

# **PMSM SENSORLESS CONTROL**

Done By

KEERTHANA M G (99007891)

DANESH PATTED (99007458)

GURUKIRAN (99007901)

## INDEX

S NO.	Content	Page No.
1	Abstract	3
2	Requirements	3
2.1	Three phase inverter modelling	3
2.2	Transmission from a,b,c to d-q axis	3
2.3	Calculation of speed, theta, current parameters by modelling	4
3	5W's & 1H	6
4	Swot Analysis	7
5	Equations	8
5.1	Three phase inverter modelling	8
5.2	Clark and park transformation	9
5.3	Motor modelling	10
6	Flow chart	11
7	Output	11
7.1	VSI Output	11
7.2	Id-Iq Output	11
7.3	Speed Output	12
7.4	Rotor Position Output	12

## **1. ABSTRACT:**

The aim of this project is to find the rotor position speed and torque without the use of sensors. Initially taking optimum parameters into consideration and feeding these values in the inverter model that we have designed we obtain the line voltages. With the Clark and Park transformation we transform these values in d-q reference frame. Further rearranging the terms, we solve for currents flowing through the motor i.e.,  $i_d$  and  $i_q$  currents.

## **2. REQUIREMENTS:**

### **2.1 THREE PHASE INVERTER MODELLING**

#### High Level Requirements

ID	Description
HLR_1	To convert direct dc voltage to three phase ac voltage.
HLR_2	To come up with the Simulink Model and thereby verify the result.

#### Low Level Requirements

ID	Description
LLR_1.1	To come up with the required circuit diagram.
LLR_1.2	To analyse the circuit and writeup the required equations.
LLR_2.1	Various Simulink blocks are to be used and thereby modelling is done according to the question.

## 2.2 TRANSMISSION FROM A,B,C (STATIONARY) TO D-Q (ROTATIONAL) AXIS

### High Level Requirements

ID	Description
HLR_1	To move from stationary axis to rotational axis
HLR_20	Come up with equations required to build the model and building the equations model in Simulink

### Low Level Requirements

ID	Description
LLR_1.1	To make use of Clark transform to move from abc axis to alpha and theta axis
LLR_1.2	To make use of park transform to move from alpha and theta axis to d-q axis
LLR_2.1	Making blocks use of basics blocks available to implement it
LLR_2.24	Analysing the output from the block

## 2.3 CALCULATION OF SPEED, THETA, CURRENT PARAMETERS BY MODELLING

### High Level Requirements

ID	Description
HLR_1	To come up with equivalent circuit equations of motor.
HLR_2	To model the motor using various equations obtained from circuit diagram.

## Low Level Requirements

ID	Description
LLR_1.1	To understand the equivalent circuit diagram using basic components.
LLR_1.2	To come up with equivalent circuit equations using electrical laws.
LLR_2.1	To find various parameters like speed, torque, current and thereby estimate the position of the rotor.
LLR_2.2	To model all these parameters in Simulink further verify the results.

### **3. 5W & 1H**

**WHERE:**

While designing the Permanent Synchronous Motor.

**WHY:**

To reduce the cost of position sensor.

**WHAT:**

To sensor the position of rotor without using the sensor.

**WHO:**

Circuit design engineer.

**WHEN:**

When there is a need to reduce the cost of sensor.

**HOW:**

By transforming a,b,c to dq axis and thereby finding the parameters.

## 4. SWOT ANALYSIS

### STRENGTHS

- Sensing rotor position and thereby controlling it
- Modelling based on equations

### WEAKNESSES

- Complicated circuit Equation
- Analysing the circuit is complicated

### OPPORTUNITIES

- Can reduce the cost of position sensor
- Can reduce the space consumed by the sensor

### THREATS

- One parameter determines other one
- Failure of one parameter might fail the other one

## 5. EQUATIONS

### 5.1 INVERTER

$$V_{ao} = V_{an} + V_{no}$$

$$V_{bo} = V_{bn} + V_{no}$$

$$V_{co} = V_{cn} + V_{no}$$

$$V_{an} = V_{dc}/3(2V_{ao} - V_{bo} - V_{co})$$

$$V_{bn} = V_{dc}/3(2V_{bo} - V_{co} - V_{ao})$$

$$V_{cn} = V_{dc}/3(2V_{co} - V_{ao} - V_{bo})$$

### 5.2 CLARK AND PARK TRANSFORMATION

$$\begin{pmatrix} V_q \\ V_d \\ V_0 \end{pmatrix} = \frac{2}{3} \begin{pmatrix} \cos\theta & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \sin\theta & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix} \begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix}$$

