Transient Stability Analysis of Six Phase Transmission System with Integration of WPGS and STATCOM with Smart Grid

T. Charan Singh, K. Raghu Ram, B.V. Sanker Ram

***Abstract:** In recent times Transient stability analysis has become a major concern in the operation of power systems due to the rising stress on power system networks. These difficulties require assessment of a power system's ability to with stand instability while maintaining the excellence of service. Many different techniques have been projected for transient stability analysis in power systems, especially for a multi machine system. This paper describes simulation of six phase multi-machine power system (MMPS) with wind power generator integration in dynamic operation. By the introduction of wind power generation system (WPGS) in multi-machine at weak bus in parallel with STATCOM can improve the generator load angle deviation during fault condition. The MMPS performance is analysed by placing six phase line between different buses. The replacement of transmission line can reduces the line impedances, which results in reduced angle distortion of machines and improved stability .The proposed WPGS based MMPS phase angle and frequency variations are analyzed during symmetrical and asymmetrical fault conditions. The MATLAB/Simulation software is used to test the behavior of proposed system.*

***Index Terms:** Wind system, six phase transmission line, STATCOM, multi-machine system, stability.*

I. INTRODUCTION

At present , the consumption of electrical energy has been increasing day by day due to worlds rapid industrialization along with the technological advancement, reliability of sophisticate machines and to meet this growing power consumption and requirement of future mankind, the fossil fuels are being exploited non-judicious manner to increase more power generation. For the sake of future generation's natural fuel sources are to be preserved as a part of this evolution, the search for renewable sources and utilization soaring high and researches have also been under the way [1][2][3]. As a part of sophisticated scientific technology, innovative and intricate modes of power generation at free of cost; natural, renewable source such wind has been the preferable option owing to its abundance and cheap availability. When the wide range is taken as of a renewable energy source, it is feasible in consideration that the availability of wind energy has been more useful in utilization.

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There are some small scale offshore wind farms (OWF) are under evaluation and some large scale OWF have been under operation commercially. Due to industrialization power transmission for long distances is needed here the impact of power quality has been a concern when an extensive quantity of electric power of OWF fed to power grids due to the power angle swings, reactive power and surges[4][5][6]. One of the solutions to overcome such adverse impacts is improve the power system by introducing FACTS devices. With the help of FACTS devices the stability of the power system can be greatly improved and extract the effective control of the power flow and quality. The one more cause for improving the transmission capability of lines and reducing the power swings is by reducing the transmission line impedance and incorporating the FACT devices at week bus. In the proposed system WPGS and the STATCOM are used for compensating the reactive power and power oscillations due to surges. However doubly fed induction generator (DFIG) is used in wind power generation system (WPGS) with variable speed wind turbine. The ability of DFIGWPGS is the high power conversion efficiency due to that, it is suitable for compensation as well as power feeding. The after case is the utilization of six phase transmission lines instead of three phase transmission. The six phase transmission line can reduce line reactance between different buses, STATCOM and WPGS are analyzed [5][6][7][8][9].in collaboration with 6-phase transmission system has advantages over a double-circuit line e.g. compact conductor gradients, better stability characteristics and potentially low audible noise levels, radio interference levels etc[10]. The New York State Electric Goudey Station (NYSEG)6-phase transmission demonstration project has provided an experimental system to explore the construction and operation [11].One of the significant aspects in the development of six-phase systems is the design of an ample protective scheme. This requires a comprehensive fault analysis for such systems. Venkata et al. did revolutionary work in the analysis of 6-phase faulted power system [12].

II. DFIG BASED WPGS DESIGN

Fig.1 shows representation of proposed system. WPGS and STATCOM devices are connected between bus 6 and bus 9 of a proposed multi machine system. The WPGS is fed with DFIG type of induction generator and run with variable-speed wind turbine (VSWT) with a proper gearbox. The required mathematical modeling of the system considered is described as below.

