efficients (SA) of phase A for normal condition and LL faults in phases A-B, B-C & C-A respectively have been presented in Table 3.

Tab. 3. SA at Different Line to Line fault conditions

SA of Ia_N	SA of ia_ab	SA of ia_bc	SA of ia_ca
-0.020	-0.028	-0.051	-0.020
-0.020	-0.028	-0.051	-0.020
-0.020	-0.028	-0.051	-0.020
-0.0202	-0.027	-0.050	-0.020
-0.021	-0.023	-0.044	-0.021
-0.132	-0.068	-0.068	-0.132
0.079	-0.283	-0.253	-0.395
-0.262	-0.881	-0.484	-0.896
-2.867	-3.833	-3.414	-3.843

Variation of skewness of approximate co-efficient with respect different DWT levels has been shown in Fig. 3.

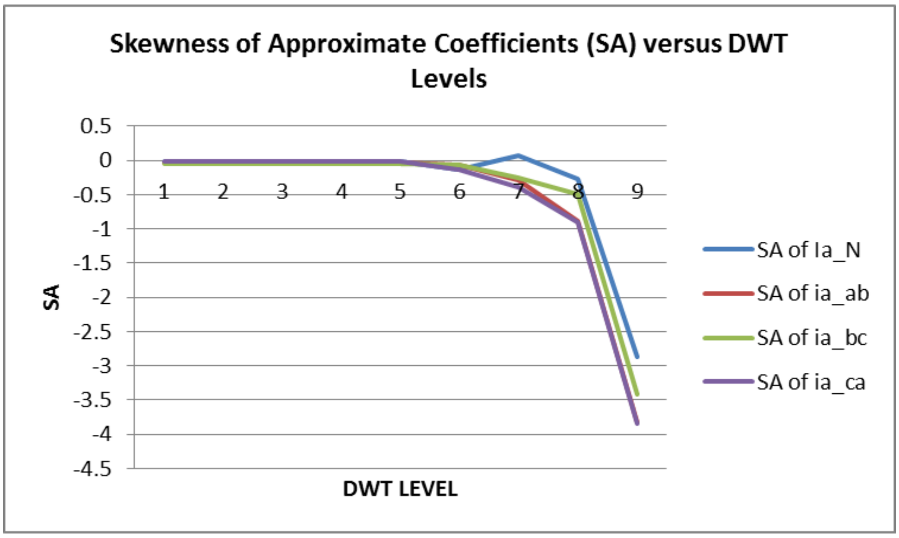

Fig. 3 SA versus DWT Levels

It shows that SA is different for different fault conditions at DWT level eight and nine. At 8th and 9th level SA is lowest during healthy condition. At these levels SA deceases during line to line short circuit fault and is minimum when line to line short circuit fault occurs in between phases A & B and phase C & A; in both cases Phase A is faulty phase. When fault occurs in between phase B & C and phase A remains healthy, SA at 8th and 9th level is less than that of normal but greater than SA when Phase A becomes faulty. Thus monitoring of SA at DWT level nine may be an effective tool for identification of faulty phases.

Skewness values for detailed coefficients (SD) of phase A for normal condition and LL faults in phases A-B, B-C & C-A, respectively, have been presented in Table 4.

Tab. 4. SD at Different Line to Line fault conditions

SD of Ia_N	SD of ia_ab	SD of ia_bc	SD of ia_ca
-1.612	-8.799	-6.759	-8.799
-0.102	-0.996	-0.359	-0.756
0.035	0.240	-0.016	0.056
0.062	0.748	0.575	0.225
-0.097	0.129	0.039	-0.102
-0.038	-0.027	-0.048	-0.038
-0.027	-0.004	-0.004	-0.027
0.033	0.073	-0.091	0.032
0.416	0.271	0.061	0.416

Variation of skewness of detailed co-efficient with respect different DWT levels has been shown in Fig. 4.

