Transient stability improvement of microgrids by using Resistive type SFCL and series active power filters

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ABSTRACT. Nowadays Microgrids have placed a major role because usage of electrical energy is increased. In this work Microgrid having three DGs photo voltaic energy, wind energy, and fuel cell. Here in a microgrid, the frequency and powers are matched on the source side and load side by using PLL measurement circuits. Due to the combining of three DGs fault current levels are increased, that fault current is limited using R-SFCL (Resistive type superconducting fault current limiter) R-SCL gives a very fast response and limits fault current magnitudes in the first half cycle. R-SFCL is not improving complete transient stability because the presence of reactive components in the transmission line so voltage profile is not balanced, at that situation by using Series active power filters we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids. Series active power filters are introducing the reactive components into the transmission line then transmission line reactive power is balanced. This planned effort is done using MATLAB / Simulink.

RÉSUMÉ. De nos jours, les microgrilles jouent un rôle majeur lorsque la consommation d'énergie électrique augmente. Dans ce travail, le micro-réseau dispose de trois générations distribuées (DG): énergie photovoltaïque, énergie éolienne et piles à combustible. Ici, dans un micro-réseau, la fréquence et les puissances sont adaptées du côté de source et du côté de charge en utilisant des circuits de mesure PLL. En raison de la combinaison de trois DGs, les niveaux de courant de défaut sont augmentés, ce courant de défaut est limité par R-SFCL (limiteur de courant de défaut supraconducteur de type résistif), R-SCL fournit une réponse très rapide et limite l'amplitude du courant de défaut dans le premier demi-cycle. Le R-SFCL n'améliore pas la stabilité transitoire complète car la ligne de transmission contient des composants réactifs et la distribution de la tension est déséquilibrée, dans cette situation, en utilisant des filtres de puissance active en série, nous équilibrons le profil de tension, augmentons la capacité de transfert de puissance, réduisons les harmoniques et améliorons la stabilité transitoire dans les microgrilles. Les filtres de puissance active en série introduisent les composants réactifs dans la ligne de transmission, puis la puissance réactive de la ligne de transmission est équilibrée. Cet projet planifié est réalisé à l'aide de MATLAB / Simulink.

KEYWORDS: distributed generation (DG), resistive type superconducting fault current limiter (R-SFCL), phase locked loop (PLL), series active power filter (SAPF).

1. Introduction

In this work Microgrid having three DGs photo voltaic energy, wind energy, and fuel cell. Here in a microgrid, the frequency and powers are matched on the source side and load side by using PLL measurement circuits. Due to the combining of three DGs fault current levels are increased, that fault current is limited using R-SFCL (Resistive type superconducting fault current limiter) R-SFCL gives a very fast response and limits fault current magnitudes in the first half cycle. R-SFCL is not improving complete transient stability because the presence of reactive components in the transmission line so voltage profile is not balanced, at that situation by using Series active power filters we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids R-SFCL gives a very fast response and limit fault current magnitudes in the first half cycle generally it creates low impedance path at microgrid is in healthy condition and it creates high impedance path at faulty conditions due to that high impedance fault currents are limited Generally, conservative protective devices like circuit breaker and relays have not protected the system in a good manner, because conservative protective devices having some time delay so it allows one to two cycles of short-circuit currents due to that short-circuit currents the system is damaged. R-SFCL limit fault current within the first half cycle then the system is protected from abnormal conditions. R-SFCL having the following advantages less weight, occupies less space and high efficiency. To maintain complete transient stability I added series active power filters (SAPF) into the transmission lines generally series active power filters inject the reactive components into the transmission lines; these reactive components reduce the reactive power in the transmission line. The main aim of the series active power filter is to balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in microgrids is not improving complete transient stability because presence of reactive components in the transmission line so voltage profile is not balanced and power transfer capability is reduced, at that situation by using SAPF we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids. SAPF having a power source, load, converter, hysteresis controller, injection transformer and filter. SAPF connected in between the source and load SAPF is mainly used for filtering current harmonics, reduce voltage distortions (sag, swell). In SAPF hysteresis controller is always compare operating voltage with a reference voltage and it generates gate pulses that gate pulse gives to inverter then inverter send that compensated voltages to a transmission line with the help of injection transformer the structure of the series active power filter. Here hybrid system consists three DGs Fuel cell, P-V power, and Wind power these three

