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Evaluation of the Impact of Island Mode for Renewable Energy Systems on the Adaptation Protection under Fault Conditions

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ABSTRACT

This paper presents the effect of atmospheric turbulence, which is the main factor affecting energy production in renewable sources such as photovoltaic (PV) and wind energy systems. The power generated by PV and wind systems could be affected by partial shading, the temperature of shaded cells increases and thus reduces the energy generation of the shaded photovoltaic and the same is occurred in wind farm(WF) , over the day wind speed or wind direction are varying. In fact, weather instability not only affects the energy production for PV and wind farms but also effects on the sustainability and reliability (RES) during conversion to island mode operation for protection of microgrid which are a part of adaptive protection of the smart grid. On the other hand, It's deal with the determination of fault current (During three phase short circuit (SC) and phase to ground fault) at different configurations in model, each overcurrent relay (OCR) will be adapted based on the status of the grid that by monitoring the parameters of the grid or microgrid for RES where each OCR's has several settings (two or more). In adaptive protection system, it's a centralized supervisory system and it modifying the OCR settings centrally based on the grid configuration. Main advantage of using adaptive protection of OCR to choose the optimum setting that to eliminates the consequences of incorrect OCR coordination values when applied .That will be lead to wrong decision whether incorrect trip event or no response of OCR under fault conditions. That will be facilitated maintain the energy reliability in smart grid.

Keywords: Wind Farm, Photovoltaic, Smart Grid, Microgrid, Adaptive Protection, Island Mode.

I. INTRODUCTION

Egypt has one of the most favorable environments for the largest production of RES in the world and its exploitation is critical for national sustainable development through efficient energy planning and a gradual independence from fossil fuels. Egypt has a long term plan for expansion in different directions to energy sources that to withstand the proportional population growth which reflect to growing of energy demand, one of these energy sources is RES. Equitable access to energy is a basic requisite for economic development and an important condition to galvanize economic growth. The PV and wind systems can be high reliable energy source in the world, which is the sustainably for using it a RES, so the sustainable solution to the next energy crisis, use a new generation technologies which is cheaper than conventional energy sources. But in another side, the real application for RES face many challenges for example when the wind speed or wind direction are varying over the day and the same for PV system, the solar radiation and ambient temperature variation .Refer to the test manufacturers for solar energy performance for the PV module is under the standard test period conditions (temperature is 25 ° C, solar irradiance (I_r) equal 1000 W / m^2.

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It is very important to know how these weather disturbances like light intensity, dust, temperature or shading has impact performance for PV system and the wind speed and wind direction variation will be effected directly on performance of wind system. Furthermore, this paper presents the effect of atmospheric turbulence, which is the main factor affecting energy production in renewable sources such as PV and wind energy systems.

Undoubtedly, the main goal of adaptation protection specially for smart grid where sometime the system will be forced to convert to connected mode or island about the grid, specially through the operation process for Photovoltaic arrays and wind system, [1] then the short circuit (SC) rating and time setting whether in three phase SC fault or single phase to ground fault, will be varied based on the current configuration whether in island /connected mode.

By determination of fault current (During the symmetrical three phase short circuit and phase to ground fault) at different configurations in model, each OCR will has several settings (two or more). The objective of the adaptive protection is ability of OCR to choose the optimum setting that to eliminate the consequences of incorrect OCR coordination values when applied, it will be lead to wrong decision whether incorrect trip event or no response of OCR under fault conditions.