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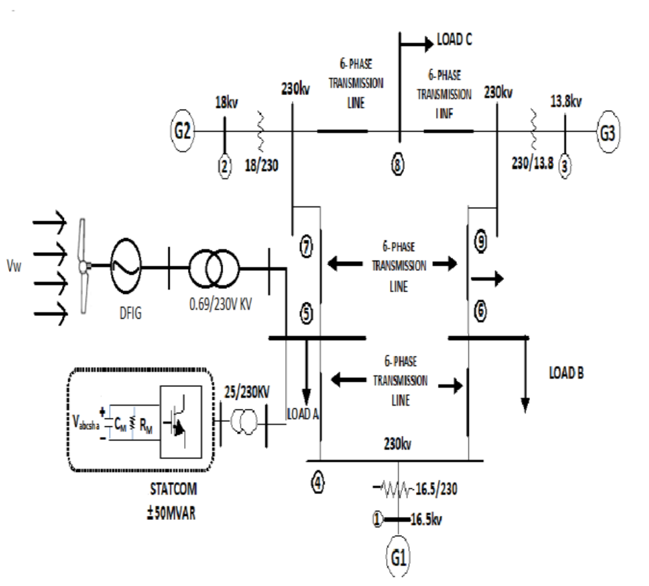

Fig .1 Proposed Smart grids with six phase transmission line and integrated with STATCOM and WPGS.

A. *Wind Turbine*

The prime mover power captured (in W) by a variable-speed wind turbine (VSWT) can be written by

$$P = \frac{1}{2}\rho \cdot A \cdot V_{\omega}^{3} \cdot C_{p} \qquad (1)$$

The power coefficient of the VSWT C_P is given by

$$C_P = 0.5[(116/\lambda_i) - .4\cdot\beta - 5]e^{-21/\lambda i} + 0.0068\cdot\lambda \qquad (2)$$

Whereλ is the Tip Speed ratio [7], β is the Pitch angle of the blade

$$\lambda = \frac{WR}{V\omega} \qquad (3)$$

Where W is the Rotor angular speed in rad/sec, R is the Rotor blade radius in meter

$$\frac{1}{\lambda_i} = \frac{1}{\lambda + 0.088\beta} + \frac{0.035}{\beta^3 + 1} \qquad (4)$$

Pitch Angle controller will starts at when the wind speed reaches to its rated or above rated value. Up to cut in to rated speed will maintain zero for optimum power extraction from the wind. The wind profiles of VSWT are 5, 12, and 19 m/s. When V_W > 14 m/s, $\beta = 0^0$. When V_W>14 m/s, the pitch-angle control is used to maintain constant turbine output power.

III. INTEGRATION OF STATCOM AND WPGS

A. *WPGS Model with DFIG*

DFIG stator and rotor is fed to primary side of 0.57/230-kV step-up three phase transformer and the rotor is fed with an inverter, a grid-side rectifier, DC link between RSC and GSC and a transmission line. For rated operation of a DFIG, inverter and rectifier effectively controls the real and reactive power. Fig. 2 represents controller designed for inverter control, and the working of inverter depends on $i_{qrw}$and i_{drw} to track the required reference position based on system real power and the transformer primary side voltage at the pre mentioned reference values. The voltage need for the inverter (v_{rw}) is getting by adjusting the per- unit d-axis and q-axis currents of the inverter.

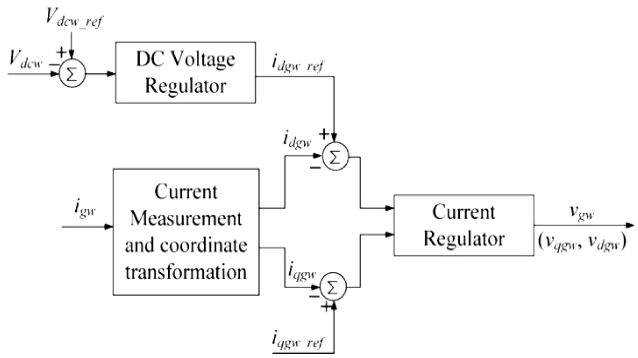

Fig. 2 Current controller for the GSC of the proposed system

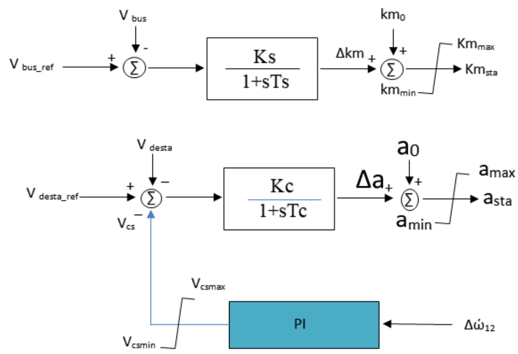

Fig.3 Controller block diagram

The voltage need for the inverter (v_{rw}) is getting by adjusting the per- unit d-axis and q-axis currents of the inverter. The controller used for grid-side converter is given in Fig. 3. The I_{pu} of d-axis and q-axis of rectifier, i_{qgw}andi_{dgw}, are track to get required values that are calculated by tracking the DC line voltage V_{dcw} at pre-determined reference point to maintain rectifier voltage (V_{gw}) at unity power factor. The needed voltage level of the rectifier is getting by maintain the I_{pu} of d-axis and q-axis rectifier [13].