DGs are interconnected with main grid, here fuel cell can supply 10 KW, P-V power can supply 250KW and Wind power supply 150KW to loads. we connected three 3-phase inductive loads these capacities are (150+j25) KVA, (450+j30) KVA and (200+j20) KVA respectively. Here rating of the transmission line is (0.27+j0.347) Ω/km frequency of the microgrid is designed to50 Hz, voltage levels at transmission level is10.5 KV and at distribution level 415 volts. This distribution level 415 volts gives to the loads. Microgrids have placed a major role because usage of electrical energy is increased. In this work Microgrid having three DGs photo voltaic energy, wind energy, and fuel cell. Here in a microgrid, the frequency and powers are matched on the source side and load side by using PLL measurement circuits. Due to the combining of three DGs fault current levels are increased, that fault current is limited using R-SFCL (Resistive type superconducting fault current limiter) R-SCL gives a very fast response and limits fault current magnitudes in the first half cycle. R-SFCL is not improving complete transient stability because the presence of reactive components in the transmission line so voltage profile is not balanced, at that situation by using Series active power filters we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids. Series active power filters are introducing the reactive components into the transmission line then transmission line reactive power is balanced. Generally, conservative protective devices like circuit breaker and relays have not protected the system in a good manner, because conservative protective devices having some time delay so it allows one to two cycles of short-circuit currents due to that short-circuit currents the system is damaged. R-SFCL limit fault current within the first half cycle then the system is protected from abnormal conditions. R-SFCL having the following advantages less weight, occupies less space and high efficiency. It has one shunt element (Inductive/Resistive), this element is protected Resistive type superconducting fault current limiter from abnormal conditions. In microgrid we create one LLL-G fault in wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant short circuit current is raises up to 1250 amperes. When R-SFCL is connected in the power system network then fault current is reduces to 800 amps, because R-SFCL acts as a high impedance path at the time of fault. When SAPF is connected to the power system network then fault current is reduces to 700 amps, because voltage levels are compensated. R-SCL gives a very fast response and limits fault current magnitudes in the first half cycle. R-SFCL is not improving complete transient stability because the presence of reactive components in the transmission line so voltage profile is not balanced, at that situation by using Series active power filters (SAPF) we balance the voltage profile, increases the power transfer capability, reduce the harmonics.

Integrated Microgrid protection is very difficult because the combination of two or more DGs, these DGs interconnection with the main grid is also difficult to process and identification of fault is difficult. In the process of distributed generators interconnection short-circuit currents are increased this short circuit current is known as fault currents, due to that short-circuit currents voltage levels are reduced and power transfer capability is reduced finally system not having stability in high voltage applications. At that situation our conservative protective devices like circuit

breaker and relays have not protected the system in a good manner, generally conservative protective devices having some time delay so it allows one to two cycles of short circuit currents. To overcome these disadvantages Resistive type superconducting fault current limiter and Series active power filters are introduced.

R-SFCL gives a very fast response and limit fault current magnitudes in the first half cycle generally R-SFCL creates low impedance path at microgrid is in healthy condition and it creates high impedance path at faulty conditions due to that high impedance fault currents are limited. Moon Fil-jong said R-SFCL is a good device to reduce short circuit currents within the first half cycle (Moon & Kim, 2013). X Ying. said the operation, advantages, and applications of R-SFCL (Liu *et al.,* 2015).

To maintain complete transient stability I added series active power filters (SAPF) into the transmission lines generally series active power filters inject the reactive components into the transmission lines; these reactive components reduce the reactive power in the transmission line. The main aim of the series active power filter is to balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids. Here fault is created at wind distributed generator using MATLAB/Simulink. The obtained results are meet our requirement the system is working effectively (Sung *et al.,* 2009; Tsai, 2004).

2. Super conducting fault current limiter (Resistive type)

Inside R-SFCL gives a very fast response and limit fault current magnitudes in the first half cycle generally it creates low impedance path at microgrid is in healthy condition and it creates high impedance path at faulty conditions due to that high impedance fault currents are limited.

Referred from (Moon *et al.,* 2013). And (Lo *et al.,* 2011). Mathematical modelling of R-SFCL is

$$
R(t) = \begin{cases} 0 & t < t_0 \\ R_{SFCL}\left[1 - \exp(-\dfrac{t - t_0}{\tau})\right]^{\frac{1}{2}} & t_0 \leq t < t_1 \\ a_1(t - t_1) + b_1 & t_1 \leq t < t_2 \\ a_2(t - t_2) + b_2 & t_2 \leq t \end{cases}
$$

