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THREE-PHASE SYMMETRICAL FAULT ANALYSIS AND IMPROVEMENT IN THE POWER SYSTEM PARAMETERS USING INTERLINE POWER FLOW CONTROLLER IN AN IEEE -14 BUS SYSTEM

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ABSTRACT—

This Research article aims to understand the effects of a “Three-phase short circuit symmetrical fault in a power system”. The reason for choosing this particular fault for the analysis is because the symmetrical fault is the most severe one. However, its occurrence is not very common, leading to the highest fault currents, and causing the maximum damage. This fault, if not analyzed properly and timely action not taken, may even result in cascaded fault and result in a blackout, thus causing hardship to critical loads. This fault analysis is crucial for protective device coordination and aids in determining voltage and current during fault conditions. It is versatile – as it provides critical information about fault locations, their impact on the system, and management of faults, thus ensuring efficient and stable operation of the system.

Keywords: cascaded fault, symmetrical faults

I.INTRODUCTION :

The power system represents an interconnected network, where generation, transmission and distribution of electrical energy takes place. They are complex systems constituting various components like synchronous generator, motors, transformers, circuit breakers, etc. There are various types of faults, Open Circuit fault, ground fault, symmetrical fault, and Asymmetrical fault. Types of faults are three-phase fault, L-L fault Short Circuit fault, LL-G fault, and three phase Open Circuit fault. Symmetrical fault works severely though, but occurrence is quite rare. During this fault, all the three phases of the input are short-circuited with each other, or all of them are grounded. During this fault, huge Short Circuit current will flow from all three phases to ground. This will cause loss of equipment due to high current passing through it causing damage. It could burn insulators and wires of motors and transformers. In this research work, Symmetrical Fault

An analysis is performed on an IEEE-14 Bus System. In this research work, the Symmetrical Fault Analysis was conducted on Bus 1(close to generator 4, which is of the highest capacity,), on the taken test system (IEEE-14 Bus System). The behavior of the system was keenly observed and understood. Necessary tabulations, related circuit diagrams, and test results were provided. The tabulated values were used to plot the following parameters – short circuit current (fault current) and voltage (Prior fault, during fault, and post fault). These plots help us acknowledge the variations that occur in the Power System during the occurrence of fault, thus upsetting the system's normal operation.

In further extension of the research, Symmetrical Fault Analysis is planned to be conducted on Bus 13 (close to Load 1), on the taken test system (IEEE 14-Bus System). The study of the system and tabulation of the parameters during fault will be done. Later, an Interline Power Flow Controller (IPFC), one of the FACTS devices, will be suitably connected on the Power System for creating betterment in the result, by aiding the improvement in the system stability.

II.METHODOLOGY OF THE WORK :

The test system that we have used in our project is IEEE 14 Bus-System. This is a simplified representation of a real power system, consisting of 14 buses, 17 transmission lines, 5 generators, 3 transformers (two-winding), and 11 loads. The 14 buses are labeled from bus 1 to bus 14. These buses are connected by 17 transmission lines, forming a network that represents interconnections in a power grid.

This system is accompanied by data that includes parameters like line impedances, bus voltage magnitudes, angles, generation and load values. This data is used for simulation and analysis purposes.

MILD MODIFICATIONS IN OUR TEST SYSTEM:

1. The reactive power limits of generator were taken as 0.85 for lagging and 0.95 for leading. This data was not available for the standard system. These values were taken to match the typical generator values for model purposes.
2. All 5 were taken as generators, for distributed generation throughout the network.
3. The capacitor banks were placed near few load ends, to aid in power factor improvement and voltage regulation.
4. For the transmission lines, as the susceptance values were not available, we have considered 3.6 micro Siemens in order to have betterment in ETAP results.