II. ADAPTIVE OVERCURRENT PROTECTION IN DISTRIBUTION SYSTEMS

The objective of adaptive protection is to determine SC fault current flows from the sources to the fault, when a symmetrical three-phase short circuit occurs at any position (buses or lines) in a power system. As a result of the process, the result by simulation which determined the SC rating is to slow us how to select circuit breakers, what should be their current ratings (steady state and transient state), and voltage ratings as well . As shown in Fig. 1, the model used in simulation has three generation plant. Infinite bus (IB) is connected with step down transformer 55.5 MVA .It is connected to the 125 kV bus and Wind farm contains 12 unit of DFIG unit 1.5 MW. It is connected to the 575 V bus and PV farm 1MW. It is connected to the 400 V.The Adaptive OC protection done in scheme in Fig. 1 ,which will be fixed the trouble both in microgrid connected and also in island mode.[2] The difference between conventional and adaptation protection system can be clarified ,where in conventional type ,the coordination's of OCR (i:e current and time settings) are predetermined in protection study in project plan and these values are fixed ,not changed and couldn't linked with grid, in adaptive protection system executes the adaptation of OCR coordination's based on the status of grid configurations (Config) .The smart grid which contains adaptive protection consists of secured communication system ,to secure the data transfer between DCS (Distributed central system) and adaptive OCR in each bus and inhibits hack attacks from hackers.

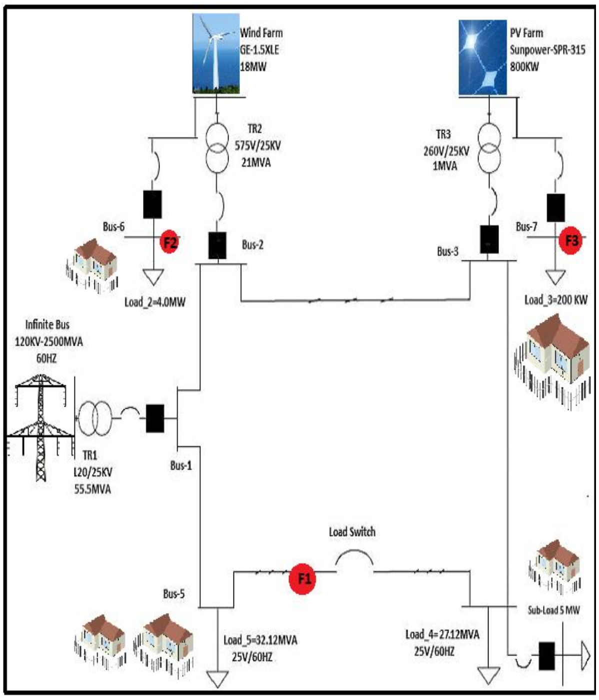


Fig.1: Model scheme

By simulation done by matlab under the 3ph-SC fault or 1ph-ground identified at three red location F1, F2 & F3 located in Bus4, Bus2 and Bus3 respectively as shown in Fig.1.The results will be illustrated the fault current under SC fault located in F1 , F2 and F3 "at the separate entity", when it's connected with grid and in another hand will be measured the SC fault current in F2 & F3 "at the separate entity", when it's island about grid "Act as WF and PV microgrid ".

III. ANALYSIS OF THREE PHASE SHORT CIRCUIT

It must inspect all prospective types of fault or abnormal conditions which may execute in the energy power.The analysis of power systems under faulted condition provides info regarding selection of CB, OCR settings. Under symmetrical three phase SC fault occurred in certain bus of the model, fault current can be determined by using the simulation of this model by matlab.

This remarkable performance of adaptation protection in smart grid is achieved through careful planning, design, installation and operation of a very complex network of generators, transformers, and transmission and distribution lines. The objective is to find how much short circuit current flows from the sources to the fault, when a symmetrical three-phase short circuit occurs at any position (buses or lines) in a power system. By using the simulation the current flow over the buses, it will be valued for various configurations over the microgrid /grid. Furthermore, SC measurement by simulation expressed on the actual grid configuration and the generation units (GU) connection status determined by several simulations of fault. The SC currents are measured by the OCRs under different configurations and fault conditions. The results are illustrated the load current of different config. When all GU in connected mode as shown in Table 1.