RSFCL = normal resistance of SFCL

τ = time constant

t0, t1 and t2 are the different time intervals

a1, a2, b1 and b2 are the different coefficients

Figure. 1 indicates the recovery and quench characteristics of R-SFCL at different time intervals, at each interval R-SFCL resistance is changed.
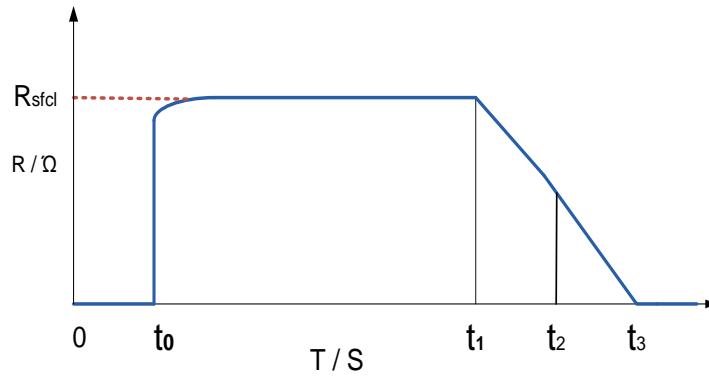
Figure 1. Recovery and quench characteristics of R-SFCL

Generally, conservative protective devices like circuit breaker and relays have not protected the system in a good manner, because conservative protective devices having some time delay so it allows one to two cycles of short-circuit currents due to that short-circuit currents the system is damaged. R-SFCL limit fault current within the first half cycle (Chenetal, 2014). then the system is protected from abnormal conditions. R-SFCL having the following advantages less weight, occupies less space and high efficiency. It has one shunt element (Inductive/Resistive), this element is protected Resistive type superconducting fault current limiter from abnormal conditions as shown in figure 2.
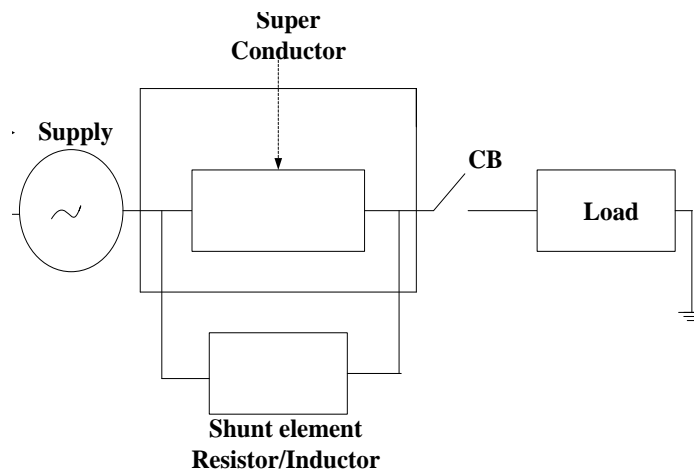
Figure 2. Super conducting fault current limiter (Resistive type)

3. Series active power filters

R-SFCL is not improving complete transient stability because presence of reactive components in the transmission line so voltage profile is not balanced and power transfer capability is reduced, at that situation by using SAPF we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability (Kim *et al.,* 2004). in Microgrids. SAPF having a power source, load, converter, hysteresis controller, injection transformer and filter. SAPF connected in between the source and load SAPF is mainly used for filtering current harmonics, reduce voltage distortions (sag, swell). In SAPF hysteresis controller is always compare operating voltage with a reference voltage and it generates gate pulses (Ribeiro & Barbi, 2006), that gate pulse gives to inverter then inverter send that compensated voltages to a transmission line with the help of injection transformer the structure of the series active power filter is shown in figure 3. In SAPF hysteresis controller operation depends upon the following equation.

$$V_{INJ} = V_L - V_S$$

V_{INJ} = Injected voltage

V_L = Voltage at load

V_S = Voltage at source
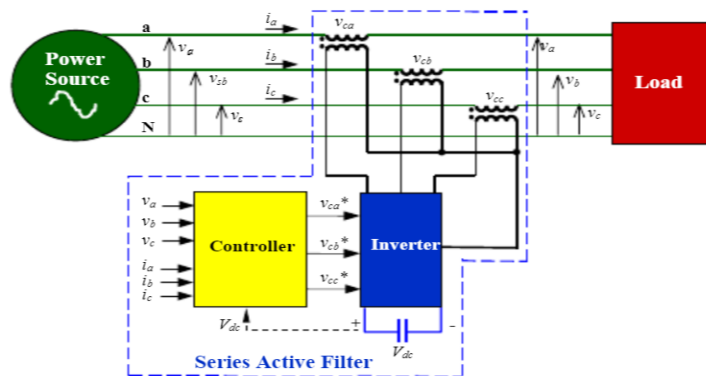
Figure 3. Series active power filter

4. Hybrid power system

This hybrid system consists three DGs Fuel cell, P-V power, and Wind power these three DGs are interconnected with main grid, here fuel cell can supply 10 KW, P-V power can supply 250KW and Wind power supply 150KW to loads.

In this power system network, we connected three 3-phase inductive loads these capacities are (150+j25) KVA, (450+j30) KVA and (200+j20) KVA respectively.

