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ANALYSIS OF FAULTS AND TRANSIENT STABILITY IN MULTI PHASE SYSTEM

Pramod Kumar Baghmar[1], Payal Roy[2], Ashish Dewangan[3]

[1] *Department of Electrical Engineering, CCET, Bhilai (India) pramodbaghmar@gmail.com*
[2] *Department of Electrical Engineering, CCET, Bhilai (India) payalroy010684@gmail.com*
[3] *Department of Electrical Engineering, CCET, Bhilai (India) dewangan.aniket86@gmail.com*

Abstract — *High phase order transmission system is being considered a viable alternative for increasing the power transmission capability of overhead electric power transmission over existing right-of-way. This paper presents the faults and transient stability analysis of six-phase transmission system. In this context, fault analysis has been conducted on the Goudey-Oakdale 2-bus test system. The results of these investigations are presented in the form of typical time responses. The PSCAD/EMTDC is used for the simulation studies.*

Keywords- *Power transmission, power transmission fault, fault currents, power system simulation, PSCAD, Six phase, three phase, transmission line, overhead line .*

I. INTRODUCTION

The future growth of power systems will rely more on increasing capability of already existing transmission systems, rather than on building new transmission lines and power stations, for economical and environmental reasons. The external pressure have mounted on the power transmission to find the best solutions about the need to transmit greater amounts of power through long distances with fewer aesthetic and electrical impacts on the environment. The pressures have led to re-examination of basics of the three-phase system. In some applications, for transmitting power over very long distances it may be more economical to convert the EHV ac to EHV dc, transmit the power over two lines, and invert it back to ac at the other end. But the main disadvantage of the dc link is the production of harmonics which requires filtering, and a large amount of reactive power compensation required at both ends of the line. For other applications, it has seemed advantageous to optimize some form of ac. These have renewed interest in techniques to increase the power carrying capacity of existing right-of-ways (ROW) by using the higher order transmission system. Six-phase transmission appears to be the best solution to the need to increase the capability of an existing transmission line and at the same time, responds to the concerns relating to economical and environmental effects. A good deal of research effort applied since early 1970's has proved the economic viability of three to six-phase conversion of an existing three-phase double-circuit line.

Conversion of an existing three-phase double-circuit overhead transmission line to six-phase single-circuit operation is needed phase conversion transformers to obtain the 60° phase shift between adjacent phases. Three-phase double-circuit transmission line can be easily converted to a six-phase single-circuit transmission line by using two pairs of identical delta-wye three-phase transformers connected at each end of the line as shown in Fig. 1. One of each pair of transformer has reverse polarity to obtain the required 60° phase shift.

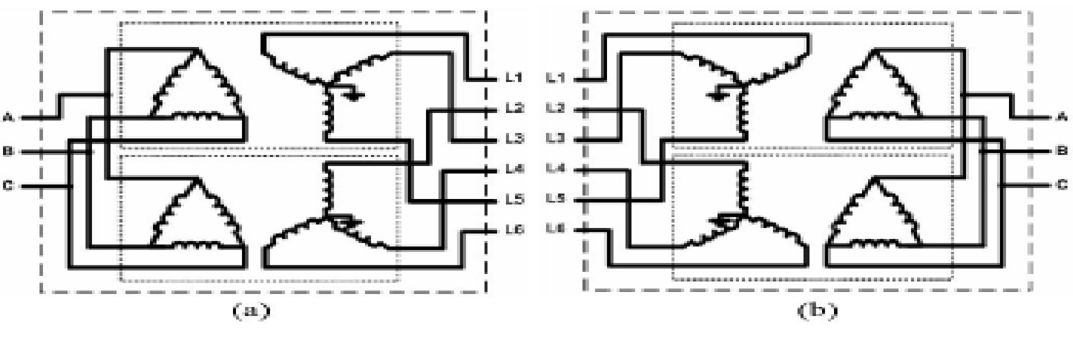


Fig. 1. Two pairs of identical delta-wye three-phase transformer. One of each pair of transformer has reverse polarity. (a) Sending end , (b) Receiving end

The aim of this paper is to analysis of fault and transient stability of six phase transmission line.To demonstrate the effects of six-phase conversion, test system has been simulated using PSCAD/EMTDC.