The Symmetrical Fault was simulated on Bus 1(close to generator 4), on the test system (IEEE-14 Bus System). The transmission lines 9 and 10 are connected to this bus. The generator 4 is also connected to the shorted Bus 1. So, these two transmission lines and generator 4 will be facing the maximum effect of the fault created. The symmetrical fault is induced at 2 sec, in Bus 1, of the given test system. The fault is set to stay for 200 milliseconds. The fault current in Bus 1, is plotted. Also, the voltage versus time graphs is plotted, in bus 1 and buses 1 to 5 (buses closer to bus 1), and in bus 13 (bus away from bus 1), prior fault, during fault and post fault. Observing these, we clearly get to understand how the Power system behaves once it is struck with a phase short circuit symmetrical fault. It is also found that the whole test system is affected by one fault being simulated at bus 1. The reason for this is that the power system is an interconnected power system, and the fault gets transmitted and affects the whole system. Thus, we can clearly understand the need for detecting the fault quickly and rectifying it soon, to protect all the equipment and the system itself also as a whole.

In this research work, we have used ETAP [Electrical Transient and Analysis Program], for simulation purposes. This software was chosen because it provides a wide range of tools specifically designed for power system analysis, including detailed short circuit analysis features tailored for three-phase systems. These comprehensive capabilities help in accurate simulation. It is known to provide reliable results for short-circuit system fault analysis. Its automation capabilities streamline the analysis process, reducing the time required to perform complex calculations and simulations. This software typically provides comprehensive reporting features, allowing engineers to generate detail reports and documentation of the short-circuit analysis, which would be crucial for decision-making requirements.

III.RESULTS AND DISCUSSIONS

The following represents the simulation in ETAP of the test system

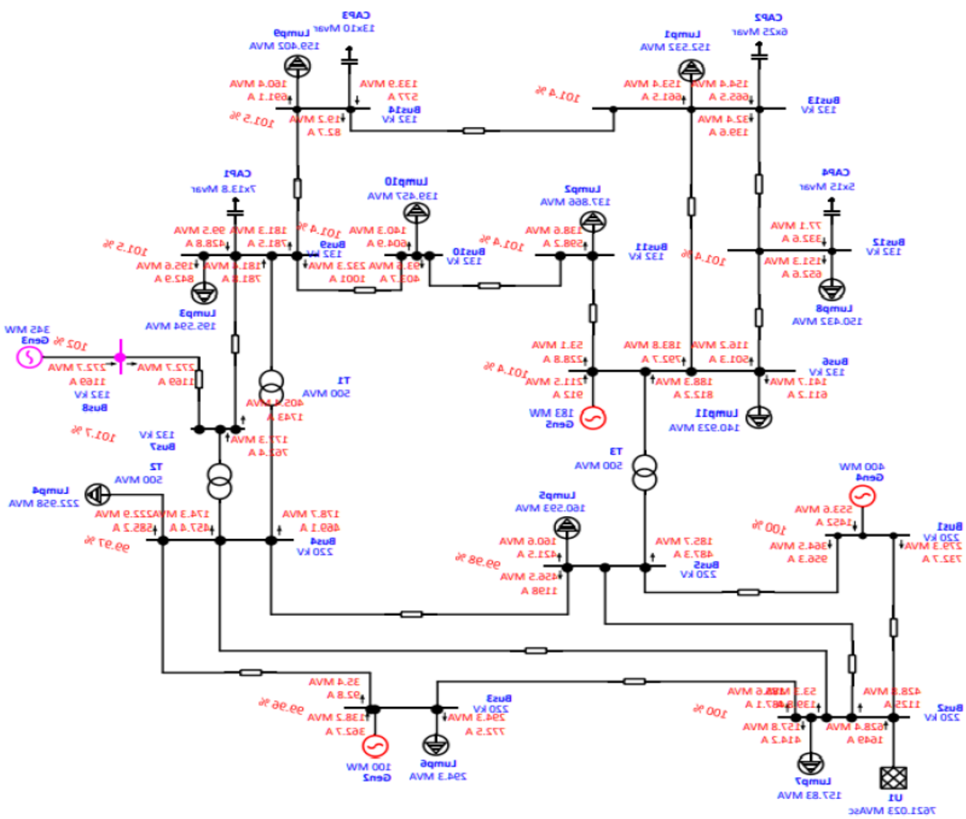

Fig: 1 Standard Load Flow Analysis in ETAP

This is our test system prior introduction of fault.

The load flow analysis was carried out before the introduction of the fault using ETAP as shown above in Fig: 1. later in the perspective of the research symmetrical fault was introduced in the generator side as shown below.