Here rating of the transmission line is (0.27+j0.347) Ω/km frequency of the microgrid is designed to50 Hz, voltage levels at transmission level is10.5 KV and at distribution level 415 volts. This distribution level 415 volts gives to the loads as shown in the figure. 4.
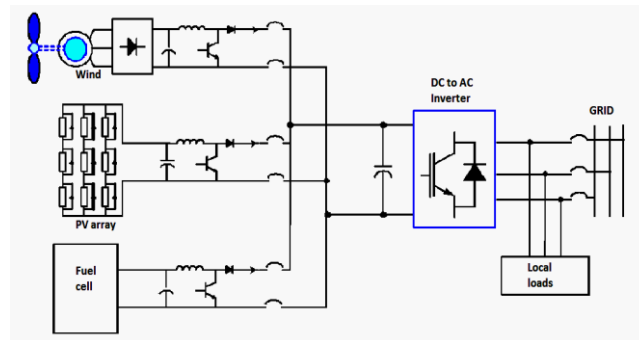

Figure 4. Hybrid power system

5. Simulation model

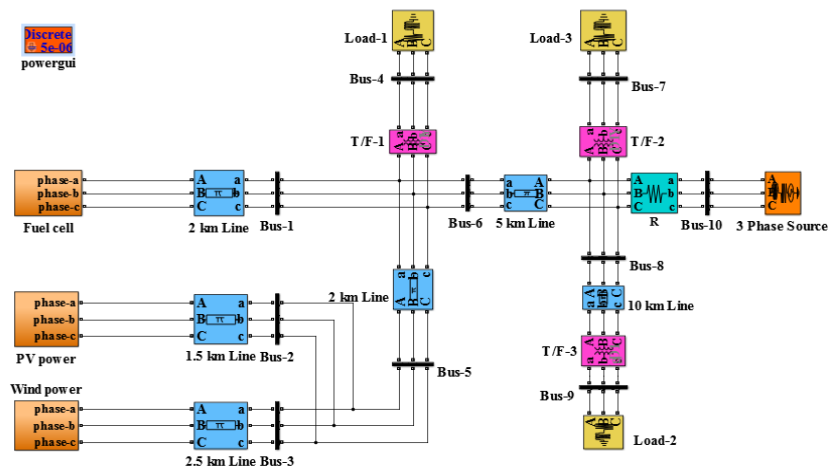This microgrid is developed using MATLAB/Simulink, as compared to PSPICE and EMTP Matlab having so many advantages. Figure.5 shows the Simulink diagram of microgrid without fault.

Figure 5. Simulink diagram of microgrid without fault

Figure.6 shows the Simulink diagram of a microgrid with LLL-G fault, R-SFCL and series active power filter (SAPF).
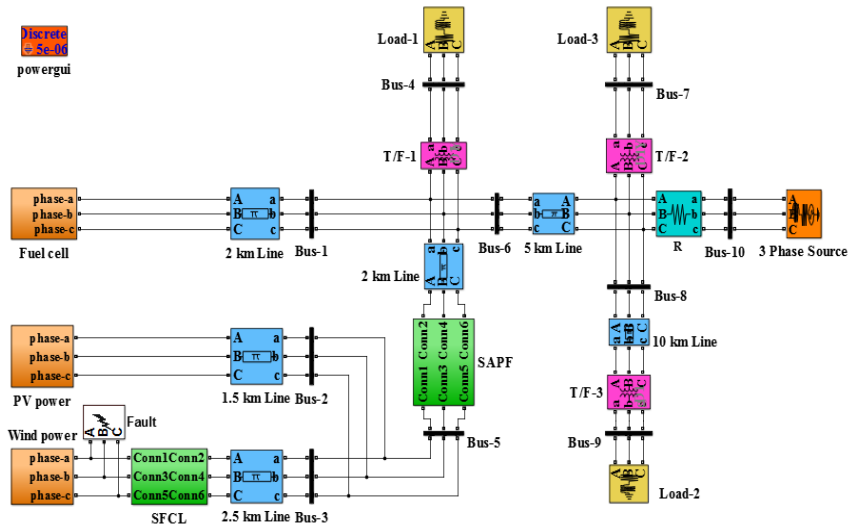
Figure 6. Simulink diagram of a microgrid with LLL-G fault, R-SFCL and SAPF

