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**Question 3:**

Field-Oriented Control (FOC) is a method that models and controls three-phase voltages/currents applied to a load as vectors. These vectors are generally split in two components: direct axis (denoted by "d") and orthogonal axis (denoted by "q"). Explain in simple words the advantages and disadvantages of such transformation, taking in consideration such implementation on a microcontroller.

**R:**

The FOC controlling method, uses these two components (“d” and “q”) to do the Park transform, after the Clarke one.

With this in mind, and the knowing that the “d” is the direct axis angle, and “q” the 90° angle from the other variable we can setup a control system to maximize the motor torque even under dynamic loads, startup, and braking by using a microcontroller which bring us some advantages and disadvantages.

Advantages:

+lower audible noise.

+higher motor efficiency.

+retain higher motor speed under load conditions.

+sensor less method, lowering the costs of encoders and others.

Disadvantages:

- Need to do a computationally complex calculation with the microcontroller.

- Micro controller CPU time is very important in other to calculate as fast as possible, the Park and Clarke transform and the right PWM frequencies to control our application.

-Software’s protections can be complex in sensor less method.

- Implementation may use debugging efforts.

*Question 4 in the next page

**Question 4:**

Describe how to control the speed of a permanent magnet synchronous motor without a speed sensor on the motor shaft. Represent your proposal in the form of a block diagram and explain each step.

**R:**

We can use the sensor less method of the Field-Oriented Control (FOC) to control this motor. To determine the rotor angle, we can use the back EMF while the motor is rotating.

**Steps:**

1- Convert Iu, Iv, Iw into I_alfa and I_beta using the Clarke transform.
2- The back-EMF takes the motor parameters like, speed, current and others to determine the rotor angle while the engine is running.
3- The Park transform takes I_alfa, I_beta and the Rotor Position angle, by the back-EMF technique, and compute the “d” and “q” vectors.
4- The Pi controller are applied to maximize “q” and minimize “d” to allow the control system to setup all the torque perpendicularly to the rotor (90°).
5- The inverse park and Clarke are used to return the PWMs variable used for the inverter control.
6- The inverter controls the motors parameters.

**Diagram:**