Active Power Observation through Stability Analysis in IEEE 14 Bus System

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ABSTRACT

Active power flow through a transmission line is one of the main index for reliable operation of power system. During abnormal condition this power can be observed using stability analysis. In this paper, IEEE 14 bus system has been selected for this time domain simulation. A three phase fault has been considered as an abnormal condition for the power system. In addition, this work also observed the rotor angle of the synchronous generators of the system. Results of these observations would be helpful for an operator to take necessary steps for normal operation of a power system as well as planning to improve the system.

Keywords: Stability analysis, Three phase fault, Rotor angle.

1 Introduction

Stability analysis is one of the main analysis required both for the planning and operation of power system. A stable power system has an ability to turn an abnormal system to the normal operating power system whenever fault has been cleared [1]. An effective analysis generally starts considering a stander system taken from the resource of Institute of Electrical and Electronics Engineers (IEEE). A good number of research papers reported in literature have addressed the issues of power system stability analysis [2-5]. Although a few of them are considered a three phase fault for an abnormal condition they were not observed active power in time domain. Those works also not addressed both active power flow in a transmission line and the rotor angle of the synchronous generators in a single work. In [2] worked on transient stability for IEEE 14 bus system using power world simulator. Transient stability analysis was divided into three different analyses. Those were rotor angle stability, bus voltage stability, and frequency stability. According to that analysis, fast fault clearing and fault location factors can be approved for system stability.

This paper [3] presents an analysis on IEEE 14 bus system using power world simulator for high quality electrical energy in a secure & economic manner. The quality power with minimum pollution level would be supplied to the consumer by maintaining a number of important constraints voltage security, environmental constraints. This system considered with or without Flexible AC Transmission System (FACTS) controller. The simulation results are compared & matched with other simulator's results.

In [4] IEEE-14 bus system has been analysed using PSAT simulator. It evaluated the performance of the system, integrating with wind power system, when subjected a three-phase fault at various buses. They addressed the voltage variations in all the buses in time domain with or without connected a wind power system. Their results show that the integration of wind power system has improved the transit stability of the system.

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The stability of the IEEE 14 bus system was analysed with and without photovoltaic (PV) and wind power system in [5]. In this work ETAP software is used for transient stability and load flow analysis where showed that the real and reactive power compensation in a system reduces transmission losses, fuel cost and finally showed the improvement of stability of the system.

2 Methodology

Active power flowing through a transmission line and variation of rotor angle of a generator have been described in the following two sections.

2.1 Active Power in Transmission Line

Fig. 1 shows a transmission line connected between Bus 1 and Bus 2 [6]. Active power or real power flows from Bus 1 to Bus 2. Equation 1 is the expression for the active which is the function of bus voltages and impedance of the transmission line.

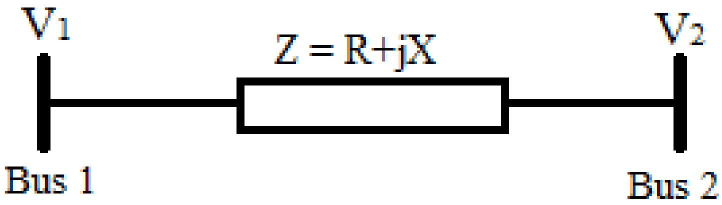


Fig. 1 Transmission line between two buses.

$$P_{12} = \frac{1}{R^2 + X^2}\left(R|V_1|^2 - R|V_1||V_2|cos\gamma + X|V_1||V_2|\sin\gamma\right) \tag{1}$$

Where,

$\boldsymbol{V}_1 = |V_1|\angle\theta_1$

$\boldsymbol{V}_2 = |V_2|\angle\theta_2$

R= Resistance of transmission line

X= Reactance of transmission line

$\gamma = \theta_1 - \theta_2$

2.2 Rotor Angle in Generator

Variation of rotor angle of a synchronous generator can be expressed using equation 2.

$$\frac{H}{180f}\frac{d^2\delta}{dt^2} = P_m - P_e \tag{2}$$

Where,

δ = Rotor angle of the synchronous generator

P_m= Mechanical power input

P_e= Electrical power output

H= Rotor inertia constant

f= frequency

3 Procedures

An IEEE 14 bus system shown in Fig. 2 has been designed for this work using the software Dig SILENT 15.1. This system has 14 Buses, 5 Generators, 11 Loads, 20 Transmission lines and 3 Transformers, Table I shows the data of load demand and Table II shows the data for the generators where mention real and reactive power. Out of five generators two synchronous generators supply real power while three generators supply only the reactive powers. The system has total real power load 259 MW and reactive power load 75.5 MVAr. Table III shows the transmission line data and Fig. 3 shows the voltage magnitudes of all 14 bus of the system.