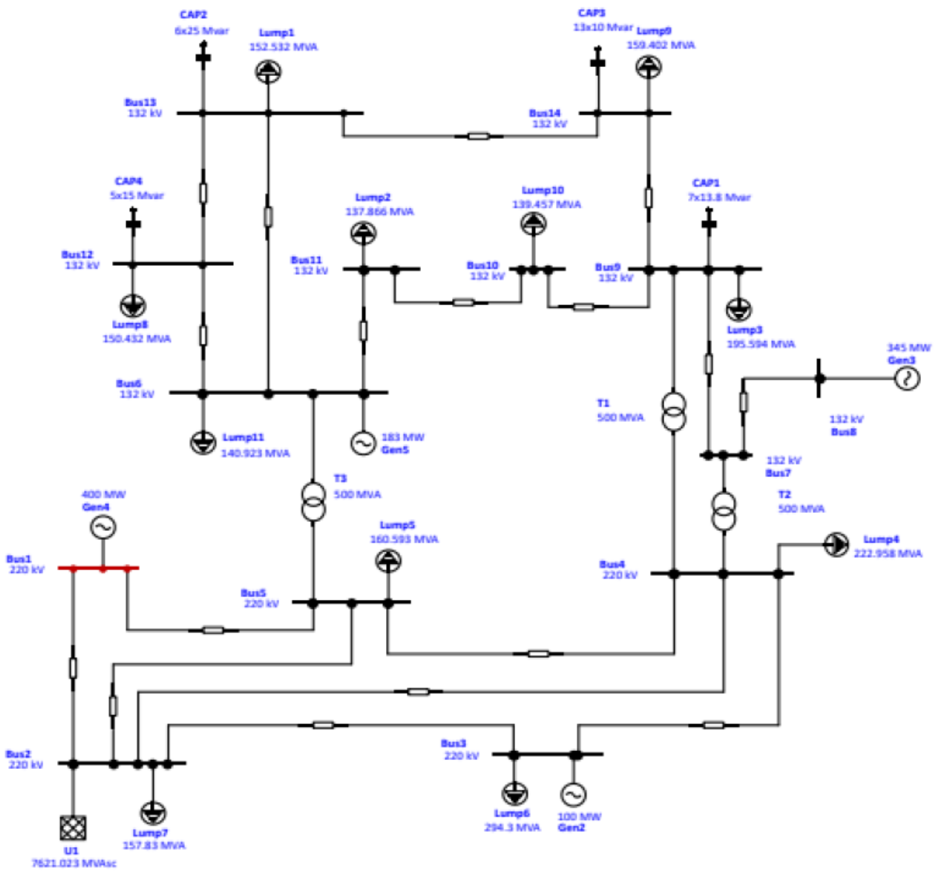

Fig: 2: Generator side fault

The red color line indicates the symmetrical fault at the generator end. In the test system, after a short circuit fault has been simulated in bus1. A symmetrical short circuit fault is simulated on bus1 of the given test system. The transmission lines 9 and 10 are shorted, as they are directly connected to this bus. The generator 4 is also connected to the shorted bus 1, which will thus be faulted.

In this research article, a typical symmetrical fault analysis is triggered. The following are descriptive tables that explain the data used in this research analysis.

Table: 1: Bus input data

Bus					Initial Voltage	
ID	Type	Nom. kV	Base kV	Sub-sys	%Mag.	Ang.
Bus1	Gen.	220.000	220.000	1	102.00	0.00
Bus2	SWNG	220.000	220.000	1	100.00	0.00
Bus3	Gen.	220.000	220.000	1	102.00	0.00
Bus4	Load	220.000	220.000	1	100.00	0.00
Bus5	Load	220.000	220.000	1	100.00	0.00
Bus6	Gen.	132.000	132.000	1	102.00	0.00
Bus7	Load	132.000	132.000	1	100.00	0.00
Bus8	Gen.	132.000	132.000	1	102.00	0.00
Bus9	Load	132.000	132.000	1	100.00	0.00
Bus10	Load	132.000	132.000	1	100.00	0.00
Bus11	Load	132.000	132.000	1	100.00	0.00
Bus12	Load	132.000	132.000	1	100.00	0.00
Bus13	Load	132.000	132.000	1	100.00	0.00
Bus14	Load	132.000	132.000	1	100.00	0.00

All voltages reported by ETAP are in % of bus Nominal kV. Base kV values of buses are calculated and substituted by ETAP. There are 14 buses in total. Bus 1 to bus 5 are rated at 220 KV. Bus 6 to bus 14 are rated at 132 KV.

