Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2021, 8(12):190-197

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Operation and Protection of Electrical Grid with Distributed Generators

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Abstract This paper presents a novel technique for protection of an electrical grid with distributed generators. The technique uses the current statues for all the three phases at the two sides of each transmission line terminals. The status measures the direction of an incoming and outgoing current at all transmission line. The proposed technique is applied on a part of 11 kV network of the network which is connected to wind farm; the simulating is done by using MATLAB/ SIMIULINK soft ware. The proposed technique depends on standalone decision at the two terminals of transmission line. The results indicate that the proposed technique is stable and reliable to detect, classify and determine the location of the various types of faults.

Keywords instantaneous voltage and current measurements, wind farm, system protection terminals, transmission line and correlation factor

1. Introduction

System disturbances in power systems are a challenging problem for the utility industry because of the large scale and the complexity of the power system. When a major power system disturbance occurs, protection and control actions are required to stop the power system degradation, restore the system to normal state, and a minimize the impact disturbance. The present control actions are not designed for a fast-developing disturbance and may be too slow. Further, dynamic simulation software is applicable only for off-line analysis. The operator must therefore deal with a very complex situation and rely on heuristic solutions and policies. Today, local automatic actions protect the system from the propagation of the fast developing emergencies. However, local protection systems are not able to consider the overall system, which may be affected by the disturbance [1]. From the technology perspective, there has been a spectacular growth in the past twenty year from advances in computer and communication sciences. Together with the emergence of the synchrophasor technology, these advances provide the opportunity for feasible and economical implementation of controls in the large electric power system. Many recent publications have analyzed the requirements. The setup and applications of comprehensive area systems are introduced in [2-3]. A power system is not only capable to meet the present load but also has the flexibility to meet the future demands. A power system is designed to generate electric power in sufficient quantity, to meet the present and estimated future demands of the users in a particular area, to transmit it to the areas where it will be used and then distribute it within that area, on a continuous basis. To ensure the maximum return on the large investment in the equipment, which goes to make up the power system and to keep the users satisfied with reliable service, the whole system must be kept in operation continuously without major breakdowns. Transmission line protection based on alienation technique is proposed in [6]. while the alienation factor is related to correlation factor but in this paper the detection of the fault is absolute. The modern electricity supply network is a complex system, the wind farms involved in this system as one of the most important sources of renewable energy. In this paper we will apply protection technology on system which have distributed generator. This technique uses the multiplication factor between current status measurements at the two sides of each transmission line. The measured signals are used to calculate the I status at each transmission lines.

2. System Description

A part of 11 kV network of the network which is connected to distributed generator. Figure (1) shows the single line diagram of the selected eleven buses, the single line diagram includes tow power stations, (two parallel) transmission lines, seven load buses, and distributed generator

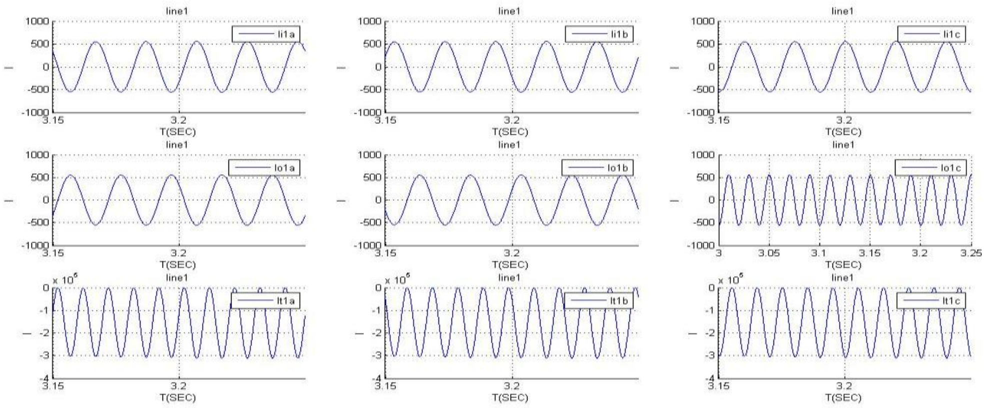

Figure 1: schematic diagram of the grid

3. The Proposed Technique

This technique is based on calculation current status each phase at two sides of each line (I_{ins}, I_{ons}).

a) Read instantaneous values of current signals of two sides of each transmission line ($i_{1s,}$ i_{2s}) for each phase ''s'' Where ($i_{is,}$ i_{os}) are the current signals at the sending and receiving ends respectively.

b) Calculating the Multiplication Factor (MF_s)

The first Multiplication factor (MF_1) is calculated between two successive windows (each window has m samples) of current signal sending end (i_{i1s}) and current signal (i_{o1s}) of phase ''s''. As shown in equation (1).

