5.4 Flux-field Weakening Control Design and Analysis

In order to produce the maximum torque, which main component is proportional to q-axis component of the armature current, it is convenient to control the inverter-fed PMSM by keeping the direct, d-axis, current component to be i_d as long as the inverter output voltage doesn't reach its limit.

At that point, the motor reaches its maximum speed, so-called rated speed (called also base speed when talking about flux-weakening). Beyond that limit, the motor torque decreases rapidly toward its minimum value, which depends on a load torque profile. To expand the speed above the rated value, the motor torque is necessary to be reduced. A common method in the control of synchronous motors is to reduce the magnetizing current, which produces the magnetizing flux. This method is known as field- weakening. With PM synchronous motors it is not possible, but, instead, the air gap flux is weakened by producing a negative d-axis current component ,i_d.

Because nothing has happened to the excitation magnetic field and the air gap-flux is still reduced ,so is the motor torque, this control method is called flux-weakening. As a basis for this analysis, the PMSM current and voltage d-q vector diagrams from the previous section Fig are used. During flux- weakening, because the demagnetizing (negative)i_d current increases, a phase current vector i_s rotates toward the negative d-semi-axis. The rotation of the phase voltage vector is determined by a chosen flux weakening strategy, but at the end of flux-weakening it always rotates toward the positive q-semi axis because of i_q current,i.e v_d voltage magnitude decrease.

Hence ,the voltage-to-current phase shift decreases to zero and increases in negative direction either to the inverter phase shift limit (usually 30^0), or a load torque dictated steady-state (zero acceleration), or to the zero motor torque condition (no load or generative load). A big concern of flux-weakening control is a danger of permanent demagnetization of magnets. However, large materials such as Samarium-Cobalt, allows significant i_d current which can extend the motor rated speed up to two times. Three commonly used flux-weakening control strategies are :

1) Constant-voltage-constant-power(CVCP)control

2) Constant-current-constant-power(CCCP)control

3)Optimum-current-vector(OCVorCCCV-constant-current-constant-voltage)control.