Faculty of Engineering - Power Department

Coupling and Decoupling Secondary d-q Currents based Brushless Doubly-Fed Reluctance Machine

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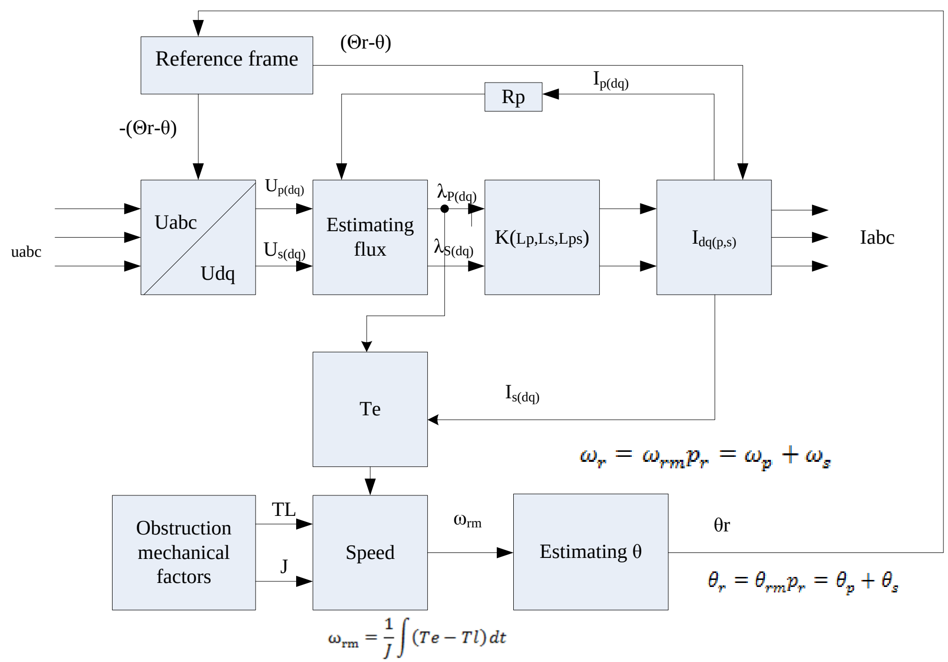
Topics

- Brushless Doubly Fed Reluctance machine (BDFRM) construction and behaviours
- Vector Control of BDFRM
- Flux Oriented Control of BDFRM
- Maximum Torque Per Ampere Inverter MTPAI

Mathematical Expression and block diagram of BDFR Machine

$$
\begin{cases}
v_{pd} = R_p i_{pd} + \dfrac{d}{dt}\bar{\lambda}_{pd} - \omega\lambda_{pq} \\
v_{pq} = R_p i_{pq} + \dfrac{d}{dt}\lambda_{pq} + \omega\lambda_{pd} \\
v_{sd} = R_s i_{sd} + \dfrac{d}{dt}\lambda_{sd} - (\omega r - \omega)\lambda_{sq} \\
v_{sq} = R_s i_{sq} + \dfrac{d}{dt}\lambda_{sq} + (\omega r - \omega)\lambda_{sd}
\end{cases}
$$



Feature and Classification of BDFR Machine

Feature:

1. Higher efficiency and simpler control as compared to the BDFIM such as wound rotor which is closely relevant in design to BDFRM machine
2. Higher reliability and free maintenance owing to its brushless structure compared with others slip ring recovery machines
3. BDFRM capability to operate in different mode as:

- ❑ conventional induction machine by simply shorting the secondary winding even such action protect the control side in the case of inverter failure.
- ❑ A second feature is that when the secondary winding is fed with DC voltage, the machine behaves like synchronous-machine.
- ❑ Finally, when partially coupled with a converter, BDFRM acts in a manner similar to any conventional doubly exited induction machine that is commonly used for wind power conversion and its association with electronics with each case accordingly.

