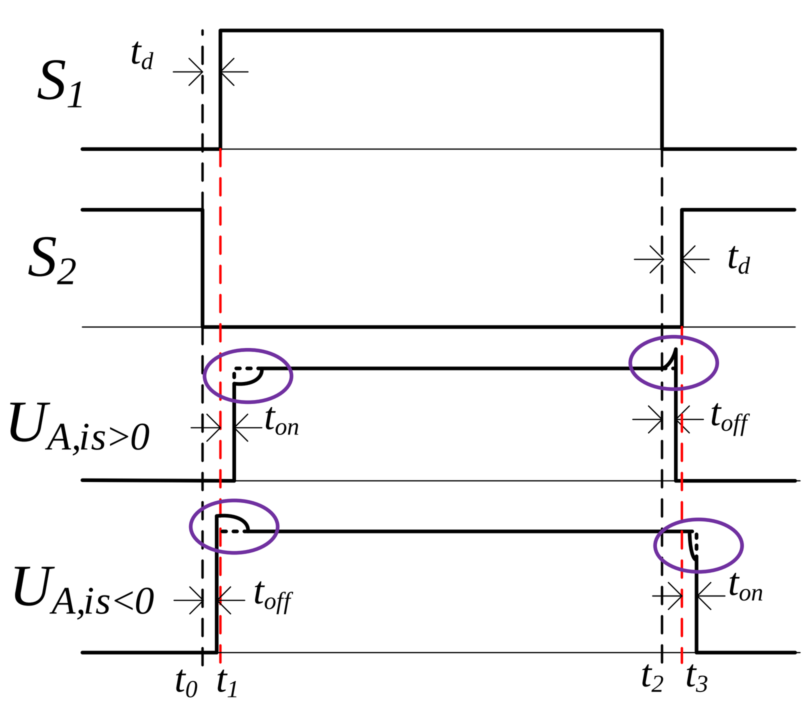
- The impact of the switching process

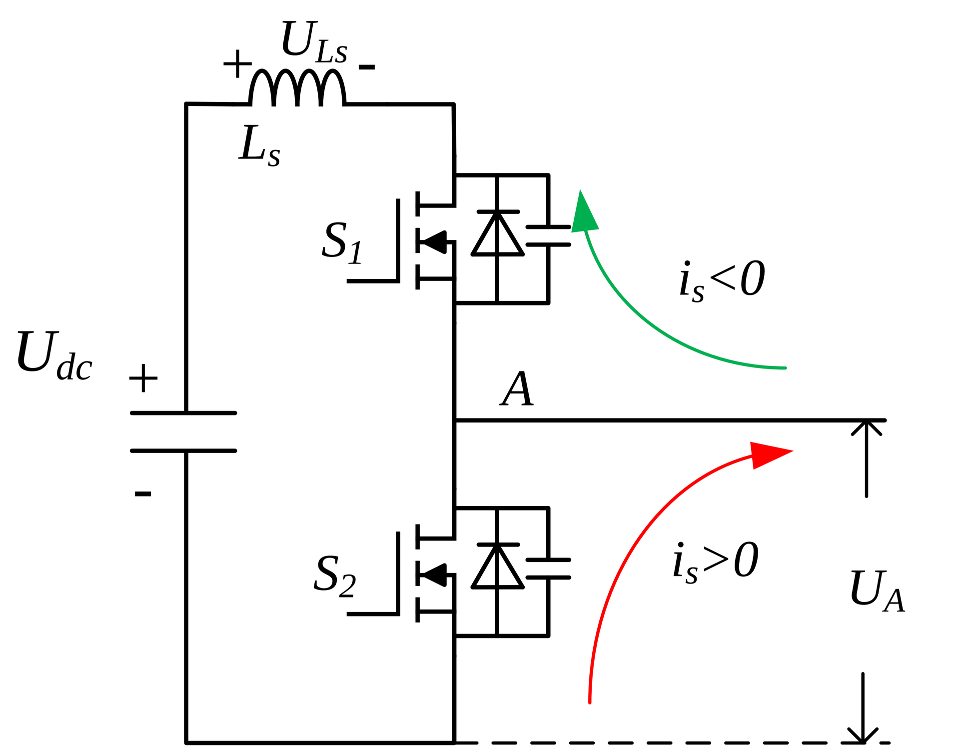


- The voltage drop of MOSFET and body diode



- The voltage drop of Stray inductance



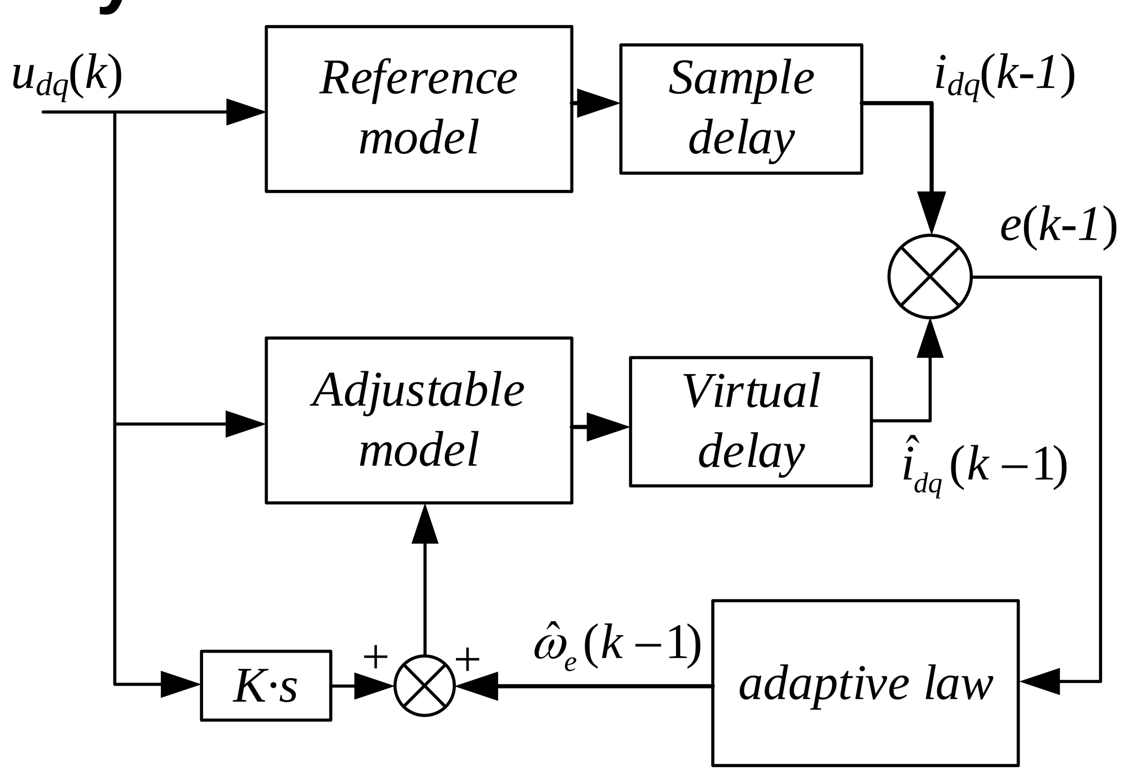