6. Simulation results

In microgrid we create one LLL-G fault in wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant short circuit current is raises up to 1250 amperes as shown in the figure 7.
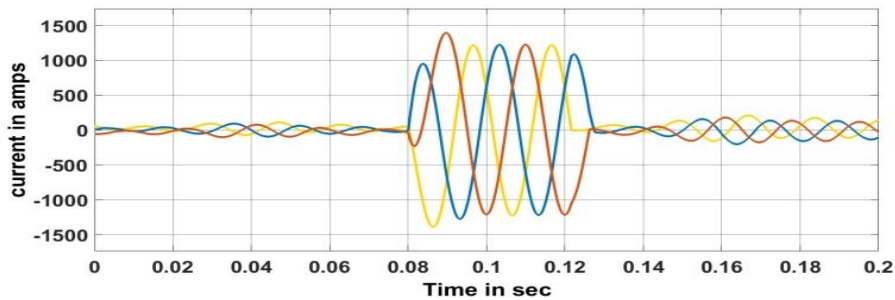
Figure 7. Short circuit currents near the fault

When R-SFCL is connected in the power system network then fault current is reduces to 800 amps, because R-SFCL acts as a high impedance path at the time of fault as shown in the figure 8.
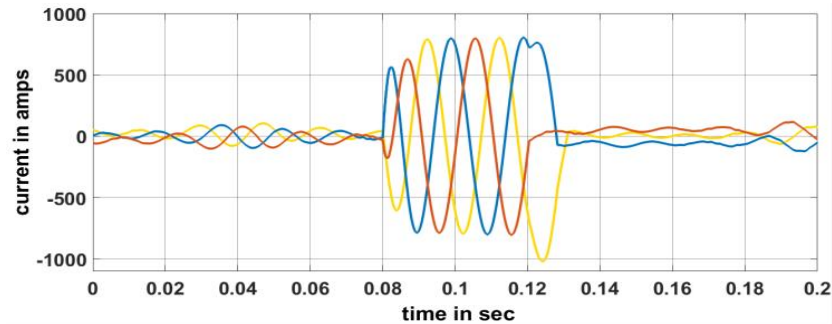
Figure 8. Short circuit currents near the fault using R-SFCL

When SAPF is connected to the power system network then fault current is reduces to 700 amps, because voltage levels are compensated as shown in the figure 9.
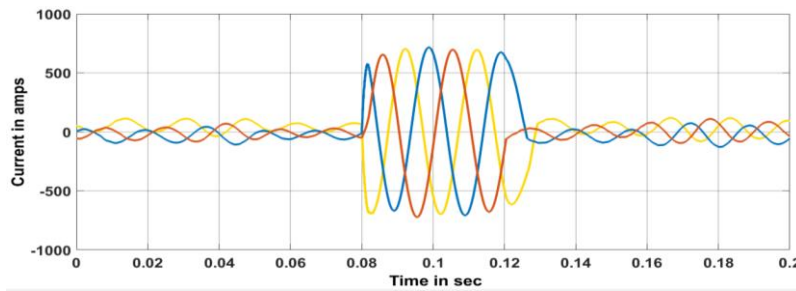
Figure 9. Short circuit currents near the fault using R-SFCL and SAPF

In microgrid we create one LLL-G fault in wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant voltage levels are reduced from 10.5 KV as shown in the figure 10.
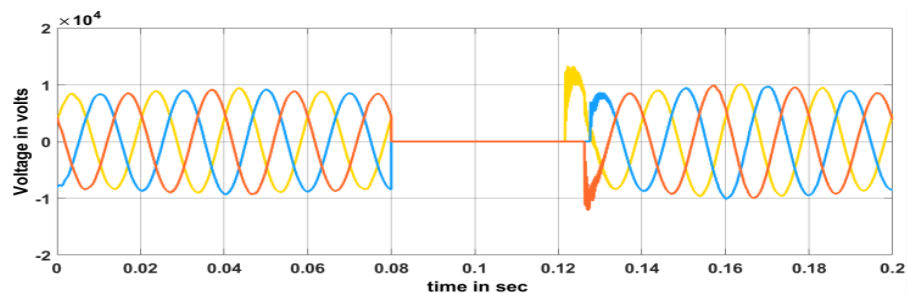
Figure 10. The voltage at fault location

Whenever R-SFCL is connected in the power system network, the fault current is reduced then voltages are nearly compensated. Due to the presence of reactive components voltage levels are not completely compensated as shown in the figure 11.
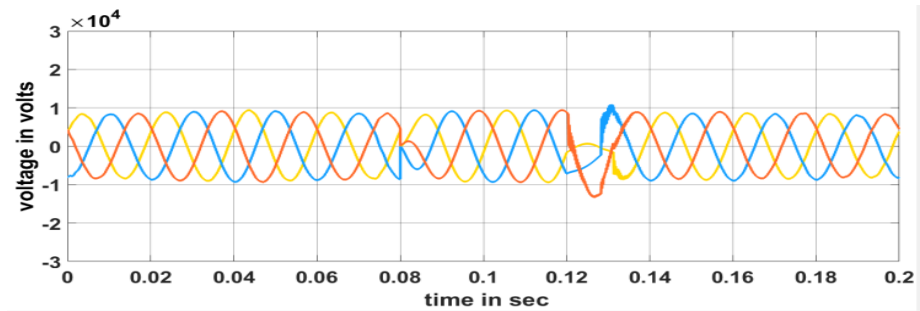
Figure 11. The voltage at fault location using R-SFCL

