Control and Optimization for Electric Propulsion: a Doubly Fed Induction Motor Case Study

Shubo Zhang[1], Gianfranco Trovato[1], Wei Hong[1], Khalil Elassi[1], Venkat Padaraju[1], Dr. Zhiqiang Gao[1]
Advisors: Dr. Linda Taylor[2], David Sadey[2]

1. Department of Electrical Engineering and Computer Science, Cleveland State University
2. Sponsored by NASA Glenn Research Center

Abstract

The control mechanism of Doubly Fed Induction Machines (DFIM) requires optimization for better performance. Biogeography Based Optimization (BBO) was used optimize a PI controller for the given electric propulsion system, and its performance was tested against the Active Disturbance Rejection Controller (ADRC). This study shows that although there is a marginal performance difference, ADRC is the optimal solution.

Biogeography-Based Optimization

BBO is derived from biology-based population dynamic algorithms. One can compare BBO to the Genetic Algorithm in the sense that non-ideal solutions to the given system will be rejected before optimal conditions are discovered. Figure [1] below shows a flow chart outlining the flow chart outlining how the algorithm would work for a PID controller.

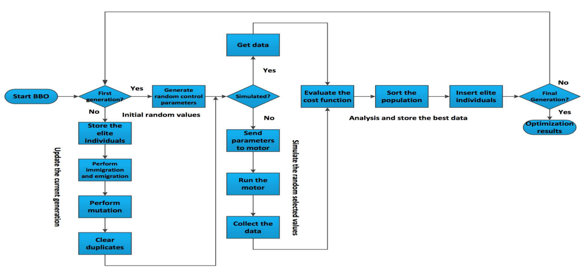

Figure [1]: BBO For DFIMotor Control Mechanism

Post BBO Tuning of the PI Controller

The BBO Algorithm returned the results shown below in Figure [2]. Interestingly, the BBO tuned PI controller is exceptional in terms of noise rejection capability. Figure [3] depicts a comparison of both PI controllers with the disturbed step input.

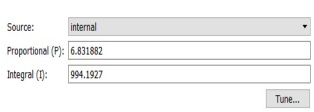

Figure [2]: Results of BBO Tuning

The PI parameters obtained by running the BBO algorithm produced values that were far different from the **original** ($K_p = 1$, $K_i = 10$)

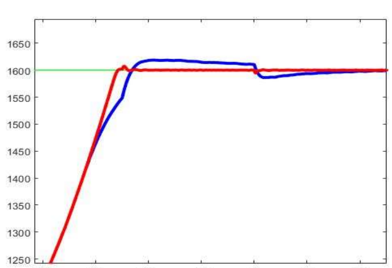

Figure [3]: Untuned PI controller vs. BBO tuned PI controller

To find the most ideal control solution, the tuned PI controller was compared to the ADRC solution in Figures [4], [5], and [6].

Internal and external disturbances were introduced to the system. Internal disturbance was increasing rotor resistance and inductance, and external was introducing a noise source.

BBO Tuned PI Controller vs. ADRC

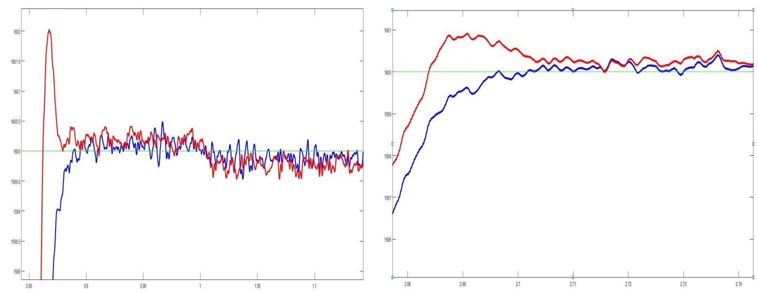

Figure [4]: ADRC vs tuned PI with an increased internal resistance (x2 left, x3 right)

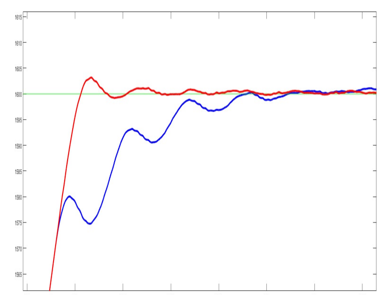

Figure [5]: ADRC vs tuned PI (Sinusoidal Disturbance)

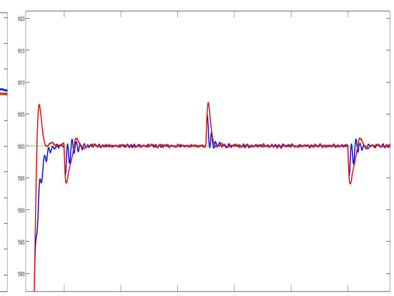

Figure [6]: ADRC vs tuned PI Internal and External Disturbance

Conclusions

Based on the results of the simulations, it can be concluded that the optimum control solution for the DFIM system is the Active Disturbance Rejection Control. Although the difference between the two is almost negligible, the ADRC does not overshoot the reference signal when disturbed. This can prevent damage to the system by rejecting any potentially external and internal disturbance.

Future Work

Going forward with the project it is important to ensure the controller design works in more than just simulation. It must be implemented onto a testbed and ensure it works practically as well as theoretically. Additionally, the implementation of a Reactive Power controller should be included to ensure that the average reactive power during operation is zero to achieve unity power factor.

References

1. David J. Sadey, Linda Taylor, and Raymond Beach. "Proposal and Development of a High Voltage Variable Frequency Alternating Current Power System for Hybrid Electric Aircraft", 14th International Energy Conversion Engineering Conference, AIAA Propulsion and Energy Forum, (AIAA 2016-4928)
2. P. Lozovyy, G. Thomas, and D. Simon, "Biogeography-Based Optimization for Robot Controller Tuning," *in Computational Modeling and Simulation of Intellect (B. Igelnik, editor) IGI Global*, 2011, pp. 162-181.
3. D.Simon, "Biogeography-based optimization." *IEEE transactions on evolutionary computation 12*, No.6, 2008, pp.702-713.
4. Ruiqing Zhang. "Frequency Domain Analysis and Active Disturbance Rejection Control of Coordinated System for Supercritical Power Unit", North China Electric Power University. 2015.6.