Table1: currents for all OCR's in different configurations

Config.		***IB+WF +PV***	***IB + WF***	***IB +PV***	***IB***	***PV***	***WF***
	kV	I(A)	I(A)	I(A)	I(A)	I(A)	I(A)
CB1	25	1160	1160	1160	1160	0	0
CB2	25	460.1	460.1	0	0	0	460.1
CB3	25	20	0	20	0	20	0
CB4&5	25	1515	1515	1175	1160	0	0
CB6	25	103.2	103.2	0	0	0	103.2
CB7	25	4.9	0	4.9	0	4.9	0

Notes:1.In Config.1 clarified the load flow by (IB,WF&PV) , (IB&WF) or (IB&PV) will be equal 1160 A where the IB is contributed with the large % of the load which equal 1160A regardless the rest generation sources as WF or PV.

To study the influence of generation units to fault current levels ,at the configuration (IB+Wind system +PV) and in connected with the grid ,the fault current will be maximum value which equal 100% from 3ph-SC and when island the PV & WF about the grid the fault current equal 72.1% from maximum 3ph-SC. The variation of magnitude of % fault current which is corresponds with GU in grid as shown in Table 2.

Table 2: SC magnitudes regard the system with GUs

Config	*3ph -SC*	*Operation mode*
IB+WF +PV	100%	Connected
IB+WF	98.7%	PV islanded
IB +PV	72.8%	Wind islanded
IB	71.6%	PV and Wind islanded
PV	1.3%	Microgrid
WF	28.4%	Microgrid

The three phase SC current values in each OCR during SC happens at certain buses in microgrid and main grid configuration, When F1 occurred at bus4&5 ,main fault current equal 20 kA at 25kV ,fault current contributed by WF “Bus2” was 17.1 kA and for PV “Bus3” was contributed with 56A and the same procedures can be applied on the rest of configurations as shows in table 3.

Table 3. SC values for all OCRs effected with 3phase-SC in main grid & microgrid config.

*Fault**	*Bus1*	*Bus2*	*Bus3*	*Bus4&5*
F1	17100	1833	56	20000
F2 [connected]	17050	20050	58	0
F2 [microgrid]	0	1860	0	0
F3 [connected]	17200	1835	20100	0
F3 [microgrid]	0	0	179	0

Notes: 1. *the values of short circuit current referred to A.

Suppose it has connected on protection CT of ratio 400/1 A in bus1 , CT of ratio 200/1 A in bus2, CT of ratio 10/1 A in bus3 and CT of ratio 400/1 A in bus4&5 and the current setting is 150%. And use it in the model shows in Fig.1.

Say a relay has a time setting 0.1. In Table.4 elaborated the actual operation time for OCR during fault occurred in different location for the five configurations and elaborated the time setting for the OCR’s at this config.
By taking an example, time setting for CB in Bus4&5 adjusted on 192 ms “The fastest” , for Bus1 time setting is 202 ms, in Bus2 equal 379 ms and in Bus3 is 524 ms. and the same procedures can be applied on the rest of configurations.

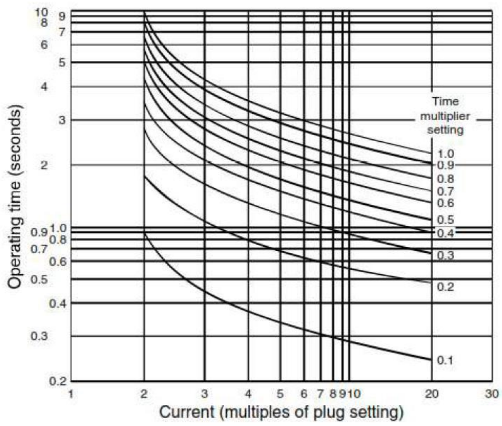
Table 4: default Time setting for all OCRs effected with 3phase-SC in main grid & microgrid config.