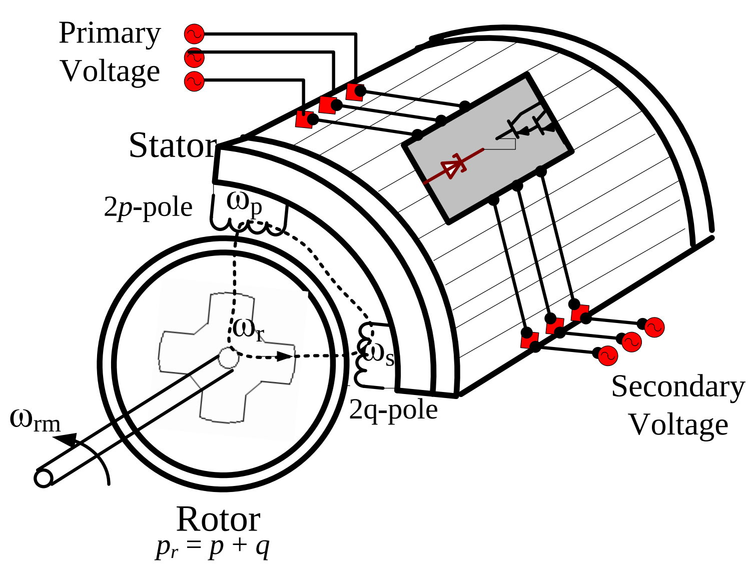
Classification:

BDFRM is classified as closely related with the brushless doubly fed induction machine (BDFIM).

BDFRM- Fundamentals

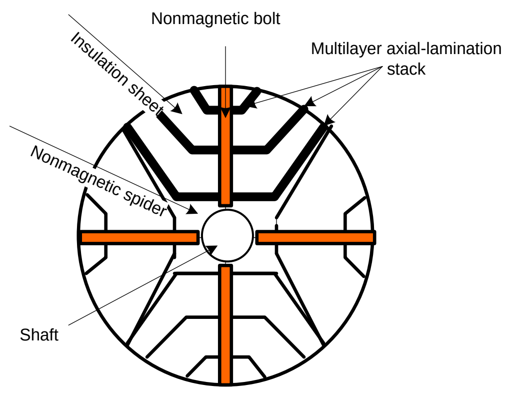
BDFRM

- Configuration Brushless doubly fed Reluctance machine.



Silense rotor of BDFRM

- Unwounded multi layer axial lamination stack
- Use to provide power flow through the machine side by exaltation the primary and secondary winding through the rotating prime mover



Coupling aspect in voltage and flux Oriented control

$$T_{evc} = \underbrace{\frac{3}{2}\, p_r\, \lambda_{md}\, i_{sq}}_{T_{foc}} - \frac{3}{2} p_r \lambda_{mq}\, i_{sd}$$

$$T_{efoc} = \frac{3}{2}\frac{L_m}{L_p} p_r\, \lambda_{md}\, i_{sq} = \frac{3}{2} p_r \lambda_m\, i_{sq} = \frac{3}{2} p_r\, \lambda_p\, i_{pq}$$

$$P_{pvc} = \frac{3}{2}\frac{T_{evc}}{p_r} = \underbrace{\frac{3}{2}\omega_p \lambda_{md}\, i_{sq}}_{P_{pfoc}} - \frac{3}{2}\omega_p\, \lambda_{mq}\, i_{sd}$$

$$P_{efoc} = \frac{3}{2}\, \omega_p\ \lambda_m\, i_{sq} = \frac{3}{2}\frac{L_m}{L_p}\omega_p\ \lambda_p\, i_{sq}$$

