ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

International Journal of Mechanical Engineering

Comparison Study Between Filter Based TCR and Fixed Filter Techniques in Protecting DFIG`s Converter

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Abstract

This research compares the performance of a filter-based (Thyristor controlled reactor) TCR and fixed filter approaches in safeguarding the Rotor Side Converter of a Doubly Fed Induction Generator (RSC) (DFIG). We will learn more about the two strategies in this research, including their philosophies, benefits, and drawbacks. Simulation with the EMTDC/PSCAD software package is used to assess the dynamic behavior of the two methods.

Keywords: DFIG, RSC, TCR

I. INTODUCTION

In today's wind energy systems, DFIG is one of the most often utilized generators. The DEIG has the advantage of being able to work at a variable speed over a wide range of speeds.
The DFIG is a wound rotor induction generator (WRIG), and its rotor is connected to the grid through two back-to-back converters with a DC connection in between, as shown in Figure 1. The grid side converters (GSC) and rotor side converters (RSC) are in charge of maintaining the DC link voltage, adjusting generator torque and speed, and managing the power factor, respectively. The GSC may be used to send reactive electricity to the grid as well.
The ability to manage active and reactive power individually, as well as the fact that its converters are rated at 25-30% of the generator rating, provide the DFIG a cost, flexibility, and reliability edge over other existing variable speed generators. DFIG is also more efficient and lightweight than other full-scale converter generators. It is, however, vulnerable to grid outages or voltage dips due to the low converter rating. [1,2]

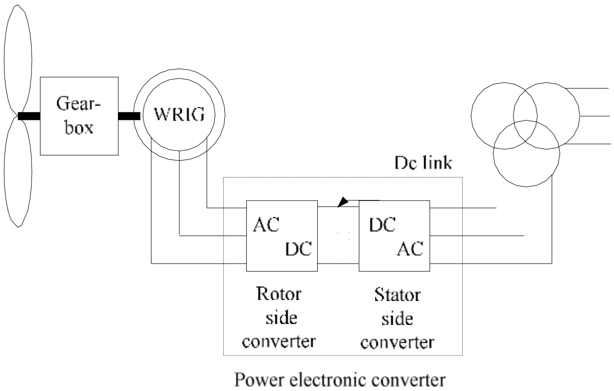


Figure 1 DFIG Scheme

As listed below, a variety of recently discovered approaches may be used to safeguard DFIG converters:
A switched resistor is positioned across the DC link terminals to avoid overvoltage, with switching managing the discharge of the DC link into the resistor. With DFIG converters, overcurrent protection is not possible [3].
The crow-bar approach entails disconnecting the RSC and placing a resistor across the rotor windings to protect the DFIG's converter from excessive current.
Instead of isolating the RSC to protect it, the DBR (dynamic braking resistance) approach includes adding a dynamic resistor to the rotor terminals. The strong rotor current produced is dampened by the dynamic resistor. However, depending on its resistance, this rotor-connected dynamic resistor might generate a large voltage. During breakdowns, a dynamic resistor can be placed to the stator as an alternative. When the RSC control is disabled, a dynamic resistor linked in series with the stator can moderate the rotor overvoltage that can occur. This might also successfully handle the large induced rotor current while avoiding DC-link overvoltage. However, it raises the stator's resistance, which might result in a drop in the stator's time constant and, as a result, a quick deterioration of natural flux [3].
Current is injected to counterbalance the inherent flux impact on the rotor in the demagnetizing current injection procedure. However, this does not meet the LVRT standards.
The technique of controlling the stator terminal voltage by connecting the stator to the grid with a Series Grid Side Converter (SGSC), which creates a voltage that restrains the negative sequence components and the DC flux at the stator windings. This eliminates the rotor overcurrent that these two components generate. However, this strategy has the significant disadvantage of incurring additional expenditures for the series converter and injection transformer [3].

II. FIXED FILTER TECHNIQUE

During the fault, a fixed high pass LR filter (A filter combined of two component inductor and resistor) is coupled to the rotor windings, as illustrated in figure 2, to suppress the unwanted rotor current component caused by natural flux. The delta connection is more efficient than the star connection. [3]
The settings of the filter are controlled by
$f_c = R \,/\, 2\pi L$ (1)
The cut-off frequency is fc, the filter resistance is R, and the filter inductance is L.