B. *STATCOM Model*

STATCOM can compensate the reactive power and unbalanced voltages. The voltages as shown bellow

$$v_{dsta} = V_{dcsta} \ . \ Km_{sta} \ .\sin(\theta_{bus} + \alpha_{sta}) \qquad (5)$$

$$v_{qsta} = V_{dcsta} \ . \ Km_{sta} \ .\cos(\theta_{bus} + \alpha_{sta}) \qquad (6)$$

Here V_{dsta} and V_{dsta} are the direct axis and Quadrature component of STATCOM. Km_{sta} and α_{sta} are the angle and index for PWM of STATCOM

$$(C_m)p\ (V_{dcsta}) = W_b\ [I_{dcsta} - (\frac{V_{dcsta}}{R_m})] \qquad (7)$$

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Here p is a differential component of time t and electrical losses of the STATCOM is

$$I_{dcsta} = i_{dsta} .Km_{sta} .\sin(\theta_{bus} + \alpha_{sta}) + i_{qsta} .Km_{sta} .\cos(\theta_{bus}+\alpha_{sta}) \quad (8)$$

IV. RESULT ANALYSIS

The proposed system consists of three machine nine bus system. Based on the load flow analysis Bus number six is finding as a weak bus. Here STATCOM and WPGS are integrated at bus number six. The proposed system performance is analyzed in different cases.

Case 1: six phase transmission line is instead in between bus number 5 and 7, the fault is occurred at bus no 5, initiated at 17 seconds and is clear after 0.9 seconds. The performance analysis of proposed system with six phase short circuit fault is shown in fig.4.

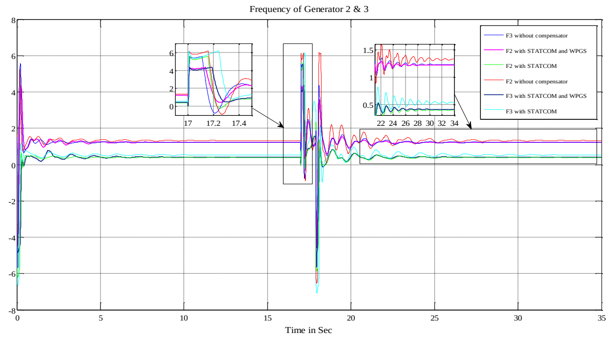

Fig. 4 (a)

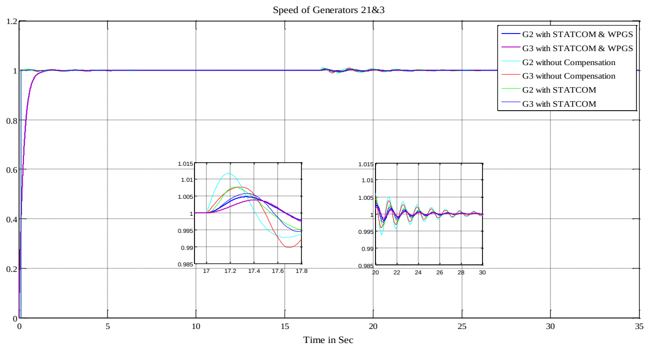

Fig. 4 (b)

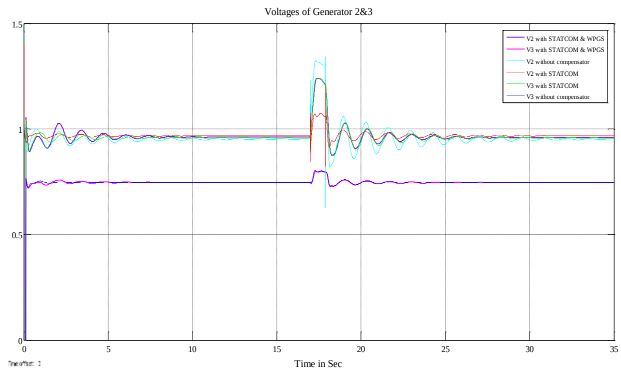

Fig. 4 (c)