Line/Cable/Busway	ohms or siemens/1000 m per Conductor (Cable) or per Phase (Line/Busway)								
			Length						
ID	Library	Size	Adj. (m)	% Tol.	#/Phase	T (°C)	R	X	Y
Line1			1000.0	0	1	75	0.17093	0.34802	0.0000036
Line2			1000.0	0	1	75	0.12711	0.27036	0.0000036
Line3			1000.0	0	1	75	0.06615	0.13027	0.0000036
Line4			1000.0	0	1	75	0.09490	0.19890	0.0000036
Line5			1000.0	0	1	75	0.08205	0.19207	0.0000036
Line6			1000.0	0	1	75	0.03181	0.08450	0.0000036
Line7			1000.0	0	1	75	0.10000	0.11001	0.0000036
Line8			1000.0	0	1	75	0.10000	0.17615	0.0000036
Line9			1000.0	0	1	75	0.05403	0.22340	0.0000036
Line10			1000.0	0	1	75	0.01938	0.05917	0.0000036
Line11			1000.0	0	1	75	0.05695	0.17388	0.0000036
Line12			1000.0	0	1	75	0.01355	0.04211	0.0000000
Line13			10000.0	0	1	75	0.05810	0.17632	0.0000036
Line14			1000.0	0	1	75	0.04699	0.19797	0.0000036
Line15			10000.0	0	1	75	0.06701	0.17103	0.0000036
Line16			1000.0	0	1	75	0.22092	0.19980	0.0000036
Line17			1000.0	0	1	75	0.12291	0.25580	0.0000036

Table 2: Line data

Line resistances are listed at specified temperatures.There are 17 transmission lines, in our test system.

Lumped Load Input Data

	Lumped Load						Motor Loads							
Load	Rating				% Load		Loading		% Imp. (Machine Base)			Time Constant		
ID	kVA	kV	Amp	% PF	MTR	STAT	kW	kvar	R	X"	R/X"	Td'	Tdc	MW/PP
Lump1	152531.6	132.000	667.15	90.00	80	20	109822.80	53189.61	1.53	15.31	0.10	.2000	0.04	109.82
Lump2	137865.8	132.000	603.01	93.00	80	20	102572.10	40539.11	1.53	15.31	0.10	.2000	0.04	102.57
Lump3	195593.5	132.000	855.50	92.00	100	0	179946.00	76656.68	1.53	15.31	0.10	.2000	0.04	179.95
Lump4	222957.5	220.000	585.11	95.00	80	20	169447.70	55694.78	1.53	15.31	0.10	.2000	0.04	169.45
Lump5	160592.8	220.000	421.45	95.00	100	0	152563.10	50145.07	1.53	15.31	0.10	.2000	0.04	152.56
Lump6	294300.0	220.000	772.34	84.84	80	20	199752.00	124624.00	1.53	15.31	0.10	.2000	0.04	199.75
Lump7	157829.9	220.000	414.20	40.01	100	0	63140.00	144650.00	1.53	15.31	0.10	.2000	0.04	63.14
Lump8	150432.1	132.000	657.97	95.00	80	20	114328.40	37577.92	1.53	15.31	0.10	.2000	0.04	114.33
Lump9	159401.9	132.000	697.20	95.00	80	20	121145.40	39818.58	1.53	15.31	0.10	.2000	0.04	121.15
Lump10	139457.4	132.000	609.97	93.00	80	20	103756.30	41007.11	1.53	15.31	0.10	.2000	0.04	103.76
Lump11	140922.7	132.000	616.38	39.11	80	20	44088.00	103760.00	1.53	15.31	0.10	.2000	0.04	44.09

Total Connected Lumped Loads (= 11): 1911885.2 kVA

Table: 3: Lumped load data

In the test system, eleven loads are connected.
With the above data symmetrical fault was done and the results were as below

