CASE STUDY ON FAULT ANALYSIS OF AN IEEE-14 BUS PV-WIND POWER SYSTEM

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***Abstract*— This paper presents the simulation and analysis of a PV and wind integrated IEEE 14 bus power system. This work analyses the effect of fault current and fault voltage in different buses in a Power System. A PV Array and Wind Turbine Generator are also integrated into a particular bus in the system and effects of faults on them are studied and reported here. The types of short circuit fault realised are line-to-ground fault, line-to-line, line-to-line and ground in this case study. IEEE 14 bus system model was developed on ETAP software and results obtained are presented here.**

***Keywords*— PV, Wind turbine, IEEE14 bus system, ETAP**

1. INTRODUCTION

Due to exponential growth of electricity demand, the electrical Power Generation, Transmission, distribution network has expanded in volume to a great extent. As the number of components, number of networks and control units increases, occurrence of faults also increases [1]. With increase in number of components, the character and complicacy of the system also increases. The burning of fossil fuels for over centuries for generation of power suffers from major disadvantages: depletion of fossil fuels and environmental pollution. The world is thus moving towards greener and cleaner means for power generation through renewable energy sources. Modern day power generating units are gravitating towards combination systems comprising of both conventional and renewable power sources, such systems also called hybrid power systems. Electrical fault is an abnormal condition which may be caused by the equipment failure or malfunctioning, human errors or environmental conditions [2]. The various reasons for faults occurring in a power system may be due to insulation failure, lightning flashover, physical damage or human error. Fault analysis and prediction is very important to detect the fault, prevent the fault, and to clear the system from abnormal conditions as well as to avoid the fault [3-5]. Prediction of fault is also important for designing and selection of device like circuit breaker and relays and it also helps to improve the power system stability and the reliability [6]. Prediction of fault helps in the planning of erection of new system and feasibility study for future provision for extension of power system due to increased load demand [7].

The fault analysis of power system is required to provide information for the selection of switchgear, settings of relay and circuit breakers for power system protection [3-5]. Faults are of different categories like shunt fault and series faults.

In this case study, different fault analysis data is obtained by developing the whole system in ETAP software and creating fault conditions (LL, LG, LLG) at various buses and studying the effect on the power system. In the proposed study voltage regulation at different buses, current directions of lines are monitored and recorded. The system comprises of two generators supplying power to two different busses whereas a PV array (PVA) and a Wind Turbine generator (WTG) also feeds power to another bus. In this paper the fault analysis of an IEEE14 Bus hybrid power system is presented [8-10]. The effects of short circuit faults on various buses especially the wind generator-PV bus is analyzed and presented here [11-12].

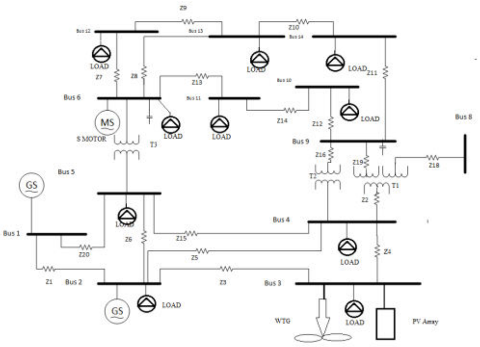

Fig. 1 IEEE 14-bus system

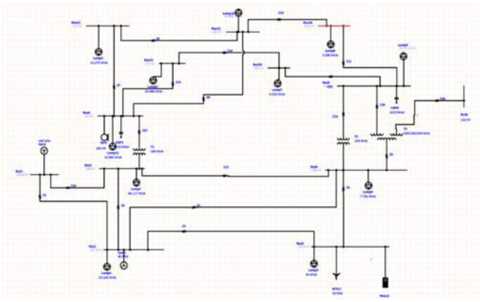

Fig. 2 IEEE 14-bus system in ETAP

Fig. 1 shows the line diagram of the PV-Wind integrated standard IEEE 14-bus system and Fig. 2 shows the modelling of the same system in ETAP software. Two Synchronous Generators (GS) are connected to Bus 1 and Bus 2 as in Fig. 1 and Fig. 2.

A synchronous motor (MS) act as synchronous condenser connected to bus 6. Wind turbine generator (WTG) and PV array (PVA) feeds power to Bus 3. Bus 8 is taken as slack bus.