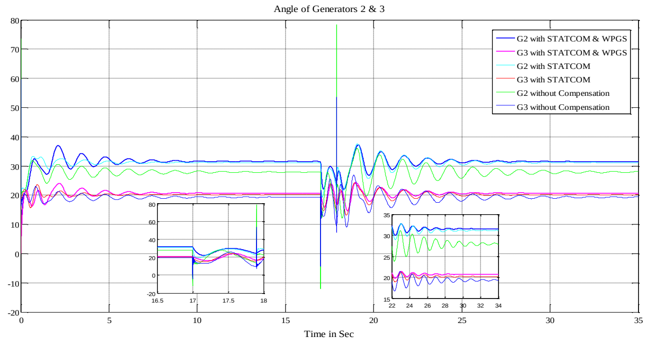

Fig. 4 (d)

Fig.4 The comparative analysis of generator 2 & 3 performance for proposed system and conventional system with L-L-G fault at bus 5, (a) Frequency variations (b) Speed variation (c) Voltage variations (d) Angle variations.However from fig.4 the maximum peak overshoots and time taken to stable the system is reduced. From fig.4 (d) the proposed WPGS with STATCOM maximum peak overshoot in generator 2 angle distortion is reduced from 17% to 6.4% and the time taken to stable the system after fault clearing is reduced from 13 sec to 8 sec, when compare with STATCOM as a compensator. By analyzing this WPGS and STATCOM integrated smart grid has more stability (Transient and Dynamic Stability) than smart grid with STATCOM. Case 2: six phase transmission line is instead in between bus number 5-7, 6-9; the fault is located at bus 5, from 11 seconds and is clear after 0.9 seconds. The proposed system with six phase transmission line between 5-7, 6-9 is subjected to L-L-L-G short circuit fault is shown in fig.5. Fig.5 have the result of smart grid with 2 six phase transmission lines between 5-7, 6-9 and all lines are instead with six phase transmission lines.

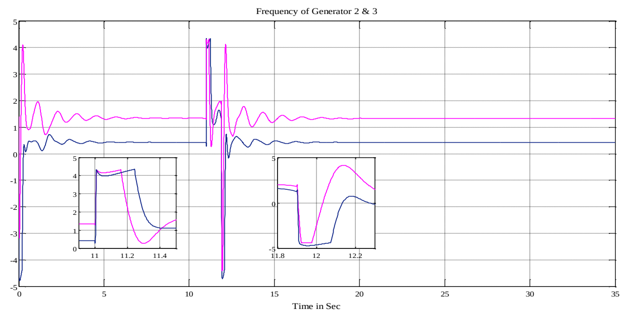

Fig. 5 (a)

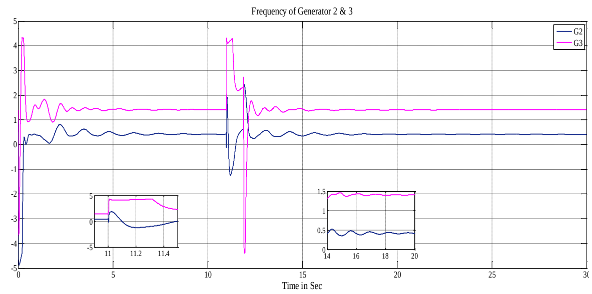

Fig. 5 (b)

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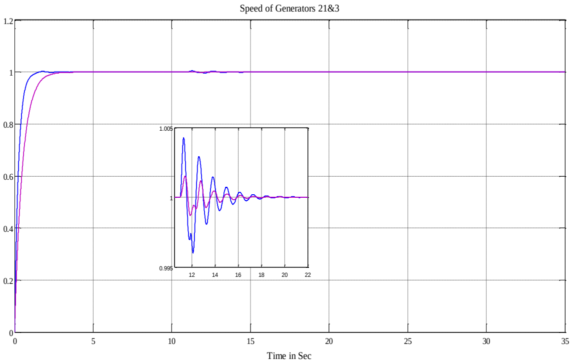

Fig. 5 (c)

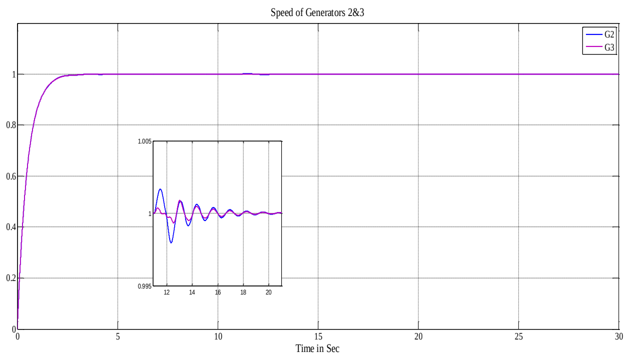

Fig. 5 (d)