TABLE I: LOAD DEMAND FOR IEEE 14 SYSTEM

Load	P (MW)	Q (MVAr)
Load 02	21.70	12.70
Load 03	94.20	19.00
Load 04	47.80	-3.90
Load 05	7.60	1.60
Load 06	11.20	7.50
Load 09	29.50	16.60
Load 10	9.00	5.800
Load 11	3.50	1.80
Load 12	6.10	1.60
Load 13	13.50	5.80
Load 14	14.90	5.00
Total	259.00	73.50

TABLE II: GENERATOR DISPATCH FOR IEEE 14 BUS SYSTEM

Generator	Dispatched P (MW)	Dispatched Q (MVAr)
Gen 1	232.40	-16.90
Gen 2	40.00	42.40
Gen 3	0.00	23.40
Gen 6	0.00	12.20
Gen 8	0.00	17.40

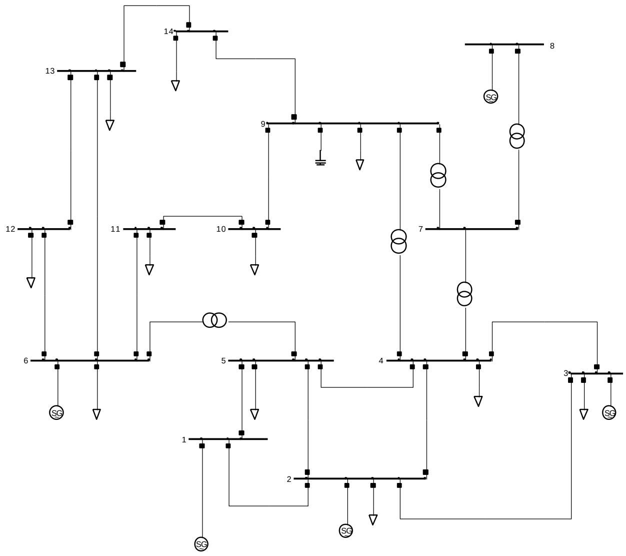


Fig. 2 IEEE 14 bus system.

TABLE III: TRANSMISSION LINE DATA FOR IEEE 14 BUS SYSTEM

Line, bus to bus	**R (p.u.)**	**X (p.u.)**	**Half line Charging susceptance (p.u.)**
L1-2	0.01938	0.05917	0.02640
L2-3	0.04699	0.19797	0.02190
L2-4	0.05811	0.17632	0.01870
L1-5	0.05403	0.22304	0.02460
L2-5	0.05695	0.17388	0.01700
L3-4	0.06701	0.17103	0.01730
L4-5	0.01335	0.04211	0.00640
L5-6	0.0	0.25202	0.0
L4-7	0.0	0.17615	0.0
L7-8	0.0	0.17615	0.0
L4-9	0.0	0.55618	0.0
L7-9	0.0	0.11001	0.0
L9-10	0.03181	0.08450	0.0
L6-11	0.09498	0.19890	0.0
L6-12	0.12291	0.25581	0.0
L6-13	0.06615	0.13027	0.0
L9-14	0.12711	0.27038	0.0
L10-11	0.08205	0.19207	0.0
L12-13	0.22092	0.19988	0.0
L13-14	0.17093	0.34802	0.0