II. SIX-PHASE FAULTS

The various types of faults likely to occur on a six-phase system may be as large as eleven in number, compared with only five in the case of three-phase systems. Six-phase faults are the most severe and least common, whereas single-line-to-ground faults are least severe but most common. In addition, faults involving two and three phases with several distinct possibilities may be more frequent in six-phase systems than in three-phase systems. In an earlier work, four types of faults (viz. six-phase, single-line-to-ground, three-phase- to-ground and five-phase-to-ground) were analyzed using the symmetrical component transformation lacking the power invariant feature. The relations were developed only for the calculation of sequence currents, without any numerical illustration. In the present investigation , all possible cases of faults are considered using power invariant symmetrical component transformations derived from group theoretic considerations, expressions for fault currents and voltages (both in sequence components and phase variables), and the connection of the sequence network in each case is also presented.

The various types of faults that can occur in a six-phase system, which is considered here, are:
(1) single-phase-to-ground fault (LG),
(2) two-phase-to-ground fault (LLG),
(3) two-phase fault (LL),
(4) three-phase-to-ground fault (LLLG),
(5) three-phase fault (LLL),
(6) four-phase-to-ground fault (LLLLG),
(7) four-phase fault (LLLL),
(8) five-phase-to-ground fault (LLLLLG),
(9) five-phase fault (LLLLL),
(10) six-phase-to-ground fault (LLLLLLG),
(11) six-phase fault (LLLLLL).

In the development to follow, the six-phase system is assumed to be balanced and unloaded, i.e. open-circuited during the pre-fault stage, and all faults are assumed to be bolted just to simplify matters for clarity of presentation.

III. TRANSIENT STABILITY

Transient stability is the ability of a power system to remain in synchronism when subjected to large transient disturbances. These disturbances may include faults on transmission elements, loss of load, loss of generation, or loss of system components such as transformers or transmission lines. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power-angle relationship. Stability depends on both the initial operating state of the system and the severity of the disturbance. Usually, the system altered so that the post disturbance steady-state operation is differs from that prior to the disturbance. Most power system engineers are familiar with plots of generator rotor angle (δ) versus time (t). Fig. 2 illustrates the behaviour of a synchronous machine for stable and unstable situations. It shows the rotor angle responses for a stable case and for two unstable cases. In the stable case (Case 1), the rotor angle increases to a maximum, then decreases and oscillates with decreasing amplitude until reaches a steady-state. In Case 2, the rotor angle continues to increase steadily until synchronism is lost. This form of instability is referred to as first-swing instability and is caused by insufficient synchronizing torque. In Case 3, the system is stable in the first-swing but becomes unstable as a results of growing oscillations as the end state is approached. This form of instability generally occurs when the post-fault steady-state condition itself is "small-signal" unstable, and not necessarily as a result of the transient disturbance.

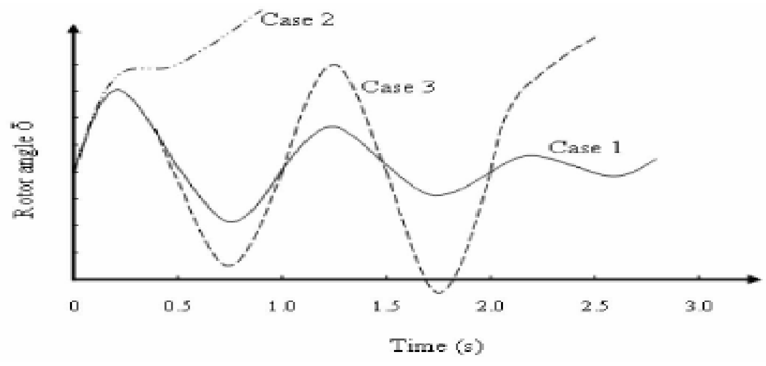


Fig. 2. Rotor angle response to a transient disturbance.