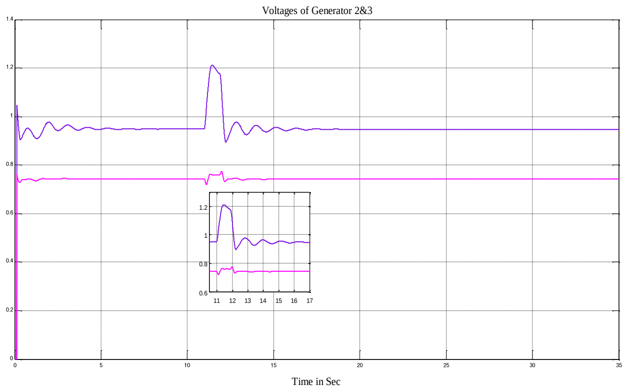

Fig. 5 (e)

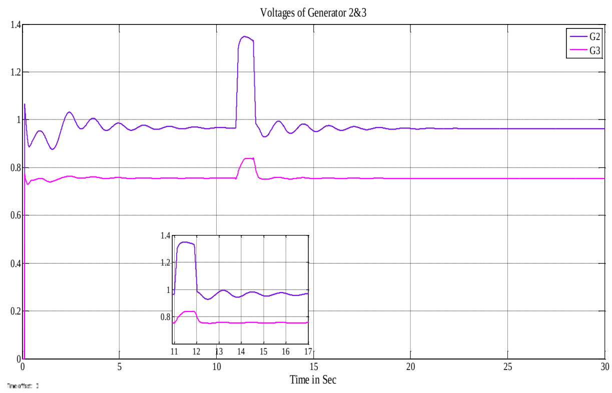

Fig. 5 (f)

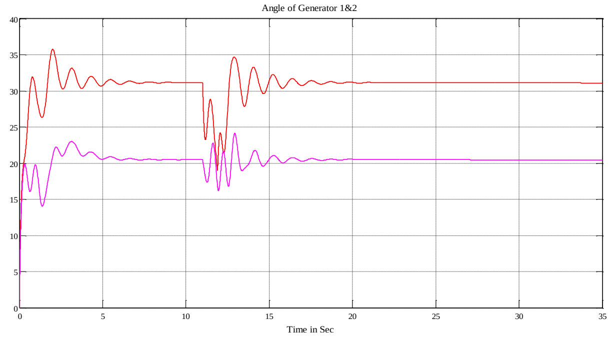

Fig. 5 (g)

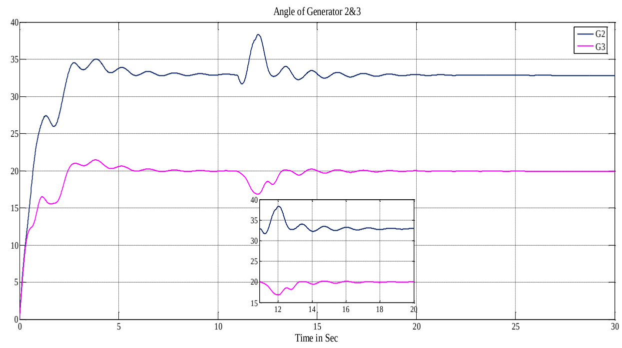

Fig. 5 (h)

Fig. 5 Generator 2 & 3 behaviour of proposed system under L-L-G fault with two six phase transmission lines between 5-7 & 6-9 (a) Frequency variations (b) Speed variation (c) Voltage variations (d) Angle variations.

Here by analysing fig.5 the maximum peak overshoot at fault initiation and time taken to reach stability after fault clearing is lesser for all six phase transmission lines than 2 lines are six phase in a smart grid.

Case 3: six phase transmission line is instead between all buses; the fault is located at bus 5, from 14 seconds and is clear after 0.9 seconds. The simulated result from fig.6 to fig.7 shows test system under different fault conditions.