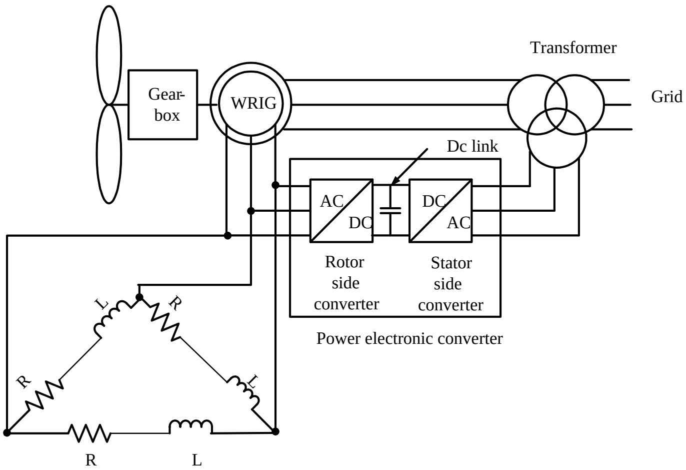


Figure 2 DFIG with fixed filter

III. FILTER BASED TCR TECHNIQUE

A TCR is set according to the rotor speed at the instant of the fault, then linked to the rotor windings during the fault to accurately suppress the undesirable rotor current component caused by natural flux, as illustrated in figure 3. [4]

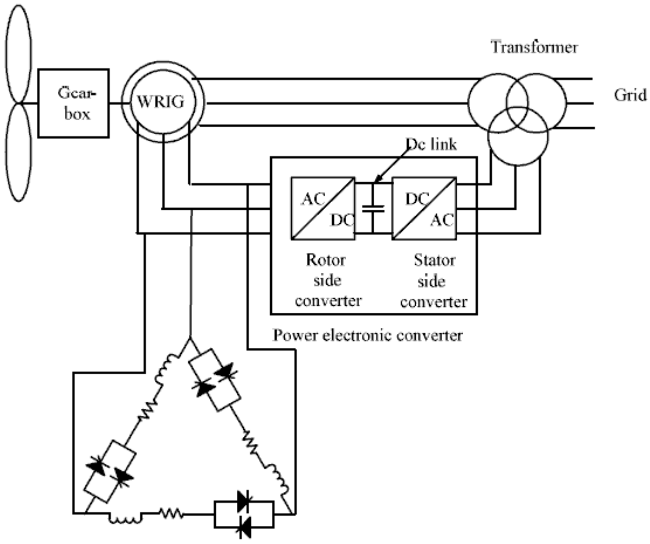


Figure 3 DFIG with filter based TCR

$\beta_{TCR}(\alpha) = \beta_{Max}(1 - \frac{2\alpha}{\pi} - \frac{\text{Sin } 2\alpha}{\pi})$ (2)

$\beta_{Max} = \frac{-1}{\omega L}$ (3)

Where β_{TCR} is susceptance and 2α is thyristor firing angle

By substituting from Equation 2 in 1

$$\frac{-1}{XL_{TCR}} = \frac{-1}{\omega L_{TCR}} = \frac{-1}{\omega L}(\frac{\pi}{\pi} - \frac{2\alpha}{\pi} - \frac{Sin(2\alpha)}{\pi})$$

$\pi\left(1 - \frac{L}{L_{TCR}}\right) = 2\alpha - Sin(2\alpha)$ (4)

The required filter inductance, on the other hand, is determined by

$L_d = \frac{R}{2\pi f_c}$ (5)

and the frequency of the cut-off

$f_c = \frac{2S}{60}$ (6)

After that, the required inductance Ld is given to the TCR controller.