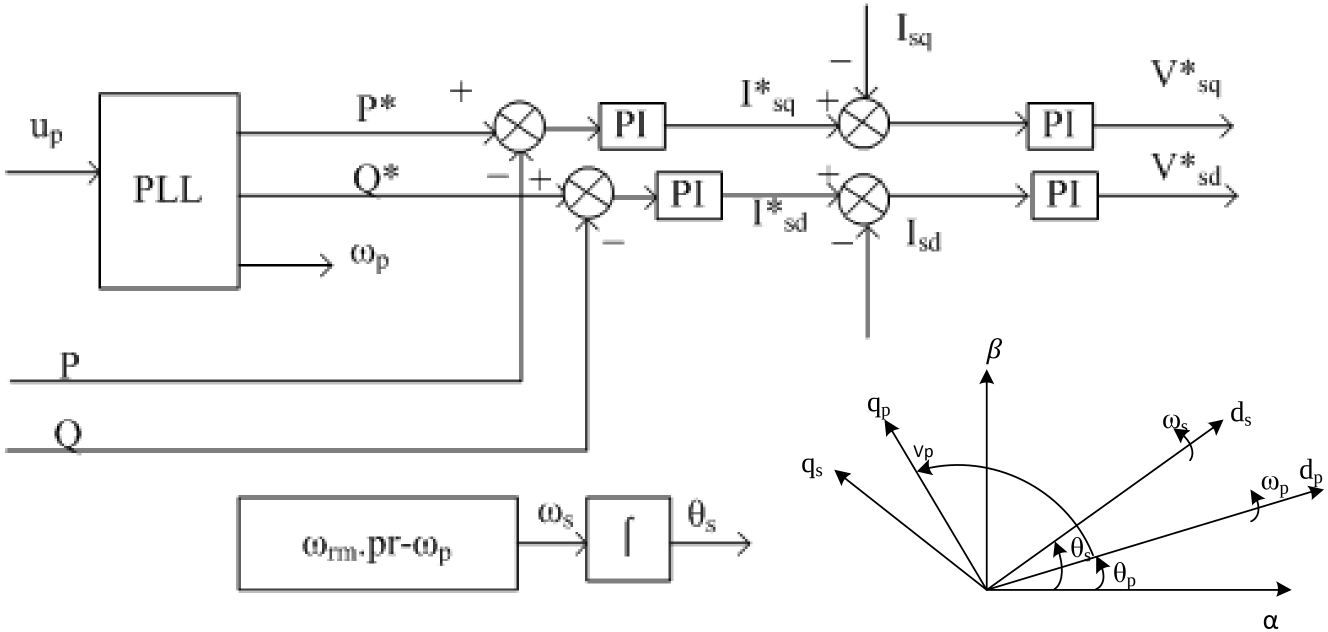
$$Q_{pvc} = \underbrace{\frac{3}{2}\omega_p\left(\frac{\lambda_p^2}{L_p} isq - \lambda_{md}\, i_{sd}\right)}_{Q_{pfoc}} - \frac{3}{2}\omega_p \lambda_{mq}\, i_{sq}$$

$$Q_{efoc} = \frac{3}{2}\frac{\omega_p\, \lambda_p}{L_p}(\lambda_p - L_m i_{sd}) = \frac{3}{2}\omega_p\ \lambda_p\, i_{pd}$$

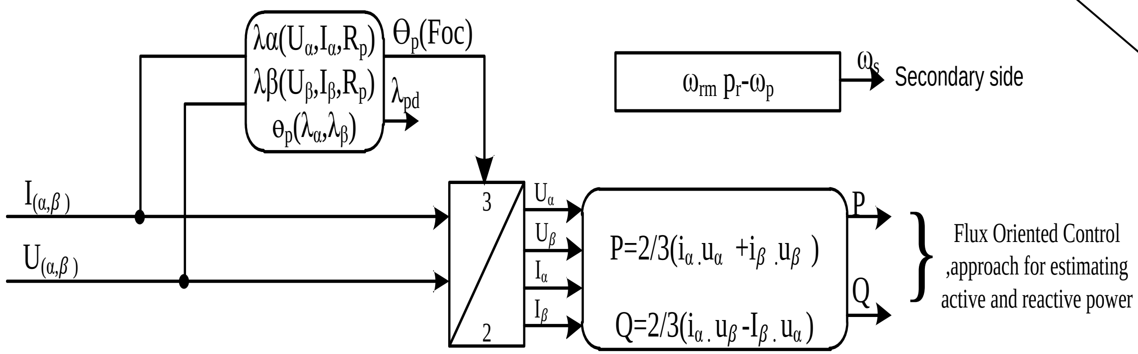
$$\omega_{rm} = \frac{\omega_p + \omega_s}{p_r} \leftrightarrow \omega_r = \omega_{rm} p_r = \omega_p + \omega_s$$

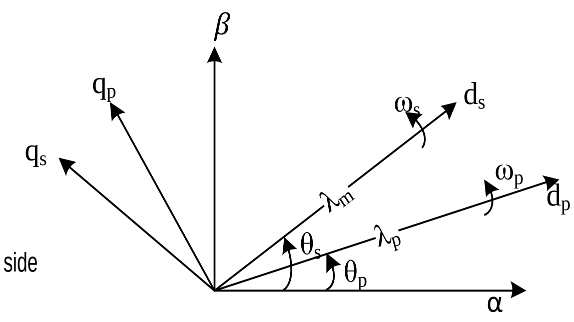
Voltage Oriented Control (Voltage Control)