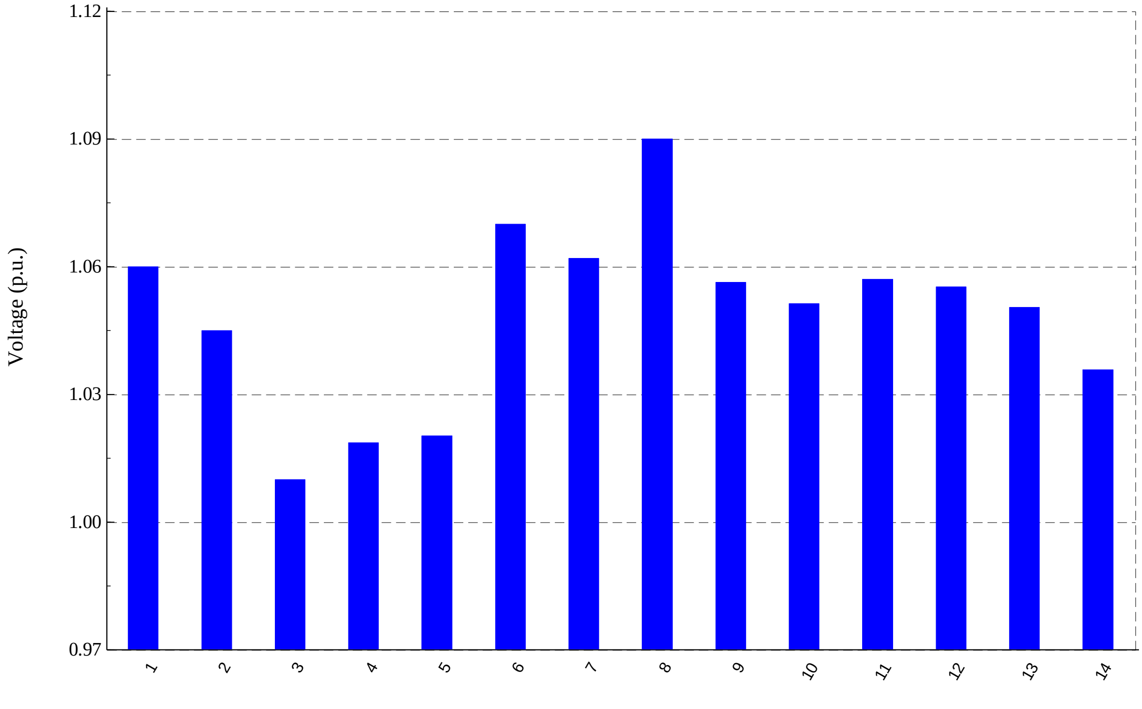


Fig. 3 Voltage magnitude of all bus of IEEE 14 bus after load flow.

4 Results And Discussions

4.1 Active Power in Line 13-14

Fig. 4 shows the active power flowing through transmission line L13-14. This value is 5.6 MW.

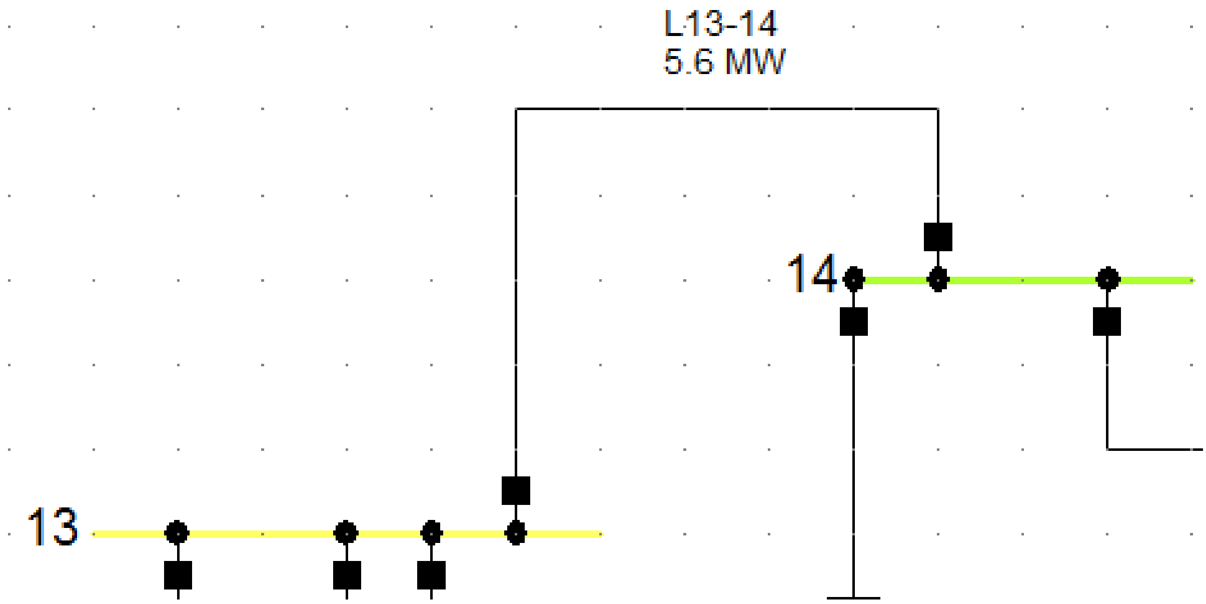
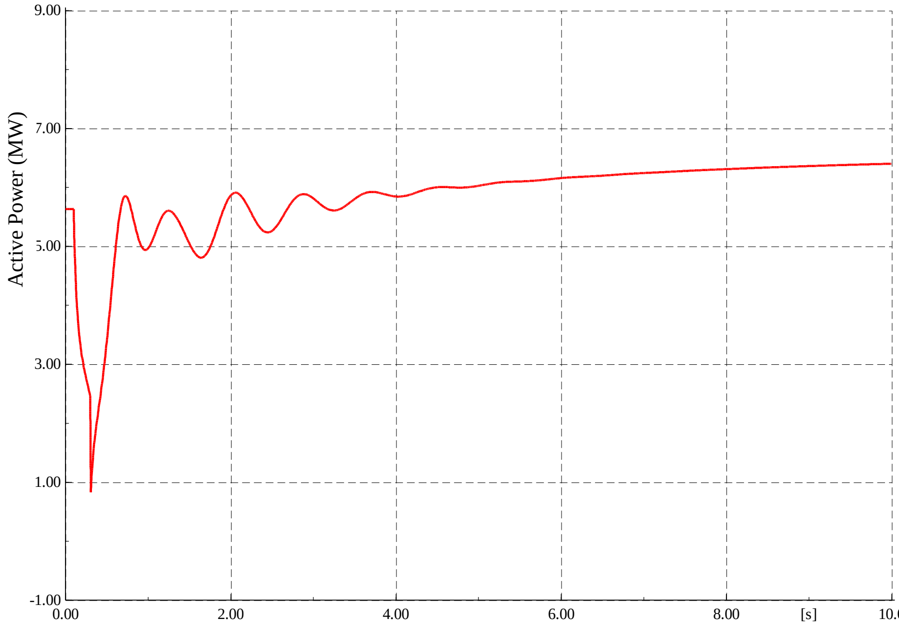