$L_d = \frac{60R}{4\pi S}$ (7)

IV. SIMULATION RESULTS

To analyze and evaluate the performance of each strategy, consider a network consisting of a 2MW wind turbine with the parameters coupled to an infinite bus bar by a 0.69 / 20 KV transformer. On the high voltage side of the transformer, a three-phase to ground failure is simulated at various generator speeds. The parameters utilized by DFIG are listed in Table 1.

Table 1. DFIG`s Parameters

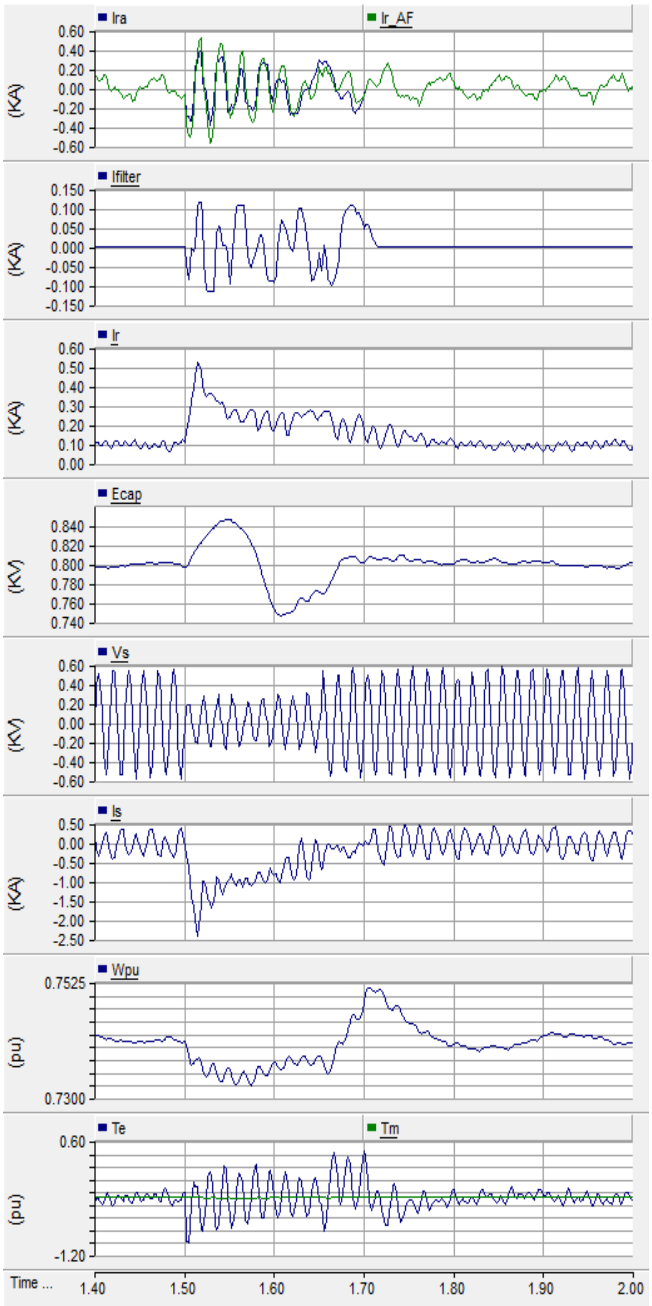
Rated Voltage (L-L)	0.69 KV
Base Angular Frequency	60 HZ
Stator/Rotor Turns Ratio	0.3
Stator Resistance	0.0054 pu
Rotor Resistance	0.00607 pu
Magnetizing Inductance	4.5 pu
Stator Leakage Inductance	0.1 pu
Rotor Leakage Inductance	0.11 pu

The performance of the DFIG is tested at speed 0.7 pu with filter based TCR and fixed filter methods, respectively, when a 50 percent voltage dip is triggered at time 1.5 s, as shown in Figs. 4 and 5. In Figure 4, the peak values of the rotor current and capacitor voltage are lower, whereas the peak values of the rotor speed and electromagnetic torque are larger.