3-Phase Fault Currents

Bus		Short Circuit Current (kA, rms)		
ID	kV	Subtransient	Transient	Steady State
Bus1	220.000	58.438	54.635	21.966

The above results indicate the fault current during sub-transient, transient, and steady-state conditions where it is noticed that the transient current surges to 54.635 kA and settles to 21.966 kA at steady state.
Prior fault - It is observed from the single line drawing, that the normal current flowing through bus1 was 1.452KA.
During fault - When the fault is simulated in bus 1, the following is observed

- Sub–transient component of fault current = 58.438 KA
- Transient component of the fault current = 54.635 KA
- Steady-state component current = 21.966 KA

From the above values, the magnitude of the fault current is observed. The following results explain the severity of the symmetrical fault in detail.

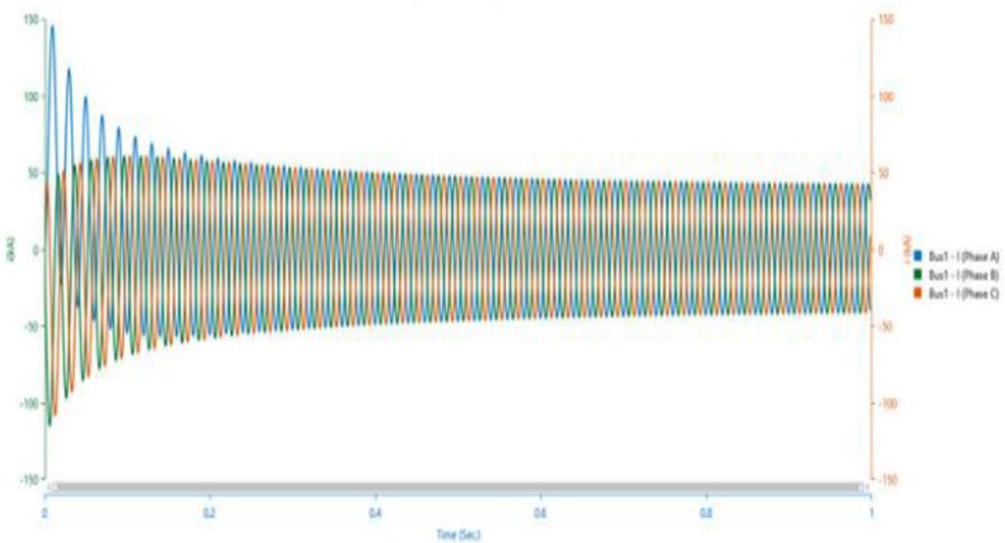

Fig 3: Magnitude of phase - A current

The magnitude of Phase A current is more compared to that in other two phases, as the fault was induced when the magnitude of current was at its peak in Phase A.
The following are some outputs obtained from ETAP the behavior of voltage during the fault.