*Time**	*Bus1*	*Bus2*	*Bus3*	*Bus4*	*Bus5*
F1	202	379	524	192	192
F2 [connected]	202	160	507	0	0
F2 [microgrid]	0	376	0	0	0
F3 [connected]	202	380	90	0	0
F3 [microgrid]	0	0	275	0	0

Notes: 1. *the values of default time setting referred to ms

The typical time curves for IEC [3],[4]&[5] and BS standards OCR (normal inverse) c/s as shown in Fig.3 can be approximated by the following equation:

Fig.3: The typical time curves for (BS142) and IEC Standard OCR (normal inverse). For: TMS= 0.1- to -1.0



$$t_{relay}=\frac{0.14}{[\frac{I_F}{CTR *PS}]^{0.02}-1} * TMS \quad (1)$$

Here it present to the application could be elaborated the main goal of adaptation protection especially for smart grid. Sometime the system will be forced to convert to connected mode or island about the grid.It can be occurred through the operation process for PV and wind system, then the SC setting will be varied based on the current configuration whether in island /connected mode. By taking an example, when fault F2 occurred in Bus2 ,so then there are two mode ,when Bus2 in connected mode or in island mode ,the fault current and the time setting for CB in Bus2 equal 19.9 kA and 160 ms(T0) respectively “The fastest in trip” that was in connected mode. If the same fault occurred at the same bus but in island mode the fault current and time setting will be equal 1865 A & 376 ms (T1) and the same procedures will be applied on the F3 in Bus3 configuration as shown in Table 5.

Table 5: Adaptation OCR for CB2 in bus2 and for CB3 in bus3

Fault at	*Bus2 (A)*	*Bus2 Time**	*Bus3 (A)*	*Bus3 Time**
F2 [connected]	19900	160 (T_0)	-	-
F2 [microgrid]	1865	376 (T_1)	-	-
F3 [connected]	-	-	19800	90 (T_0)
F3 [microgrid]	-	-	179	375 (T_1)

Notes: 1. *the values of default time setting referred to ms.

IV. ANALYSIS OF SINGLE PHASE TO GROUND FAULT

For a single phase to ground fault "unsymmetrical fault" ,there will be positive, negative and zero sequence currents ($3I_1$, $3I_2$ and $3I_0$) and voltages ($3V_1$, $3V_2$, and $3V_0$).The simulation will be done for 1ph-G (Phase A) at three location F1 , F2 & F3 which will be in these buses Bus4,Bus2 and Bus3 respectively as shown in Fig. 1. By using the simulation by matlab that to measure line-to-ground fault, where will be measured the fault current when fault location connected with grid for F1, F2 and F3. In another hand will be measured by simulation by matlab, the fault current in island mode for microgrid "WF and PV" during F2 & F3 .The results of analysis for single phase "Phase A" to ground fault at these configurations. When F1 occurred at bus4 ,main fault current equal 4343A at 25kV ,fault current contributed by "Bus1" equal 3364A and for WF "Bus2" was 443.8A and for PV "Bus3" was contributed with 481.5A and the same procedures can be applied on the rest of configurations will be shown in Table 6.

Table 6: phase to Ground fault values for all OCRs effected in main grid & microgrid config.

*Fault at**	*Bus1*	*Bus2*	*Bus3*	*Bus4&5*
F1	3364	443.8	481.5	4343
F2 [connected]	3374	4352	485	0
F2 [microgrid]	0	523.9	0	0
F3 [connected]	3370	445.8	4370	0
F3 [microgrid]	0	0	256.3	0

Notes: 1. *the values of short circuit current referred to [A].

When F1 occurred at bus4, main fault current equal 4343A at 25kV ,fault current contributed by bus1 equal 3364A , WF "Bus2" was contributed with 443.8A and for PV "Bus3" was contributed with 481.5A and the same procedures can be applied on the rest of configurations.

Suppose it has connected on protection CT of ratio 400/1 A in bus1, CT of ratio 200/1 A in bus2, CT of ratio 10/1 A in bus3 and CT of ratio 400/1 A in bus4 and the current setting is 150%.

Let us have a practical model. Say a relay has a time setting 0.1. In Table.7 elaborated the actual operation time for OCR during fault occurred in different location for the five config and elaborated the default time setting for the protection relays at this configuration. By taking an example, time setting for CB in Bus4&5 adjusted on 347 ms,for Bus1 time setting is 400 ms, in Bus2 equal 1.78 sec and in Bus3 is 195 ms "The fastest" and the same procedures can be applied on the rest of configurations.