In large power systems, transient stability may not always occur as first-swing instability. It could be the result of the superposition of several modes of oscillation causing large excursions of rotor angle beyond the first swing. As far as transient stability is concerned, the most severe switching action is the balanced six-line fault. Two concepts are essential in understanding transient stability known as the swing equation and the power-angle relationship. The swing equation describes the swings of the rotor angle S during disturbances and is given by:

$$\frac{2Hd^2\delta}{\omega_0 dt^2} = \bar{T}_m - \bar{T}_e \qquad (1)$$

H = Inertia Constant
δ = Rotor angle
ω_0 = Rated angular velocity
$\bar{T}_m$ = Mechanical torque
$\bar{T}_e$ = Electromagnetic torque

For a system to be transiently stable during a disturbance, it is necessary for the rotor angle (as its behaviour is described by the swing equation) to oscillate around an equilibrium point. If the rotor angle increases indefinitely, the machine is said to be transiently unstable as the machine continues to accelerate and does not reach a new state of equilibrium. In multi-machine systems, such a machine will "pull out of step" and lose synchronism with the rest of the machines. The second concept of transient stability is power-angle relationship which is the relationship between the electrical power of the generator Pe, and the rotor angle of the machine S and is given by:

$$P = \frac{V_1 V_2 Sin\delta}{X} \qquad (2)$$

V_1 = Phase-to-ground voltage magnitude at the sending end of the line.
V_2 = Phase-to-ground voltage magnitude at the receiving end of the line.
δ = Rotor angle
X = Positive sequence impedance of the line.

Power flow is a maximum when δ = 90°. If the angle exceeds 90°, the power decreases with increasing angle. System changes which reduce S for the same power enhance the system stability, because there is additional margin for the system to swing without exceeding the 90°. Increasing phase to ground voltage by six-phase conversion increases the voltage, thus generally enhancing system stability in the same manner as system stability is enhanced by any conversion that results in a higher line operating voltage.

IV. STUDY SYSTEMS

SIX PHASE TRANSMISSION LINE SIMULATION MODEL IN PSCAD

Conversion of existing double-circuit three-phase overhead transmission line to a six-phase operation needed phase-conversion transformers to obtain the 60° phase shift between adjacent phases. A double-circuit three-phase transmission line can easily converted to a six-phase transmission line by using two pairs of identical delta-star, three-phase transformers connected at each end of the line as shown in Fig.4.1, Goudey to Oakdale has been reconfigured from an 115kV double circuit three-phase line to a 93kV six-phase line. The line will be operated with a nominal phase-to-ground voltage of 93 kV. The phase-to-phase voltage will be 93 kV between adjacent phases (60 degrees apart), 161 kV between phases (120 degrees apart), and 186 kV between opposite phases (180 degrees apart). For reconfigured 115kV three phase-double circuits to 93kV six phase lines, here we use two, three phase delta to star with ground 115/161kV transformers at Goudey side and two, three phase star to delta 161/115kV identical transformers at Oakdale side to obtain six phase 93kV transmission line, as shown in figure 4.1