### 5.3 MOTOR MODELLING



$$V_{ds}^r = R_s i_{ds}^r + d \frac{\lambda_{rds}}{dt} - \lambda_{qs}^r \omega_r$$

$$V_{qs}^r = R_s i_{qs}^r + d \frac{\lambda_{rqs}}{dt} + \lambda_{ds}^r \omega_r$$

$$\lambda_{ds}^r = L_{ds} i_{ds}^r + \phi_f$$

$$\lambda_{qs}^r = L_{qs} i_{qs}^r$$

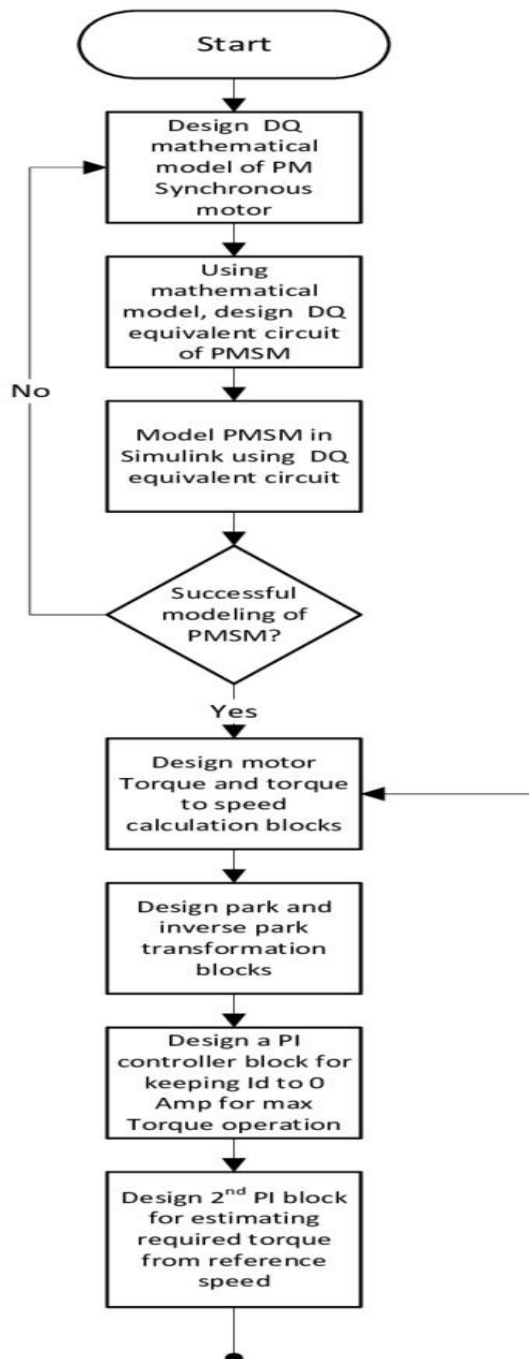
$$T_e = \frac{3}{2} \frac{P}{2} (i_{qs}^r \phi_f + (L_{ds} - L_{qs}) i_{ds}^r i_{qs}^r)$$

$$i_{ds}^r = 0$$

$$T_e = \frac{3}{2} \frac{P}{2} (i_{qs}^r \phi_f)$$

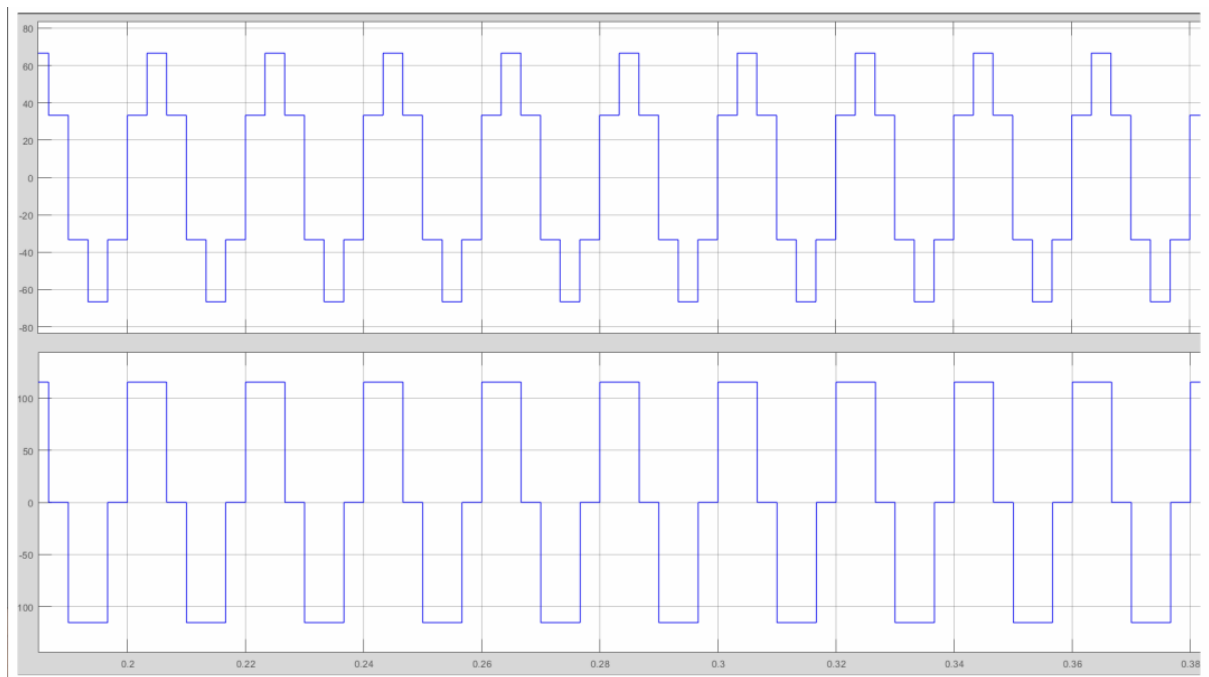
$$i_{qs}^r = \frac{T_e^*}{\frac{3P}{2} \phi_f}$$