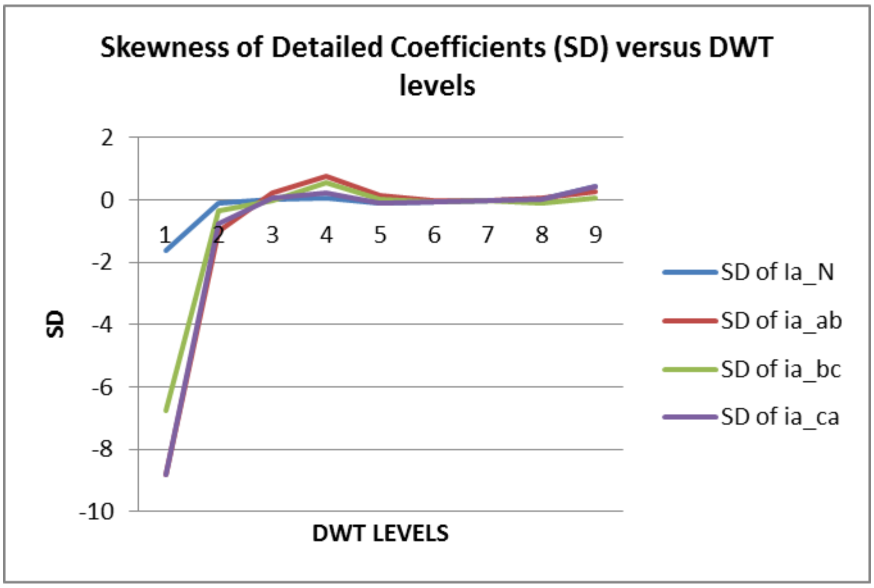

Fig. 4 SD versus DWT Levels

It shows that SD is different for different fault conditions at 1st level of DWT and then becomes equal and almost constant. At 1st level, SD is maximum during healthy condition i.e. when all phases A, B and C remain healthy. At first level SD deceases during line to line short circuit fault and is minimum when line to line short circuit fault occurs in between phases A & B and phase C & A; in both cases Phase A is faulty phase. When fault occurs in between phase B & C and phase A remains healthy, SD at 1st is less than that of normal but greater than SD when Phase A becomes faulty. Thus, monitoring of SD at 1st DWT level may be an effective tool for identification of faulty phases.

6. Discussion

In this work, at normal and line to line fault condition DC component, Total Harmonic Distortion and Skewness values have been assessed. The summary of the observations has been presented in Table 5.

Tab. 5. Summary of the Observations Made on Normal and Line to Line Fault Condition

Condition	DC components	THD	Effect in phase A	
			SA	SD
Normal	No specific relation of pattern found	Almost same in all phases	High at 8th and 9th level	High at 1st level
LL fault in Phases A & B		Lowest in phase C	Low at 8th and 9th level	Low at 1st level
LL fault in Phases B & C		Lowest in phase A	Medium at 8th and 9th level	Medium at 1st level
LL fault in Phases C & A		Lowest in phase B	Low at 8th and 9th level	Low at 1st level
Inference	No decision can be made	Lowest value indicates healthy phase referring other two faulty	Low indicates that the phase is faulty	Low indicates that the phase is faulty

Comparative analysis has been made using the observations of section 4 and 5. DC component is found not suitable for decision making. During fault, the phase showing lowest THD value refers to healthy phase. For SA, 8th and 9th level is suitable for fault detection; lowest value is indicating fault condition. For SD, 1st level is suitable for fault detection; lowest value is indicating fault condition.

In other works, described in section 1, many attempts are found for detection and classification of fault which was mainly deals with magnitude and phase comparison. Most of them lack in giving information of the non-stationary behavior of the waveforms and harmonics related information. This limitation has been overcome by this work which gives measurement of harmonic distortion and Skewness values along with detection of fault.

Conclusion

In this paper, solar PV unit has been connected through a microgrid consisting of an inverter and step up transformer with conventional grid and local electrical load unit. Signals from the output of inverter unit have been used for assessment of load bus line to line short circuit fault. Output currents of the inverter has been captured and analyzed; DC components and Total harmonics distortion of line currents are derived both at normal condition and fault condition. Then, detailed and approximate coefficients at different discrete wavelet decomposition levels have been compared between normal and fault conditions by their skewness values. It is found that DC component is not suitable for fault analysis. However, changes in THD value can be used for fault diagnosis. Among different decomposition level 8th and 9th levels for SA and 1st level for SD are found suitable for fault diagnosis. The method can also be extended for diagnosis of faults in other part of the microgrid.

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