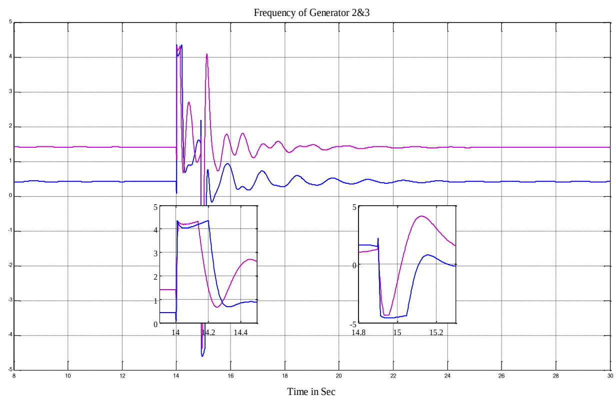

Fig. 6 (a)

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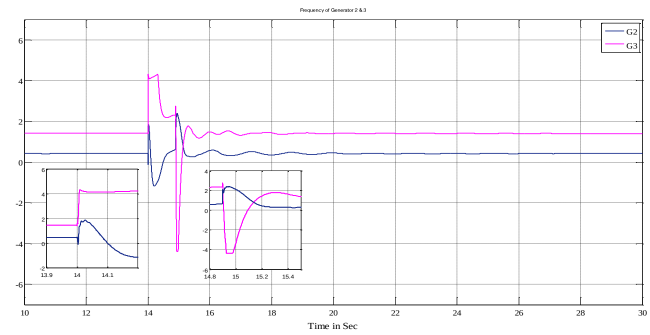

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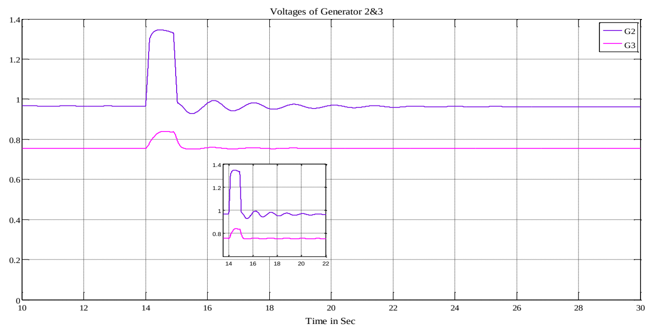

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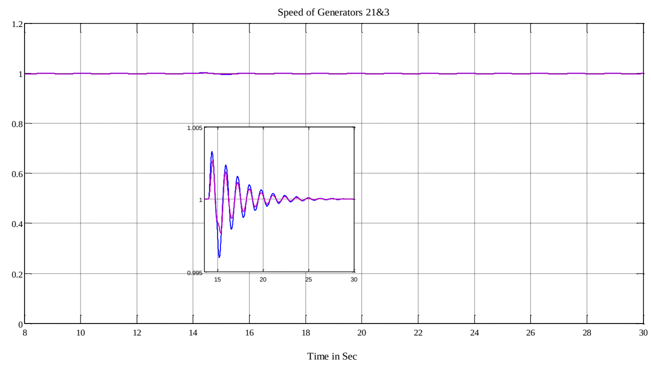

Fig. 6 (c)

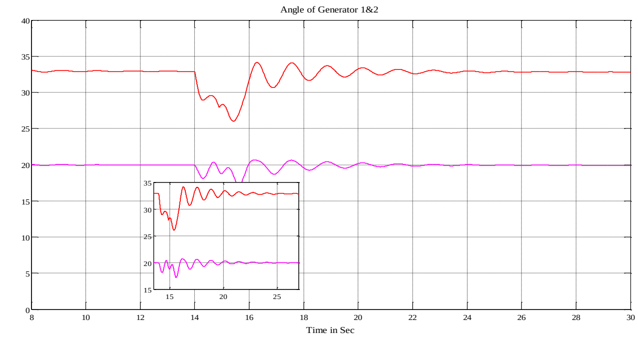

Fig. 6 (g)

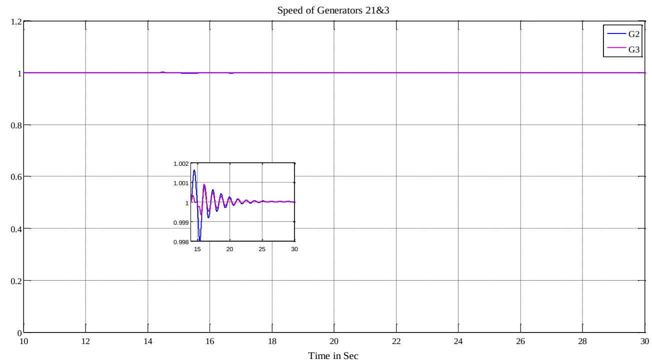

Fig. 6 (d)