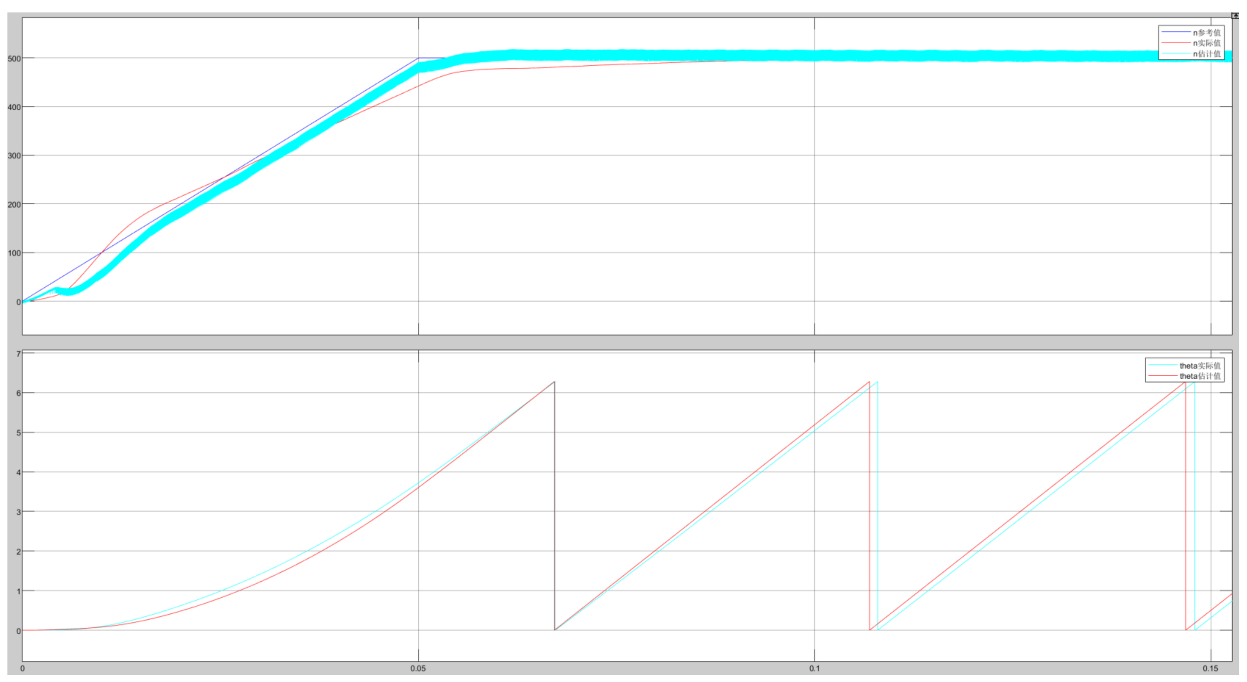
$$U_{A\_real} = U_{A\_ref} + \frac{t_{error}}{T_s}U_{dc} + sign(i_s)\frac{1}{T_s}\int_{I_1+I_2} U_{Ls}\cdot dt - sign(i_s)(V_M + \frac{2(t_d + t_{on} - t_{off})}{T_s}(V_d - V_M))$$

Compensation of Sampling delay

In the speed sensorless algorithm, the voltage signal is the reference voltage, while the current signal is the actual collected signal. Therefore, there is a delay of one sampling period in the current signal.