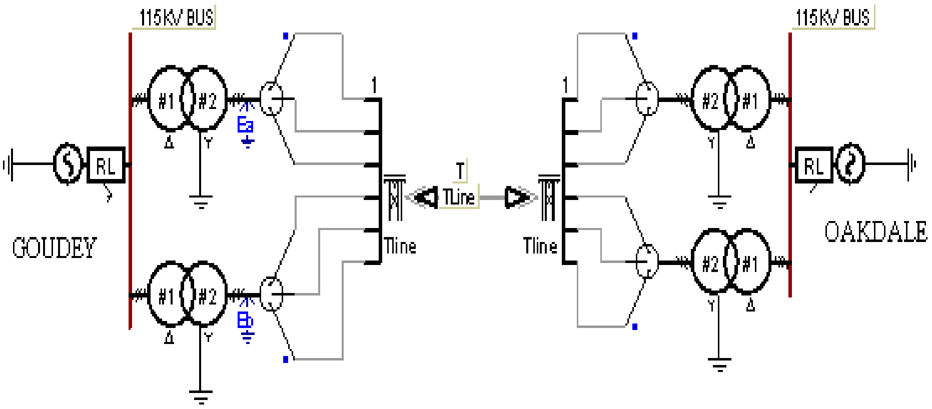


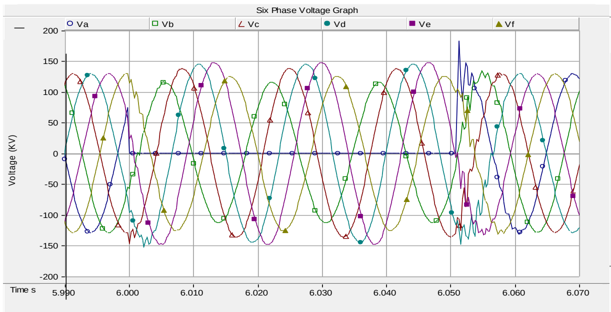
Figure-4.1 Conversion of double-circuit three-phase overhead transmission line to a six-phase line

V. ANALYSIS OF SIMULATION RESULTS

5.1. Fault Analysis

5.1.1 Transients due to Faults on Transmission Elements at Phase *A*

Single phase to ground fault occurs on phase **'a'** of six phase transmission line, at time 6.9 second phase voltage **'a'** is zero till the fault will be clear, and after 0.05 second fault will clear and voltage at phase **'a'** is increasing due to transient and after some time it attains normal position is shown in figure 5.1.1(a). The load angle graph is shown in figure 5.1.1 (b), the rotor swing high at the time of fault and oscillation is damp out and system comes in normal position. The real power P and reactive power Q are also swing due to swing in rotor and damped out with time is shown in figure 5.1.1(c) and (d).



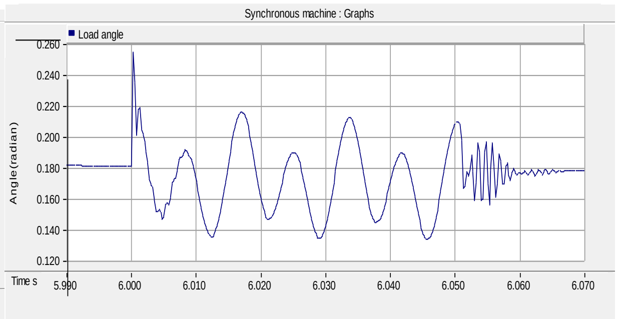
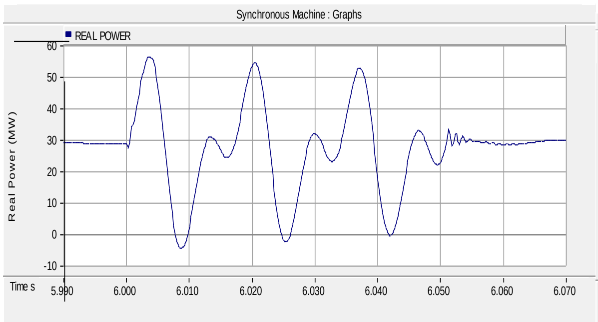


Figure 5.1.1 (a) Voltage Graph Figure 5.1.1 (b) Load Angle Graph



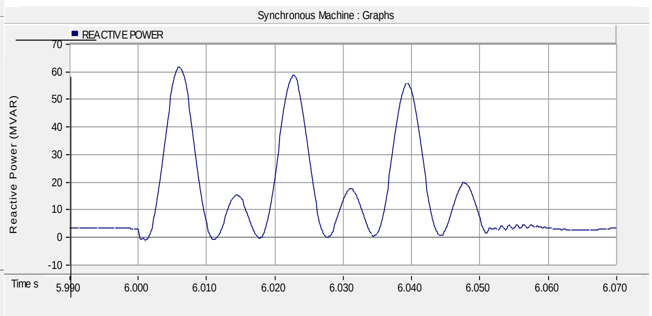


Figure 5.1.1 (c) Real Power Graph Figure 5.1.1 (d) Reactive Power Graph

5.2 Transient Stability Analysis

Transients when Six Phase Transmission Line charging at time 1.0 Second

5.2.1 Implemetation : (115 KV /161 KV)

When double three phase circuit converted in to six phase by changing the transformer connection as shown in figure 4.1 and charged with 115KV at time 1.0 second , then the transient is high at this time due to charging of line capacitors and inrush current of transformers. The voltage transient graph is shown in figure 5.2.1(a) at 1.0 second and transient is subsided in 0.09 second.

