Comparative Study of the Effects of Machine Parameters on DFIG and PMSG Variable Speed Wind Turbines During Grid Fault

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This study investigates the transient performance of two variable speed wind turbines (VSWTs), namely doubly fed induction generator (DFIG) and the permanent magnet synchronous generator (PMSG), that are widely employed in wind energy conversion, considering their machine parameters. The machine parameters of both wind turbines were changed considering different scenarios, while keeping other parameters constant, to study the behavior of the wind generators. This study was carried out using the same operating conditions of rated wind speed, based on the characteristics of both wind turbine technologies. The wind turbines were subjected to a severe three-phase to ground bolted fault to test the robustness of their controllers during grid fault conditions. Efforts were made to carry out an extensive comparative study to investigate the machine parameters that have more influence on the stability of the different wind turbines considered in this study. Simulations were carried out using power system computer-aided design and electromagnetic transient including DC (PSCAD/EMTDC). Effective machine parameter selection could help solve fault ride-through (FRT) problems cost-effectively for both VSWTs, without considering the external circuitry of and changing the original architecture of the wind turbines.

Keywords: doubly fed induction generator, permanent magnet synchronous generator, wind energy, power converters, stability, machine parameters

INTRODUCTION

Variable speed wind turbines (VSWTs) are the new norms for the installation of wind farms. These types of wind turbines have high efficiency in capturing energy, with effective voltage control (Okedu, 2019a). The doubly fed induction generator (DFIG) and permanent magnet synchronous generator (PMSG) with back-to-back power converter-type technologies have become the two wind generator alternatives, commonly employed as VSWTs. The former has a gearbox, and only 20–30% of the generator rating is required for its operating speed range of 0.7–1.3 per unit (p.u.). The latter has a drawback of high cost due to its full-rated power converters.

In the DFIG wind turbine structure, the back-to-back power converter lies between the rotor or machine side and the stator or grid side. Based on the available wind speeds, this type of wind
turbine can operate at a wide range for better wind energy capture (Godoy Simoes and Farret, 2004; Bozhko et al., 2008). In the DFIG wind turbine, rebuilding of the terminal voltage after grid disturbance is much easier due to the pitch and dynamic slip control strategy (Okedu and Barghash, 2021a,b). Moreover, the control of active and reactive power through the decoupling principles is much easier in this class of wind turbine. The power converters of the DFIG wind turbine go into standby mode (Haberberger and Fuchs, 2004) at lower voltages (El-Sattar et al., 2008; Okedu et al., 2012; Okedu and Barghash, 2021a,b); however, during grid fault, above the threshold voltages, there is fast synchronization of this type of wind generator to the power grid (Santos and Le, 2007).

On the other hand, the alternative to the DFIG wind turbine in wind energy conversion is the PMSG wind turbine technology. The PMSG wind turbine has a full-rated back-to-back power converter tied to the power grid. Consequently, there is maximum flexibility in this type of wind generator compared with the DFIG topology (Okedu, 2011; Okedu and Barghash, 2021c). Thus, real and reactive power control is more effective when using the PMSG wind turbine. However, high initial cost is the major drawback of this class of wind turbine system (Baran and Andrezej, 2020).

Based on the literature, there are many fault ride-through (FRT) control strategies in the enhancement of DFIG and PMSG wind turbines. Fault current limiters (Okedu et al., 2011a,b; Okedu, 2016), crowbar switch and DC chopper circuitry (Takahashi et al., 2006; Okedu et al., 2010a), and sliding mode controls (Okedu et al., 2010b; Bekakra and Attous, 2011) are some of the FRT schemes already reported in the literature for the improvement of the transient stability of either or both wind turbines. The assessment of DFIG using various control methods was carried out in different studies (Ali et al., 2010; Lamchich and Lachguer, 2012; Suthar, 2014), with emphasis on the use of maximum power point tracking (MPPT) pitch angle controller considering different algorithms (Noubrik et al., 2011), while peak current limitation and MPPT were employed by Nasiri and Mohammadi (Nasiri and Mohammadi, 2017) and Gencer (2018), respectively. In a study by Moghimyan et al. (2020), a series fault current limiter was employed with metal oxide varistor to improve the low-voltage ride-through (LVRT) of DFIG-based wind farms. The application of a multistep bridge-type fault current limiter for the PMSG wind turbine was reported by Firouzi et al. (2020a) for the improved performance of the wind turbine FRT. A neuro-fuzzy logic-controlled parallel resonance-type fault current limiter scheme was employed by Islam et al. (2020) to enhance the FRT capability of a wind farm composed of DFIG wind turbines, while entire power systems using fuzzy logic-controlled capacitive bridge-type fault current limiter scheme was investigated by Sadi et al. (2021). A further approach of using dynamic multicell fault current limiter was reported by Shaﬁee et al. (2020) to improve the FRT performance of the wind farms based on DFIG control, while a sliding mode controller based on the bridge-type fault current limiter was used for the DFIG FRT-improved performance (Firouzi et al., 2020b).