In microgrid we create one LLL-G fault at wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant maximum voltage per phase is reduced at load 1, load 2 and load 3 as shown in the figure 12.
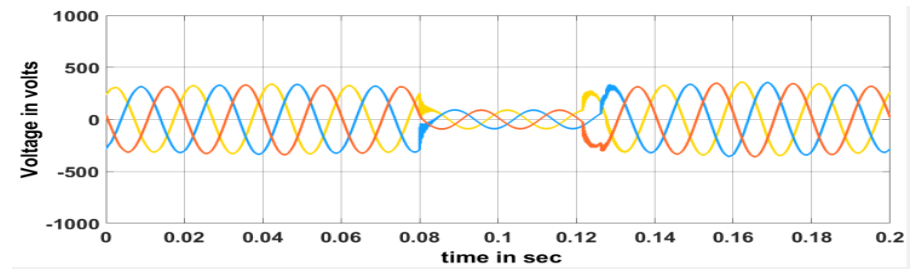
Figure 12. voltages at load-1, load-2 and load-3
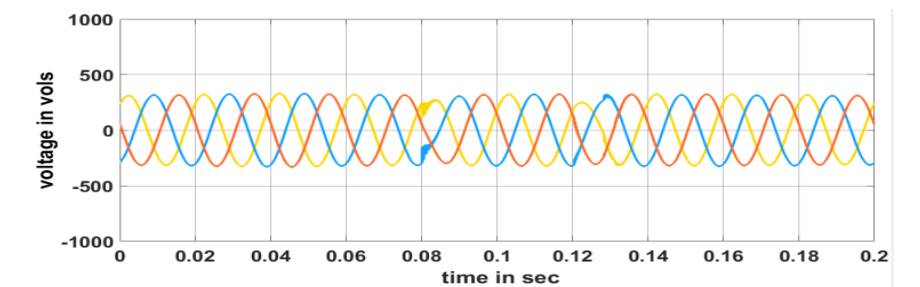
Figure 13. voltages at load-1, load-2 and load-3 using R-SFCL

When R-SFCL is connected in the power system network, the fault current is reduced then load voltages are nearly compensated. Due to the presence of reactive components load voltages are not completely compensated as shown in the figure 13.

Whenever SAPF is connected in the power system network then fault current is reduces as well as load voltages are completely compensated because of the injection of reactive components in the transmission line as shown in the figure 14.
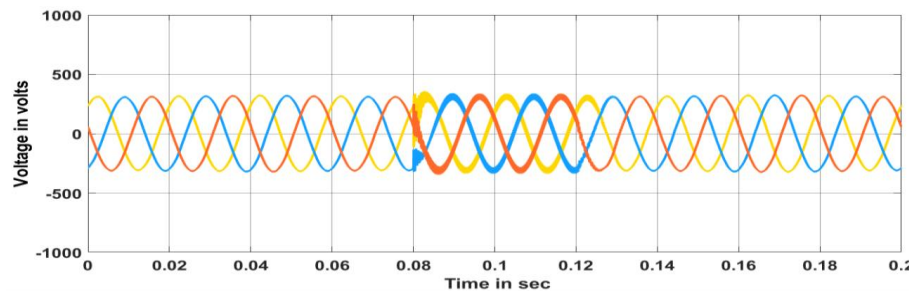

Figure 14. voltages at load-1, load-2 and load-3 using R-SFCL and SAPF

In microgrid we create one LLL-G fault at wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant voltage levels are reduced and fault currents are increases then power levels are reduced from (150+j25) KVA as shown in the figure 15.
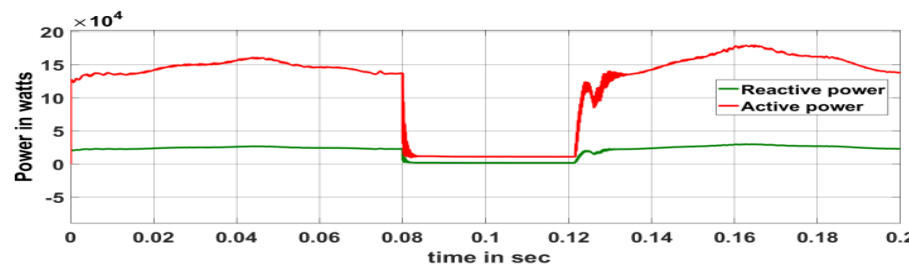

Figure 15. Under fault power on load-1

When R-SFCL is connected in the power system network, the fault current is reduced and load voltages are nearly compensated. Then power levels are nearly compensated Due to the presence of reactive components load power levels are not completely compensated as shown in the figure 16.