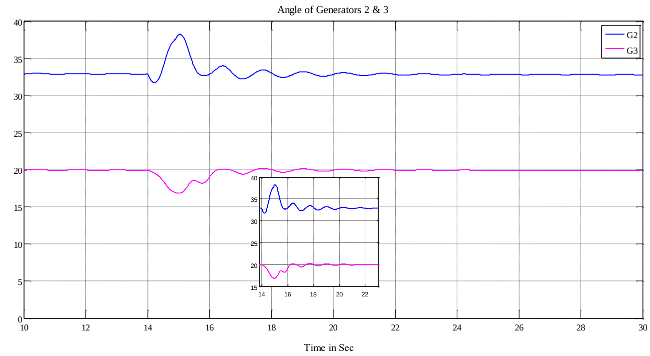

Fig. 6 (h)

Fig. 6 Generator 2 & 3 behaviour of proposed system under L-G and L-L-G fault with all six phase transmission lines instead (a) Frequency variations (b) Speed variation (c) Voltage variations (d) Angle variations.

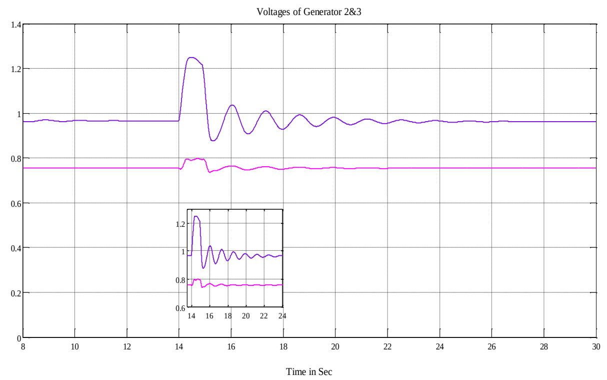

Fig. 6 (e)

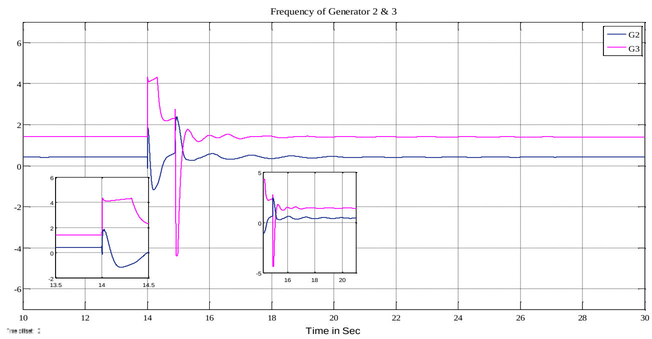

Fig. 7 (a)

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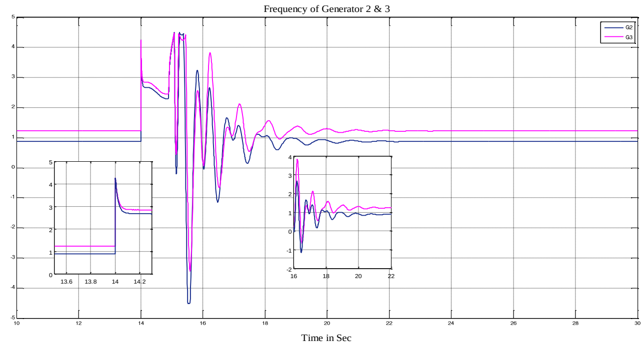
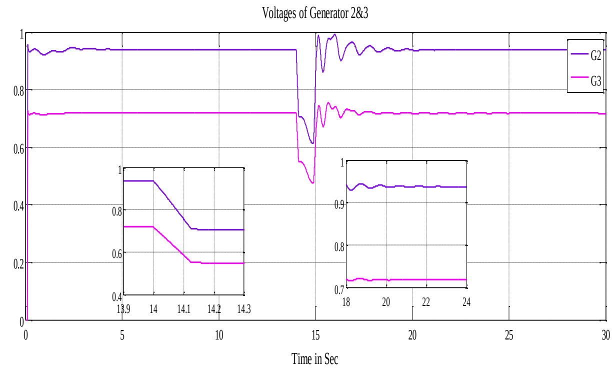


Fig. 7 (b)



