# Numerical Verification of Initial Rotor Position Detection Scheme Proposed based on Analytical Machine Model

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**Abstract — In this paper, numerical verification of an proposed initial rotor position detection method for PMSM is carried out based on finite element method (FEM). The detection method is proposed based on an analytical nonlinear PMSM model. The FEM calculated results will be compared with the simulated and experimental results to verify the scheme and implementation.**

## I. INTRODUCTION

Initial rotor position detection (IRPD) is a typical problem for PMSMs. Some of the reported IRPD methods could achieve good estimation result by applying some extra low frequency excitation to the stator windings [1][2]. However, flexible coupling on the shaft is sometimes required and the rotor oscillation cannot be avoided. Therefore, some short pulses or high frequency signal injection methods were proposed, by which the rotor could be easily kept at standstill. These signal injection methods are then classified as high frequency signal injection [3] and pulse signal injection methods [4].

In this paper, a DC voltage pulse injection based IRPD method is proposed based analytical nonlinear model of the machine [5]. Simulation, numerical calculation and experiments are conducted to verify the method.

## II. ROTOR POSITION DETECTION METHOD

The nonlinear analytical model for PMSM develop in [5] incorporates both the structural and saturation saliencies of the machine, which enables not only the rotor axis position detection but also the polarity identification. The model in rotating reference frame can be expressed as

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = R\begin{bmatrix} i_d \\ i_q \end{bmatrix} + \begin{bmatrix} L_{dd} & L_{dq} \\ L_{qd} & L_{qq} \end{bmatrix} \frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} \quad (1)$$

where $\begin{bmatrix} L_{dd} & L_{dq} \\ L_{qd} & L_{qq} \end{bmatrix} = \begin{bmatrix} L_d(1-K_{sat}\cos^2\zeta) & -\frac{1}{2}L_q K_{sat}\sin 2\zeta \\ -\frac{1}{2}L_d K_{sat}\sin 2\zeta & L_q(1-K_{sat}\sin^2\zeta) \end{bmatrix}$

The injected DC voltage pulse can be written as

$$\begin{cases} v_d = V_{in}\cos\delta \\ v_q = V_{in}\sin\delta \end{cases} \quad (2)$$

where $\delta$ is the angle between the rotor $d$-axis and the injected voltage vector.

The maximum rotor vibration angle can be derived as shown in (3), without friction and torque applied on the shaft. The IRPD procedure is shown in Fig. 1.

$$\Delta\theta_m = \pm\frac{P}{2}\lambda_m \frac{V_{in}}{J\cdot R}[\frac{1}{2}\Delta t^2 - \frac{L_q(1-K_{sat})}{R}\Delta t + \left(\frac{L_q(1-K_{sat})}{R}\right)^2\left(1-e^{-\frac{R}{L_{qq}}\Delta t}\right)] \quad (3)$$

where $V_{in}$ and $\Delta t$ represent the injected pulse magnitude and width.

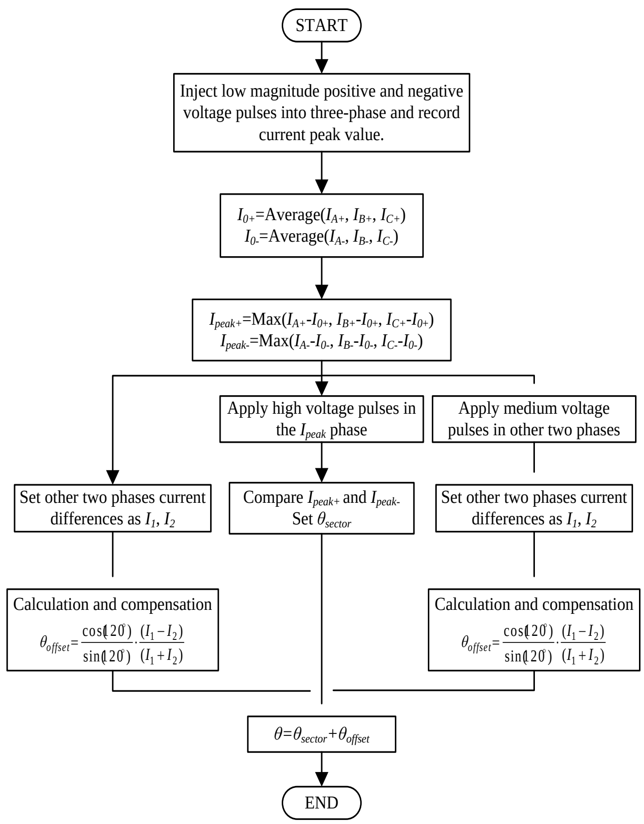

Fig. 1. Estimation principle of proposed IRPD method

## III. SIMULATION RESULTS

Firstly, the simulation model developed in [5] is utilized to verify the proposed method. Fig. 2 shows the rotor vibration under different voltage pulse excitation and Fig. 3 shows the three peak phase current response under positive and negative pulse injection. Fig. 4 shows the simulated estimation performance at different rotor positions.