Table 7: default Time setting for all OCRs effected in main grid & microgrid config..

*Time**	*Bus1*	*Bus2*	*Bus3*	*Bus4*	*Bus5*
F1	400	1780	195	347	347
F2 [connected]	400	255	195	0	0
F2 [microgrid]	0	1250	0	0	0
F3 [connected]	400	1780	116	0	0
F3 [microgrid]	0	0	240	0	0

*The values of default time setting referred to ms

Here it present to the application could be elaborated the main goal of adaptation protection especially for smart grid.[6]Sometime the system will be forced to convert to connected mode or island about the grid. It occurred through the operation process for PV and wind system. The single phase to ground fault rating will be varied based on the current configuration whether in island /connected mode.

The actual operating time and current setting for OCR will be differed based on the current configuration of the grid. By taking an example, [7],[8] when fault F2 occurred in Bus2, so then there are two mode, when Bus2 in connected mode or in island mode. The fault current and the time setting for CB in Bus2 equal 4352A and 255 ms(T_0) respectively "The fastest in trip" that was in connected mode. If the same fault occurred at the same bus but in island mode the fault current and time setting will be equal 523.9 A & 1.25 sec (T_1) and the same procedures can be applied on the rest of configurations. In table 8.as follow.

Table 8: adaptation OCR for CB2 in bus2 and for CB3 in bus3

Fault	*Bus2 (A)*	*Bus2 Time**	*Bus3 (A)*	*Bus3 Time**
F2 [connected]	4352	255 (T0)	-	-
F2 [microgrid]	523.9	1250 (T1)	-	-
F3 [connected]	-	-	4370	116 (T0)
F3 [microgrid]	-	-	256.3	240 (T1)

*The values of default time setting referred to ms.

V. SIMULATION AND ANALYSIS RESULTS

A. Three phase SC fault

In case of three phase SC fault (F2) occurred in wind system at 1.0 sec and it's connected to the grid. SC current was 20 kA and if the same fault occurred but the wind system was island about the grid the SC current was 1865 A. Similarly in PV system, SC rating was 19.8 kA that during 3phase SC fault (F3) occurred and PV system was connected with the grid and when island the PV system under the same fault the SC current rating was 179A. The fault current was contributes by Bus1 is 17.1 kA during all DG's connected to grid. The fault current in F1 reaches to 20 kA as shown in Fig. 4a As shown in Fig. 4b , the fault current by Bus1 under F1 ,F2 and F3 when PV & Wind system in connected mode. In Fig. 4c shows a fault current by WF under F1, F2 and F3 when PV & Wind system in connected mode. In Fig. 4d shows the fault current by PV under F1, F2 and F3 when PV & Wind system in connected mode. In Fig. 4e shows the WF under F2 in microgrid and Fig. 4f shows the PV under F3 in microgrid respectively.

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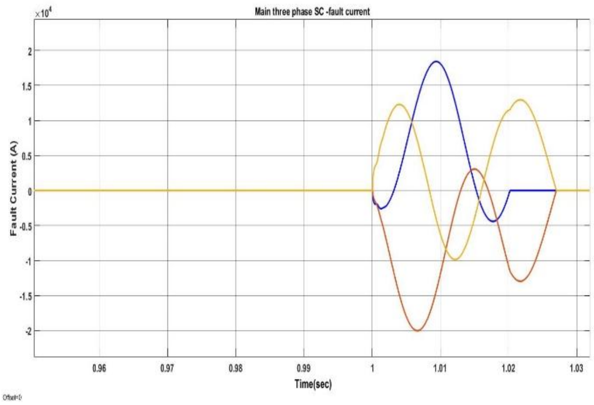