The machine parameters help in understanding the performance of the wind generators. These parameters are additional quantities that influence the behavior of the wind turbines. However, compared with the input variables, the machine parameters are held constant, or change slowly during the operation of the wind turbines (Nykamp, 2020). The machine parameters present some unique functions that should be observed in order to improve the maximum power generation output and efficiency of the wind turbines (Abolude and Zhou, 2018). The evaluation of the mechanical parameters affecting wind turbine power generation was carried out (Construction review, 2019); however, the parameters investigated were limited to the swept area, air density, wind speed, and power coefficient of the wind turbine. According to Rose and Hiskens (Rose and Hiskens, 2008), the wind turbine parameters were estimated and these effects were used to quantify their dynamic behavior. The study was limited to the estimation of certain parameters, without extensive study of their effects during transient conditions. According to Balijepalli et al. (2018), an optimized parameter design for the blades of wind turbine considering Schmitz theories and aerodynamics forces was reported.

In light of the earlier discussion, this study presents the effects of the electrical parameters of wind turbines during grid fault. There are limited reports on the effects of electrical parameters considering the DFIG and PMSG VSWTs in the literature. Therefore, this study tends to bridge this research gap. The characteristics, modeling, and control strategies of DFIG and PMSG wind turbines were presented. The extensive investigation of the effects of various parameters was considered, by varying some machine parameters while keeping the other parameters constant. In the DFIG analysis, nine scenarios were considered, while in the PMSG analysis, ten scenarios were considered. The machine parameters considered for the DFIG wind turbine are magnetizing inductance, stator leakage inductance, wound rotor leakage inductance, stator resistance, wound rotor resistance, and angular moment of inertia. The machine parameters considered for the PMSG wind turbine are stator winding resistance, stator leakage reactance, D: unsaturated reactance, D: damper winding reactance, D: damper winding reactance, Q:
damper winding resistance, and magnetic strength. The same
wind turbine capacity and the same fault condition of operation
were considered for both wind turbine technologies, and the
turbines were operated at their rated speed based on their
MPPT wind turbine characteristics. The simulation analysis
was carried out using a power system computer-aided design
and electromagnetic transient including DC (PSCAD/EMTDC)
(PSCAD/EMTDC Manual, 2016).

TURBINE CHARACTERISTICS AND
MODEL OF DFIG WIND TURBINE

The characteristics of the DFIG wind turbine used in this study
are shown in Figure 1, with the range of the rotor speed between
0.7 and 1.3 p.u. The DFIG equivalent circuit (Okedu, 2019b,
2020) tied to the power grid is shown in Figure 2, with the
back-to-back power converters linking the point of common
coupling (PCC).

As shown in Figure 2, the total power is \( P_T = P_s + P_g \),
and it is delivered based on the available wind speed through
the rotor and stator circuits of the wind turbine to the PCC, for
\( \omega_r > \omega_s \) (i.e., rotor speed is greater than synchronous speed). The stator active power \( P_s \) is delivered to the PCC through the stator circuitry \( (\omega_s < \omega_r) \) while the absorption of the active power \( P_r \) from the PCC is done via the power converter (Zubia et al.,
2012). In the \( d-q \) orientation stator frame synchronous axis, the
application of vector control would lead to the wind generator
model on the fifth order \( d-q \) representation (Kong et al., 2014).
Therefore, the stator, rotor, and the \( d-q \) components, considering
the equivalent circuit for the DFIG wind turbine as shown in
Figure 2, are