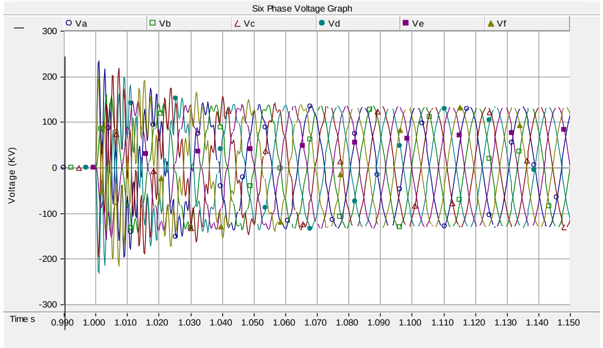


Figure 5.2.1(a) Voltage Graph for at the Time of Line charging at 1.0 Second

5.2.2 Implemetation: (115KV/161KV)

The load angle graph is shown in figure 5.2.2 (a), the rotor swing high at the time of charging and oscillation is damp out and system comes in normal position. The real power P and reactive power Q are also swing due to swing in rotor and damped out with time is shown in figure 5.2.2 (b) and (c),.

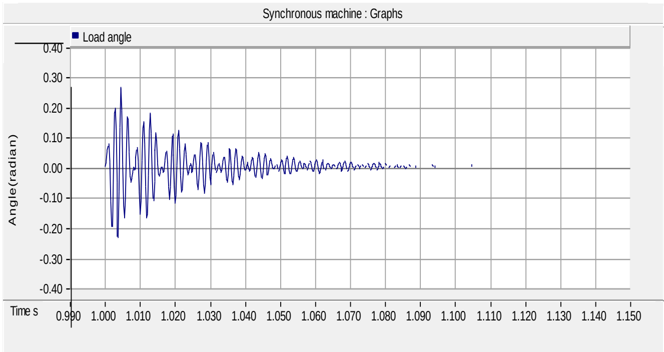


Figure 5.2.1 (a) Load Angle Graph

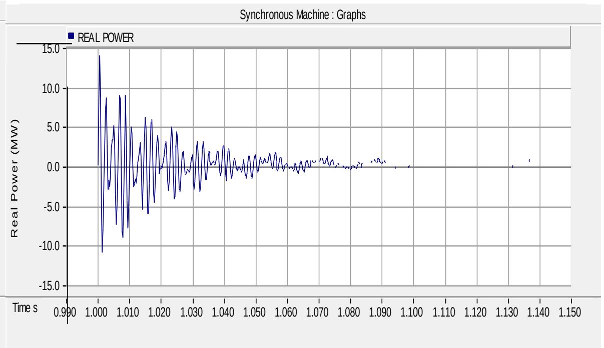


Figure 5.2.1 (b) Real Power Graph

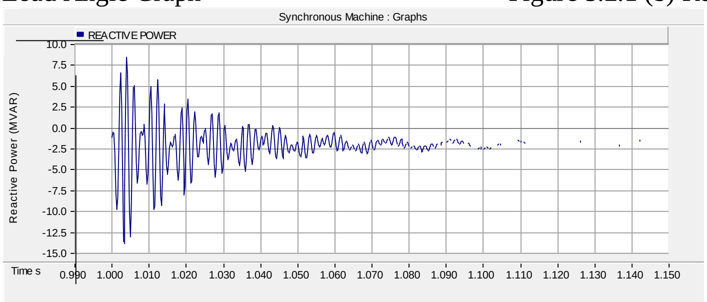


Figure 5.2.1 (c) Reactive Power Graph

5.2.3 Implemetation: Data From Captive Power Plant Korba (13.8KV/220KV)

When double three phase circuit converted in to six phase by changing the transformer connection as shown in figure 4.1 and charged with 13.8KV at time 1.0 second, then the transient is high at this time due to charging of line capacitors and inrush current of transformers.