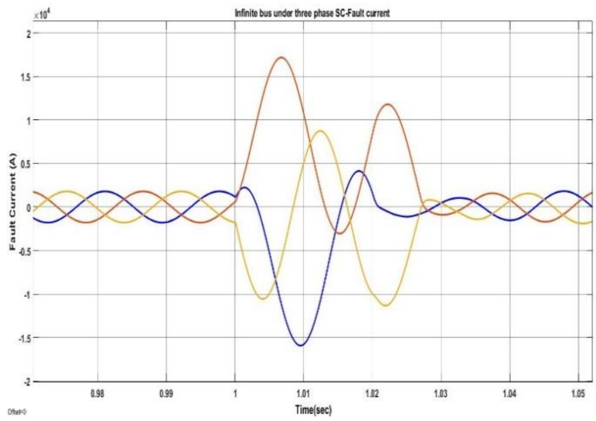

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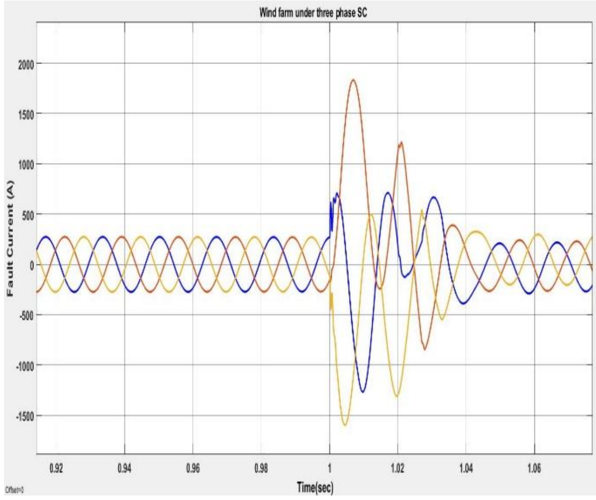

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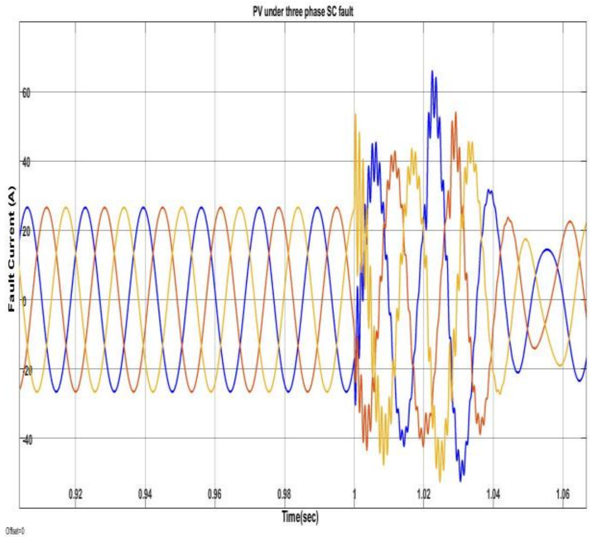

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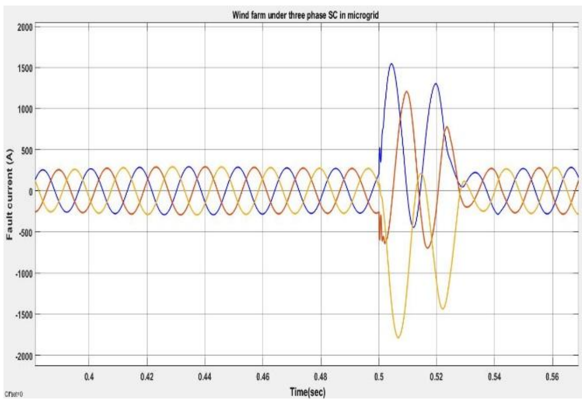