When a 50 percent voltage dip is triggered at time 1.5 s, the DFIG runs at speed 1 pu with filter based TCR and fixed filter methods, as shown in Figs. 6 and 7. The filter-based TCR approach succeeded in maintaining the peak values of rotor current, capacitor voltage, rotor speed, and electromagnetic torque lower than the fixed filter technique, as shown in Figs. 6 and 7, while the stator voltage and current are practically same.
When a 50 percent voltage drop is introduced at time 1.5 s, Figs. 8 and 9 show the behavior of the DFIG operating at 1.25 pu with filter based TCR and fixed filter methods, respectively. Once again, the peak values of the rotor current and capacitor voltage are lower in the filter-based TCR approach than in the fixed filter technique, but other parameter peak values are nearly identical.

V. CONCLUSION

This research compares the protection of DFIG's RSC using a filter-based TCR and fixed filter methods. The EMTDC/PSCAD software program was used to simulate the behavior of the DFIG under a 50 percent voltage sag at various rotor speeds with each approach used. The results showed that the filter-based TCR approach performed better, however there was little difference in most situations. Nevertheless, a more analysis should be carried out to clarify in more details the difference between the two mentioned protection techniques, also studying if we can modify any of them for more enhancements of their performance.



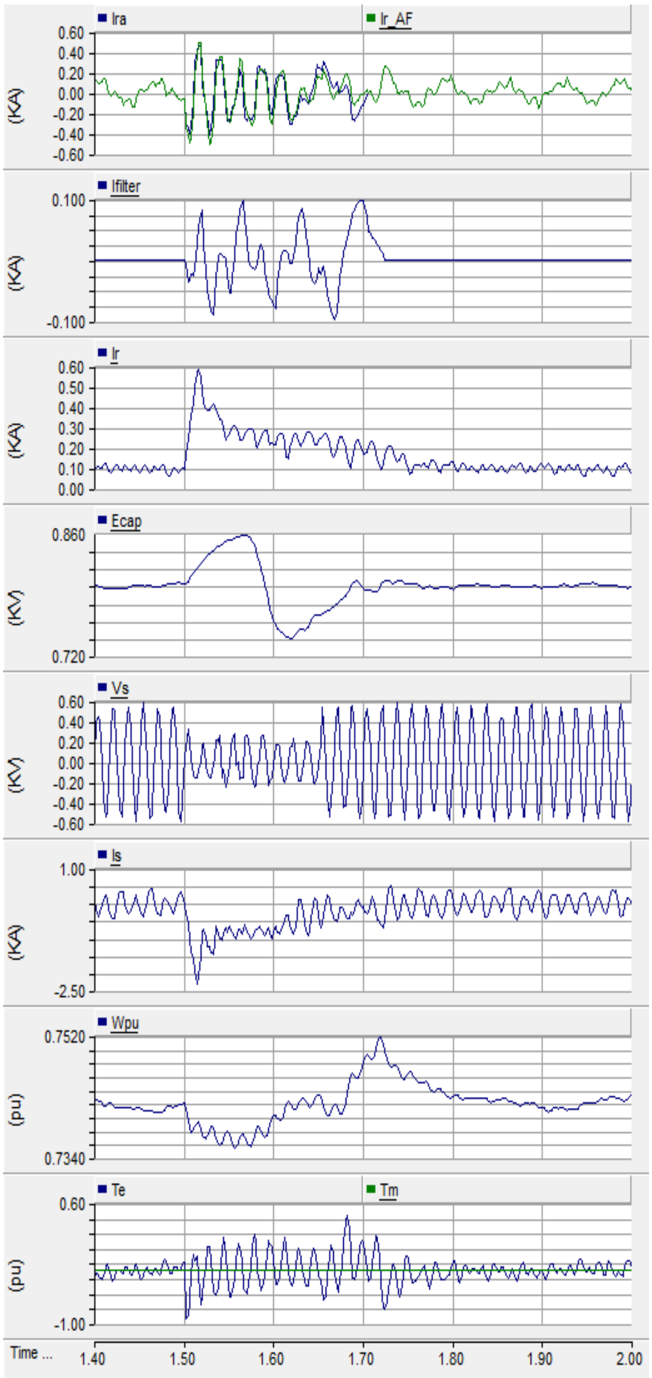


Figure 5 illustrates the performance of the DFIG with a fixed filter at 0.7 p.u. rotor speed during a 50 percent voltage sag