Fig. 4 Active power flowing through transmission line L13-14.

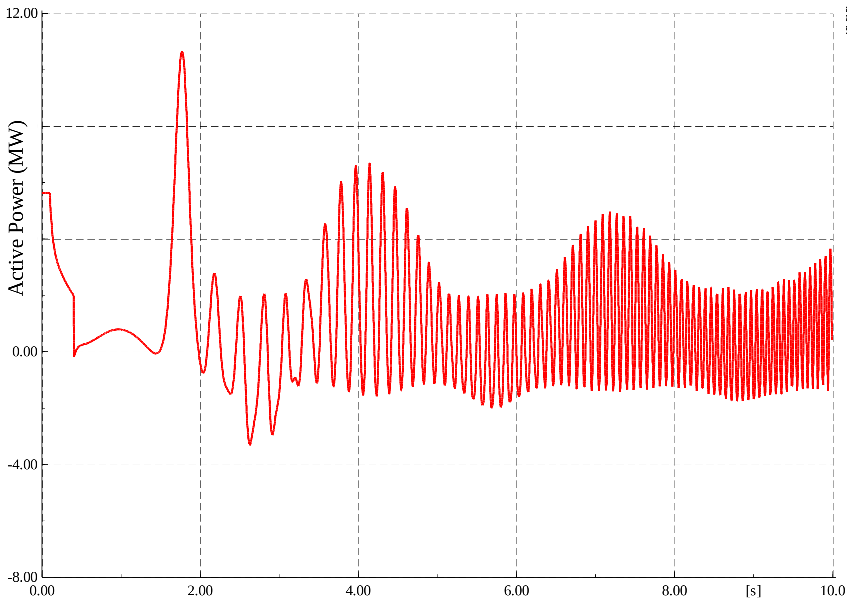
Fig. 5 shows the active power flowing through the transmission line L13-14 during fault near bus 2 and fault duration 0.2s. This value goes below 1 MW and reach 6.4 MW at 10 second.



Time (Sec.)

Fig. 5 Active power flowing through transmission line L13-14 when fault near bus 2 and duration 0.2s.

Active power flowing through transmission line become abnormal value fault duration is 0.3 second shown in Fig. 6.



Time (Sec.)

Fig. 6: Active power flowing through transmission line L13-14 when fault is near bus 2 in transmission line L2-4and duration 0.3s.

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4.2 Rotor Angle of Gen 2

Fig. 7 shows the simulation result for the rotor angle of generator 2 when fault is near bus 2 in transmission line L2-4 and fault duration 0.2s. Rotor angle is -30.52 degree at 10s which was -30.81 degree before fault.