$MF_s = (1/m) \sum^{m} I_{ins} (k) \times I_{ons} (k)$ (1).

Where (Iins (k)) is current status at certain sample k, at the sending and (I_{ons} (k)) is current status at certain sample k at receiving ends of each transmission line respectively.

MF_s is Multiplication factor

m is the number of samples per power frequency cycle (20 ms)

''*s*'' is phase and **''*n*''** is number of line.

The sign of the multiplication factor depend on the status between the measured current signals at the transmission line terminals. The current signal at sending end is different than the current signal at the receiving end by an angle smaller than 90 degree for all phases, so that the Multiplication factor (***MF_s***) for all phases are equal and positive value between (0 and +ve). While the Multiplication factor (***MF_s***) for all phases have negative values between (0 and -ve) at the receiving end. As shown in figure (2)

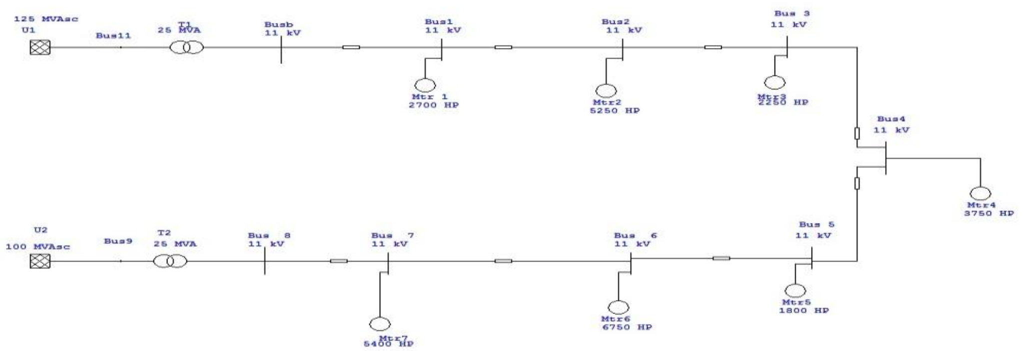

Figure 2: Values of (i_{i1s}, i_{o1s}) at two ends of the transmission line1 in case of normal operation

This technique is used as protection according to the next procedures:

a- Remote Terminal Unit (RTU): Remote Terminal Unit (RTU) is a microprocessor-based device connected to sensors, transmitters or process equipment for the purpose of remote telemetry and control. The RTU's receive the current signals from the two sides of each transmission line. The RTU's are able to run complete or parts of distributed control algorithms and can communicate directly with other RTUs, substation equipment and system protection center (SPC) as shown in figure (3).

b- Phasor Data Concentrator (PDC): The PDC is considered as a computer database that contains data from eleven system protection terminals (RTUs). Each RTU send measured status through communication system to PDC

c- System Protection Center (SPC): The system protection center (SPC) is communicated with all RTU, which is responsible for protection, monitoring and control of the power grid.

d- Data manipulation in SPC: SPC receives data stream from PDC and provides a protection depending on view, in the SPC unit the measuring values of the multiplication factor which it has positive sign in the faulted phase of fault line as described multiplied for each line