Figure 4 illustrates the performance of DFIG during 50% voltage sag with filter based TCR at 0.7 p.u. rotor speed

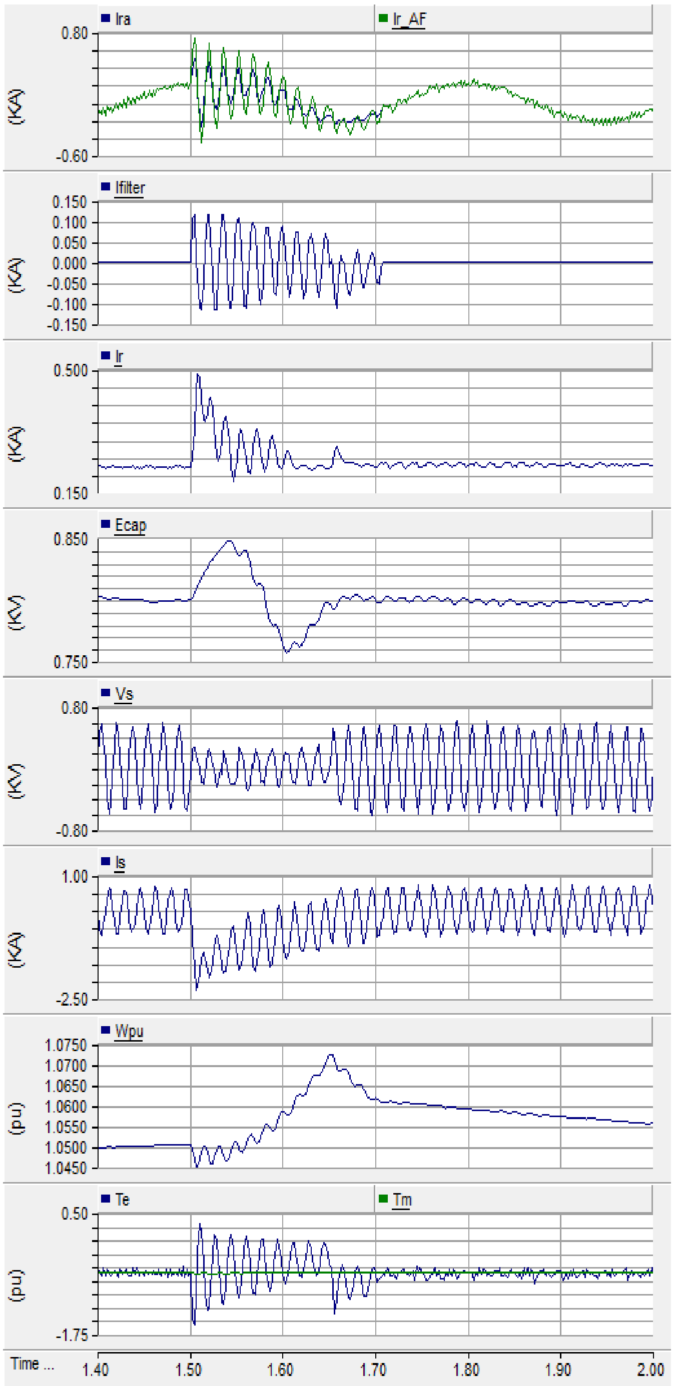


Figure 6 illustrates the performance of the DFIG with a filter-based TCR at 1 p.u. rotor speed during a 50 percent voltage sag.