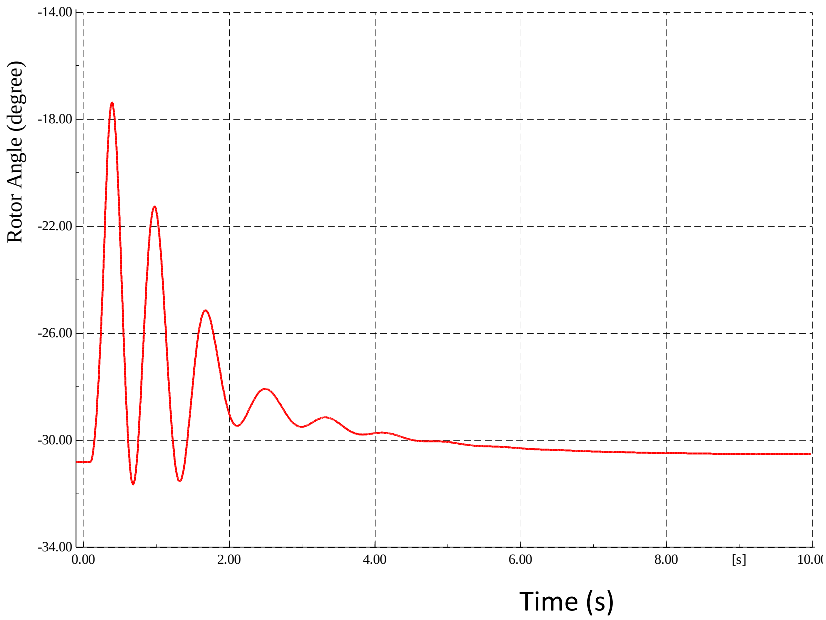

Fig. 7 Rotor angle of generator 2 when fault is near bus 2 in transmission line L2-4 and fault duration 0.2s.

Fig. 8 shows the simulation result for the rotor angle of generator 2 when fault is near bus 2 in transmission line L2-4 and fault duration 0.3s. Rotor angle is -19.69 degree at 10s which was -30.81 degree before fault.

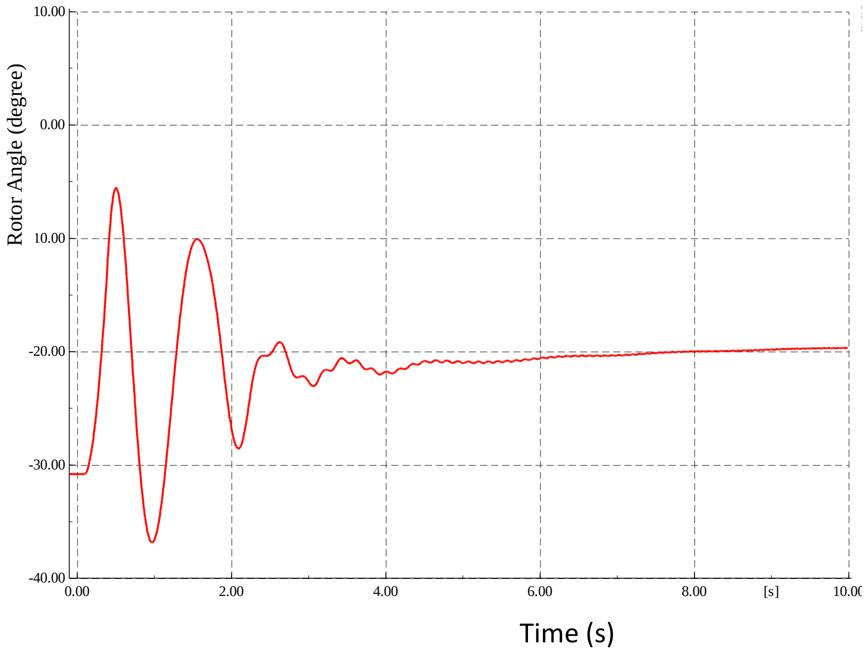

Fig. 8 Rotor angle of generator 2 when fault is near bus 2 in transmission line L2-4 and fault duration 0.3s.

Although the rotor angle remain in a few change the active power varies in a wide range when fault duration was increased. So the active power observation through the simulation is required for designing the protection of the load connected near transmission line L13-14.

5 Conclusion

A number of transient simulation for 10 second period have been made in this work where a three phase fault is considered in near the bus of the transmission line L2-4 of IEEE 14 bus system. When fault duration varies from 0.2s to 0.3s rotor angle of the nearest generator remain synchronism. Although the change in rotor angle shows small variation but the active power of a selected transmission line L13-14 varies in wide range when fault duration was increased. So the observation of active power through the transient stability analysis is required for designing the protection of the load connected near transmission line L13-14 which is located far away from fault location.

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