The voltage transient graph is shown in figure 5.2.3(a) at 1.0 second and transient is subsided in 0.09 second

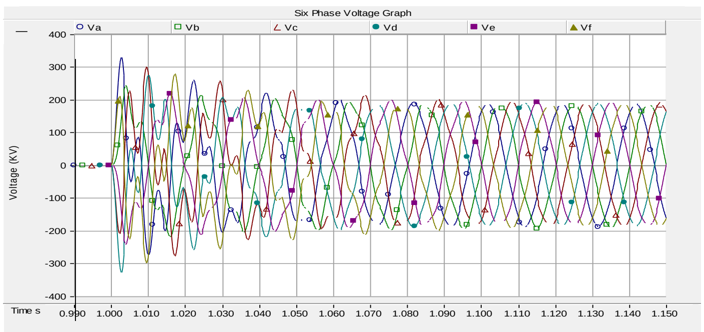


Figure 5.2.3 (a) Voltage Graph for at the Time of Line charging at 1.0 Second

5.2.4 Implemetation: Data From Captive Power Plant Korba (13.8KV/220KV)

The load angle graph is shown in figure 5.2.4 (a), the rotor swing high at the time of charging and oscillation is damp out and system comes in normal position. The real power P and reactive power Q are also swing due to swing in rotor and damped out with time is shown in figure 5.2.4 (b) and (c).

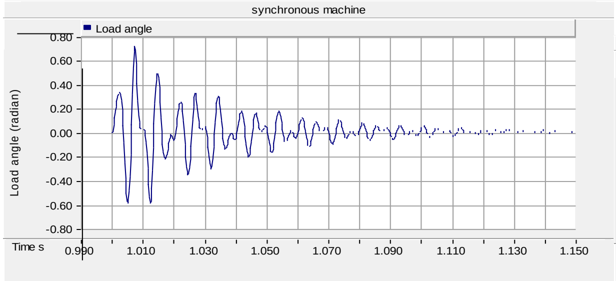


Figure 5.2.4 (a) Load Angle Graph

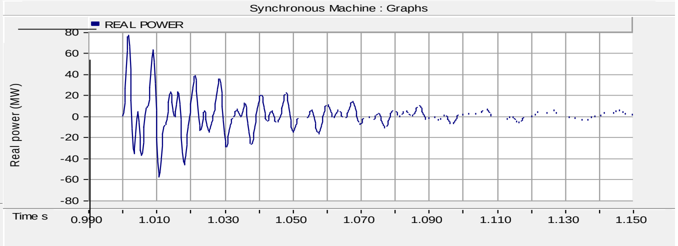


Figure 5.2.4 (b) Real Power Graph

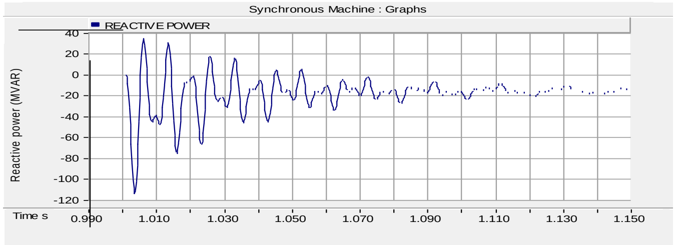


Figure 5.2.4 (c) Reactive Power Graph

VI. CONCLUSION

This paper investigates the faults analysis and transient stability of three to six-phase conversion of selected transmission line of test system. In this paper a detailed modelling of six phase transmission line in PSCAD for transient stability analysis is presented and also impacts of faults on the system are analyzed. The analysis is done by monitoring system stability of the test system. All possible types of fault on the middle of transmission lines have been applied to test systems and critical clearing times is estimated. This analysis has been conducted by using PSCAD/EMTDC.

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