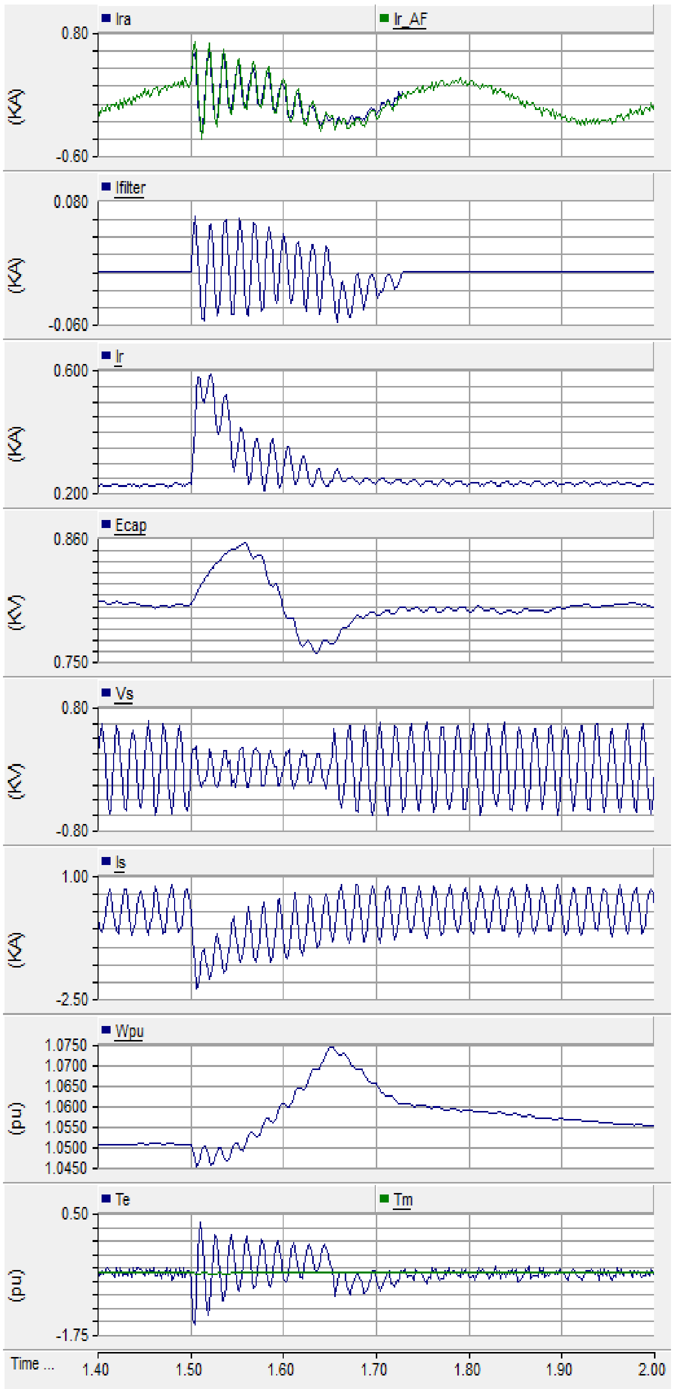


Figure 7 illustrates the performance of the DFIG with a fixed filter at 1 p.u. rotor speed during a 50 percent voltage sag.