BUS 1

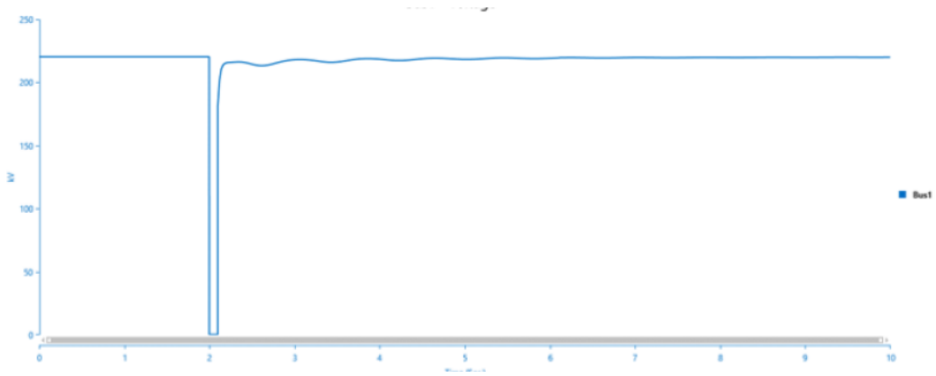

Fig: 4: Voltage at Bus 1

BUS 2

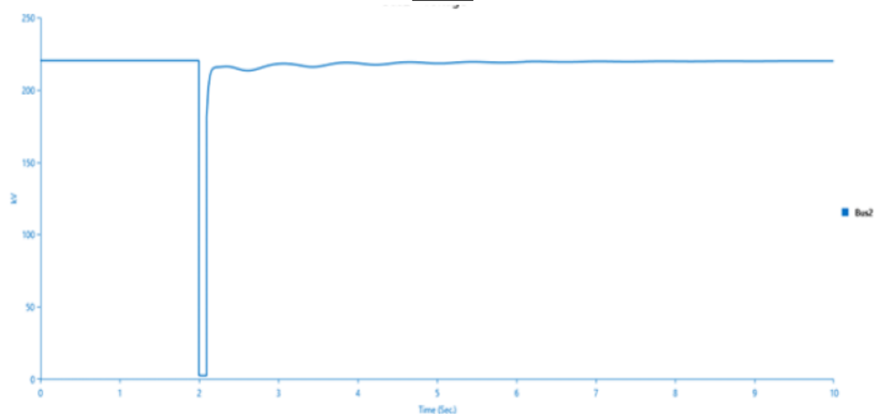

Fig: 5: Voltage at Bus 2

BUS 13

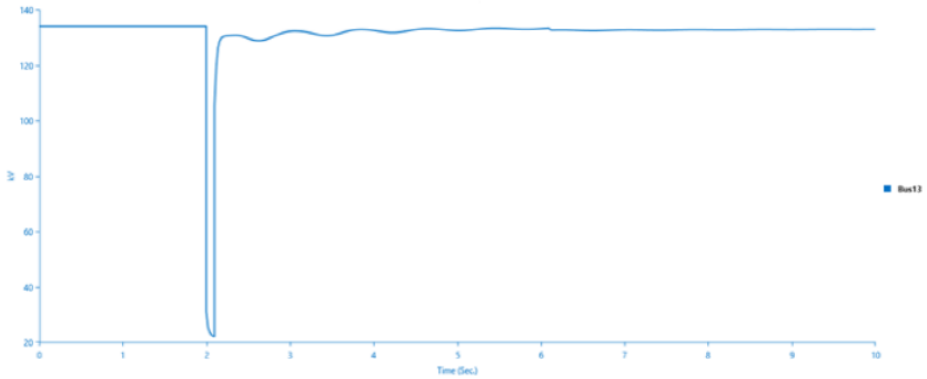

Fig: 6: Voltage at Bus 13

IV.INTERPRETATIONS AND DISCUSSIONS :

The symmetrical fault is induced at 2 seconds, in Bus 1, of the given test system. The fault is set to stay for 200 milliseconds.

Observations made from the voltage versus time plots:-

Prior fault – The voltages of bus 1 to bus 5 is at 220KV, and that of bus 13 is at 132 KV (the rated values for the given test system)

During fault - In buses 1 to 5 of the given test system, the voltage drop is from 220 KV to almost zero. Almost similar plots are observed in all these buses as they are all located very close to bus1, where the fault was simulated. But, in bus 13, the voltage waveform is a little different from the other buses considered. The reason is, it is located away from bus1. It is seen that the voltage drops in this bus too, during the fault, as it is an interconnected system and the consequence of the fault is felt throughout the system.

Post fault – Post fault, in all these buses, the system tries to bring back the voltage to normal value. That is, close to 220KV – In buses 1 to 5, and close to 132KV in bus 13, which are the rated values of the given test system.

V.CONCLUSION :

This research work focused on studying and understanding the behavior of three-phase symmetrical short circuit analysis, using a modified IEEE 14 bus system, as the test system, on which the fault was simulated, using ETAP software. The fault was simulated on bus 1 which was connected to the highest capacity
generator of 400 MW, to see the consequences of the fault on the entire interconnected network.

VI.FUTURE SCOPE :

This research offers various future prospects. It provides opportunities in power system design, protection, coordination, equipment sizing, and ensuring compliance with safety standards. It also opens doors for exploring complex scenarios, studying system behavior during faults, and enhancing the reliability and efficiency of the power systems. This knowledge is valuable to electrical engineers working in power generation and utility companies, offering a better know-how in research and development.

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