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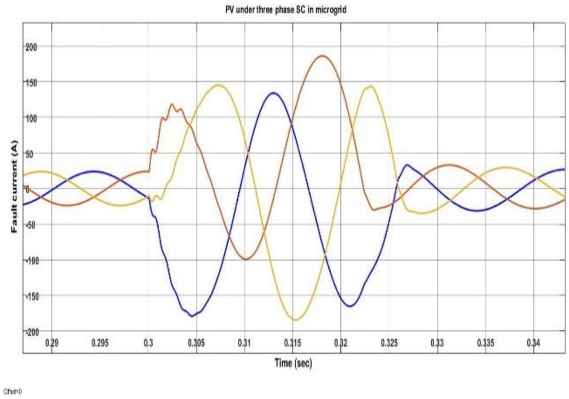
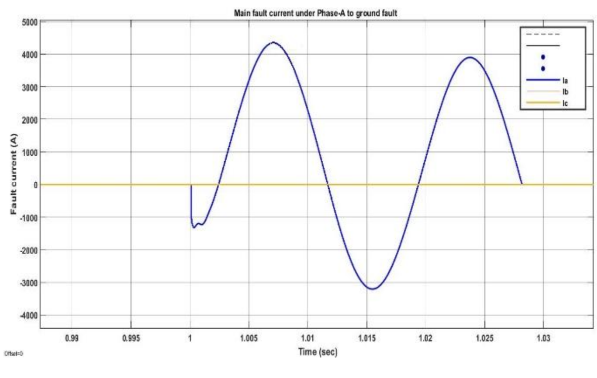


(f)

Fig.4: show,(a) the fault current at F1 , (b) fault current by Bus1 under F1 , F2 and F3 when PV & Wind system in connected mode, (c) fault current by WF under F1 , F2 and F3 when PV & WF in connected mode , (d) the fault current by PV under F1 , F2 and F3 when PV & WF in connected mode, (e) WF under F2 in microgrid and (f) PV under F3 in microgrid respectively.

B. Single phase to ground fault

In case of single phase to ground fault, (F2) occurred in wind system at 1.0 sec and it's connected to the grid ,the fault current was 4343A and if the same fault occurred but the wind system was island from the grid the fault current was 523.9 A. Similarly in PV system. The fault current was 4370 A that during single phase to ground fault (F3) occurred and PV system was connected with the grid and when island the PV system under the same fault the fault current rating was 256.9 A. The fault current flows by Bus1 is 3375A in grid connected mode. As shown in Fig. 5a illustrated the main fault current at F1 . Fig. 5b shows fault current by Bus1 under F1 ,F2 and F3 when PV&WF in connected mode. Fig. 5c shows a fault current by WF under F1, F2 and F3 when PV & Wind system in connected mode. In Fig. 5d shows the fault current by PV under F1, F2 and F3 when PV & WF in connected mode. In Fig. 5e shows the WF under F2 in microgrid and Fig. 5f shows the PV under F3 in microgrid respectively.



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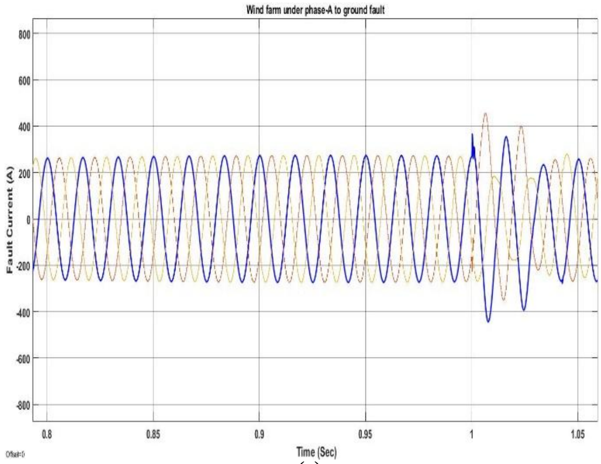

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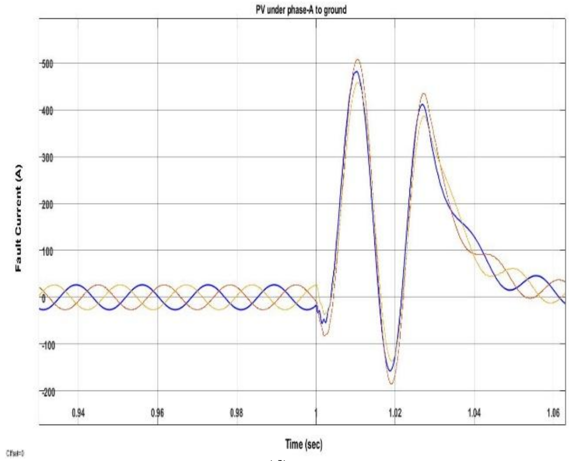