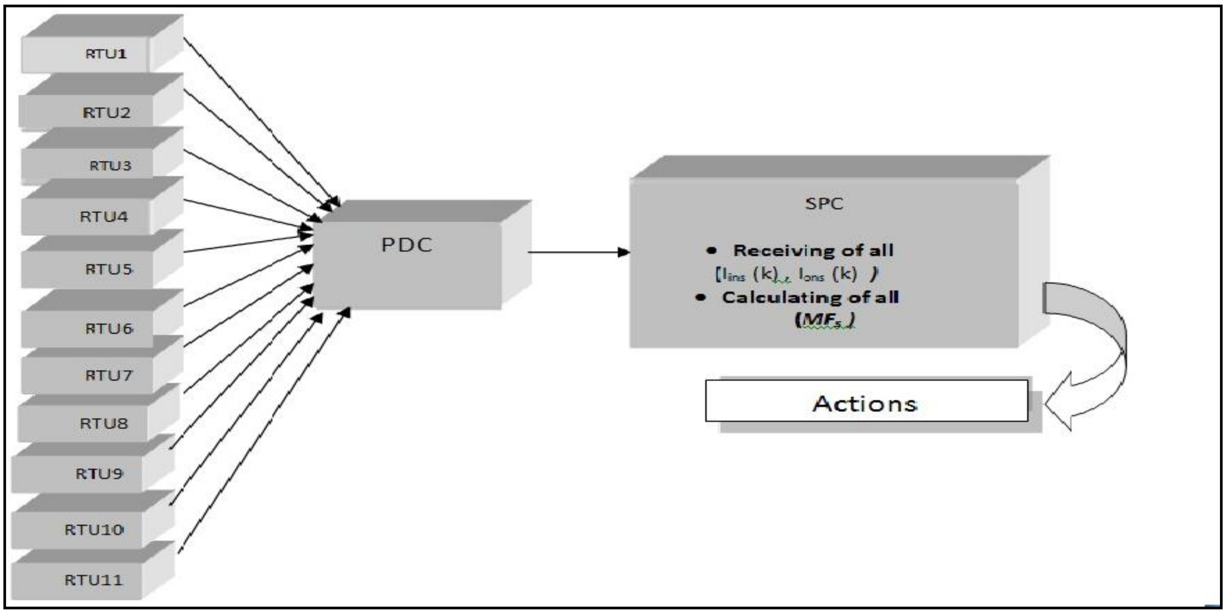

Figure 3: Configuration of protection

4. Results and Discussions

This section, the simulation has been executed to study the grid operation system under normal operation and connecting distributed generator.

4.1. Case Study (1): Next case of normal operation for the studied network. Figures (4a:d) show the signs of the I status at each side of each transmission line and the multiplication factor of each line.

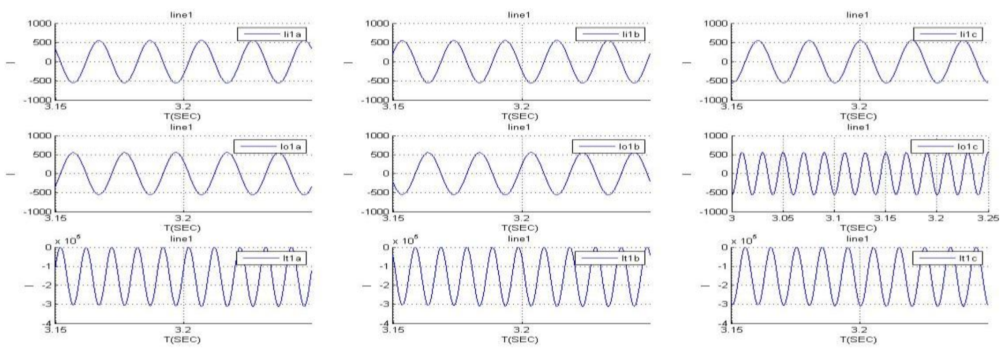

Figure 4.a: the values of (i_{i1s}, i_{o1s} and MF_{1s}) of lines1 in normal operation

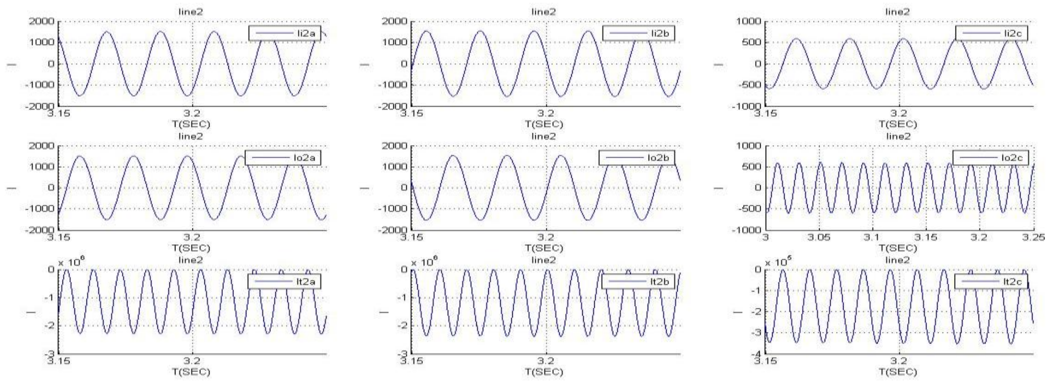

Figure 4.b: The values of (i_{i2s}, i_{o2s} and MF_{2s}) of lines2 in normal operation