Table 1: Generator parameters

SL. No.	**Impedance ID, Z(Ω)**	**R(Ω)**	**X(Ω)**
1	Z_1	0.01938	0.05917
2	Z_2	0.012	0.20912
3	Z_3	0.04699	0.197797
4	Z_4	0.06701	0.17103
5	Z_5	0.5811	0.17632
6	Z_6	0.05695	0.17388
7	Z_7	0.12291	0.25581
8	Z_8	0.06615	0.13027
9	Z_9	0.22092	0.19988
10	Z_{10}	0.17093	0.34802
11	Z_{11}	0.12711	0.27038
12	Z_{12}	0.03181	0.0845
13	Z_{13}	0.09498	0.1989
14	Z_{14}	0.08205	0.19207
15	Z_{15}	0.01335	0.04211
16	Z_{16}	0.012	1.55618
17	Z_{17}	0.012	0.25202
18	Z_{18}	0.012	0.17615
19	Z_{19}	0.012	0.11001
20	Z_{20}	0.05403	0.22304

Table 2: Line Impedances

	Type	**MVA**	**kV**	**rpm**	**X/R**	**Conn**
Gen1	Steam Turbo	188.235	139.9	1800	10	Wye
Gen2	Steam Turbo	94.118	137.9	1800	10	Wye

2. SYSTEM PARAMETERS

Table 1 enlists the generator parameters. The total MVA of two Synchronous Generators is 282.353MVA.

Table 3: Transformer Parameter

Transformer ID	MVA	Prim kV	Sec kV	Type
T3	100.00	132.000	138.000	YNd
T6	100.00	132.000	138.00	YNd

Table 4: Transformer Parameter

Transformer ID		MVA	kV
T1	Primary	100.000	138.000
	Secondary	100.000	132.000
	Tertiary	100.000	132.000

Table 2 enlists the line impedances Z_1 to Z_{20} of the transmission lines. Table 3 shows transformer specs for transformer T3 and T6. The transformer parameters of T1 which is a three winding transformer, primary, secondary and tertiary winding specs mentioned in Table 4.

The lumped loads with corresponding kVA ratings connected to the buses are shown in Table 5. There are total of eleven lumped loads connected to different buses.

Table 5: Lumped load

Lumped Load ID	kVA rating	kV	kW	kvar
Lump 1	25143	139.9	21371.6	13244.9
Lump 2	96117	139.9	81699.5	50632.8
Lump 3	50000	139.9	42500	26339.1
Lump 4	7741	139.9	6579.9	4077.8
Lump 5	12275	132	10433.8	6466.3
Lump 6	28684	132	24381.4	15110.2
Lump 7	9535	132	81.4.8	5022.9
Lump 8	3596	132	3056.6	1894.3
Lump 9	6113	132	5196.1	3220.2
Lump 10	13982	132	11884.7	7365.5
Lump 11	14985	132	12737.3	7893.8

2. CASE STUDIES OF BUS FAULTS

2.1 Case Study-1: short circuit calculation for 3 phase LG, LL, LLG faults at Bus 3

The Fig 3 below shows the ETAP simulation fault analysis data for three types of faults LG, LL, LLG at Bus no 3(red). A wind turbine Generator (WTG) and a PV based power generation unit feeds power to Bus-3. The fault at Bus-3 causes severe effect on the 14 Bus system with Bus-2 and Bus-4 being majorly affected. PV Array and WTG are connected to bus no 3 and the impacts of fault on nonconventional sources are observed.

2.2 Case Study-1: short circuit calculation for 3 phase LG, LL, LLG faults at Bus 3

The Fig 4 below shows the ETAP simulation fault analysis data for three types of faults LG, LL, LLG at Bus no 4(red). Three Winding Transformer T1 and another transformer T2 are connected at this Bus. The fault at Bus-4 causes effect on the Bus-2, 3 and 5 majorly affected. T1, T2 and T3 are also affected.

2.3 Case Study-3: short circuit calculation for 3 phase LG, LL, LLG faults at Bus 1

The Figure 5 below shows the ETAP simulation fault analysis data for three types of faults LG, LL, LLG at Bus no 1(red). Bus-1 being one of the main generator Bus of 160 MW capacity, fault at this Bus enormously effecting the other Bus voltages specially Bus-2, 3, 4 and 5. It analyzes the effect of generator bus fault on the generator.