\[
\begin{bmatrix}
    V_{ds} \\
    V_{qr} 
\end{bmatrix} =
\begin{bmatrix}
    L_s & 0 & L_m & 0 \\
    0 & L_s & 0 & L_m \\
    L_m & 0 & L_r & 0 \\
    0 & L_m & 0 & L_r 
\end{bmatrix}
\begin{bmatrix}
    I_{ds} \\
    I_{qr} \\
    I_{dr} \\
    I_{qr} 
\end{bmatrix} 
\]

\[
\begin{bmatrix}
    \omega_s \\
    \omega_r 
\end{bmatrix} =
\begin{bmatrix}
    R_s & 0 & L_m \\
    0 & R_s & 0 \\
    L_m & 0 & R_r \\
    0 & L_m & 0 
\end{bmatrix}
\begin{bmatrix}
    I_{ds} \\
    I_{qr} \\
    I_{dr} \\
    I_{qr} 
\end{bmatrix} + \begin{bmatrix}
    0 & -\omega_s \\
    \omega_r & 0 \\
    \omega_r & 0 \\
    \omega_s & 0 
\end{bmatrix}
\begin{bmatrix}
    \Psi_{ds} \\
    \Psi_{qr} \\
    \Psi_{dr} \\
    \Psi_{qr} 
\end{bmatrix} \tag{1}
\]

In Equation (4), \( C_{dc} \), \( V_{dc} \), and \( P_{dc} \) are the DC-link capacitor,
DC-link voltage, and DC-link power. The DFIG rotor side
converter (RSC) control scheme is shown in Figure 3, where
the \( q \) and \( d \) axis rotor currents \( i_{qr} \) and \( i_{dr} \) regulate the active
and reactive power \( (P_s, Q_s) \), of the stator, respectively. The stator
power of the wind generator is obtained by the MPPT scheme
of the wind turbine system. The grid side converter (GSC) of
the wind generator, as shown in Figure 4, utilizes the AC grid
reference frame to regulate the DC-link voltage and flow of reactive
power exchange (i.e., absorption and dissipation) in the PCC according
to the power flow direction of the rotor circuit of the wind turbine. The \( dq \)-to-abc and abc-to-\( dq \) voltage angles transformation based on the AC voltage synchroniza
tion is achieved with the help of phase lock loop (PLL) control strategy.

TURBINE CHARACTERISTICS AND
MODEL OF PMSG WIND TURBINE

Figure 5 shows the PMSG wind generator characteristics, for the
output power and rotational speed for different wind speeds,
based on the maximum obtainable power output of 1.0 p.u. at
1.0 p.u. rotational speed. The reference power \( P_{ref} \) of the wind
turbine is related to the rated power.

The rotating frame based on \( d-q \) reference for the model dynamics in the PMSG wind turbine is expressed as

\[
\frac{d\Psi_{sd}}{dt} = -V_{sd} - R_s I_{sd} - \omega_e \Psi_{sq} \tag{5}
\]

\[
\frac{d\Psi_{sq}}{dt} = -V_{sq} - R_s I_{sq} - \omega_e \Psi_{sd} \tag{6}
\]

Considering Equations (5) and (6),

\[
\Psi_{sd} = (L_{sd} + L_{md}) I_{sd} + \Psi_m \tag{7}
\]

\[
\Psi_{sq} = (L_{sq} + L_{mq}) I_{sq} \tag{8}
\]

where \( V_{sd} \) and \( V_{sq} \) are the voltages of the stator circuit, \( R_s \) is
the winding resistance of the stator, \( I_{sd} \) and \( I_{sq} \) are the currents
in the stator \( d \) and \( q \) reference frames, \( \omega_e \) is the rotational
speed of the wind generator, \( \Psi_{sd} \) and \( \Psi_{sq} \) are the flux linkages
of the stator circuit, \( I_{sd} \) and \( I_{sq} \) are the stator wind leakage
inductances, \( I_{md} \) and \( I_{mq} \) are the magnetizing inductances, and
\( \Psi_m \) is the flux linkage of the permanent magnet of the machine.