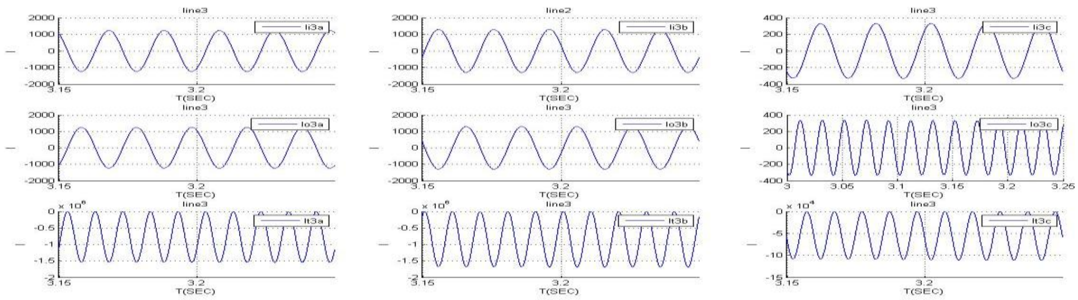

Figure 4.c: The values of (i_{i3s}, i_{o3s} and MF_{3s}) of lines3 in normal operation

From the previous description, its cleared that in case of normal operation the sign of MF_s is negative for all transmission line (for all phases), as shown in the Figures (4a) shows the values of MF's of lines 1in normal operation, and shows that the all values ranging between (0 and -ve). Figures (4b) shows the values of MF's of lines 2 in normal operation, and shows that the all values ranging between (0 and -ve).

Figures (4c) shows the values of MF's of lines 3 in normal operation, and shows that the all values ranging between (0 and -ve).

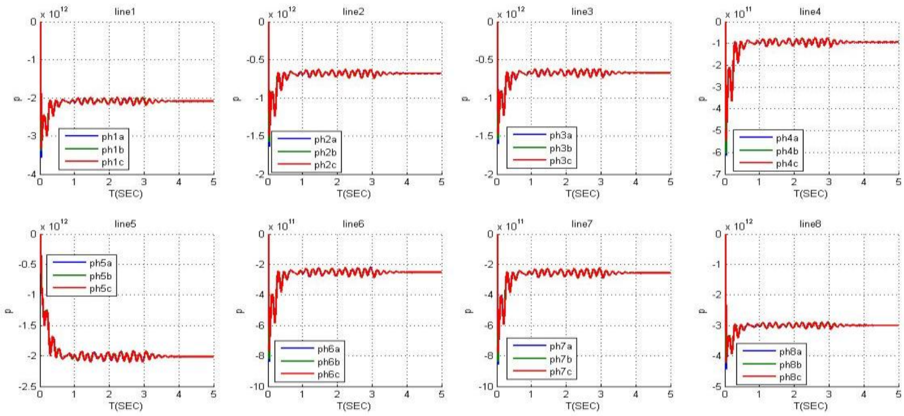

Figure 4.d: The values of (MF_s) of all lines in normal operation

Figures (4d) shows the values of MF's of all lines in normal operation, and shows that the all values ranging between (0 and -ve). As described previously.

Table (1) shows also the values of MFs for all lines and shows that the signs of them still negative for normal operation

Table 1: The values of $\boldsymbol{i_{is}}$, $\boldsymbol{i_{os}}$ and MF_s for all lines in case of normal operation

		ii			io			MF			LINE CASE		
		A	B	C	A	B	C	A	B	C	A	B	C
LINE 1	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 2	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 3	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 4	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 5	BEFORE	-	-	-	+	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER				+	+	+						
LINE 6	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 7	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			
LINE 8	BEFORE	+	+	+	-	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	+	+	-	-	-	-	-	-			

4.2. Case Study (2):

In this case study, various types of faults at different locations will be described. In case of fault condition, this fault is internally for one line and external for other lines of the network. In case of external fault at any phase of the transmission line the direction of the two currents (sending and receiving) don't changes its direction, so the status of ($\boldsymbol{i_{ins}}$) and ($\boldsymbol{i_{ons}}$) don't changed, so the sign the sign of the MF_s for all phases not changed for this line