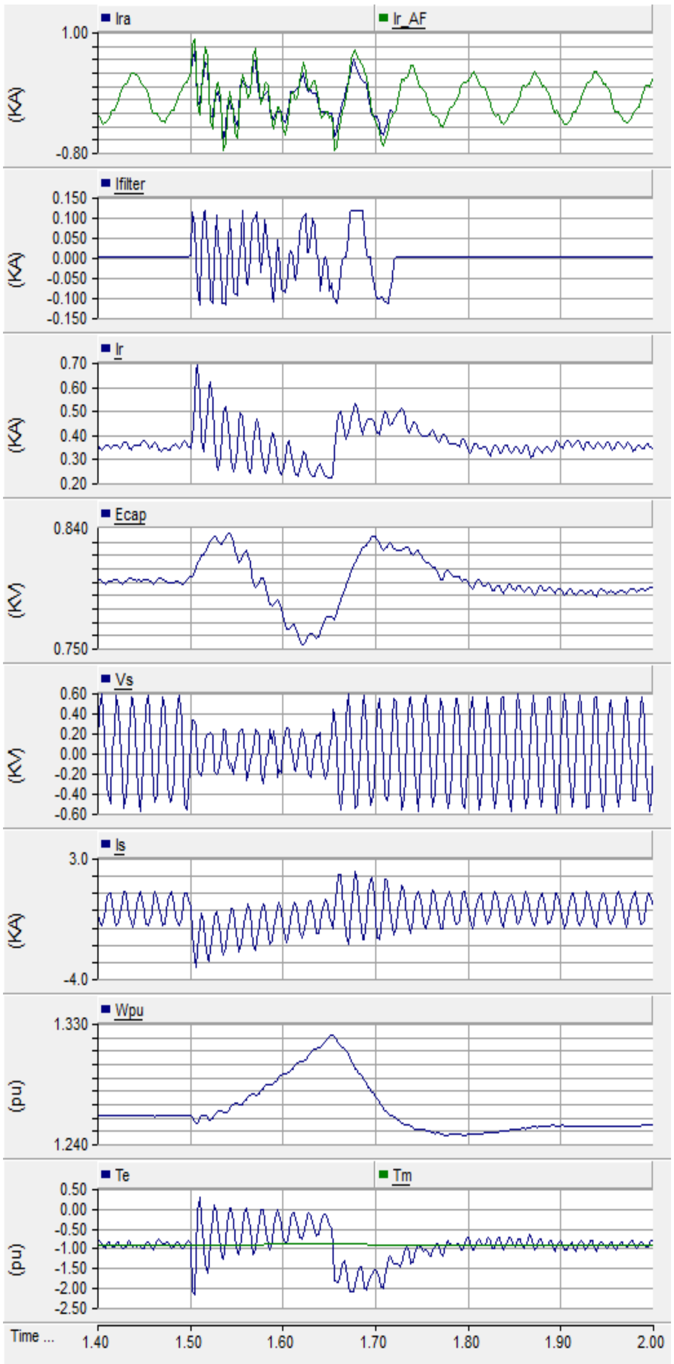


Figure 8 illustrates the performance of the DFIG with a filter-based TCR at 1.25 p.u. rotor speed during a 50 percent voltage sag.