Substituting Equations (7) and (8) into (5) and (6), the differential
equations for the PMSG wind turbine are

\[
L_{sd} \frac{dI_{sd}}{dt} = -V_{sd} - R_s I_{sd} - \omega_e L_{q} I_{sq} \tag{9}
\]

\[
L_{sq} \frac{dI_{sq}}{dt} = -V_{sq} - R_s I_{sq} + \omega_e L_{d} I_{sd} + \omega_e \Psi_m \tag{10}
\]
The electrical torque with respect to number of pole pairs is given as

$$T_e = 0.5p(\Psi_m I_{sq} + (L_d - L_q) I_{sd} I_{sq})$$  \hspace{1cm} (15)$$

Figure 6 shows the controller of the machine side converter (MSC) and the GSC of the PMSG wind turbine. The MSC regulates both active and reactive power variables of the wind generator. The angle position rotor ($\theta_r$) helps in achieving the abc to dq transformation by the rotor speed of the wind generator. The d-axis current ($I_{sd}$) controls the active power ($P_s$) of the wind generator, while the q-axis current ($I_{sq}$) regulates the reactive power ($Q_s$) of the wind generator, respectively. The MPPT technique for the characteristic of the wind turbine, as shown in Figure 5, is employed in the reference active power ($P_{ref}$). Usually, the reference reactive power ($Q_{s}^*$) is fixed at 0 to obtain the effective operation of power factor 1. The three-phase reference voltages ($V_{sa}^*$, $V_{sb}^*$, and $V_{sc}^*$) are generated for the PWM switching, through the outputs of the current controller, based on the voltage references $V_{sd}^*$ and $V_{sq}^*$. The GSC control of the wind generator is also shown in Figure 6 and is regulated.
FIGURE 3 | The rotor side converter control circuit of the DFIG.

FIGURE 4 | The grid side converter control circuit of the DFIG.
by considering the $d-q$ rotating reference frame, based on the voltage of the grid as same as the speed of rotation. The Park transformation is used in converting ($I_{ga}$, $I_{gb}$, and $I_{gc}$) and ($V_{ga}$, $V_{gb}$, and $V_{gc}$) three-phase voltage and current of the grid into their rotating reference $d-q$ frame. The extraction of the phase angle ($\theta_g$) of the grid side is done by considering the PLL.

**EVALUATION OF THE SYSTEM PERFORMANCE**

**DFIG Wind Turbine Machine Parameters Evaluation**

Simulation was carried out considering the nine scenarios summarized in Table 1, for the DFIG machine parameters in p.u. values. This type is a severe three-phase fault of 100 ms happening at 0.1 s, with the circuit breakers operation sequence opening and reclosing at 0.2 and 1.0 s, respectively, on the faulted line at the terminals of the DFIG wind turbine. The system performance was evaluated using PSCAD/EMTDC environment. Some of the simulation results for the cases considered are shown in Figures 7–15B, based on the design machine parameters obtained from the manufacturers of the wind turbine.

In the first part of the analysis, cases 1–3 were considered. In case 1, the values of the machine parameters were the original values used by the DFIG wind generator. The machine parameters were changed for cases 2 and 3, considering a uniform increment for all the parameters. As shown in Figure 7, when the machine parameters were too high or too low, the DC-link voltage variable had more voltage dip with less recovery time. Since the DC-link voltage is related to the response of the active power of the wind generator, the same pattern of response could be observed in Figure 8 for the active power of the DFIG wind generator, where case 2 gave an improved performance. As shown in Figure 9, more reactive power was dissipated by increasing the machine parameters of the DFIG wind generator; consequently, an improved terminal voltage response was observed and is shown in Figure 10. However, in case 3, there was more overshoot of the terminal voltage variable compared with case 2. Figure 11 shows that lower machine parameters of the DFIG wind generator would result in less oscillation of the rotor speed variable during transient state; however, it could be trade off compared with the improved performance obtained for the other variables of the wind generator.