$$\omega = \Lambda(u_{dq,k}, i_{dq,k-1})$$

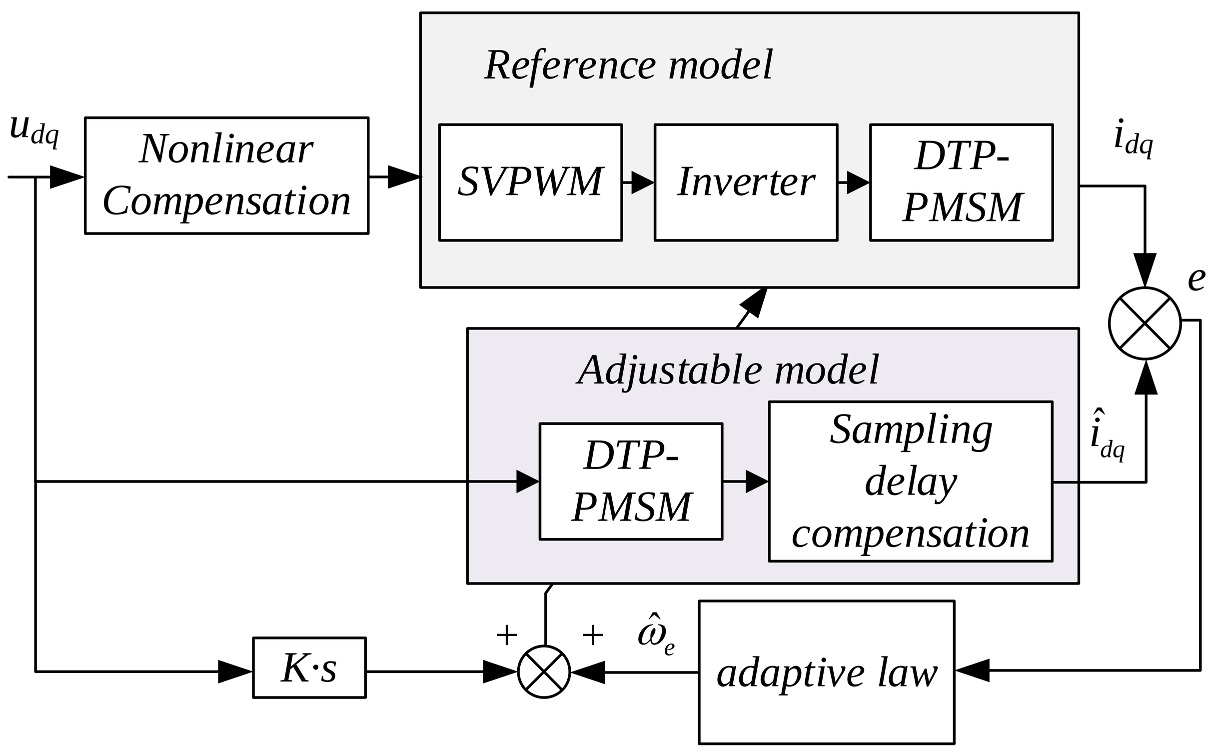


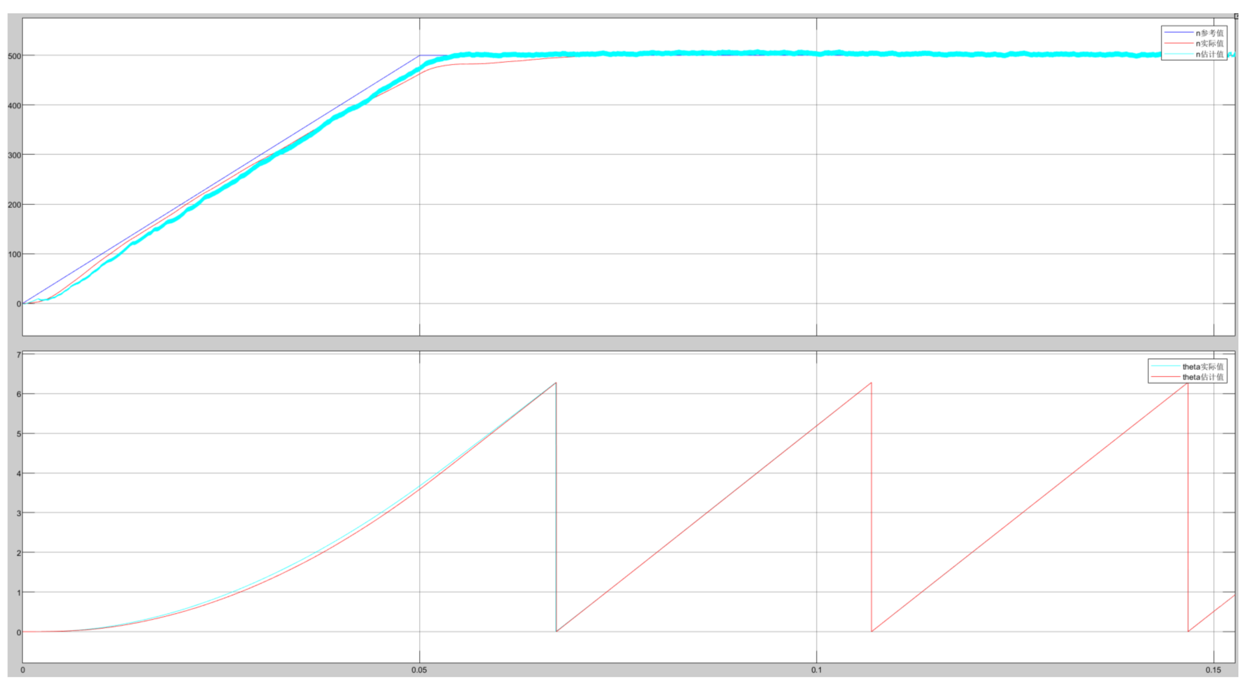


(a)Traditional MRAS

MRAS Model considering Inverter Nonlinearity

Two compensations were added to the model. The nonlinear compensation is used to compensate the voltage deviation due to inverter nonlinearity. The sampling delay compensation is used to compensate for current differences due to sampling time.





(b)Improved MRAS