When SAPF is connected in the power system network then fault current is reduces as well as load voltages are completely compensated because injection of reactive components in the transmission line, finally power transfer capability increases as shown in the figure 17.
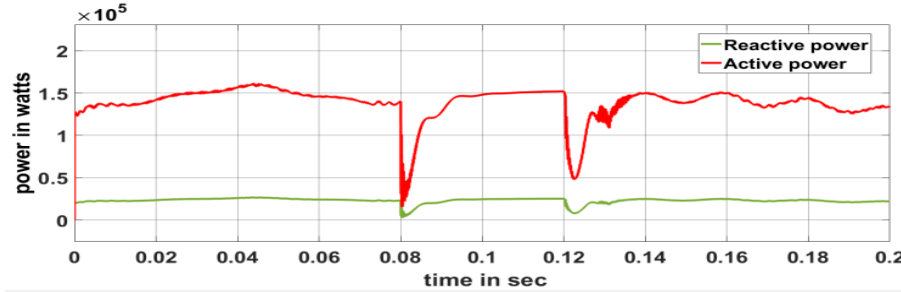
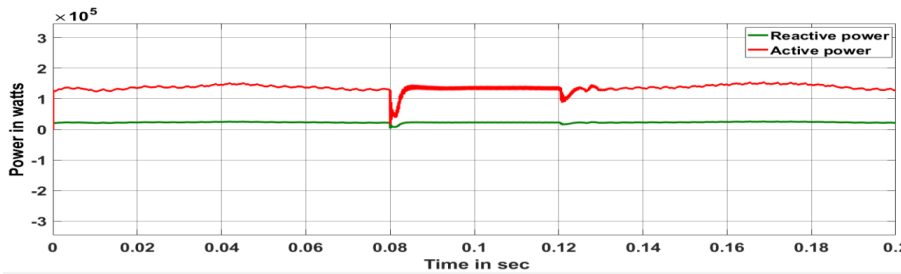*Figure 16. Under fault power on load-1 using R-SFCL*

Figure 17. Under fault power on load-1 using R-SFCL and SAPF

In microgrid we create one LLL-G fault at wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant voltage levels are reduced and fault currents are increases then powers are reduced from (450+j30) KVA as shown in the figure 18.
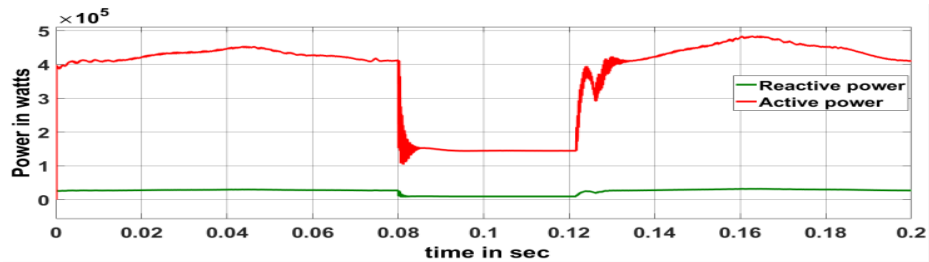

Figure 18. Under fault power on load-2

Whenever R-SFCL is connected in the power system network, the fault current is reduced and load voltages are nearly compensated. Then power levels are nearly

compensated Due to the presence of reactive components load power levels are not completely compensated as shown in the figure 19.
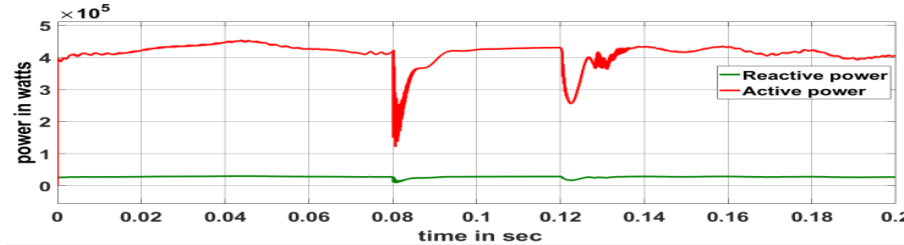