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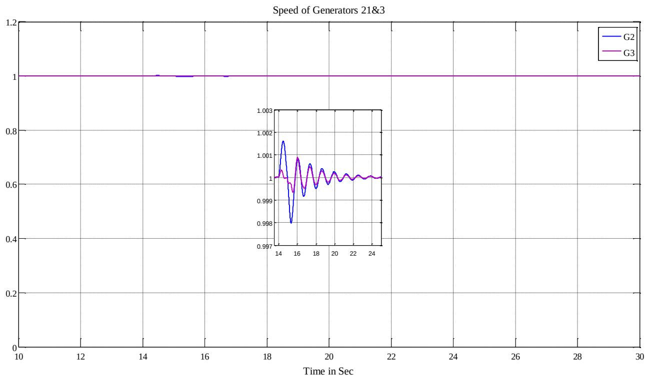

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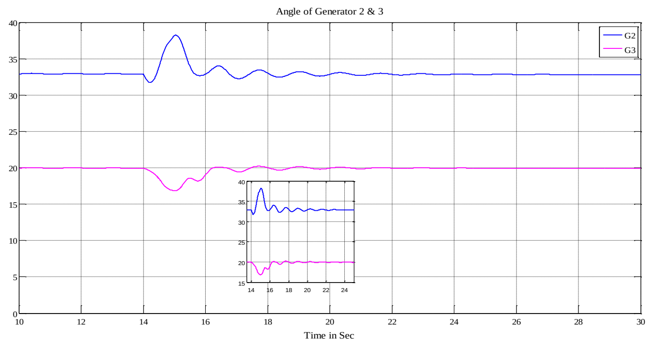
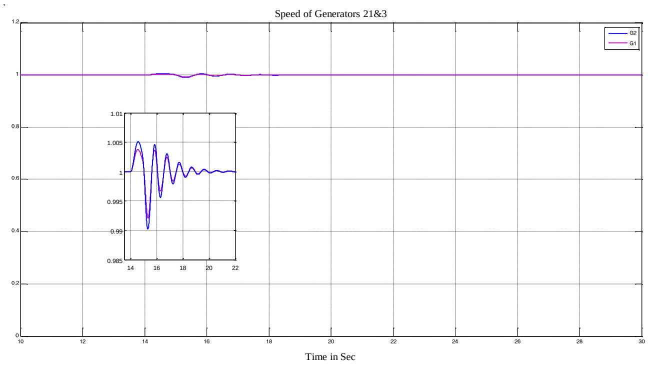


Fig. 7 (g)



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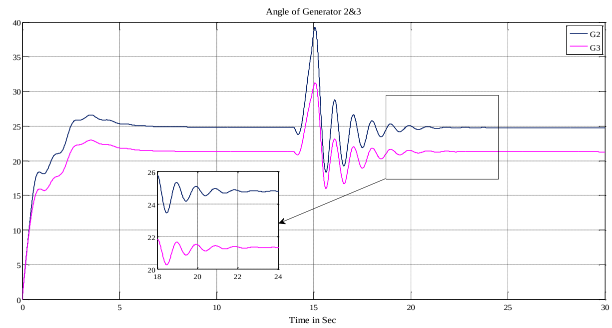

Fig. 7 (h)

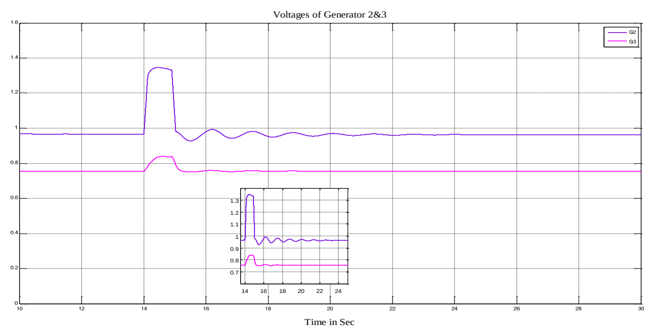

Fig. 7 (e)

Fig. 7 Generator 2& 3 behaviour of proposed system under L-L-L-G and L-L-L-L-L-G fault with all six phase transmission lines instead (a) Frequency variations (b) Speed variation (c) Voltage variations (d) Angle variations.

V. CONCLUSION

This paper describes the performance evaluation of multi-bus power system with six phase transmission line. Here the transient stability of proposed system is increased by introducing WPGS in conventional multi-bus power system with STATCOM. The stability enhancement is analyzed based on the simulation results shown in fig.4. The proposed system stability is analyzed with different case studies; from thosethe proposed system with all six phase transmission lines between the buses has shown better stability. From the results it can be concluded that the WPGS can reduces maximumpeak overshoot and time taken to reach stability during abnormal conditions.

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