## 6. FLOW CHART

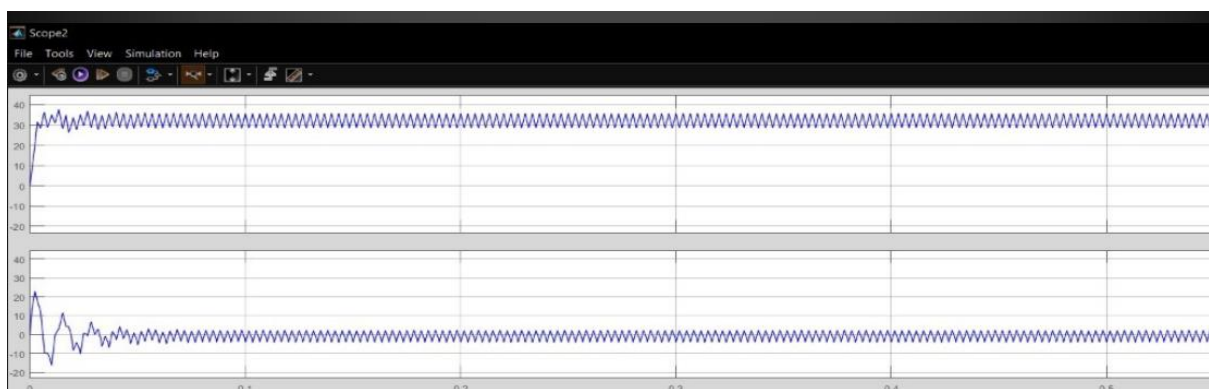


## 7. OUTPUT

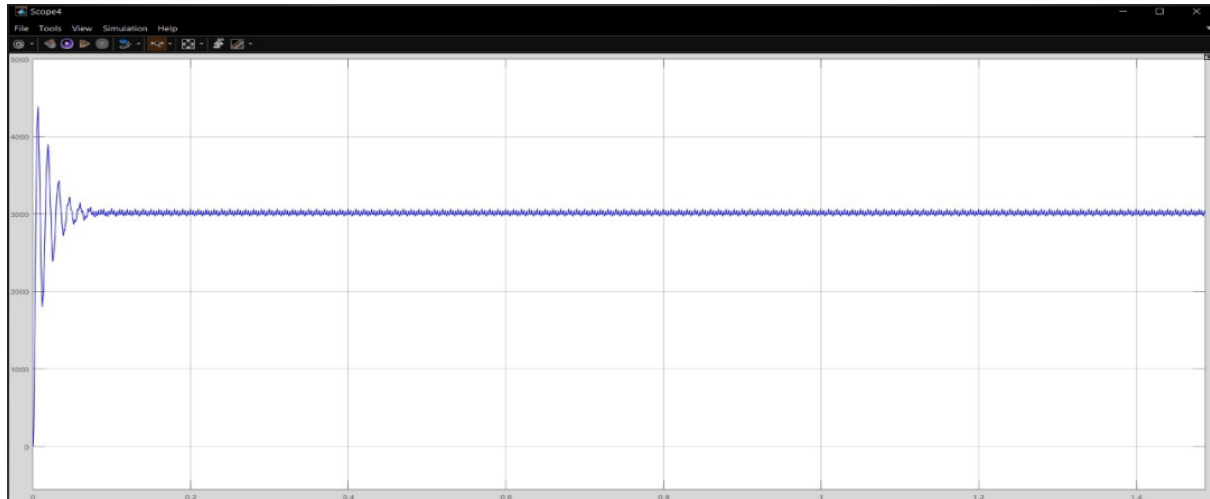
### 7.1 VSI Output



### 7.2 Id-Iq Output



## 7.3 Speed Output



## 7.4 Rotor Position Output