Figure 19. Under fault power on load-2 using R-SFCL

Whenever SAPF is connected in the power system network then fault current is reduces as well as load voltages are completely compensated because injection of reactive components in the transmission line, finally power transfer capability increases as shown in the figure 20.
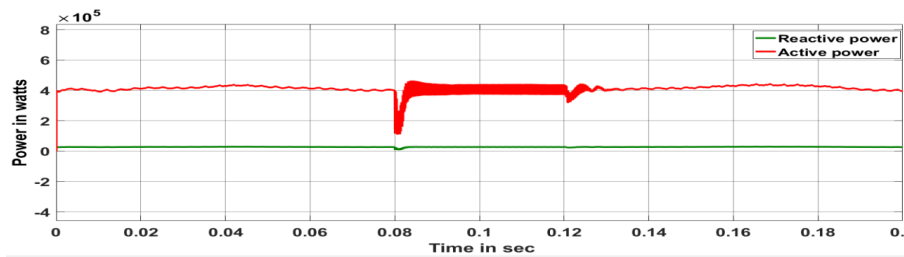

Figure 20. Under fault power on load-2 using R-SFCL and SAPF

In microgrid we create one LLL-G fault at wind distributed generation; the fault time is 0.08 sec to 0.12 sec at that instant voltage levels are reduced and fault currents are increases then power levels are reduced from (200+j20) KVA as shown in the figure 21
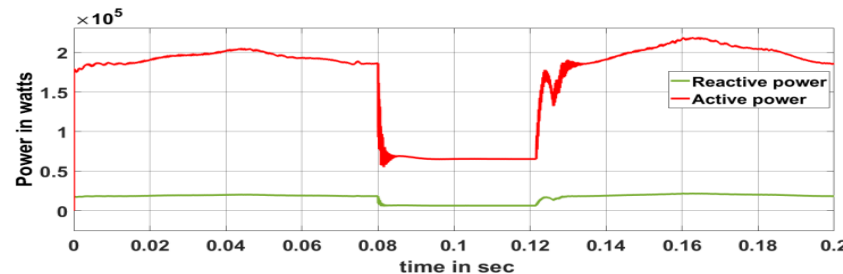

Figure 21. Under fault power on load-3

R-SFCL is connected in the power system network, the fault current is reduced and load voltages are nearly compensated. Then power levels are nearly compensated Due to the presence of reactive components load power levels are not completely compensated as shown in the figure 22.
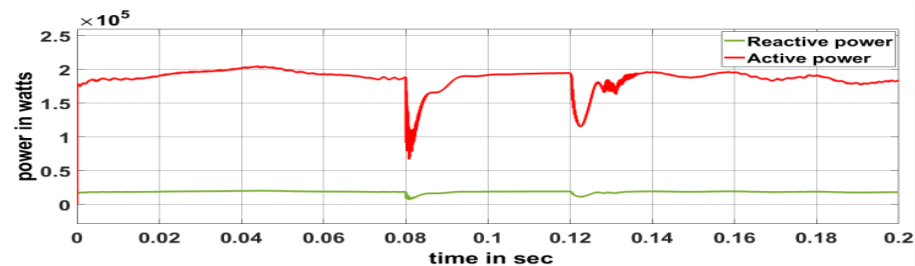

Figure 22. Under fault power on load-3 using R-SFCL

SAPF is connected in the power system network then fault current is reduces as well as load voltages are completely compensated because injection of reactive components in the transmission line, finally power transfer capability increases as shown in the figure 23.
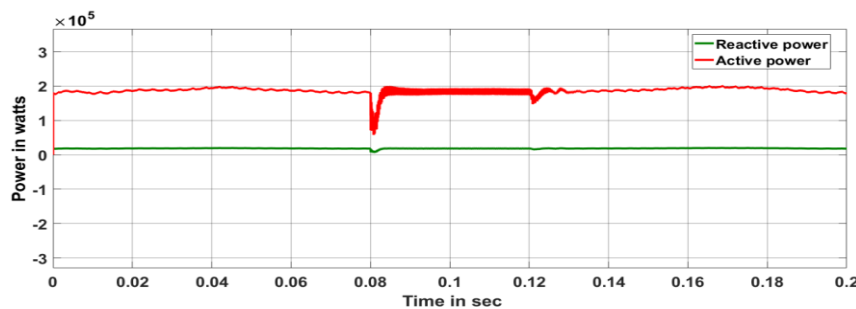

Figure 23. Under fault power on load-3 using R-SFCL and SAPF

7. Conclusion

In this work Microgrid having three DGs photovoltaic energy, wind energy, and fuel cell. Due to the combining of three DGs fault current levels are increased, that fault current is limited using R-SFCL (Resistive type superconducting fault current limiter) R-SCL gives a very fast response and limits fault current magnitudes in the first half cycle. R-SFCL is not improving complete transient stability because the presence of reactive components in the transmission line so voltage profile is not balanced, at that situation by using Series active power filters (SAPF) we balance the voltage profile, increases the power transfer capability, reduce the harmonics and improvement of transient stability in Microgrids.

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