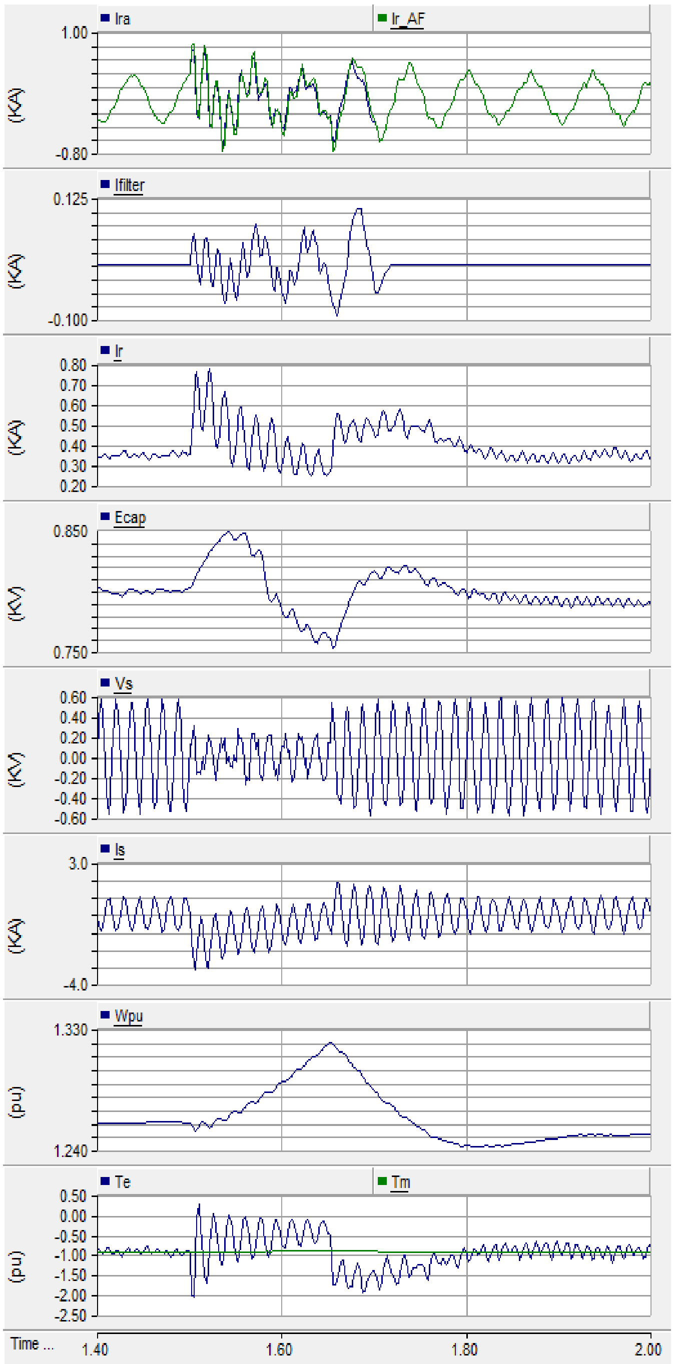


Figure 9 illustrates the performance of the DFIG with a fixed filter at 1.25 p.u. rotor speed during a 50 percent voltage sag.

REFERENCES

1. Leonardo Francisco da Silva, Daniel Krejci, Bruno Wanderley França, Mauricio Aredes & Josep M. Guerrero “Modeling, Control, and Experimental Verification of a DFIG With a Series-Grid-Side Converter With Voltage Sag, Unbalance, and Distortion Compensation Capabilities “IEEE Transactions on Industry Applications (Volume: 56 , Issue: 1 , Jan.-Feb. 2020)
2. Zhen Xie, Xuguang Zhang, Xing Zhang, Shuying Yang, Lingxiang Wang “Improved Ride-Through Control of DFIG During Grid Voltage Swell” IEEE Transactions on Industrial Electronics (Volume: 62, Issue: 6, June 2015)
3. Hadi M. EL-Helw, Ahmed Khaled, Mostafa I. Marei “A Technique for Protecting the Rotor Side Converter of the Doubly Fed Induction Generator” 978-1-5386-2910-9/18/$31.00 ©2018 IEEE
4. Ahmed Khaled, Almoataz Y. Abdelaziz, Hadi M. El-helw, Mohamed Ezzat “Protecting Doubly Fed Induction Generator`s Converter Using A Filter Based TCR” 978-1-7281-7455-6/20/$31.00 ©2020 IEEE
5. Zakiud Din, Jianzhong Zhang, Yaodong Zhu, Zheng Xu, Ahmed El-Naggar “Impact of Grid Impedance on LVRT Performance of DFIG System with Rotor Crowbar Technology” 10.1109/ACCESS.2019 .29 38207

6. C. Heising, J. Fang, V. Staudt, A. Steimel “Doubly Fed Induction Generator model for Analysis of Fault-Ride Through and Asymmetrical Generator-Side Faults” 7th Mediterranean Conference and Exhibition on Power Generation, Transmission, Distribution and Energy Conversion 7-10 November 2010, Agia Napa, Cyprus (Paper No. MED10/232) Gustavo Figueiredo Gontijo, Thiago Cardoso Tricarico
7. Hammam Soliman, Huai Wang, Dao Zhou, Frede Blaabjerg, Mostafa I. Marie “Sizing of the series dynamic breaking resistor in a doubly fed induction generator wind turbine“ 2014 IEEE Energy Conversion Congress and Exposition (ECCE)
8. Jesús López, Eugenio Gubía, Eneko Olea, Josu Ruiz & Luis Marroyo “Ride Through of Wind Turbines With Doubly Fed Induction Generator Under Symmetrical Voltage Dips” IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, VOL. 56, NO. 10, OCTOBER 2009
9. Gustavo Figueiredo Gontijo, Thiago Cardoso Tricarico, Leonardo Francisco da Silva, Daniel Krejci, Bruno Wanderley França, Mauricio Aredes & Josep M. Guerrero “Modeling, Control, and Experimental Verification of a DFIG With a Series-Grid-Side Converter With Voltage Sag, Unbalance, and Distortion Compensation Capabilities“ IEEE Transactions on Industry Applications (Volume: 56 , Issue: 1 , Jan.-Feb. 20