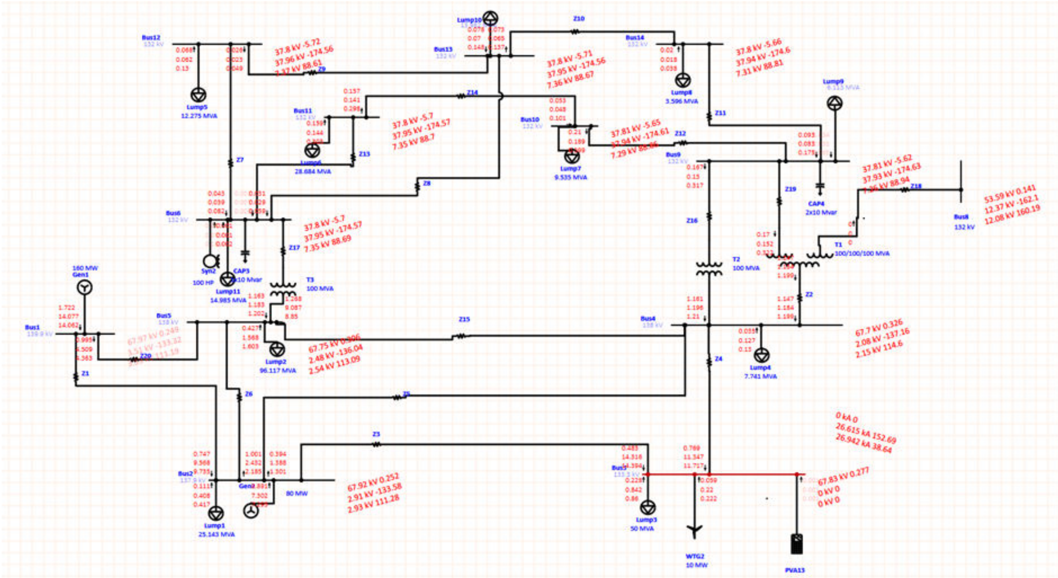

Fig. 3. Fault at Bus 3 in an IEEE-14 bus system

Fault at bus: **Bus3**

Prefault voltage = 133.300 kV = 100.00 % of nominal bus kV (133.300 kV)
= 95.28 % of base kV (139.900 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault				
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0
Bus3	Total	0.00	25.260	0.00	94.61	93.46	28.342	28.342
Bus2	Bus3	3.52	13.772	3.82	91.50	90.42	14.951	14.488
Bus4	Bus3	2.42	10.484	2.88	91.37	90.15	12.503	13.893
WTG3	Bus3	100.00	0.221	100.00	100.00	100.00	0.196	0.000
Lump3	Bus3	95.28	0.850	95.28	95.28	95.28	0.752	0.000
PVA13	Bus3	0.00	0.001	0.00	94.61	93.46	0.001	0.000