P&Q VC Control

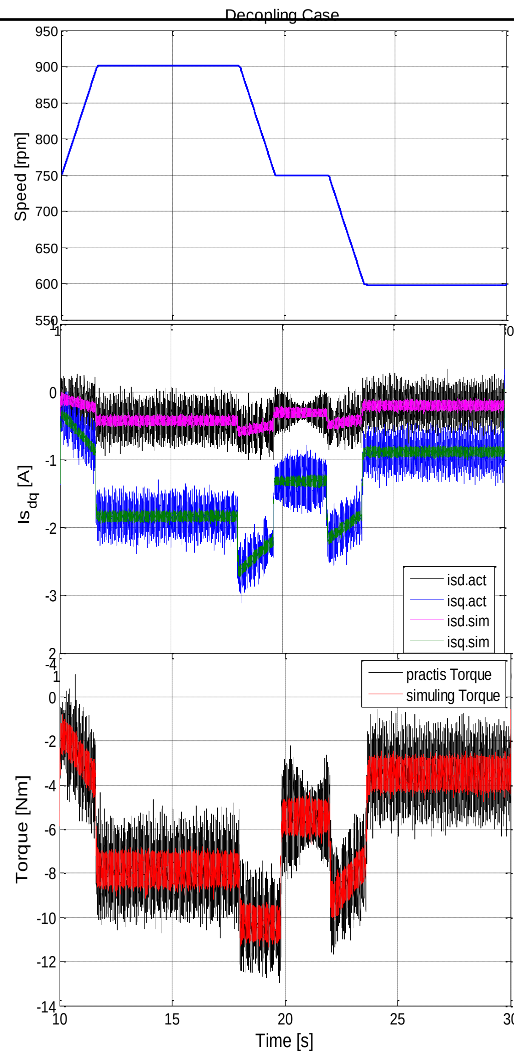


Flux Oriented Control (FOC)

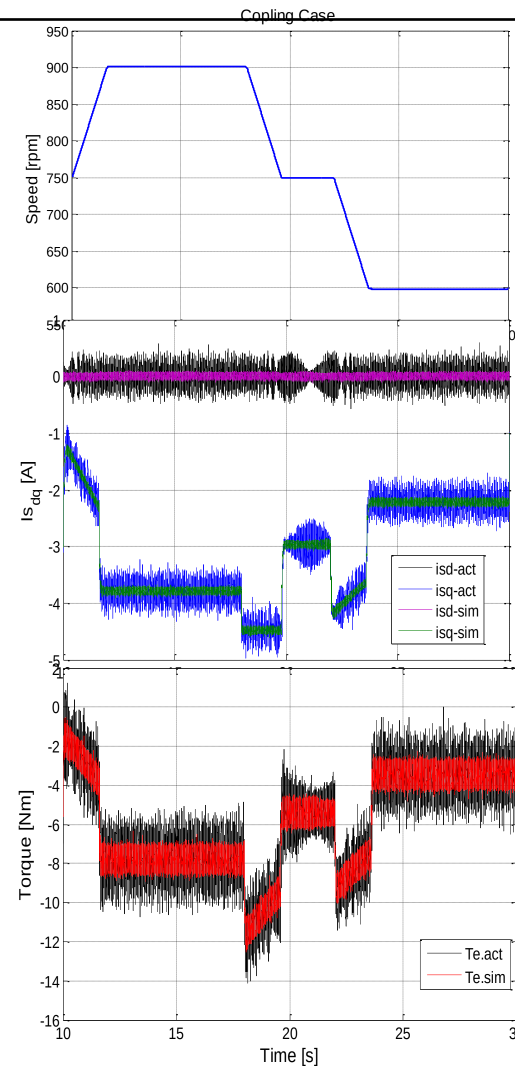




The results：



Coupling behavior under VC algorithm



Decoupling behaviors Due FOC Performance

Actual performance of BDFRM based dSPACE application

Conclusion and feature work

- Evaluating control algorithms of VC and FOC gives a clear advantage for the Flux oriented control algorithm over Voltage oriented Control to enable it to tracking changes in the speed with a bit of **inherited decupling**.

- The effect of **MTPAI** to achieve the control side stable under sudden change, by Enabling reactive current I_{sq} to have big role in torque production when I_{sd} minimizing to zero.

- The most important feature for the **BDFRM** machine simple dealing partially with the converter and good response fore **VC** & **FOC** control algorithms dealing with the active P and reactive Q power control.
- The compatibility of **dSPACE** Application to provide the suitable and accuracy result in practice.


Thank you for your attention!