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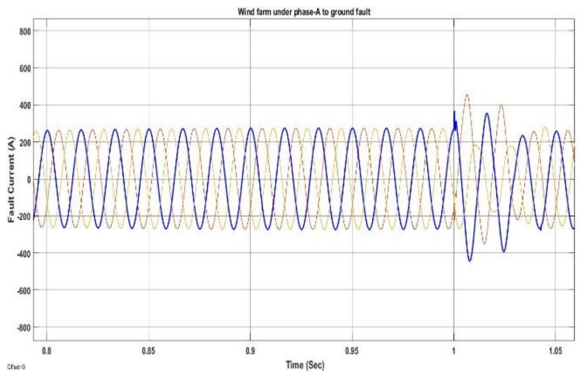

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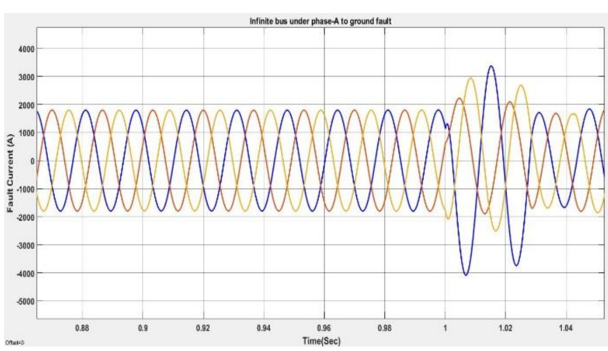

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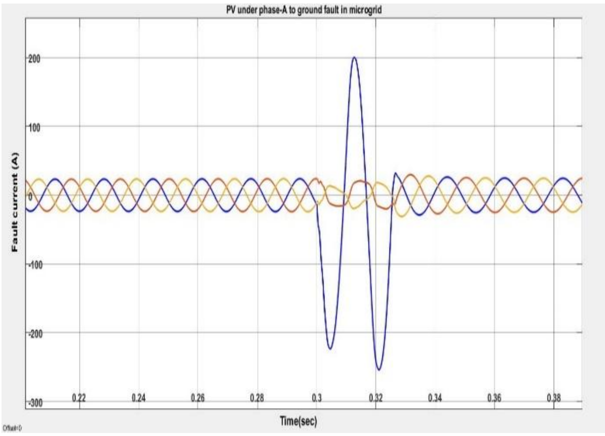

Fig.5: show, (a) the fault current at F1 , (b) fault current by Bus1 under F1 , F2 and F3 when PV & Wind system in connected mode, (c) fault current by WF under F1 , F2 and F3 when PV & WF in connected mode , (d) the fault current by PV under F1 , F2 and F3 when PV & WF in connected mode, (e) WF under F2 in microgrid and (f) PV under F3 in microgrid respectively.

VI. CONCLUSIONS

This paper treats the adaptation protection specially for smart grid where sometime the system will be forced to convert to connected mode or island about the grid, specially through the operation process for PV and wind system, then the fault current rating and time setting of OCR will be varied based on the current configuration whether in island /connected mode. The actual operating time and current setting for OCR will be differed based on the current configuration of the grid. This study is expected to be very useful for design engineers responsible for designing and implementation a PV & wind systems in smart grid . By investigating a balanced three phase SC fault "symmetrical “and phase to ground fault "unsymmetrical”, it’s can be known, how much a short circuit current flows from the sources to the fault, what’s the time setting for protection relay to isolate the fault when a three-phase short circuit occurs or phase to ground fault at any position (buses or lines) in a power system. This remarkable performance and main goal of adaptation protection in smart grid is present to the application could be elaborated, sometime the system will be forced to convert to connected mode or island about the grid, specially through the operation process for PV and wind system, then the fault whether under three phase short circuit or phase to ground fault rating will be varied based on the current configuration whether in island /connected mode.

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