A further analysis was carried out considering the best values for case 2, where an improved performance of the DFIG wind turbine variables was obtained during transient state. The machine parameters were changed and kept constant for cases 4–9, as summarized in Table 1, to understand the behavior of the DFIG variables during grid fault. Some of the simulation results for this analysis are given in Figures 12–15B.

In case 4, the stator resistance of the DFIG wind turbine was changed, while keeping the other machine parameters constant based on the best obtained values in case 2. In case 5, the wound rotor resistance was changed, while in case 6, the angular moment of inertia was changed. In cases 7 and 8, the magnetizing inductance and the stator leakage inductance were changed, respectively. In case 9, the wound rotor leakage inductance was changed. It could be observed that varying...
the stator resistance has a huge effect on the DC-link voltage and active power of the DFIG as shown in Figures 12, 13. In addition, cases 5 and 6 have significant effect on the DC-link voltage of the wind generator. However, cases 7–9 have no effect on the performance of the DFIG DC-link voltage during transient state. As shown in Figure 14, there is much effect on the reactive power of the DFIG wind turbine, considering cases 4 and 6. However, more reactive power was dissipated for case 5, while cases 7–9 have no significant effect on the reactive power of the wind turbine. Cases 4 and 6 have more effect on the terminal voltage of the DFIG wind turbine, while cases 5–9 have no significant effect on the terminal voltage variable of the wind turbine. Case 5 gave the best performance of the rotor speed of the DFIG wind turbine.
TABLE 1 | DFIG machine parameters (Hitachi Heavy Equipment Construction, 2012).

| Case | Magnetizing inductance | Stator leakage inductance | Wound rotor leakage inductance | Stator resistance | Wound rotor resistance | Angular moment of inertia |
|------|------------------------|---------------------------|-------------------------------|------------------|-----------------------|--------------------------|
| 1    | 3.5                    | 0.15                      | 0.15                          | 0.01             | 0.01                  | 3.0                      |
| 2    | 3.9                    | 0.19                      | 0.19                          | 0.05             | 0.05                  | 3.5                      |
| 3    | 4.3                    | 0.23                      | 0.23                          | 0.09             | 0.09                  | 3.9                      |
| 4    | 3.9                    | 0.19                      | 0.19                          | 0.01             | 0.05                  | 3.5                      |
| 5    | 3.9                    | 0.19                      | 0.19                          | 0.05             | 0.01                  | 3.5                      |
| 6    | 3.9                    | 0.19                      | 0.19                          | 0.05             | 0.05                  | 3.5                      |
| 7    | 3.5                    | 0.15                      | 0.19                          | 0.05             | 0.05                  | 3.5                      |
| 8    | 3.9                    | 0.19                      | 0.15                          | 0.05             | 0.05                  | 3.5                      |
| 9    | 3.9                    | 0.19                      | 0.15                          | 0.05             | 0.05                  | 3.5                      |

Compared with the other cases. It can be seen from the above results that the variation of the stator resistance in case 4 has much influence on the transient stability of the DFIG during grid fault.

PMSG Wind Turbine Machine Parameters Evaluation

Simulation was carried out considering ten scenarios, as summarized in Table 2, for the PMSG machine parameters in p.u. values. The same fault conditions and scenarios used for the DFIG wind turbine in section (A) were considered for the PMSG wind turbine analysis in this section. This type is a severe three-phase fault of 100 ms happening at 10.1 s, with the circuit breakers operation sequence opening and reclosing at 10.2 and 11.0 s, respectively, on the faulted line at the terminals of the PMSG wind turbine. In the first part of the analysis, cases 1–3 were considered. The values of the machine parameters in case 1 were the original values used by the PMSG wind generator. The machine parameters were changed for cases 2 and 3, considering a uniform increment for all the parameters. Some of the simulation results are shown in Figures 15C–18B, based on the design machine parameters obtained from the manufacturers of the wind turbine.