Fig. 4. Short Circuit analysis with fault at Bus 3

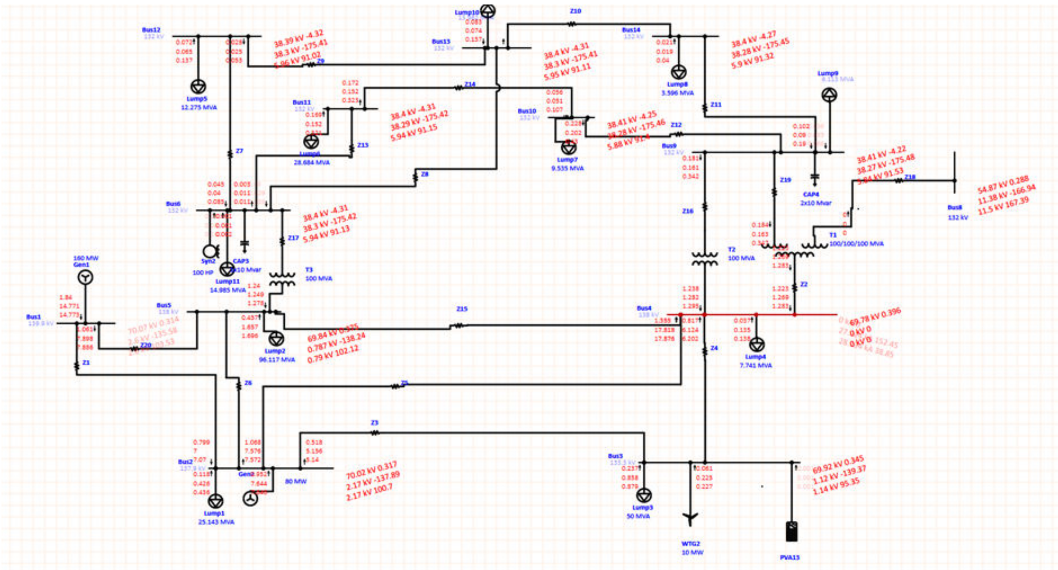

Fig. 5. Fault at bus 4 in an IEEE-14 bus system

Fault at bus: **Bus4**

Prefault voltage = 138.000 kV = 100.00 % of nominal bus kV (138.000 kV)
= 98.64 % of base kV (139.900 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault				
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0
Bus4	Total	0.00	26.456	0.00	94.49	93.08	29.826	29.826
Bus16	Bus4	0.07	0.255	0.39	93.06	91.67	1.515	3.676
Bus3	Bus4	1.48	6.181	1.47	97.84	96.50	6.167	4.682
Bus2	Bus4	2.72	3.569	2.75	94.62	93.37	3.601	2.978
Bus5	Bus4	0.97	17.449	1.02	94.50	93.13	18.350	16.090
Bus34	Bus4	5.41	0.228	55.29	56.42	94.61	1.446	3.560 *
Lump4	Bus4	98.64	0.136	98.64	98.64	98.64	0.121	0.000
PVA13	Bus3	1.48	0.001	1.47	97.84	96.50	0.001	0.000

Fig. 6. Short Circuit analysis with fault at Bus 4

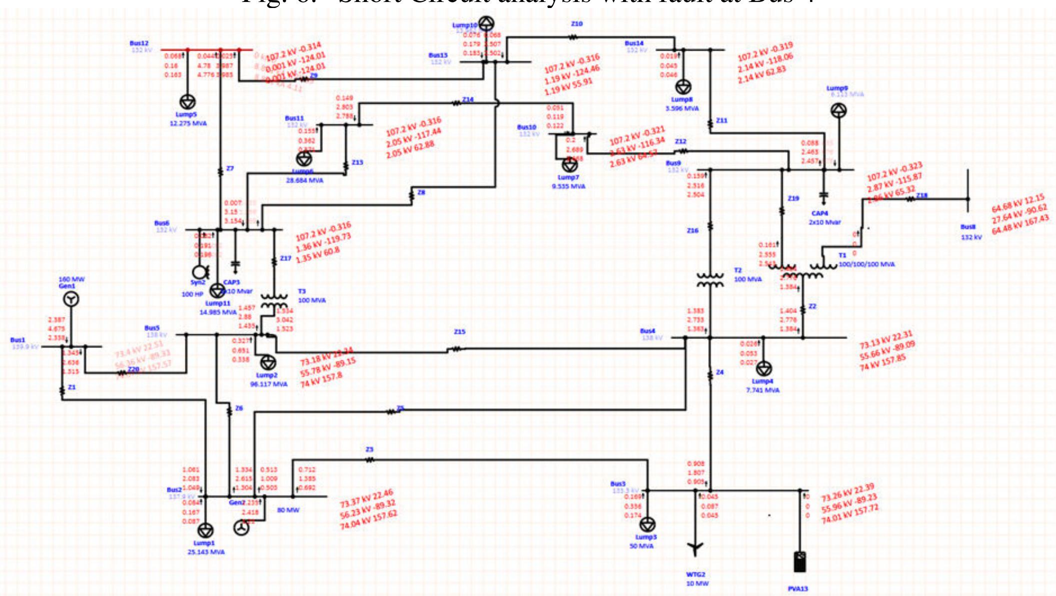

Fig. 7. Fault at bus 12 in an IEEE-14 bus system

Fault at bus: **Bus12**

Prefault voltage = 132.000 kV = 100.00 % of nominal bus kV (132.000 kV)
= 98.64 % of base kV (133.817 kV)

Contribution		3-Phase Fault		Line-To-Ground Fault				
From Bus ID	To Bus ID	% V From Bus	kA Symm. rms	% Voltage at From Bus Va	Vb	Vc	kA Symm. rms Ia	3I0
Bus12	Total	0.00	9.338	0.00	173.21	173.21	0.000	0.000
Bus6	Bus12	1.90	5.102	0.00	173.21	173.21	0.000	0.000
Bus13	Bus12	1.66	4.235	0.00	173.21	173.21	0.000	0.000
Lump5	Bus12	100.00	0.107	0.00	173.21	173.21	0.000	0.000
PVA13	Bus3	71.08	0.001	103.53	103.53	103.53	0.000	0.000

Fig. 8. Short Circuit analysis with fault at Bus 12

2.4 Case Study-4: short circuit calculation for 3 phase LG, LL, LLG faults at Bus 12

The Fig 7 shows the ETAP simulation fault analysis data for three types of faults LG, LL, LLG at Bus no 12 (red). Bus-12 being one of the load bus. When fault occurs at this bus enormously effecting the other Bus voltages specially Bus-2,3,4,5,6 and 13. Effecting es specially Bus-2,3,4,5,6 and 13.

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