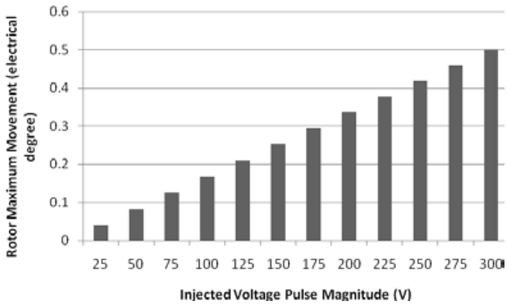


Fig. 2. Maximum rotor movement under different pulse magnitudes

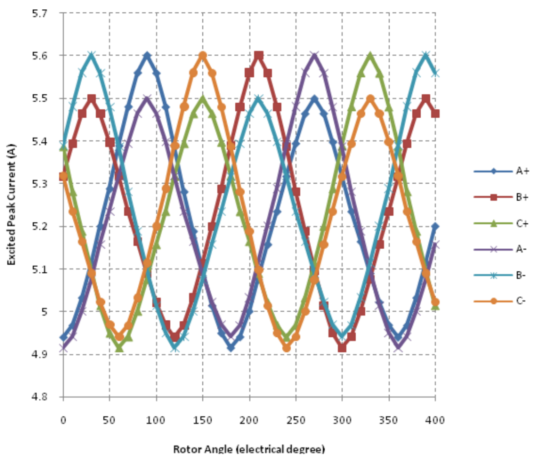


Fig. 3. Three phase peak current values with high positive and negative pulse injected

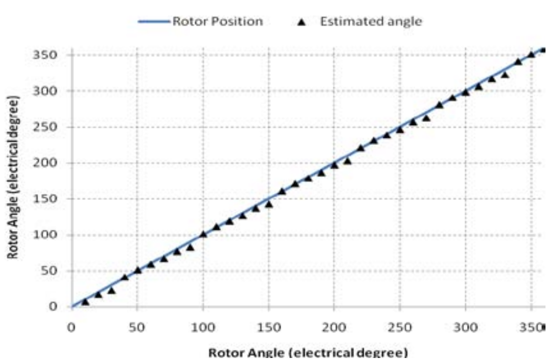


Fig. 4. Estimated initial rotor position

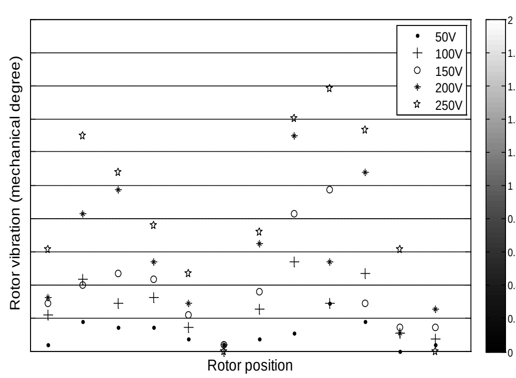


Fig. 5. Rotor maximum vibration angles with different voltage levels at different initial positions

## IV. Experimental Results

Experiments are then provided on an SPMSM test platform. The positive and negative pulses are injected the three phases and the rotor vibration is then recorded as in Fig. 5.

## V. FEM Based Verification

To verify the proposed method, the 2-dimensional FEM is applied to numerically calculate the magnetic field of the machine. Fig. 6 shows the magnetic field distribution, where the DC voltage pulse is injected in stator phase *a*.

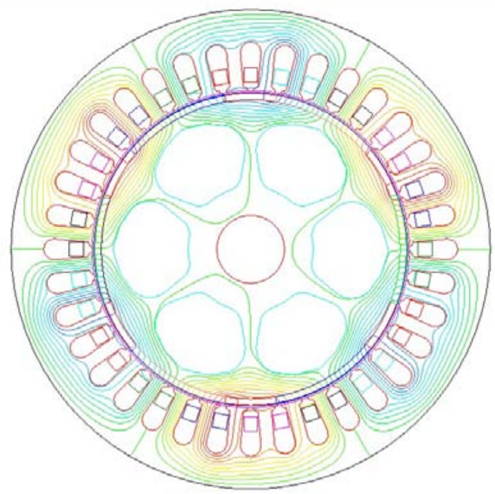

Fig. 6. Magnetic field distribution when voltage pulse is added in phase *a*.

More details about the proposed method, experimental implementation, tested results, FEM algorithm and the comparison results of rotor vibration and position estimation will be presented in the full paper. A list of full references will also be provided.

## VI. References


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