4.2. A. Single line to ground at line 4:

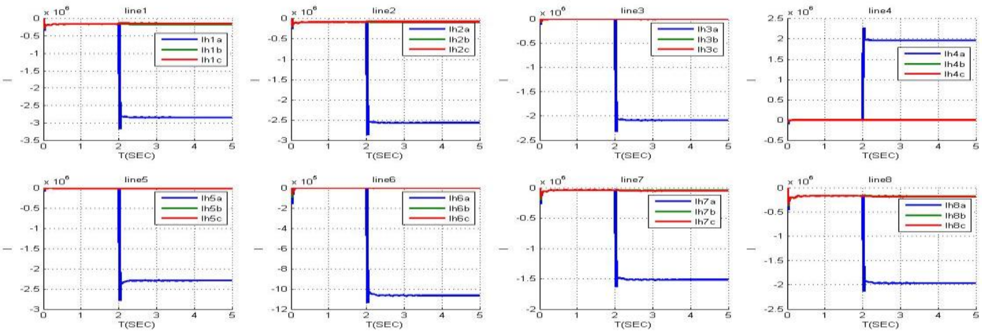

Figure 5: The values of MF's of all lines in case of AG fault at line 4

In case of single line to ground fault at line 4 at phase A (Rf=1ohm at 2 sec the status i_{ins} and i_{ons} are in opposite of (for all phase)for all lines. except the status of i_{i4a} and $i_{o4a\ of\ line\ 4}$. so the status of MF_s is negative (for all phases) for all line except the status of (MF_{4a}) of line 4, then this case is single line to ground fault at line 4at phase a.

Figure (5) shows the values of multiplication factors of each line, also table (2) shows the values of MF_s for all lines and shows the status of them still negative for all lines except phase A of line 4 which it is faulted phase.

Table 2: the values of i_{is}, i_{os} and MF_s for all lines in case of AG fault at line 4

		Ii			Io			MF			LINE CASE		
		A	B	C	A	B	C	A	B	C	A	B	C
LINE 1	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 2	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 3	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 4	BEFORE	-	+	+	+	-	-	-	-	-	F	NORMAL	NORMAL
	AFTER	+	-	-	+	+	+	+	-	-			
LINE 5	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	-	-	+	+	+	-	-	-			
LINE 6	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 7	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 8	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			

4.2. B. Double line to ground at line 6:

In case of the double line to ground fault at line 6 at phases A and C (Rf =1ohm at 2 sec**)**

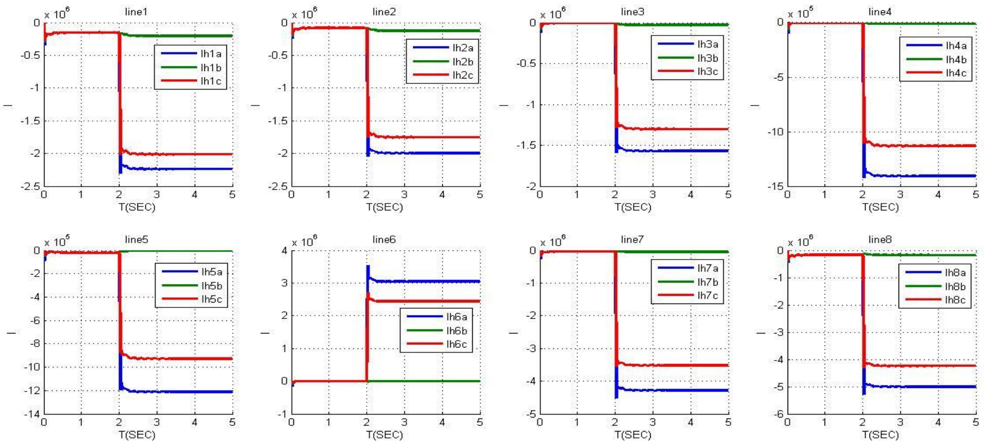

Figure 6: The values of MF's of all lines in case of ACG fault at line 6

Figure 6 shows the values of MFs for all lines and shows the status of them still negative for all lines except phases A and C of line 6 which it is faulted phase. the status of i_{ins} and i_{ons} are In opposite (for all phases) for all line except the status of (i_{i6a-c} and i_{o6a-c}) of line 6, so the stats of MFs is negative (for all phases) for all line except the status of (MF_{a-c}) of line 6, then this case is double line to ground fault at line 6 at phases A and c. so shows the values of the multiplication factors of each line, also table(3).