As shown in Figures 15C,D, case 3 gave the best performance of the DC-link and active power of the PMSG wind turbine during transient state, with faster recovery, short settling time,
and less oscillations. The same behavior could be observed for the reactive power of the GSC, terminal voltage, and rotor speed of the PMSG wind turbine as shown in Figure 16, respectively. From the results, too low values of the machine parameters of the PMSG wind turbine led to poor performance compared with the use of higher values of the PMSG machine parameters. Thus, the best values of case 3 were used for further analysis of the PMSG wind turbine machine parameters in cases 4–10 by varying the parameters. In case 4, the Q: damper winding reactance was changed and other machine parameters were kept constant, while in case 5, the D: damper winding reactance was changed. In case 6, the D: damper winding resistance was changed, while in case 7, Q: unsaturated reactance was changed. The D: unsaturated reactance was changed in case 8, while in case 9, the stator leakage reactance was changed. Case 10 considered the variation of the stator winding resistance machine parameters of the PMSG wind turbine. A further analysis of the effect of the machine parameters was considered by varying these parameters for cases 4–10 as summarized in Table 2. Some of the simulation results are shown in Figures 17, 18.
| PMSG wind turbine (5 MVA) | Stator winding resistance | Stator leakage reactance | D: unsaturated reactance | Q: unsaturated reactance | D: damper winding resistance | Q: damper winding reactance | Q: damper winding resistance | Magnetic strength |
|---------------------------|---------------------------|-------------------------|-------------------------|-------------------------|-----------------------------|-----------------------------|-----------------------------|------------------|
| Case 1                    | 0.01                      | 0.064                   | 1.00                    | 0.70                    | 0.056                       | 1.00                        | 1.175                        | 1.4              |
| Case 2                    | 0.05                      | 0.068                   | 1.04                    | 0.74                    | 0.059                       | 1.04                        | 1.179                        | 1.44             |
| Case 3                    | 0.09                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 4                    | 0.09                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 5                    | 0.09                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.00                        | 1.183                        | 1.48             |
| Case 6                    | 0.09                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 7                    | 0.09                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 8                    | 0.09                      | 0.064                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 9                    | 0.09                      | 0.064                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |
| Case 10                   | 0.01                      | 0.072                   | 1.08                    | 0.78                    | 0.063                       | 1.08                        | 1.183                        | 1.48             |

**FIGURE 15** | (A) Terminal voltage of DFIG (cases 4–9). (B) Rotor speed of DFIG (cases 4–9). (C) DC-link voltage of PMSG (cases 1–3). (D) Active power of PMSG (cases 1–3).
influence on the PMSG variables. As shown in Figure 17C, the reactive power variable of the PMSG is much affected in case 10, compared with the other cases, while as shown in Figure 18A, cases 5 and 10 have minimal influence on the terminal voltage variable of the PMSG, compared with the other cases with no significant effect. Figure 18B shows that case 10 has a huge influence on the rotor speed of the PMSG wind turbine, by increasing its value compared with case 5, with less effect and the other cases with insignificant effect on the variable of the PMSG. From the results, it could be observed that the variation in the stator winding resistance of the PMSG wind turbine machine parameter...
in case 10 has great significance in its performance during grid fault.

CONCLUSION

The performance of two VSWTs, namely DFIG and PMSG, was investigated during severe grid fault, considering their machine parameters. The commercial values of the machine parameters (case 1) used in this study for both wind turbines, were obtained from Hitachi Laboratory, Hokkaido, Japan. When the machine parameters are way higher or lower than the reference commercial values, the performance of the DFIG wind turbine during transient state, was greatly affected. The moderate values of the machine parameters of the DFIG wind turbine are better for improved performance during grid fault. In addition, the stator resistance parameter has much influence on the variables of the DFIG wind turbines during transient state. Too low machine parameters affect the PMSG wind turbines during transient state. The stator winding resistance of the PMSG affects greatly the performance of the PMSG variables during transient state.

Therefore, for both wind turbine technologies, the stator winding resistance machine parameter has a significant effect on the wind turbine compared with the other parameters. Consequently, a careful selection of the stator winding resistance based on the design of the wind turbine could help improve the performance of the wind turbines.

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DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

KO did the conceptualization, literature review, simulation results, analysis, and writing of the paper. SA did part of the literature review and sponsorship of the paper. MA did part of the literature review and sponsorship of the paper. All authors contributed to the article and approved the submitted version.

FUNDING

The work is sponsored by the National University of Science and Technology, Muscat, Oman and the Nisantasi University, Istanbul, Turkey.
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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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