Table 3: The values of i_{is}, i_{os} and MF_s for all lines in case of ACG fault at line 6

		ii			io			MF			LINE CASE		
		A	B	C	A	B	C	A	B	C	A	B	C
LINE 1	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 2	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 3	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 4	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 5	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 6	BEFORE	+	-	-	-	+	+	-	-	-	F	NORMAL	F
	AFTER	+	+	+	+	-	-	+	-	+			
LINE 7	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 8	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			

4.2. C. Three line to ground at line 3:

In case of the three line to ground fault at line 3 at phases A, B and C (Rf =1ohm at 2 sec).

Figure 7 shows the values of MFs for all lines and shows the status of them still negative for all lines except phases A, B and C of line 3 which it is faulted phase. The status of i_{ins} and i_{ons} are In opposite (for all phases) for all line except the status of ($i_{i3a-b-c}$,and $i_{o3a-b-c}$) of line 3, so the stats of MFs is negative (for all phases) for all line except the status of (MF_{a-b-c}) of line 3, then this case is three line to ground fault at line 3 at phases A, B and C .so shows the values of the multiplication factors of each line, also table(4).

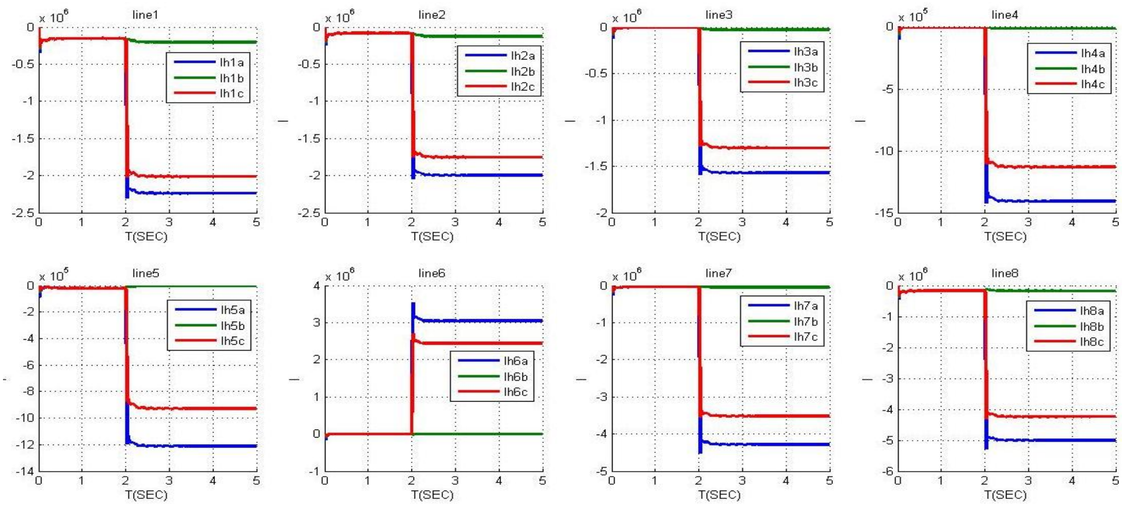

Figure 7: The values of MF's of all lines in case of ABC fault at line 3

Table 4: the values of i_{is}, i_{os} and MF_s for all lines in case of ABC fault at line3

		Pi			Po			MF			LINE CASE		
		A	B	C	A	B	C	A	B	C	A	B	C
LINE 1	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 2	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	+	-	-	-	+	+	-	-	-			
LINE 3	BEFORE	-	+	+	+	-	-	-	-	-	F	F	F
	AFTER	+	-	-	+	-	-	+	+	+			
LINE 4	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 5	BEFORE	-	+	+	+	-	-	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 6	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 7	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			
LINE 8	BEFORE	+	-	-	-	+	+	-	-	-	NORMAL	NORMAL	NORMAL
	AFTER	-	+	+	+	-	-	-	-	-			

5. Conclusion

The paper presents a protection of electrical grid with distributed generators. The protection scheme has successfully identified the faulted line. The suggested technique uses the multiplication factor between current status at the two sides of each transmission line. The method depends on standalone decision at the two terminals of transmission line, the communication between system protection center (SPC) and all RTU's to transfer status not data results indicate that proposed technique is stable and reliable to discriminate between various locations of faults and various types of faults.

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